LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Environnement

Luxembourg's National Inventory Report 1990-2006

Submission under the United Nations Framework

Convention on Climate Change

and voluntary submission under the Kyoto Protocol

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Project management

Eric De Brabanter – Ministry of the Environment

Authors

Georges Blasen – Environment Agency

Eric De Brabanter – Ministry of the Environment

Pierre Dornseiffer – Environment Agency

Serge Less – Environment Agency

Jean-Marie Ries – Water Management Administration

Frank Thewes – Environment Agency

Frank Wolter – Water & Forests Administration

with the help of Traute Köther – Umweltbundesamt Austria

and contributions from:

- Kirsten Becker – SEG Umwelt-Service GmbH
- Wilfried Winiwarter – Austrian Research Centers GmbH - ARC
- LuxSpace Sàrl

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Executive Summary

ES.1. Background Information

As a Party to the United Nations Framework Convention on Climate Change (*UNFCCC*), Luxembourg is required to produce and regularly update national greenhouse gas (*GHG*) inventories. To date, such inventories have been produced for the years 1990 to 2006.

With decision 18/CP.8 (see document FCCC/CP/2002/8/Add.2), the Conference of the Parties (*COP*) adopted the UNFCCC guidelines on reporting and reviewing (FCCC/CP/2002/8). According to this decision, Parties shall submit a National Inventory Report (*NIR*) containing detailed and complete information on their inventories, in order to ensure its transparency (paragraph 38 of FCCC/CP/2002/8).

This report is an update of the previous NIRs submitted in 2006 and 2007.[1] It is based on data submitted to the UNFCCC in the Common Reporting Format (*CRF*) on 23 April 2008: **submission 2008v1.2**.[2] Besides being a submission under the UNFCCC, **submission 2008v1.2 is also a voluntary submission under the Kyoto Protocol**.

The structure of this NIR follows as much as possible the arrangement suggested in Annex I of document FCCC/SBSTA/2006/9. First, there is an Executive Summary that gives an overview of Luxembourg's GHG inventory. Chapters 1 and 2 provide general information on the inventory preparation process, summarize the overall trends in GHG emissions and describe specific national circumstances that influence Luxembourg's GHG emission trends and structure. Comprehensive information on the activity data, emission factors and methodologies used for estimating Luxembourg's GHG emissions is presented in Chapters 3 to 8 – each chapter dealing with one CRF sector. Chapters 3 to 8 also depict actions planned to further improve the inventory and changes made (recalculations) for each CRF sector. These further improvements and recalculations are summarized in Chapter 9.

This report has been compiled by Eric De Brabanter, from the Ministry of the Environment, with the help of the Umweltbundesamt in Austria. Specific responsibilities for this 2008 NIR have been as follows:

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1 Luxembourg's National Inventory Reports of 29 December 2006 and 17 April 2007 (both covering inventory years 1990 to 2004), and of 4 June 2007 (covering inventory years 1990 to 2005).

2 Submission 2008v1.2 can be downloaded from:
a) the Central Data Repository of the European Environment Information and Observation Network (*EIONET*) of the European Environment Agency (*EEA*): http://cdr.eionet.europa.eu/lu/eu/ghgmm/envsa9e_q;
b) from the UNFCCC web site:
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/4303.php.

- Executive Summary: Eric De Brabanter
- Chapters 1 and 2: Eric De Brabanter (except 1.6 Kirsten Becker & 1.9: Georges Blasen)
- Chapter 3: Georges Blasen, Serge Less & Frank Thewes (Environment Agency)
- Chapter 4: Pierre Dornseiffer (Environment Agency)
- Chapter 5: Pierre Dornseiffer & Frank Thewes (Environment Agency)
- Chapter 6: Eric De Brabanter
- Chapter 7: Frank Thewes (Environment Agency), Frank Wolter (Water & Forests Administration) with Willibald Croi (Luxspace Sàrl)
- Chapter 8: Serge Less (Environment Agency), Jean-Marie Ries (Water Management Administration)
- Chapter 9: Eric De Brabanter

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

In 2006, as underlined by Table 1 on page 5, carbon dioxide (*CO_2*) was the main source of GHG in Luxembourg. This source counted for a bit less than 91% of the total GHG emissions calculated in CO_2 equivalents (*CO_2e*) – total excluding land-use, land-use change and forestry (*LULUCF*). The second source of GHG was nitrous oxide (*N_2O*) with about 5% of the total emissions excluding LULUCF. Methane (*CH_4*) was the third source with 3.5%. Fluorinated gases (*F-gases*) only accounted for 0.7% of the total emissions excluding LULUCF, with hydrofluorocarbons (*HFCs*) representing 0.65% of the total and sulphur hexafluoride (*SF_6*) representing 0.03% of the total. There were no known sources of perfluorocarbons (*PFCs*) in Luxembourg.

In 2006, total GHG emissions excluding LULUCF amounted to 13 322 Gg CO_2e, 1.03% above their level for the base year.[3] For the different GHG, trends over the period 1990-2006 were as follows:

- CO_2: .... -0.91%
- CH_4: .... +0.77%
- N_2O: .... +34.48%
- F-gases: ...... +431,12%

For carbon dioxide, the relatively close values estimated in 1990 and 2006 respectively hide a U-shape evolution over the period as well as important changes in the sources of CO_2 emissions: declining emissions in industrial and thermal power plant combustion, increasing emissions from transport and for natural gas fired power plants. Methane emissions have increased by less than a percent over the period. This result is the conjunction of reduced methane emissions in agriculture (-4%) and in waste management (-30%) with growing emissions in energy use (+49%), the latter

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3 The base year for CO_2, CH_4 and N_2O is 1990. For the F-gases, the base year is 1995. However, due to lack of data on F-gases for the first half of the 1990s, 1995 emission estimates are equalled to 1990 emission estimates.

being mainly due to an increase in road transportation emissions and due to an upward trend for fugitive emissions from natural gas distribution and use. Nitrous oxide emissions development is closely linked to an increase of road transportation emissions that could not be balanced by declining emissions from the agriculture sector. Finally, with regard to F-gases, HFCs emissions were 6 times higher in 2006 than in the base year, whereas SF_6 emissions showed a 33% increase.

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

Table 2 on page 5 splits up total GHG emissions of Luxembourg for the 7 CRF sectors to be included in the inventories. In 2006, the energy sector accounted for almost 89% of the total CO_2e GHG emissions, excluding LULUCF. Two sectors represent between 5 and 6% of the total emissions, excluding LULUCF: industrial processes (5.7%) and agriculture (5.2%). The remaining sectors[4] (solvent and other product use, waste[5]) were not even reaching 1% of the total GHG emitted in Luxembourg in 2006.

For the different sectors, trends over the period 1990-2006 were as follows:

- Energy: .... +10.08%
- Industrial Processes: .... -53.22%
- Solvent and Other Product Use: .... -17.66%
- Agriculture: .... -10.45%
- Waste: .... -8.15%

Emission reductions observed in all sectors but one could not balance the growth of energy use and production related emissions whose contribution to total GHG emissions, excluding LULUCF, ranged from 80 to 90% over the period 1990 to 2006. Within the energy sector, the fastest growing sub-sector was transport (1A3): +162% between 1990 and 2006 with, as a result, a share in the total energy related GHG emissions rising from 26 to 62%. For the other sub-sectors, the observed trends between 1990 and 2006 are +13% for energy industries (1A1), -69% for manufacturing industries (1A2), +1% for the other sectors (1A4) and +116% for fugitive emissions from fuels (1B).[6]

The second largest sector in Luxembourg with regard to GHG emissions, i.e. industrial processes, 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). This

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4 The sector “other” is not reported for Luxembourg.

5 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).

6 Fugitive emissions growth is closely linked to natural gas use in Luxembourg.

industry moved from blast to electric arc furnaces between 1990 and 1998. As a consequence, emissions in CO_2e decreased by 83% since 1990.

Trends in agriculture were also favourable between 1990 and 2006: declining GHG emissions were observed for the 3 categories for which emissions are recorded in Luxembourg: enteric fermentation (4A: -12%), manure management (4B: -1%) and agricultural soils (4D: -13%).

In the waste sector, the main source of GHG was solid waste disposal on land (6A), but its weight decreased over the period 1990-2006 due to the combination of reduced amounts of landfilled waste and of increased emissions arising from composting activities (6D). However, GHG emissions reduction for solid waste disposal on land (-47% between 1990 and 2006) still drove a reduction for the overall waste sector despite composting and wastewater handling (6B) rising emissions (+11% for category 6B following the important population and commuter growths Luxembourg faced over the period).

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

ES.4. Emission Estimates and Trends of Indirect GHG and SO_2

Some indirect GHG – NOx, CO, NMVOCs – and SO_2 emissions are recorded in the inventory. Nevertheless, they need to be re-evaluated in the light of the revision of the inventories Luxembourg is compiling for the UNECE Convention on Long-Range Transboundary Air Pollution (*CLRTAP*). Consequently, these emissions will not be discussed in this NIR and generating better emission estimates for these gases are part of our planned improvements.

Table 1 – Luxembourg's GHG emissions and removals – overview by main gases: 1990-2006

Gg (1000 t.) CO_2 e	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2	12219.20	12498.00	12326.14	12571.85	11766.55	9312.46	9377.07	8723.05	7968.03	8558.01	9040.46	9349.65	10157.90	10534.19	12167.49	12064.29	12108.29
	92.66%	*92.65%*	*92.28%*	*92.43%*	*92.18%*	*90.11%*	*89.91%*	*89.07%*	*88.00%*	*88.46%*	*88.76%*	*89.24%*	*89.85%*	*90.31%*	*90.78%*	*90.77%*	*90.89%*
CH_4 (1)	460.04	468.61	462.73	473.77	455.18	469.75	478.48	477.62	479.22	490.89	486.64	483.63	481.88	475.25	471.17	469.18	463.56
	3.49%	*3.47%*	*3.46%*	*3.48%*	*3.57%*	*4.55%*	*4.59%*	*4.88%*	*5.29%*	*5.07%*	*4.78%*	*4.62%*	*4.26%*	*4.07%*	*3.52%*	*3.53%*	*3.48%*
N_2O (2)	490.15	505.83	550.77	538.77	526.38	535.48	550.34	564.13	572.79	584.50	611.33	588.73	603.28	585.27	685.53	670.83	659.15
	3.72%	*3.75%*	*4.12%*	*3.96%*	*4.12%*	*5.18%*	*5.28%*	*5.76%*	*6.33%*	*6.04%*	*6.00%*	*5.62%*	*5.34%*	*5.02%*	*5.11%*	*5.05%*	*4.95%*
HFCs (3)	14.21	14.21	14.21	14.21	14.21	14.21	19.97	25.73	31.49	37.25	43.01	50.92	58.82	66.73	74.63	82.54	87.04
	0.11%	*0.11%*	*0.11%*	*0.10%*	*0.11%*	*0.14%*	*0.19%*	*0.26%*	*0.35%*	*0.39%*	*0.42%*	*0.49%*	*0.52%*	*0.57%*	*0.56%*	*0.62%*	*0.65%*
PFCs (3)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
SF_6 (3)	2.91	2.91	2.91	2.91	2.91	2.91	3.03	3.15	3.28	3.40	3.52	3.57	3.62	3.68	3.73	3.78	3.86
	0.02%	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.03%*	*0.03%*	*0.03%*	*0.04%*	*0.04%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*
Total GHG excluding LULUCF	13186.51	13489.55	13356.75	13601.50	12765.21	10334.81	10428.89	9793.68	9054.81	9674.04	10184.97	10476.50	11305.50	11665.12	13402.55	13290.61	13321.90
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Source: Environment Agency and Ministry of the Environment.

Notes:

(1) the methane emissions are converted in CO_2 equivalents 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.

(2) the nitrous oxide emissions are converted in CO_2 equivalents 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.

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

Table 2 – Luxembourg's GHG emissions and removals – overview by main CRF Sectors: 1990-2006

Gg (1000 t.) CO_2 e	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Energy	10730.04	11109.78	11043.81	11313.88	10604.45	8510.75	8643.58	8112.02	7526.63	8101.10	8579.38	8958.99	9776.39	10233.46	11875.14	11828.22	11812.00
	81.37%	*82.36%*	*82.68%*	*83.18%*	*83.07%*	*82.35%*	*82.88%*	*82.83%*	*83.12%*	*83.74%*	*84.24%*	*85.52%*	*86.47%*	*87.73%*	*88.60%*	*89.00%*	*88.67%*
2. Industrial Processes	1612.68	1535.59	1465.61	1445.58	1352.51	992.16	942.47	839.46	686.29	729.84	761.99	713.53	737.19	686.27	735.85	702.42	754.48
	12.23%	*11.38%*	*10.97%*	*10.63%*	*10.60%*	*9.60%*	*9.04%*	*8.57%*	*7.58%*	*7.54%*	*7.48%*	*6.81%*	*6.52%*	*5.88%*	*5.49%*	*5.29%*	*5.66%*
3. Solvent and Other Product Use	18.31	18.00	17.67	17.41	17.13	16.86	16.59	16.29	16.01	15.68	15.17	14.59	14.68	14.72	14.78	14.90	15.08
	0.14%	*0.13%*	*0.13%*	*0.13%*	*0.13%*	*0.16%*	*0.16%*	*0.17%*	*0.18%*	*0.16%*	*0.15%*	*0.14%*	*0.13%*	*0.13%*	*0.11%*	*0.11%*	*0.11%*
4. Agriculture	775.94	781.73	785.78	777.29	755.31	778.76	789.17	786.73	784.28	785.50	782.40	747.40	737.47	686.70	732.61	699.92	694.86
	5.88%	*5.80%*	*5.88%*	*5.71%*	*5.92%*	*7.54%*	*7.57%*	*8.03%*	*8.66%*	*8.12%*	*7.68%*	*7.13%*	*6.52%*	*5.89%*	*5.47%*	*5.27%*	*5.22%*
5. LULUCF	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
6. Waste	49.53	44.44	43.89	47.34	35.82	36.28	37.08	39.17	41.60	41.91	46.02	42.00	39.76	43.97	44.17	45.16	45.49
	0.38%	*0.33%*	*0.33%*	*0.35%*	*0.28%*	*0.35%*	*0.36%*	*0.40%*	*0.46%*	*0.43%*	*0.45%*	*0.40%*	*0.35%*	*0.38%*	*0.33%*	*0.34%*	*0.34%*
7. 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*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Total GHG including LULUCF	12891.58	13194.62	13061.82	13306.57	12470.28	10039.88	10133.96	9498.75	8759.88	9379.11	9890.04	10181.57	11010.57	11370.19	13107.62	12995.68	13026.97
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*
Total GHG excluding LULUCF	13186.51	13489.55	13356.75	13601.50	12765.21	10334.81	10428.89	9793.68	9054.81	9674.04	10184.97	10476.50	11305.50	11665.12	13402.55	13290.61	13321.90
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Source: Environment Agency and Ministry of the Environment.

Notes:

Percentages are relative to the total GHG emissions excluding LULUCF.

Land-use change and forestry emissions are based on constant estimates of 294.93 Gg of CO_2 for changes in forest and other woody biomass stocks (CRF 5A).

1. Introduction

The updated UNFCCC Reporting Guidelines on Annual Inventories following incorporation of the Provisions of Decision 14/CP.11 that was published on 18 August 2006,[7] reproduces the Guidelines for the preparation of National Communications by Parties included in Annex I to the Convention. This document indicates, in paragraph 38, that "Annex I Parties shall submit to the COP, through the Secretariat, a NIR containing detailed and complete information on their inventories".

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 and 14/CP.11 of the COP, and with European Parliament and Council Decision 280/2004/EC 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 NIRs submitted in 2006 and 2007.[8] It is based on data submitted to the UNFCCC in the Common Reporting Format (*CRF*) on 23 April 2008: **submission 2008v1.2**.[9] Besides being a submission under the UNFCCC, **submission 2008v1.2 is also a voluntary submission under the Kyoto Protocol**.

The GHG inventory reviewed in the present NIR covers the period 1990-2006 and contains information on anthropogenic emissions by sources and removals by sinks for direct GHG (CO_2, CH_4, N_2O, PFCs, HFCs, and SF_6). As regards indirect GHG (CO, NOx, NMVOCs) and SO_2, though recorded in the inventory, they need to be re-evaluated in the light of the revision of the inventories Luxembourg is compiling for the UNECE CLRTAP. Consequently, indirect GHG and SO_2 emissions will not be discussed in this NIR and generating better emission estimates for these gases are part of our planned improvements.

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7 Document FCCC/SBSTA/2006/9.

8 Luxembourg's National Inventory Reports of 29 December 2006 and 17 April 2007 (both covering inventory years 1990 to 2004), and of 4 June 2007 (covering inventory years 1990 to 2005).

9 Submission 2008v1.2 can be downloaded from:
a) the Central Data Repository of the European Environment Information and Observation Network (*EIONET*) of the European Environment Agency (*EEA*): http://cdr.eionet.europa.eu/lu/eu/ghgmm/envsa9e_q;
b) the UNFCCC web site:
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/4303.php.
CRF tables relating to this submission are not reproduced in this document since they can easily be accessed and printed out from these two web sites.

This first chapter will start with an overview of Luxembourg's latest inventory submissions to both the UNFCCC and the European Commission (*EC*). It will then cover the various sections suggested in Annex I of document FCCC/SBSTA/2006/9 for the "Introduction" chapter. It will conclude with some information on Luxembourg's National Registry.

1.1. A Brief History of Luxembourg's Submissions to the UNFCCC and the EC

For years Luxembourg was transmitting incomplete sets of CRF tables. It is only in December 2006, concomitantly with the preparation of the Initial Report under the Kyoto Protocol, that Luxembourg started to deliver a more complete and transparent inventory[10] and initiated a working program to make its inventories compliant with the reporting requirements under the UNFCCC, the Kyoto Protocol and the EC monitoring mechanism. Hence, it would not be superfluous to briefly recapitulate the various submissions prepared from December 2006 onwards because, since then, Luxembourg's inventories experienced dramatic positive changes with regard to their transparency, consistency, comparability, completeness and accuracy.

Table 1-1 on the next pages presents an overview of Luxembourg's latest submissions, starting with the one of December 2006. For each submission, a short description of its content is provided as well as where it can be downloaded. Each submission is also briefly commented. The transition between each submission is symbolized by an arrow and a concise note summarizing the main data processing improvements and changes.

More details on the on the main methodological and/or data processing changes that occurred since the ICR of June 2007 are presented at the start of each of the CRF main sectors Chapters 3 to 8.

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[10] Both the Initial Report and the related inventory are available on the UNFCCC web site: http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/items/3765.php.

Table 1-1 – Overview of the latest GHG inventory submissions

Submission	Content	Available at ...	Comments
2006v3 29 December 2006	a) two sets of CRF tables – 1990-2004 b) partial NIR c) Initial Report	http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/items/3765.php (NIR & Initial Report) & http://cdr.eionet.europa.eu/lu/eu/ghgmm/envrbtsdw (CRF tables & NIR)	*This submission was a first attempt to provide a complete set of CRF tables for the years 1990 to 2004. This inventory was in fact spread over two sets of tables: A and B. A files contained tables with emission estimates – and, therefore, were in line with previous submissions – whereas B files contained tables mostly made of not estimated, estimated elsewhere and/or not occurring cells. The "old" CRF format was used. This inventory was used as a basis for the Initial Report under the Kyoto Protocol.*
		data transfer to CRF Reporter 3.1.11 completeness & consistency exercise (especially notation keys)	
2007v1.1 27 March 2007	a) CRF tables – 1990-2004 b) NIR (17 April 2007)	http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/items/3765.php & http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3734.php & http://cdr.eionet.europa.eu/lu/eu/ghgmm/envrgjxpg	*Update of submission 2006v3. This update was the first to be generated with CRF Reporter. Hence, it included for the first time all the CRF tables for the years 1990 to 2004, as requested by UNFCCC decisions (see document FCCC/SBSTA/2006/9). The only exception related to tables 8 (the recalculation tables) that were not produced by CRF Reporter since Luxembourg was lacking complete submissions in the past. Recalculation information, however, were available in the NIR. The emissions recorded in this new set of tables were identical to those from submission 2006v3, providing numbers rounding differences and two small data corrections (one in 2000 and one in 2003).*
		accuracy exercise for methods and emission factors inclusion of the inventory year 2005	
2007v2.1 17 May 2007	a) CRF tables – 1990-2005 b) NIR (4 June 2007)	http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3929.php (NIR) & http://cdr.eionet.europa.eu/lu/eu/ghgmm/envrkxjjg	*This submission corresponds to the one due 15 April 2007. It included all the CRF tables for the years 1990 to 2005 with the exception of tables 8 (recalculation tables) that have not been produced since v2.1 presented identical data than those in submission 2007v1.1 for the inventory years 1990 to 2004.* *Compared to submission 2007v1.1, changes were:* *a) inventory year 2005 included;* *b) 1990-2004: correction for methods used and emission factors for road transportation;* *c) 1990-2004: removal of IPCC Sub-category 2AG Other - "Cooling Plants", an activity that only emits NH_3, a gas not to be recorded in CRF tables.*

		first ever ICR for Luxembourg took place 11-16 June 2007 numerous improvements before, during and after the in-country review national Regulation for the setting-up of a National Inventory System in Luxembourg	
2007v3.1 – ERT version 27 July & 10 August 2007	a) CRF tables – 1990-2005 b) ICR response	http://cdr.eionet.europa.eu/lu/eu/ghgmm/envrqqlqa	*This delivery was containing numerous improvements by taking into account the recommendations made by the ERT during the ICR of the Initial Report and of the 2006 GHG inventory submission that took place in June 2007. It had been forwarded to these experts for their consideration and acceptance and was approved in November 2007 (see "Report of the individual review of the GHG inventory of Luxembourg submitted in 2006", doc. FCCC/ARR/2006/LUX).*
		official submission only possible after acceptance of both ARR and IRR reports by the ERT of the UNFCCC	
2007v3.1 –UNFCCC version 11 December 2007	CRF tables – 1990-2005	http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3929.php & http://cdr.eionet.europa.eu/lu/eu/ghgmm/envr10nda	*This submission contained the same data than those transmitted to the experts of the UNFCCC end July 2007 and that were approved in November 2007 (see "Report of the individual review of the GHG inventory of Luxembourg' submitted in 2006", doc. FCCC/ARR/2006/LUX).*
		some revised and new activity data inclusion of the inventory year 2006 data transfer to CRF Reporter 3.2	
2008v1.1 21 January 2008	CRF tables – 1990-2006	http://cdr.eionet.europa.eu/lu/eu/ghgmm/envr5rpbw	*This submission had been delivered to the EC only in accordance with Decision 280/2004/EC. Compared to submission 2007v3.1, changes are: a) inventory year 2006 included; b) some revised activity data for the year 2005; c) 2002-2005: corrections for fuel use in IPCC Subcategories 1A2b, 1A4a and 1A4b; d) 1997-1999: new activity data for goats (IPCC Categories 4A, 4B and 4D); e) 2000-2005: revised activity data for some crops (IPCC Category 4D).*
		new activity data and reallocation of some activity data data transfer to CRF Reporter 3.2.1	
2008v2.1 23 April 2008	a) CRF tables – 1990-2006 b) NIR (19 July 2008)	http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/4303.php & http://cdr.eionet.europa.eu/lu/eu/ghgmm/envsa9e_q	*Submission this NIR is relating to. It has been delivered to both the UNFCCC and the EC. Compared to submission 2008v1.1, changes are relating to CRF Sector 4 – Agriculture with the addition of 3 new animal categories under "Other Livestock" (1997-2006) and the reallocation of crops activity data between N-fixing and non N-fixing crops (all years). Consequently, the base year (1990) has been modified (+0.14%).*

1.2. Institutional Arrangement for Inventory Preparation

1.2.1. Obligations for Luxembourg

Some obligations are directly linked with GHG emission reporting:

- annual obligations under 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 (known as the "Monitoring Decision") 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).

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 (1979) comprising the annual reporting of national emission data on SO_2, NOx, NMVOCs, NH_3, CO, TSP, PM_{10}, and $PM_{2.5}$ as well as on the heavy metals Pb, Cd and Hg and persistent organic hydrocarbons (*PAHs*), dioxins and furans and hexachlorobenzene (*HCB*);

- annual obligations under Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants, (known as the "NEC Directive") comprising the annual reporting of national emission data on SO_2, NOx, NMVOCs and NH_3;
- obligations according to Article 15 of the European IPPC Directive 1996/61/EC is to implement a European Pollutant Emission Register (*EPER*). EPER was displaced and upgraded by Regulation (EC) 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register (*E-PRTR*). EPER and E-PRTR are associated with Article 6 of the Aarhus Convention (United Nations: Aarhus, 1998) which refers to the right of the public to access environmental information and to participate in the decision-making process of environmental issues.
- obligations under the framework of the European Union Emission Trading Scheme (*EU-ETS*) established by Directive 2003/87/EC of the European Parliament.

1.2.2. National Inventory System

One of the main conclusions of the June 2007 ICR was that Luxembourg's National Inventory System (*NIS*) was not complying with the requirements laid out in the Guidelines under Article 5, paragraph 1, of the Kyoto Protocol.[11] ERT's report on potential problems and further questions[12] listed the lacks and defaults and recommends some action to be taken as soon as possible.

During the review, Luxembourg acknowledged the fact that it was lacking a proper and efficient NIS. Therefore, urgent measures had to be taken to set up a legal framework enabling the implement of a NIS complying to the Kyoto Protocol Guidelines. The Environment Agency, in collaboration with the Ministry of the Environment, prepared a Regulation for the setting-up of a NIS. This Regulation has been discussed and adopted by the Government during its session of 20 July 2007. Dated 1st August 2007, it has been published on 7 August 2007 in the Mémorial (Luxembourg's Official Journal).[13] The text adopted by the Government is presented in Annex I of this report (text in French) and some of its main features are presented in the sub-sections below.

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[11] As well as with provisions in Article 4, paragraph 4, of the EC Monitoring Decision 280/2004/EC.

[12] *Potential Problems and Further Questions from the ERT formulated in the course of the in-country review of Luxembourg's Initial Report under the Kyoto Protocol and 2006 Inventory Submission*, Luxembourg, 16 June 2007.

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

The Regulation 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 will be involved in the inventory preparation in the future.

Now that Luxembourg has a legal text defining the context and the framework to set up a NIS, the next step is to write implementation rules and procedures in accordance with the Kyoto Protocol Guidelines. This will be done in the coming weeks ahead of Luxembourg's next ICR planned for mid-October 2008.

1.2.2.1. Single National Entity and other cross-cutting roles

The Regulation designates the Environment Agency (*Administration de l'Environnement*)[14] as the "Single National Entity with overall responsibility for the GHG Inventory". Overall management of the Single National Entity is assigned to one staff member of the Environment Agency that is nominated GHG Inventory Focal Point. The Agency also acts as "National Inventory Compiler" compiling and checking the information and GHG emission estimates coming from sector experts working in other administrations or services (see Table 1-2).

The Environment Agency has therefore the "technical" knowledge and responsibility for the GHG Inventories, but the "political" responsibility is staying with the Ministry of the Environment acting as UNFCCC National Focal Point. It is thus 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).

1.2.2.2. 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 Sectors except Agriculture, LULUCF and Wastewater Handling (see Table 1-2 below). 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, compiles the GHG emissions estimates produced by sector experts;

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

- prepares the NIR (notably on the basis of chapters received from the sector experts), including the Key Source Analysis (*KSA*) 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 1-2 – CRF Sector responsibilities within the NIS

CRF Sector	AD	Choice of EFs	Emissions estimation methods
Energy, excl. road transportation – CRF 1 except 1A3b	AEV – DEN – STATEC	AEV	AEV
Road transportation – CRF 1A3b	ADA – DEN – SNCT	AEV	AEV
Industrial Processes – CRF 2	AEV	AEV	AEV
Solvent and Other Product Use – CRF 3	AEV	AEV	AEV
Agriculture – CRF 4	ASTA – SER	ASTA – SER	ASTA – SER
LULUCF – CRF 5	AEF – MEV	AEF – MEV	AEF – MEV
Waste – CRF 6A, 6B & 6D	AEV (Waste Division)	AEV (Waste Division)	AEV (Waste Division)
Wastewater Handling – CRF 6B	AGE	AGE	AGE

Note: this table has been built on the basis of the table in Annex I of the *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* that is reproduced in Annex I of this report.

Abbreviations used in Table 1-2:

Ministry of Agriculture:
ASTA = Agriculture Technical Services Administration (*Administration des Services Techniques de l'Agriculture*): http://www.asta.etat.lu/ and
SER = Agriculture Economic Service (*Service d'Economie Rurale*): http://www.ser.public.lu/

Ministry of Economic Affairs & External Trade:
DEN = Energy Directorate (*Direction de l'Energie*): http://www.eco.public.lu/index.html and STATEC = National Statistical Institute:
http://www.statec.public.lu/fr/index.html

Ministry of the Environment (MEV): http://www.emwelt.lu/:
AEF = Water & Forestry Administration (*Administration des Eaux et Forêts*) and AEV = Environment Agency (*Administration de l'Environnement*)

Ministry of Finance:
ADA: Customs & Excises Administration (*Administration des Douanes et Accises*): http://www.do.etat.lu/

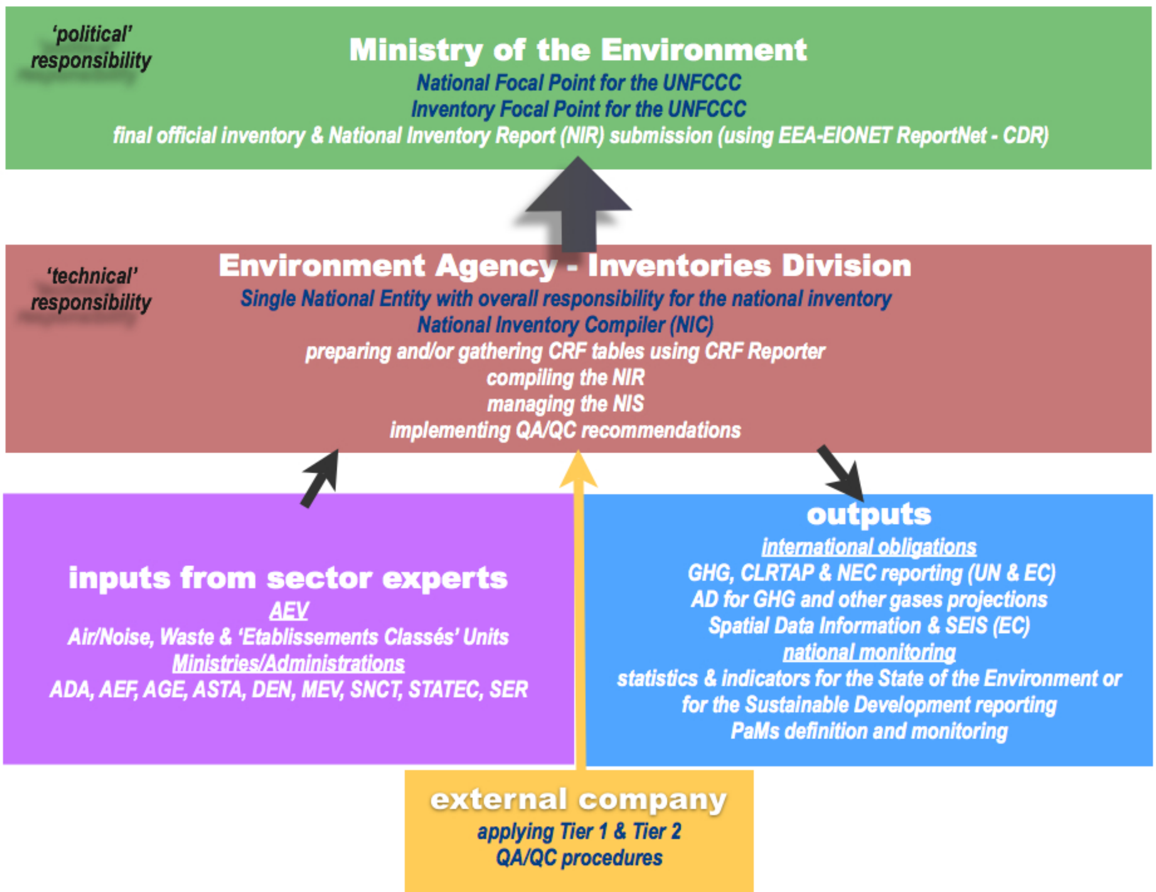
Ministry of Internal Affairs and Spatial Planning:
AGE = Water Agency (*Administration de la Gestion de l'Eau*): http://www.eau.public.lu/

Ministry of Transport
SNCT = Vehicles Check Administration (*Société Nationale de Contrôle Technique*): http://www.snct.lu/snct/home.nsf

1.2.2.3. NIS – an overview

The diagram below summarizes the organization of the GHG reporting in Luxembourg in accordance with the national Regulation for the setting-up of a NIS.

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



It is worth noting that the Inventories Division of the Environment Agency, a Division part of the Air/Noise Unit of this Agency, is not dealing only with GHG reporting but also with reporting under the UNECE CLRTAP 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 would also allow consistency between different reporting schemes. As an example, indirect GHG and SO_2 emissions that are to be recorded in the GHG inventory – and that, as indicated previously, need to be re-evaluated in the light of the revision of the inventories Luxembourg is compiling for the UNECE CLRTAP and under the "NEC Directive" – will be 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 Unit of the Environment Agency ensure easy access to facilities' reported fuel and/or emissions that could subsequently be integrated in GHG emissions calculations. The Environment Agency also gathers information from establishments and installations subordinated to a permit to carry out certain activities, the so-called "*établissements classés*". There, too, valuable information for the inventories can be found. More details on these AD and, sometimes, EF sources are presented in Section 1.4 below.

As regards outputs from the Inventory Division, not only are they used for the various inventories obligations (GHG, CLRTAP, NEC), but also for other reporting activities, such as those linked to Spatial Data Information (such as the EC INSPIRE Directive[15]) and under the Shared Environmental Information System.[16] Of course, these are also utilized for various national publications as well as for defining policies and measures (*PaMs*).

Finally, though the national Regulation for the setting-up of a NIS only indicates that an agent, belonging to the Environment Agency, should apply a QA/QC plan, it has been decided that QA/QC activities will be performed by an external company so to guarantee an independent review process. More on this in Section 1.6 below.

A second illustration below goes over the data flow process that is implied by the setting-up of the NIS. The Inventories Division of the Environment Agency not only collects and validates AD, EF, parameters and emission estimates from sector experts – to which the Environment Agency belongs too (see Table 1-2 above) – but also produces emission estimates when those are not made by sector experts (which is mainly the case for CRF sectors 1, 2 and 3 – see Table 1-2). This flexibility is introduced in Luxembourg's system due to resource constraints in most administrative departments but, essentially, in order to ensure a better quality for the reporting of GHG emissions.

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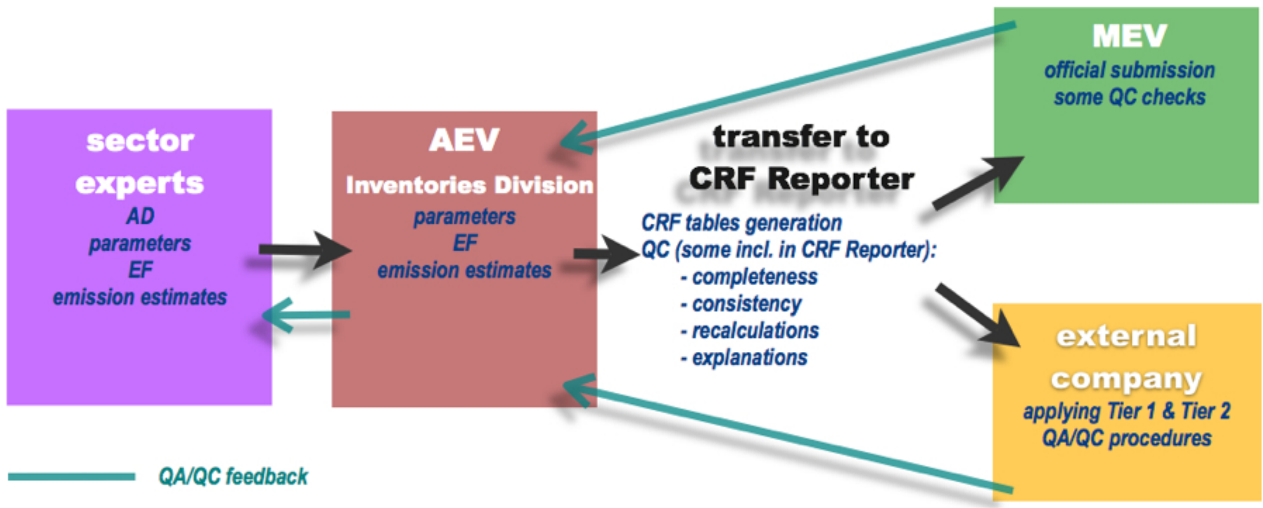
15 See http://inspire.jrc.it/

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

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



1.3. Inventory Preparation Process

Inventory submission 2008v1.2 for Luxembourg has been prepared **using the latest version of CRF Reporter**, i.e. **version 3.2.1**. It covers the inventory years **1990 to 2006**.

A large number of GHG source categories are not occurring in Luxembourg. Moreover, as it will be explained in Chapter 7, LULUCF data are not yet fully developed in Luxembourg. Consequently, for one inventory year, values – other than notation keys – to be included in CRF Reporter amount to around one hundred. This is why, so far, CRF Reporter has been "manually" populated by having recourse to "copy-paste" from Microsoft Excel™ inventory work files. For the future, it is foreseen to use some specific software tools for the preparation and the compilation of air emission inventories and estimates (GHG, emissions in the framework of the CLRTAP) from which it might be envisaged to develop automated routines for transferring emission estimates directly to CRF Reporter.[17] 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.

[17] That does not mean that, as of today, no specific computer programs have been used. Indeed, CollecER and COPERT, for instance, are used in the preparation of GHG emissions for CRF sector 1 – Energy. But, there is no automated transfer from these programs directly into CRF Reporter: CollectER and COPERT results are reported in Microsoft Excel™ sheets before being copied to CRF Reporter.

For preparing submission 2008v1.2, Luxembourg did refer to the note by the Secretariat FCCC/SBSTA/2006/9 of 18 August 2006 on updated UNFCCC Reporting Guidelines on Annual Inventories following incorporation of the Provisions of Decision 14/CP.11. IPCC Guidelines have been applied as much as possible. These Guidelines are:

- the Revised 1996 IPCC Guidelines for National GHG Inventories;
- the 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (*2000 IPCC-GPG*);
- and, punctually, the 2006 IPCC Guidelines for National GHG Inventories.

The 2003 IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (*2003 IPCC-GPG-LULUCF*) have not been used yet for the making of GHG inventories since, as it will be explained in Chapter 7, LULUCF data reporting is still very limited for Luxembourg.

Information on the methods and sources used for preparing the inventory are, of course, presented in each of the Chapters 3 to 8 dealing with a CRF sector. They are also summarized in the next section of this first chapter.

For estimating GHG emissions reported in submission 2008v1.2, Luxembourg did use a mix of specific computer programs and of Microsoft Excel™ spreadsheets: see Table 1-3.

Table 1-3 – Programs and software used for generating submission 2008v1.2

CRF Sector	Emissions calculated using ...
Energy, excl. road transportation – CRF 1 except 1A3b	CollectER – ReportER – MS Excel
Road transportation – CRF 1A3b	COPERT III – MS Excel
Industrial Processes – CRF 2	MS Excel
Solvent and Other Product Use – CRF 3	CollectER – ReportER – MS Excel
Agriculture – CRF 4	MS Excel
LULUCF – CRF 5	not applicable
Waste – CRF 6	MS Excel

As Table 1-3 shows, data management is mainly carried out by using Microsoft Excel™ spreadsheets, sometimes in combination with Visual Basic™ macros. This way of proceeding is offering a very flexible system that can easily be adjusted to new requirements. It is only when activity and background data are classified under the SNAP nomenclature[18] that dedicated computer programs developed for the European Environment Agency (*EEA*) are employed. These programs are:

18 SNAP stands for Selected Nomenclature for sources of Air Pollution. It has been designed by the European Topic Centre on Air and Climate Change (*ETC/ACC*) of the EIONET as a nomenclature to be used for estimating emissions of all kinds of air pollutants, not only GHG. SNAP is, therefore, also used for CLRTAP inventories (see EMEP/CORINAIR Guidebooks).

- **CollectER II** (*Collect Emission Register*) is a tool dedicated to national air emission experts in order to update a national emission inventory. It is part of a set of software tools developed by the European Topic Centre on Air and Climate Change (*ETC/ACC*) to assist national experts in compiling an air emission inventory. The program CollectER II therefore includes the following main functions:
  - it supports collecting air emission data of area and point sources;
  - it stores these data in an emission inventory in a spatial resolved database, using EUROSTAT's NUTS territorial definition.
- **ReportER II** (*Report Emission Register*) is a software tool determined for national experts on air emissions. Based on the national emissions inventory data stored in the CollectER annual inventory databases, the latest version (December 2002) of ReportER can create a set of UNFCCC reports and UNECE/CLRTAP/EMEP reports.
- **COPERT III** (*Computer Programme to Calculate Emissions from Road Transport*) is a Microsoft Windows™ software tool for the calculation of emissions from road transport.[19] Furthermore, emissions from internal combustion engines used in off road applications are also covered. The emissions calculated include all major pollutants (CO, NOx, VOC, PM) and several more (N_2O, NH_3, SO_2, ...).

Data produced by these various tools has to be transformed according to the IPCC Guidelines into the UNFCCC CRF to comply with the reporting obligations under the UNFCCC.

Finally, submission 2008v1.2 has been produced in a transitory period characterized by the progressive implementation of the provisions of the national Regulation for the setting-up of a NIS in Luxembourg (see Section 1.2.2 above). That means, that for this submission, the 3 usual stages for a GHG inventory preparation – i.e. (i) inventory planning, (ii) inventory preparation and (iii) inventory management – were not fully observed.

More precisely, with the help of our partner – the Umweltbundesamt of Austria – emissions have been calculated by the institutions indicated in Table 1-4.

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19 Chariton Kouridis, Leonidas Ntziachristos and Zissis Samaras, *COPERT III - Computer programme to calculate emissions from road transport - user manual (version 2.1)*.Technical Report N°50, European Environment Agency, Copenhagen, 2000.

Table 1-4 – CRF Sector responsibilities for submission 2008v1.2

CRF Sector	AD	Choice of EFs	Emissions estimation methods
Energy, excl. road transportation – CRF 1 except 1A3b	AEV DEN STATEC	AEV	AEV
Road transportation – CRF 1A3b	DEN SNCT	AEV	AEV
Industrial Processes – CRF 2	AEV	AEV	AEV
Solvent and Other Product Use – CRF 3	AEV	AEV	AEV
Agriculture – CRF 4	ASTA SER	MEV	MEV
LULUCF – CRF 5	not applicable	not applicable	not applicable
Waste – CRF 6A, 6B & 6D	AEV	AEV	AEV
Wastewater Handling – CRF 6B	AGE	AGE	AGE

Note: for the abbreviations used, see Table 1-2 above.

GHG estimates produced by those different contributors have been centralized and verified by the Ministry of the Environment. It is also at the Ministry level that data have been "manually" transferred to CRF Reporter. Consequently, for submission 2008v1.2, it is the Ministry of the Environment that acted as the National Inventory Compiler. Quality control and plausibility assessments of the estimates have, therefore, also been performed by the Ministry[20] using Microsoft Excel™ as well as the various checking procedures included in CRF Reporter. It is worth noting that **all the checks included in CRF Reporter have been passed successfully by submission 2008v1.2**. In other words, submission 2008v1.2 is consistent through time[21] and is complete: all the cells/entries have been filled, all the notation keys and recalculations are fully documented. Hence, if empty cells or missing information are encountered in some CRF tables – tables 8(b), e.g. – for some years, **this is not due to missing information from the side of Luxembourg but to conversion problems in CRF Reporter** when CRF tables were created.[22]

1.4. Methodologies and Data Sources Used

The following table briefly presents the AD sources, the types of EFs used as well as the methods applied for estimating GHG emissions reported in submission 2008v1.2. A much more detailed table – based on the table in Annex I of Commission Decision 2005/166/EC, which itself is an expansion of CRF table Summary 3 – is provided in Annex II of this report.

20 And its partner, the Umweltbundesamt in Austria.

21 For those big yearly changes (in %) that were identified as outliers by CRF Reporter procedures, Luxembourg can provide an explanation.

22 This has been observed, notably, for table 8(b) for which, for some years, several recalculation explanations have not been reported.

Table 1-5 – Methodologies, data sources and EFs used by Luxembourg for submission 2008v1.2 – main CRF Sectors

CRF Sector	CO_2			CH_4			N_2O		
	method applied	*AD*	*EF*	*method applied*	*AD*	*EF*	*method applied*	*AD*	*EF*
Energy, excl. road transportation – CRF 1 except 1A3b	Tier 1 Tier 2	EJ NS PS Q TÜV	D	Tier 1 C	EJ NS PS Q TÜV	D C	Tier 1	EJ NS PS Q TÜV	D
Road transportation – CRF 1A3b	CIII	NS	D	CIII	NS	D	CIII	NS	D
Industrial Processes – CRF 2	Tier 2 CS	NS PS	CS PS	NA	NO	NA	NA	NO	NA
Solvent and Other Product Use – CRF 3	C	TÜV	C	NA	NA	NA	CS	NS	CS
Agriculture – CRF 4	NA	NA	NA	Tier 1 Tier 2	EJ NS	CS D OTH	Tier 1	EJ NS	D
LULUCF – CRF 5	CS	EJ	CS	NA	NE	NA	NA	NE	NA
Waste – CRF 6	Tier 2	NS Q	D	Tier 1 Tier 2	NS Q PS	D	Tier 1	NS Q PS	CS D

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

Abbreviations:

C = CORINAIR CS = Country Specific CIII = COPERT III D = IPCC Default

EJ = Expert Judgement NS = National Statistics OTH = Other PS = Plant Specific Data

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

Detailed information on data sources for activity and emission data, as well as for EFs used by sector, can be found in the Chapters 3–8. A few general comments are, however, presented in the next two sub-sections.

1.4.1. 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*);
- coming from information supplied directly by facilities;
- extracted from statistical information received from other ministries (for example Ministry of Economic Affairs and External Trade for energy, Administrations under the authority of the Ministry of Agriculture for agriculture, etc.);
- on occasion, from specific surveys or questionnaire and from expert judgements.

For large point sources – and after careful assessment of data plausibility – emission data that are reported by facilities are preferably used. Indeed, these data usually reflect the actual emissions better than data calculated using general EFs, because the facility is supposed having the best information about its own emissions. So far, such plant specific data have only been used for CRF sector 2. Luxembourg's planned improvement for the future foresees to considerably extent the use of emission data provided by facilities either in the framework of the EU-ETS and of the E-PRTR.

Besides plant specific data collected under EU legal requirements, national obligations can also be a source of activity and emission data for single facilities. This is the case under the law for "*établissements classés*"[23] that imposes regular reporting obligations to those units – the "*établissements classés*" – which, by their activities, could represent a risk as regards security, public health and convenience for both the citizens and the workers occupied in these units, as well as regards the environment.[24] 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 EU or national obligations, are actually transmitted and managed by the Environment Agency which should ease a more systematic use of data provided directly by facilities. Thus, and as already mentioned, a more systematic use of facilities' data is one of the major planned improvements Luxembourg has identified for its GHG inventories (see also Chapters 3, 4 and 9). In particular, it will be 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.

1.4.2. Emission factors

For EFs, besides plant specific factors derived from emission data transmitted by facilities (see above), it is mainly made use of default IPCC values published in the Revised 1996 or the 2006 IPCC Guidelines, as well as in the 2000 IPCC-GPG. Other sources for EFs are the EMEP/CORINAIR Guidebook and national studies or calculations leading to country specific EFs.

1.5. Key Category Analysis

The identification of key categories is described in the 2000 IPCC-GPG, Chapter 7 and in the 2003 IPCC-GPG-LULUCF, Chapter 5.4. 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

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

24 "Permitting activities", i.e. activities subordinated to a permit.

of the 2000 IPCC-GPG, 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 2000 IPCC-GPG. The identification includes all reported GHG CO_2, CH_4, N_2O, HFC, PFC and SF_6, and all IPCC categories.

The key category analysis was performed by the Ministry of the Environment on the basis of submission 2008v1.2 to the UNFCCC. It comprises a level assessment for all years between 1990 and 2006, as well as a trend assessment for the trend of the year 2006 with respect to base year emissions, i.e. 1990. It was not yet possible to follow the recommendations stipulated in the 2003 IPCC-GPG-LULUCF that suggest to first identify key source categories excluding LULUCF and then to repeat the key category analysis for the full inventory including LULUCF categories. Indeed, LULUCF emissions are based on rough estimates kept unchanged during the period 1990-2006 (see Chapter 7 for details). Performing therefore a key source analysis including LULUCF would not make much sense.

1.5.1. Key categories for Luxembourg – submission 2008v1.2

This sub-section presents the results of Luxembourg's key category analysis. The methodology is described in sub-section 1.5.2.

The identified key categories are listed in Table 1-6. The key source categories comprise 12 707.31 Gg CO_2e in the year 2006, which is a share of 95.4% of Luxembourg’s 2006 total GHG emissions (excluding LULUCF).

Table 1-6 – Key categories based on emission data recorded in submission 2008v1.2

IPCC	IPCC source category	Fuel	Gas	2006 emissions Gg CO_2e	Share in 2006 national total GHG emissions (excl. LULUCF)
1A1a	Public Electricity and Heat Production	Gaseous	CO_2	1385.61	10.40%
1A1a	Public Electricity and Heat Production	Solid	CO_2	0.00	0.00%
1A2a	Iron and Steel	Gaseous	CO_2	308.78	2.32%
1A2a	Iron and Steel	Solid	CO_2	1.18	0.01%
1A2f	Other	Gaseous	CO_2	762.40	5.72%
1A2f	Other	Liquid	CO_2	241.00	1.81%
1A2f	Other	Solid	CO_2	295.61	2.22%
1A3b	Road Transportation	Diesel oil	CO_2	5564.92	41.77%
1A3b	Road Transportation	Diesel oil	N_2O	140.85	1.06%
1A3b	Road Transportation	Gasoline	CO_2	1403.62	10.54%
1A3b	Road Transportation	Gasoline	N_2O	126.64	0.95%
1A4a	Commercial/Institutional	Gaseous	CO_2	300.98	2.26%
1A4a	Commercial/Institutional	Liquid	CO_2	312.84	2.35%
1A4a	Commercial/Institutional	Solid	CO_2	2.66	0.02%

IPCC	IPCC source category	Fuel	Gas	2006 emissions Gg CO_2e	Share in 2006 national total GHG emissions (excl. LULUCF)
1A4b	Residential	Gaseous	CO_2	300.98	2.26%
1A4b	Residential	Liquid	CO_2	316.39	2.37%
1A4b	Residential	Solid	CO_2	2.66	0.02%
1A4c	Agriculture/Forestry/Fisheries	Liquid	CO_2	75.13	0.56%
2A1	Cement Production	-	CO_2	431.20	3.24%
2C1	Iron and Steel Production	-	CO_2	170.49	1.28%
4A1	Enteric Fermentation – Cattle	-	CH_4	232.03	1.74%
4D	Agricultural Soils	-	N_2O	331.34	2.49%

Table 1-7 indicates which source categories have been identified as key categories for every reported years 1990 to 2006.

Table 1-7 – Key categories (qualitative) based on emission data recorded in submission 2008v1.2: 1990-2006

IPCC	IPCC source category	Fuel	Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2006
				LA	LA	LA	LA	LA	LA	LA	LA	LA	LA	LA	LA	LA	LA	LA	LA	LA	TA
1A1a	Public Electricity and Heat Production	Gaseous	CO_2					X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A1a	Public Electricity and Heat Production	Solid	CO_2	X	X	X	X	X	X	X	X										
1A2a	Iron and Steel	Gaseous	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
1A2a	Iron and Steel	Solid	CO_2	X	X	X	X	X	X	X	X										X
1A2f	Other	Gaseous	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A2f	Other	Liquid	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A2f	Other	Solid	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A3b	Road Transportation	Diesel oil	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A3b	Road Transportation	Diesel oil	N_2O						X	X	X	X	X	X	X	X	X	X	X	X	X
1A3b	Road Transportation	Gasoline	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1A3b	Road Transportation	Gasoline	N_2O									X			X						
1A4a	Commercial/ Institutional	Gaseous	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
1A4a	Commercial/ Institutional	Liquid	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
1A4a	Commercial/ Institutional	Solid	CO_2		X	X	X														
1A4b	Residential	Gaseous	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
1A4b	Residential	Liquid	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
1A4b	Residential	Solid	CO_2			X	X														
1A4c	Agriculture/Forestry/ Fisheries	Liquid	CO_2						X	X	X	X	X	X	X	X	X				
2A1	Cement Production	-	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2C1	Iron and Steel Production	-	CO_2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4A1	Enteric Fermentation – Cattle	-	CH_4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
4D	Agricultural Soils	-	N_2O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

1.5.2. Description of methodology

The identification of key source categories follows the Tier 1 method - quantitative approach described in the 2000 IPCC-GPG, Chapter 7 (Methodological Choice and Re-calculation) but not, as indicated above, the 2003 IPCC-GPG-LULUCF, Chapter 5.4 (Methodological Choice – Identification of key categories).

The analysis includes all GHG reported under UNFCCC: CO_2, CH_4, N_2O, HFC, PFC and SF_6. All IPCC categories are included.

As indicated above, key categories were only identified for the inventory excluding LULUCF. Therefore, the identification of key categories consisted of four steps:

a) identifying categories;

b) Level Assessment excluding LULUCF;

c) Trend Assessment excluding LULUCF;

d) qualitative considerations.

The qualitative criteria considered were: mitigation techniques, high expected growth of emissions/removals and unexpected low or high emissions/removals. No additional key source categories were identified with those qualitative criteria.

1.6. Quality Assurance and Quality Control (QA/QC)

In April 2008, the Environment Agency contracted the German company SEG[25] for implementing a performing Quality Management System (*QMS*) for the GHG emission reporting. The kick-off meeting took place on 14 May 2008, during which the work programme for setting up the QMS was presented as well as a timetable.

This implementation will take into account the 2000 IPCC-GPG and the 2003 IPCC-GPG-LULUCF. It will also capitalize on the draft Quality Management Manual prepared by the Umwemtbundesamt in Austria for the ICR response that Luxembourg provided during the summer of 2007.[26]

1.6.1. Timetable

The following timetable has been agreed during the kick-off meeting:

25 See http://www.seg-online.de/

26 See Annex III of the *Response to the report formulated by the ERT following the in-country review of Luxembourg's Initial Report under the Kyoto Protocol and the 2006 Inventory Submission* available at http://cdr.eionet.europa.eu/lu/eu/ghgmm/envrqqlqa.

- June 2008: identifying sector experts and responsibilities and discussing with them the objectives and improvements for the GHG inventory. This will lead to a QA/QC plan with identified deadlines for the important tasks;
- July 2008: on the basis of the June discussions and of the content of the present NIR, a QA/QC documentation will be produced. Also, the draft Quality Management Manual prepared by the Umwemtbundesamt in Austria will be amended and adapted accordingly. Then, sector experts will be asked to test the checklists included in the QMS; checklists that are in accordance with the IPCC Guidelines;
- August 2008: review of the implemented system and the documentation created up to that date. This review will also allow to identify deficits in the generation of data, in the documentation and in the organisation of the QMS.
- September 2008: the report of the review performed in August will be the basis for a following QA/QC plan and will allow to optimize the proposed QMS.

Table 1-8 on the next page (in German) details the timetable up to the next ICR for Luxembourg that is planned for the week of 13-18 October 2008.[27]

1.6.2. Quality Management Manual

The basis of the QA/QC documentation is the Quality Management Manual with the following content:

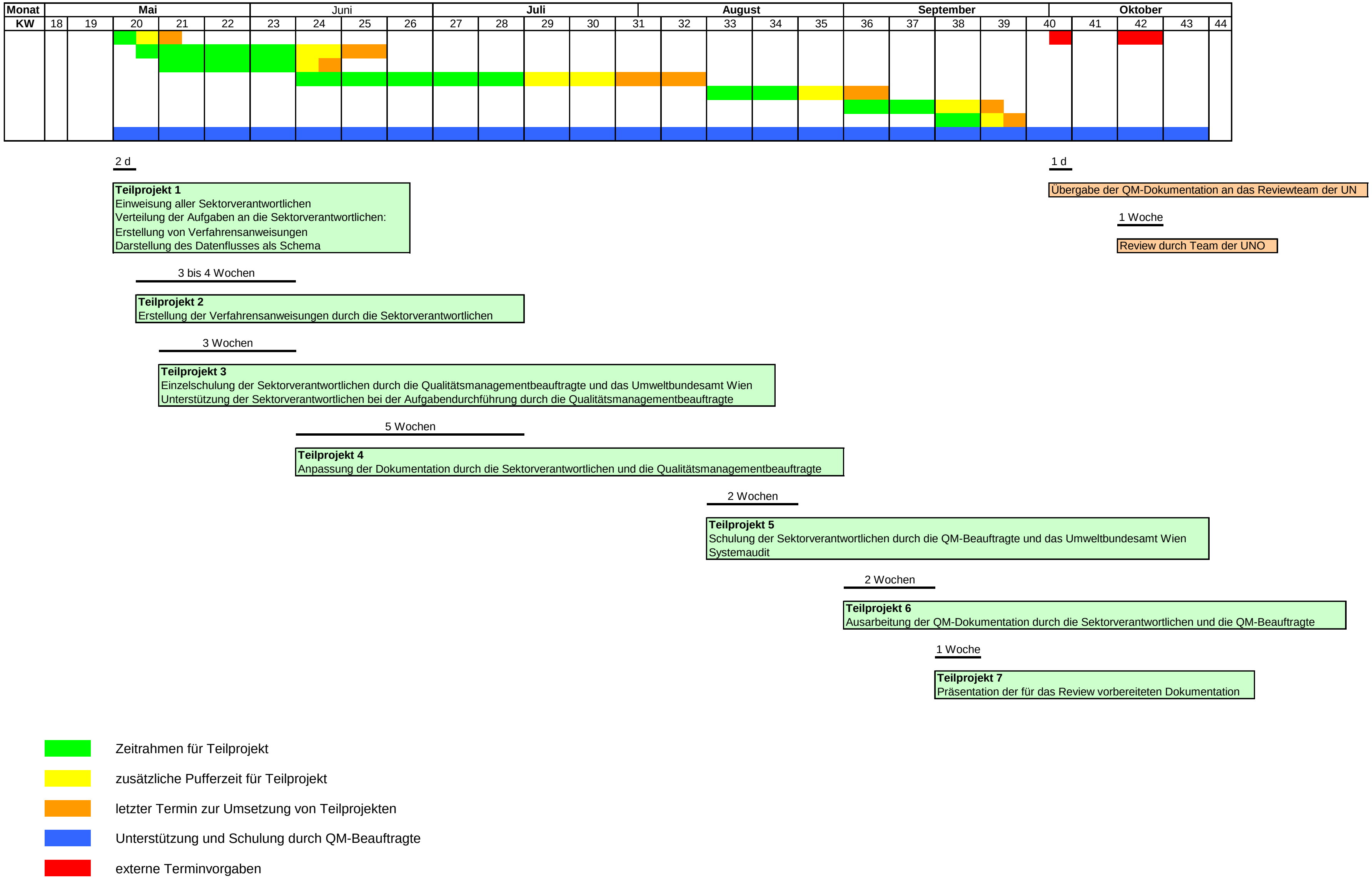
- organisation of QA/QC (responsibilities,…);
- QA/QC plan;
- reports of reviews;
- organisation of the inventory work (responsibilities,…);
- timetable for the inventory work;
- instructions for doing the inventory;
- instructions for archiving documents;
- instructions for proceeding in case of unexpected problems.

The Quality Management Manual itself will not contain each document in connection with the GHG inventory but rather name them, show where they can be found and how they are linked to other documents and the various inventory related tasks.

27 See the notification letter from Vitaly Matsarski dated 28 April 2008.

Table 1-8 – Timetable for the definition and the implementation of a QMS for the GHG inventory of Luxembourg

Projektplan (Stand 28.04.08)



For more information on Section 1.6, please contact:
Kirsten BECKER
SEG Umwelt-Service GmbH
Auf der Haardt 2
D - 66693 Mettlach
Tel: (+49) 6864 9103-20
Fax: (+49) 6864 910333
E-Mail: kbecker@seg-online.de

1.7. Uncertainty Assessment

In December 2007, the Environment Agency contracted Austrian Research Centers GmbH - ARC[28] for performing a detailed uncertainty analysis of Luxembourg's GHG inventory.

A qualitative assessment of Luxembourg's industrial and economic conditions was used as a setting against which uncertainty estimates, derived from several national studies from different countries, were applied. Quantitative uncertainty estimates could be derived for all input data, and both error propagation (according to a spreadsheet presented concomitantly with the IPCC Guidelines) and a Monte-Carlo approach were used to calculate overall uncertainty. Differences between these approaches follow the theoretical expectations: the overall uncertainty of the inventory is lower for the error propagation approach (2.86% vs. 4.04% for the Monte-Carlo method in 2006), which is not able to fully reflect statistical dependencies between input parameters. Such dependencies occur in several instances of the data used for the analysis. This also affects the uncertainty of the trend (difference between 2006 and 1990 emissions), where error propagation yields 1.77%-points compared to 2.34%-points in the Monte-Carlo approach.

Due to the importance of fossil fuel emissions from transport and industry, which are in general very well supported by statistical and measurement information, and the smaller importance of agricultural activities, the uncertainties of Luxembourg's GHG inventory are fairly low. Still in Luxembourg, as in all countries that offer detailed uncertainty analysis, the uncertainty related to the emission factor of N_2O from soils determines most strongly the overall uncertainty of the emission inventory. The factors most strongly influencing the trend refer to solid fossil fuels formerly used in iron and steel industry, an activity that has been overturned fully since 1990. The structural changes in Luxembourg are well reflected in the emission changes and also in the related uncertainties.

The full report on the uncertainty analysis of Luxembourg's GHG inventory – submission 2008v1.2 – is available in Annex III of this NIR.

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28 See http://www.arcs.ac.at/

For more information on Section 1.7, please contact:
Wilfried WINIWARTER
Austrian Research Centers GmbH - ARC
Donau-City Straße 1
A – 1220 Wien
Tel: (+43) 50550-4500
Fax: (+43) 50550-4599
E-Mail: wilfried.winiwarter@arcs.ac.at

1.8. Completeness

CRF table 9(a) on completeness have been filled for every reported year 1990 to 2006. As indicated above (see Section 1.3), 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 have been passed successfully by submission 2008v1.2. Hence, if missing information is encountered in table 9(a) for some years, **this not due to a lack of explanations from the side of Luxembourg but well due to conversion problems in CRF Reporter** when CRF tables were 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. Sources and sinks

All sources and sinks included in the IPCC Guidelines are covered, though, as indicated before, improvements are needed with regard to LULUCF. No additional sources and sinks specific to Luxembourg have been identified.

1.8.2. Gases

Both direct GHGs as well as precursor gases are covered by Luxembourg's inventory. However, indirect GHG – NOx, CO, NMVOCs – and SO_2 need to be re-evaluated in the light of the revision of the inventories Luxembourg is compiling for the UNECE CLRTAP. Generating better emission estimates for these gases are part of our planned improvements (see Chapter 9).

1.8.3. Geographic coverage

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

1.8.4. 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 9 of document FCCC/SBSTA/2006/9 of 18 August 2006.

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. For emissions by sources and removals by sinks of GHG marked by NE, check-ups are in progress to establish if they actually are NO (not occurring). As part of the improvement programme of the inventory, it is planned that these source or sink categories are either estimated or allocated to NO.

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. As part of the improvement programme of the inventory, it is planned to revise all the NA notation keys to confirm whether they are indeed NA or rather NE or NO.

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. So far, no confidential information has been identified in Luxembourg's GHG inventory.

1.8.5. Transparency and completeness indexes

Transparency and completeness indexes are calculated as follows:

- Transparency (*TR*) [%] = [1 – (number of IE/number of estimates)]*100
- Completeness (*CP*) [%] = [1 – (number of NE/number of estimates)]*100

In Table 1-9, transparency and completeness of the pre-ICR submission – submission 2007v2.1 – and of Luxembourg's latest submission –submission 2008v1.2 – are compared. The exercise focuses on the inventory year 2005 and the sectoral report tables only. The level of detail for CRF sources and categories is up to 4 digits for the energy sector (e.g. IPCC Sub-category 1A1a) and 3 digits for the other sectors (e.g. IPCC Sub-category 4D3). Finally, only the 6 GHG are covered by this counting exercise. Under these conditions, 317 cells have been scrutinized: 86 for CRF sector 1, 105 for CRF sector 2, 10 for CRF sector 3, 59 for CRF sector 4, 39 for CRF sector 5 and 18 for CRF sector 6.

As it can be seen in Table 1-9, the transparency has remained the same between the two submissions except for CRF sectors 2 and 6. For the former, this is due to the fact that some sources previously recorded as NE are now known as being included in other sub-categories (hence, the notation key IE). For the latter, waste incineration, that was previously recorded in CRF Sector 6, has now been transferred to CRF Sector 1, since the energy produced during waste burning in the sole incinerator of the country is recovered.

With regard to completeness, the improvement of the inventory is quite remarkable with completeness rising from 66 to 81%. A similar trend was observed for all the sectors except for LULUCF which remains, as already mentioned earlier, the sector where the biggest improvements have to be made.

Table 1-9 – Transparency and completeness in UNFCCC submissions 2007v2.1 and 2008v1.2: 2005

CRF Sector	Submission 2007v2.1				Submission 2008v1.2			
	IE	*NE*	*TR*	*CP*	*IE*	*NE*	*TR*	*CP*
Energy (sectoral approach) – CRF 1	10	26	*88%*	*70%*	10	5	*88%*	*86%*
Industrial Processes – CRF 2	0	23	*100%*	*78%*	2	13	*98%*	*88%*
Solvent and Other Product Use – CRF 3	1	5	*90%*	*50%*	1	4	*90%*	*60%*
Agriculture – CRF 4	0	11	*100%*	*81%*	0	1	*100%*	*98%*
LULUCF – CRF 5	0	36	*100%*	*8%*	0	36	*100%*	*8%*
Waste – CRF 6	0	6	*100%*	*67%*	3*	2	*83%**	*89%*
Total	11	107	*97%*	*66%*	16	61	*95%*	*81%*

* includes waste incineration that is reported under IPCC Sub-category 1A1a since the energy produced while burning waste is recovered.

1.9. National Registry

Submission 2008v1.2 is also a voluntary submission under the Kyoto Protocol for Luxembourg. In this context, a Party included in Annex I to the Convention that is also Party to the Kyoto Protocol – such as Luxembourg – could start reporting supplementary information from the year 2008 onwards, though these elements, according to Articles 5, 7 and 8 of the Kyoto Protocol, will only be compulsory for the first year of the commitment period after the Protocol has entered into force for that Party.[29] Luxembourg will not provide the whole spectrum of supplementary information it **could** report in the Kyoto Protocol reporting scheme at the moment, but rather focus on one element: its National Registry.

1.9.1. A consolidated system for the National Registry

Luxembourg and Belgium maintain a consolidated registry system with both registries operating independently but sharing the same hardware environment. The software application is based on the "Community registry software" provided under a free license by the European Commission.

The following project partners are involved in the registry activities:

- software development: ....Dr. Lippke & Dr. Wagner Gmbh, Berlin
- software maintenance: ....Dr. Lippke & Dr. Wagner Gmbh, Berlin
- hardware and network hosting: ....Colt Telecom Gmbh
- technical support and adaptive maintenance:.....Colt Telecom Gmbh

The different tasks of the partners are summarised in Table 1-10 below.

Table 1-10 – National Registry – partners' tasks

Partners	Tasks
Registry administrators Belgium-Luxembourg	- project coordination, planning, development - coordination with software provider, support/hosting company, other Registries, ITL/CITL - incident solving
Support/hosting company	- adapting interface - keep the Registry running - Internet/server security - incident solving - back-up/disaster recovery - 2nd level helpdesk
Database manager	- 1st level user helpdesk - daily administration - test of new software versions
Software provider	- version development - incident solving - 3rd level helpdesk

1.9.2. National Registry accesses

A public access to the Registry is possible from the environment web portal of Luxembourg: http://www.environnement.public.lu/air_bruit/dossiers/registre_national_quotas_GES/index.html.

29 See letter to the Parties from the UNFCCC Secretariat of 13 March 2008 on the submission of information under Articles 5, 7 and 8 of the Kyoto Protocol.

The following information is available to the public on this web page:

- international policy context;
- National Allocation Plan (*NAP*);
- FAQ;
- helpdesk;
- access to the secured site for the National Registry: https://www.climateregistry.lu.

1.9.3. Database structure and capacity of the National Registry

The database structure and capacity correspond to the requirements of the Data Exchange Standards (*DES*) as found out during the review of Luxembourg's national GHG inventories in June 2007 and during the IAR awarding process which ended up in a positive recommendation for the National Registry as forwarded by the UNFCCC Secretariat to the ERT on 10 December 2007.[30]

More details concerning the database structure and the technical standards for data exchange are to be found in the readiness questionnaire together with additional clarifications handed to the UNFCCC secretariat before the closure of the IAR process.

1.9.4. National Registry security

Prior to opening an account in the Registry, an ID-Check (= passport copy, paper signature) is performed before granting access trough a Username/Password combination. An automatic logoff ensures that no unauthorised person may have access to an account in absence of the holder.

The Registry System is secured by a SSL/VPN secure login whereas data integrity is checked during a reconciliation every night. In order to re-establish coherent databases, manual interventions are performed by the Registry administrator in case of a negative result from a reconciliation.

Updating of software is only performed after thorough tests in a test environment in order to minimise the risk that updates and patches might destabilising the system.

Internet/server hardware are monitored 24/7 year round. At the hosting company level, the registry software is running on dedicated servers which are backed-up according to procedures detailed in the above-mentioned readiness questionnaire.

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30 See the IAR report: http://unfccc.int/kyoto_protocol/registry_systems/independent_assessment_reports/items/4061.php as well as paragraph 127 of the Report of the review of the initial report of Luxembourg (doc. FCCC/IRR/2007/LUX of 14 December 2007): http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/items/3765.php.

1.9.5. National Registry Data Centre

The Data Centre in Berlin is equipped with a redundant power supply, with UPS systems as well as with emergency power supplies for longer outages. Air-conditioning is maintained by separate systems at 20-25 °C and 40-60% RH.

Access to the Data Centre is very limited and strictly controlled.

A redundant fire detection system is in place and communication is ensured by 2 Internet Service Providers trough multiple access points.

1.9.6. Persons and moral persons holding Registry accounts

The Government of Luxembourg did not allocate specific authorizations as regards the various Kyoto units. In fact, if one person or a moral person opens an account in the Registry, it is automatically authorized to hold any type of Kyoto units. Table 1-11 below lists the moral persons and the persons holding an account in the National Registry. This list is compliant with Article 6 of Decision 2005/166/EC.[31]

Table 1-11 – National Registry – authorized persons and moral persons

Moral persons authorised to hold any unit type in the Registry		
Installation	Operator	Categories of activities
Cegyco S.A.	Cegyco S.A.	Combustion
Centrale énergétique "Power"	Dupont de Nemours Luxembourg	Combustion
Installation de cogénération	Ceduco S.A.	Combustion
Guardian Luxguard I S.A.	Guardian Luxguard I	Glass
Guardian Luxguard II S.A.	Guardian Luxguard II	Glass
Usine Intermoselle	Ciments Luxembourgeois S.A.	Cement clinker
Kronospan Luxembourg S.A.	Kronospan Luxembourg S.A.	Combustion
Centrale d'énergie du Kirchberg	Luxénergie S.A.	Combustion
Centrale d'énergie Stade Josy Barthel	Luxénergie S.A.	Combustion
Luxlait Association Agricole	Luxlait Association Agricole	Combustion
Arcelor Rodange - Site d'Esch-Schifflange	Arcelor Rodange S.A.	Pig iron or steel
Arcelor Profil Luxembourg - Site de Differdange	Arcelor Profil Luxembourg S.A.	Pig iron or steel
Arcelor Profil Luxembourg - Site d'Esch-Belval	Arcelor Profil Luxembourg S.A.	Pig iron or steel
Primorec S.A.	Primorec S.A.	Pig iron or steel
Centrale TGV d'Esch/Alzette	Twinerg S.A.	Combustion
Persons holding accounts		
Carbon Management Consulting LTD		
Cegedel SA		

31 Commission Decision 2005/166/EC of 10 February 2005 laying down rules implementing Decision 280/2004/EC of the European Parliament and of the Council concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol.

For more information on Section 1.9, please contact:

Georges BLASEN
Administration de l'Environnement
16, rue Eugène Ruppert
L-2453 Luxembourg
Tel: (+352) 40 56 56 556
Fax: (+352) 48 50 78
E-mail: georges.blasen@aev.etat.lu

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For more information on Chapter 1 as a whole,
please contact:

Eric DE BRABANTER
Ministère de l'Environnement
18, Montée de la Pétrusse
L-2918 Luxembourg
Tel: (+352) 247-86842
Fax: (+352) 247-86835
E-mail: eric.debrabanter@mev.etat.lu

2. Trends in GHG Emissions

According to the Kyoto Protocol, Luxembourg's GHG emissions will have 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 have 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"[32] 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.

When appreciating 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. This is the reason why this chapter starts with a section examining specific national circumstances. These specific conditions are relating to socio-economic characteristics that have significant effects on Luxembourg's GHG total emissions when applying IPCC accounting rules.

The second section of this chapter will provide an overview of the GHG emission trends for Luxembourg as they can be figured out from the GHG inventory.

2.1. National Circumstances

2.1.1. Demography, geography and climate

2.1.1.1. Demographic structure and workforce

End 2006, the population of Luxembourg amounted to 476 200 inhabitants. Within 45 years, the residential population has grown by some 161 000 inhabitants or about 51% – almost 24% since 1990. Compared to neighbouring countries Luxembourg shows a rather unique development of its demographic growth rates.

Table 2-1 – Population growth: 1960-2006

calculated on 31st December	1960	1990	2000	2001	2002	2003	2004	2005	2006
(x 1000)	314.9	384.4	439.0	444.0	448.3	455.0	461.2	469.1	476.2

Source: STATEC, *Statistical Yearbook*, Table B.1100: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1058

Demographic growth in Luxembourg is dominated by immigration. Nationals themselves saw their number stagnating and without immigrants taking the citizenship of Luxembourg they would even have fallen. Population growth is one of the key drivers for domestic energy use,

32 Council Decision of 25 April 2002 (2002/358/EC) concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the UNFCCC and the joint fulfilment of commitments thereunder (OJ L130, 15.5.2002). See also document FCCC/CP/2002/2.

mainly in the housing and transportation sector. Thus, the past and future developments had and will have a significant impact on energy use and, consequently, on Luxembourg's GHG emissions.

In addition to the population growth in Luxembourg, end 2006, 129 000 cross-border commuters from neighbouring regions were working in Luxembourg: 50.8% of the commuters came from France, 26.1% from Belgium and 23.1% from Germany. In total, the commuters accounted for about 43% of all paid workers in Luxembourg and for about 27% (i.e. more than a quarter) of the residential population.[33] A dominant share of workers from abroad commute by car. 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 2-2 – Cross-border commuters: 1980-2006

calculated on 31st December	1980	1990	2000	2001	2002	2003	2004	2005	2006
(x 1000)	11.9	35.3	90.3	100.1	104.9	108.8	114.4	121.2	129.0

Source: STATEC, *Statistical Yearbook*, Table B.5107: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1178

Note: from 2001 onwards, calculated on 30th September.

2.1.1.2. Geography

The total land surface of Luxembourg covers 2 586 km². The maximum distance from north to south is some 82 km, from west to east about 57 km. Of the total area of Luxembourg, in 2003, about 87% was agricultural land and land under forest. The built-up areas occupied about 8% of the total surface and land covered by water and transport infrastructure about 5%.

Table 2-3 – Land use in Luxembourg: 1972-2006

(percentages)	1972	1990	2000	2005	2006
Total land	100.0	100.0	100.0	100.0	100.0
Agricultural & wooden area	93.2	91.8	87.4	86.5	86.4
Built-up area	3.1	4.3	8.1	8.7	8.8
of which industrial area & other	*…*	*…*	*2.7*	*2.8*	*2.8*
Transport network & sheets of water	3.2	3.4	3.9	4.2	4.2
Watercourses	0.5	0.5	0.6	0.6	0.6

Source: STATEC, *Luxembourg in Figures 2007*, page 6: http://www.statistiques.public.lu/fr/publications/horizontales/luxChiffresEN/index.html

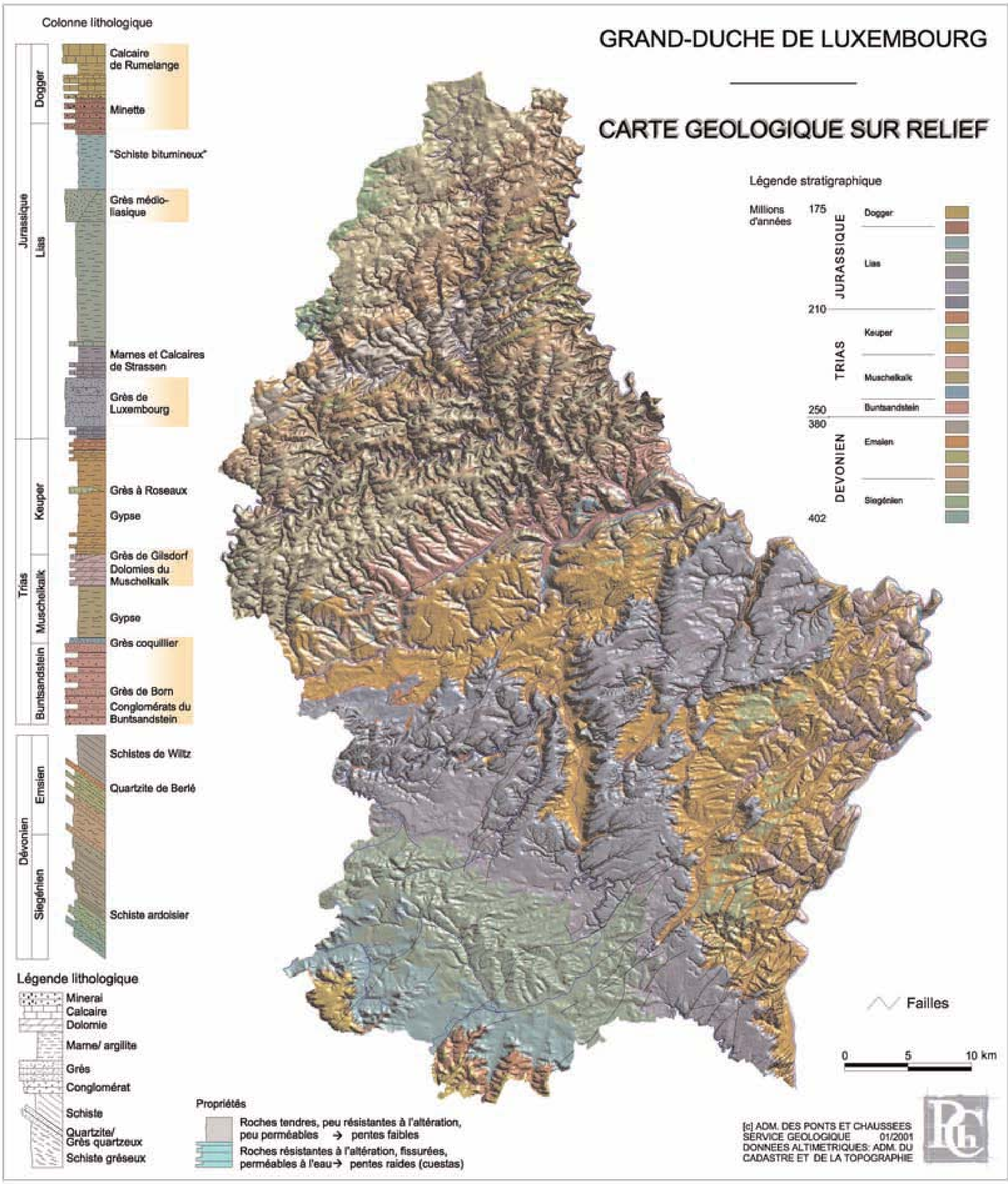
The north of Luxembourg is a part of the Ardennes and is called "Ösling". Its altitude is at an average of 400 to 500 meters above sea level. The "Ösling" landscape is affected by hills and deep river valleys, as for instance the Sure River (Sauer). With 560 m, the highest elevation is called the "Kneiff"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

33 Figures presented in this paragraph come from STATEC, *Statistical Yearbook*, tables B.5100 and B.5107 (situation in September 2006 for B.5107): http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1171 for B.5100 and http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1178 for B.5107.

confluence of the Moselle and the Sure rivers in Wasserbillig. Most important rivers are the Moselle, the Sure, the Our – all three delimiting the border with Germany – and the Alzette.

A geological map of Luxembourg is presented below (in French).

Illustration 2-1 – Geological map of Luxembourg's territory



Source: STATEC, *Annuaire statistique du Luxembourg 2007*, page 5: http://www.statistiques.public.lu/fr/publications/horizontales/annuaireStatLux/index.html

2.1.1.3. Climate

The climate in Luxembourg is a moderate Western European climate with mild winters and comfortable summers. For the city of Luxembourg, average temperatures in January, the coldest month, are about 0.8°C. Highest temperatures are reached typically during the summer months July and August. At this time the average temperature is about 17.5°C. Minimum and maximum temperatures reach from minus 10°C in January to more than 30°C in July. For the inventory reporting, according to definitions in place, with an annual average temperature below 15°C, Luxembourg lies in a **cool climate region**.

Table 2-4 – Climate in the city of Luxembourg: averages for the period 1971-2000

	January	April	July	October	12 months
Average temperature – °C	0.8	8.3	17.5	9.5	9.0
Maximum temperature – °C	10.4	21.8	30.9	20.2	20.5
Minimum temperature – °C	-10.0	-3.4	6.0	-1.7	-1.3
Rainfall – mm	69.0	50.6	62.9	63.8	782.2

Source: STATEC, *Statistical Yearbook*, Table A.2000: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1017

Climate conditions have a significant impact on energy use for heating purposes. An increase in average temperature in the upcoming years should have a positive impact on energy use, especially in the residential, commercial and institutional sectors. Such an increase in average temperature is observed over the last year, as it can be seen from Table 2-5.[34] Nevertheless, other meteorological parameters do not show clear trends.

Table 2-5 – Evolution of some meteorological parameters for the city of Luxembourg: yearly averages 1961-2006

(12 months averages)	1961-1990	1990	2000	2003	2004	2005	2006
Average temperature – °C	9.0	9.3	9.9	9.9	10.8	10.5	11.1
Rainfall – mm	NE	781.9	1022.0	678.0	710.4	610.8	848.7
Sunshine hours	1631	1949	NE	NE	1402	NE	1601
Humidity – %	80	78	81	73	79	80	NE

Source: STATEC, *Statistical Yearbook*, Table A.2100: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1018

2.1.2. Economic structure

Gross value added in Luxembourg is mainly generated in the financial and corporate service sector. The share of total gross value added in this branch has increased from about 39% in 1995 to nearly 48.5% in 2006. While the commercial sector has maintained a constant share at about 21 to 23%, the share of the industry sector has decreased significantly from 15% in 1995 to a bit more than 9% in 2006. Other service activities ranged between a share of 15 to 17%. Construction kept a constant share in total gross value added at a low level of about 6%, with drops during years char-

34 For monthly details, see table A.2100 in STATEC's *Statistical Yearbook:* http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1018

acterized by an economic slowdown (2000 and 2006 e.g.). The contribution of the agricultural sector is negligible with less than 1%.

The increasing shares in gross value added from less energy and carbon intensive sectors (as financial and services) has a positive effect on the carbon intensity of the Luxembourg economy.

Table 2-6 – Sectoral gross value added at current prices: 1995-2006[35]

(mio. €)	1995	2000	2001	2002	2003	2004	2005	2006
Agriculture, hunting, forestry and fishing (A & B)	140.6	134.3	136.5	143.6	141.3	139.9	116.8	109.7
%	1.0%	0.7%	0.7%	0.7%	0.6%	0.6%	0.4%	0.4%
Total industry, including energy (C to E)	2088.6	2475.1	2519.8	2523.9	2552.5	2607.1	2592	2847.1
%	15.3%	12.6%	12.4%	11.7%	11.0%	10.6%	9.7%	9.3%
Construction (F)	884.1	1126.4	1247.2	1446.5	1495.8	1528	1634.3	1615.6
%	6.5%	5.7%	6.2%	6.7%	6.5%	6.2%	6.1%	5.3%
Wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods; hotels and restaurants; transport, storage and communication (G to I)	2915.7	4274.1	4567.5	4848.8	5000.3	5371.1	5714.8	6415.2
%	21.3%	21.8%	22.5%	22.5%	21.6%	21.9%	21.3%	21.0%
Financial intermediation; real estate, renting and business activities (J& K)	5366.0	8587.2	8362.2	8975.5	10052.8	10548.8	12274.2	14835.4
%	39.2%	43.8%	41.2%	41.7%	43.5%	43.1%	45.7%	48.5%
Other services (public aministration and defence, compulsory social security; education; health and social work; other community social and personal service activities; private households with employed persons (L to P)	2279.9	3026.3	3439.8	3603.9	3879.7	4290.6	4521.7	4787.7
%	16.7%	15.4%	17.0%	16.7%	16.8%	17.5%	16.8%	15.6%
Total: all NACE branches	13675.1	19623.4	20273.1	21542.2	23122.3	24485.6	26853.8	30610.8

Source: STATEC, *Statistical Yearbook*, Table D.1304: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1428

2.1.3. UNFCCC and Kyoto Protocol: a demanding challenge for Luxembourg

2.1.3.1. Location and corresponding 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 (see Illustration 2-2) and, therefore, has traditionally had a high volume of road transit traffic for both goods (freight transport) and passengers (tourists on their way to 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 consumes less than one quarter of the total road fuels sold in Luxembourg.

35 Data prior to 1995 have not yet been translated into the new System of Economic Accounts (SEC).

Illustration 2-2 – Geographic location of Luxembourg

Source: http://www.gouvernement.lu

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 almost 80% of the emissions (with an upward trend since the early 1990s) cannot be assigned to vehicles registered in Luxembourg and are actually emitted mostly abroad. This phenomenon is referenced as "road fuel export", i.e. fuel sold to non-residents – whether they are in transit or commuting for work or leisure. Luxembourg thus exhibits a completely untypical and unique structural feature in its GHG emissions balance: in 2006, of the approx. 7.25 Mio. tonnes of CO_2-equivalents (*t CO_2e*) produced by the road transportation sector, almost 5.6 Mio. t CO_2e, or 77%, was the result of road fuels bought by non-residents and were, consequently, merely emitted abroad. That amount represented around 41.7% of the total GHG emissions for Luxembourg (excluding LULUCF). According to the baseline scenario used by Luxembourg for its second NAP, this proportion may increase up to 46% by 2012.[36]

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36 See also tables and figures in Section 2.2 below.

Since Luxembourg's public finances have to rely on overall lower specific rates of taxation and excises, 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 are higher than those in the surrounding countries, it is 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.

2.1.3.2. 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.

These last years, the construction of a single power station, the ultra-modern TWINerg gas and steam plant, represents a further illustrative example: the plant, located in Esch-sur-Alzette, is a gas and steam turbine power station running on natural gas, with an electrical output of 350 MWel (efficiency 57% new).[37] There are plans for decoupling heat at a later stage (28 MWth) for remote heating of the new Belval-Ouest district project.[38] When TWINerg started its operation in mid-2002, Luxembourg, which to all intents and purposes did not have so far any substantial electricity generating capacity to call its own, saw, at once, its GHG emissions increasing by about 1 Mio. t CO_2e. To give another illustration on how this project affected the GHG emissions pattern in Luxembourg, one can underline that it represents an extra 40% to the emissions volume of the whole GHG ETS sector.

The impact that single industrial projects might have, plays also the other way round when a production unit or a plant is closed down. If this problematic might not be an issue for large economies, it is for Luxembourg, as shown by the examples discussed above.

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37 See http://www.twinerg.lu/data/fr/home.htm

38 See http://www.agora.lu.

2.1.3.3. 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 are 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 more than half of Luxembourg's total GHG emissions in 1990 – total emissions from industry and electricity generation – i.e. largely the sectors covered by the ETS – decreased to just approx. 2.4 Mio. t CO_2e in 1998 – or approx. 26% of total GHG emissions (excluding LULUCF) – coming from approx. 8.2 Mio. t CO_2e in 1990.

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 combined heat-power (*CHP*) installations and the ultramodern gas and steam power station (TWINerg) that have been promoted and are operating in Luxembourg since 1998 have led to an additional amount of approx. 1.2 Mio. t CO_2e in the GHG balance.[39] It is therefore clear that any new fossil-fuel power generating installation that might be constructed will inevitably lead to a deterioration of Luxembourg's GHG balance. This also implies that the implementation of the EU CHP installation guidelines, which in other countries may lead to CO_2 reductions thanks to increased efficiency, is counterproductive for Luxembourg.

2.1.3.4. The "origin" principle of the IPCC reporting Guidelines vs. the "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" approach produce. The "origin" principle is in favour of Luxembourg in the fact 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 export emissions are recorded in Luxembourg's GHG balance.

Now, if the "polluter pays" principle is used as a yardstick, Luxembourg's assessment is that, at present,[40] its GHG emissions according to the IPCC Guidelines are approx. 2.5 Mio. t CO_2e "too high". The same correction for the year 2012 has been evaluated in the framework of the second

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39 1Mio. t CO_2e for the TWINerg and 0.2 Mio. T CO_2e for CHP installations.

40 Estimates for the year 2004 realized while producing the second NAP.

NAP for Luxembourg. For the baseline scenario, it gave a difference of approx. 4.8 Mio. t CO_2e between the "origin" and the "polluter pays" principles with the former higher than the latter.

Thus, Luxembourg's efforts to develop efficient, low-carbon electricity production is 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 use based upon renewable energies and, for all these policies, further developments are still in the offing. The impact of these policies has been evaluated: it has been estimated that electricity imports – with an average emission factors of 0.78 (kt CO_2 per GWh) – have fallen by more than 2 000 GWh since 1998 and have been replaced by national electricity generation with an average emission factor of 0.41 (kt CO_2 per GWh).

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.

2.2. Description of Emission Trends for GHG Emissions

This section presents Luxembourg's GHG emission trends between the base year (1990) and the latest year covered by submission 2008v1.2, i.e. 2006. For the purpose of an accurate analysis of Luxembourg's emissions, the classical examination of GHG source and sink categories as defined in the CRF (Section 2.2.1 to 2.2.4) will be completed, in Section 2.2.5, by:

- an alternative combination of the CRF source and sink categories so to clearly isolate the major drivers behind GHG emission trends and structure in Luxembourg;
- tables and figures on energy consumption and production.

2.2.1. GHG trend overview

In 2006, as underlined by Table 2-7, carbon dioxide was the main source of GHG in Luxembourg. This source counted for a bit less than 91% of the total GHG emissions calculated in CO_2e – total excluding LULUCF.[41] The second source of GHG was nitrous oxide with about 5% of the total emissions. Methane was the third source with 3.5%. Fluorinated gases only accounted for 0.7% of the total emissions, with hydrofluorocarbons representing 0.65% of the total and sulphur hexafluoride representing 0.03% of the total. There were no known sources of perfluorocarbons in Luxembourg.

In 2006, total GHG emissions amounted to 13.322 Mio. t CO_2e, 1.03% above their level for the base year.[42] As Figure 2-1 shows, several phases can clearly be distinguished over the period 1990 to 2006:

- firstly, from base year up to 1994, Luxembourg's emissions remained rather stable;
- then, between 1995 and 1998, they started to decrease significantly to reach their lowest value in 1998;
- from 1999 up to 2004, emissions augmented recurrently;
- from 2004 onwards, a stabilisation around 13.3 Mio. t CO_2e is observed.

The evolution during those 17 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.

A major 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 (see Section 3.4.3). This process change was the main driver for the reduction in GHG emissions observed between 1995 and 1998. Changes also occurred in the industrial and residential/commercial/institutional sectors, where the consumption of liquid fuels (residual oil, gasoline) was reduced in favour of natural gas in conjunction with the extension of the natural gas network in Luxembourg.

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41 In Section 2.2, when it is referred to "total GHG emissions" it is meant "total GHG emissions excluding LULUCF". Nevertheless, as actual LULUCF emission estimates reported in the inventory are constant (see Table 2-7 and Chapter 7), excluding or including LULUCF does not change trends but only the weights of each gas and/or sector in a total, whether it includes or excludes LULUCF.

42 The base year for CO_2, CH_4 and N_2O is 1990. For the F-gases, the base year is 1995. However, due to lack of data on F-gases for the first half of the 1990s, 1995 emission estimates are equalled to 1990 emission estimates (see Table 2-7).

Table 2-7 – Luxembourg's GHG emissions and removals – overview by main gases and CRF Sectors: 1990-2006

Gg (1000 t.) CO_2 equivalent	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2 emissions, incl. net CO_2	11924.27	12203.07	12031.21	12276.92	11471.62	9017.53	9082.14	8428.12	7673.10	8263.08	8745.53	9054.72	9862.97	10239.26	11872.56	11769.36	11813.36
from LULUCF (1)	*92.50%*	*92.49%*	*92.11%*	*92.26%*	*91.99%*	*89.82%*	*89.62%*	*88.73%*	*87.59%*	*88.10%*	*88.43%*	*88.93%*	*89.58%*	*90.05%*	*90.58%*	*90.56%*	*90.68%*
CO_2 emissions, excl. net CO_2	12219.20	12498.00	12326.14	12571.85	11766.55	9312.46	9377.07	8723.05	7968.03	8558.01	9040.46	9349.65	10157.90	10534.19	12167.49	12064.29	12108.29
from LULUCF	*92.66%*	*92.65%*	*92.28%*	*92.43%*	*92.18%*	*90.11%*	*89.91%*	*89.07%*	*88.00%*	*88.46%*	*88.76%*	*89.24%*	*89.85%*	*90.31%*	*90.78%*	*90.77%*	*90.89%*
CH_4 (2) emissions, incl. net CH_4	460.04	468.61	462.73	473.77	455.18	469.75	478.48	477.62	479.22	490.89	486.64	483.63	481.88	475.25	471.17	469.18	463.56
from LULUCF (1)	*3.57%*	*3.55%*	*3.54%*	*3.56%*	*3.65%*	*4.68%*	*4.72%*	*5.03%*	*5.47%*	*5.23%*	*4.92%*	*4.75%*	*4.38%*	*4.18%*	*3.59%*	*3.61%*	*3.56%*
CH_4 (2) emissions, excl. net CH_4	460.04	468.61	462.73	473.77	455.18	469.75	478.48	477.62	479.22	490.89	486.64	483.63	481.88	475.25	471.17	469.18	463.56
from LULUCF	*3.49%*	*3.47%*	*3.46%*	*3.48%*	*3.57%*	*4.55%*	*4.59%*	*4.88%*	*5.29%*	*5.07%*	*4.78%*	*4.62%*	*4.26%*	*4.07%*	*3.52%*	*3.53%*	*3.48%*
N_2O (3) emissions, incl. net N_2O	490.15	505.83	550.77	538.77	526.38	535.48	550.34	564.13	572.79	584.50	611.33	588.73	603.28	585.27	685.53	670.83	659.15
from LULUCF (1)	*3.80%*	*3.83%*	*4.22%*	*4.05%*	*4.22%*	*5.33%*	*5.43%*	*5.94%*	*6.54%*	*6.23%*	*6.18%*	*5.78%*	*5.48%*	*5.15%*	*5.23%*	*5.16%*	*5.06%*
N_2O (3) emissions, excl. net N_2O	490.15	505.83	550.77	538.77	526.38	535.48	550.34	564.13	572.79	584.50	611.33	588.73	603.28	585.27	685.53	670.83	659.15
from LULUCF	*3.72%*	*3.75%*	*4.12%*	*3.96%*	*4.12%*	*5.18%*	*5.28%*	*5.76%*	*6.33%*	*6.04%*	*6.00%*	*5.62%*	*5.34%*	*5.02%*	*5.11%*	*5.05%*	*4.95%*
HFCs (4)	14.21	14.21	14.21	14.21	14.21	14.21	19.97	25.73	31.49	37.25	43.01	50.92	58.82	66.73	74.63	82.54	87.04
	0.11%	*0.11%*	*0.11%*	*0.10%*	*0.11%*	*0.14%*	*0.19%*	*0.26%*	*0.35%*	*0.39%*	*0.42%*	*0.49%*	*0.52%*	*0.57%*	*0.56%*	*0.62%*	*0.65%*
PFCs (4)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
SF_6 (4)	2.91	2.91	2.91	2.91	2.91	2.91	3.03	3.15	3.28	3.40	3.52	3.57	3.62	3.68	3.73	3.78	3.86
	0.02%	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.03%*	*0.03%*	*0.03%*	*0.04%*	*0.04%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*
1. Energy	10730.04	11109.78	11043.81	11313.88	10604.45	8510.75	8643.58	8112.02	7526.63	8101.10	8579.38	8958.99	9776.39	10233.46	11875.14	11828.22	11812.00
	81.37%	*82.36%*	*82.68%*	*83.18%*	*83.07%*	*82.35%*	*82.88%*	*82.83%*	*83.12%*	*83.74%*	*84.24%*	*85.52%*	*86.47%*	*87.73%*	*88.60%*	*89.00%*	*88.67%*
2. Industrial Processes	1612.68	1535.59	1465.61	1445.58	1352.51	992.16	942.47	839.46	686.29	729.84	761.99	713.53	737.19	686.27	735.85	702.42	754.48
	12.23%	*11.38%*	*10.97%*	*10.63%*	*10.60%*	*9.60%*	*9.04%*	*8.57%*	*7.58%*	*7.54%*	*7.48%*	*6.81%*	*6.52%*	*5.88%*	*5.49%*	*5.29%*	*5.66%*
3. Solvent and Other Product Use	18.31	18.00	17.67	17.41	17.13	16.86	16.59	16.29	16.01	15.68	15.17	14.59	14.68	14.72	14.78	14.90	15.08
	0.14%	*0.13%*	*0.13%*	*0.13%*	*0.13%*	*0.16%*	*0.16%*	*0.17%*	*0.18%*	*0.16%*	*0.15%*	*0.14%*	*0.13%*	*0.13%*	*0.11%*	*0.11%*	*0.11%*
4. Agriculture	775.94	781.73	785.78	777.29	755.31	778.76	789.17	786.73	784.28	785.50	782.40	747.40	737.47	686.70	732.61	699.92	694.86
	5.88%	*5.80%*	*5.88%*	*5.71%*	*5.92%*	*7.54%*	*7.57%*	*8.03%*	*8.66%*	*8.12%*	*7.68%*	*7.13%*	*6.52%*	*5.89%*	*5.47%*	*5.27%*	*5.22%*
5. LULUCF (5)	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
6. Waste	49.53	44.44	43.89	47.34	35.82	36.28	37.08	39.17	41.60	41.91	46.02	42.00	39.76	43.97	44.17	45.16	45.49
	0.38%	*0.33%*	*0.33%*	*0.35%*	*0.28%*	*0.35%*	*0.36%*	*0.40%*	*0.46%*	*0.43%*	*0.45%*	*0.40%*	*0.35%*	*0.38%*	*0.33%*	*0.34%*	*0.34%*
7. 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*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Total GHG including LULUCF	12891.58	13194.62	13061.82	13306.57	12470.28	10039.88	10133.96	9498.75	8759.88	9379.11	9890.04	10181.57	11010.57	11370.19	13107.62	12995.68	13026.97
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*
Total GHG excluding LULUCF	13186.51	13489.55	13356.75	13601.50	12765.21	10334.81	10428.89	9793.68	9054.81	9674.04	10184.97	10476.50	11305.50	11665.12	13402.55	13290.61	13321.90
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Source: Environment Agency and Ministry for Environment.

Notes:

(1) these percentages are relative to the total GHG emissions, including LULUCF.

(2) the methane emissions are converted in CO_2 equivalents by multiplying the emissions by 21, i.e. the global warming potential (GWP) value for methane based on the effects of GHG over a 100-year time horizon.

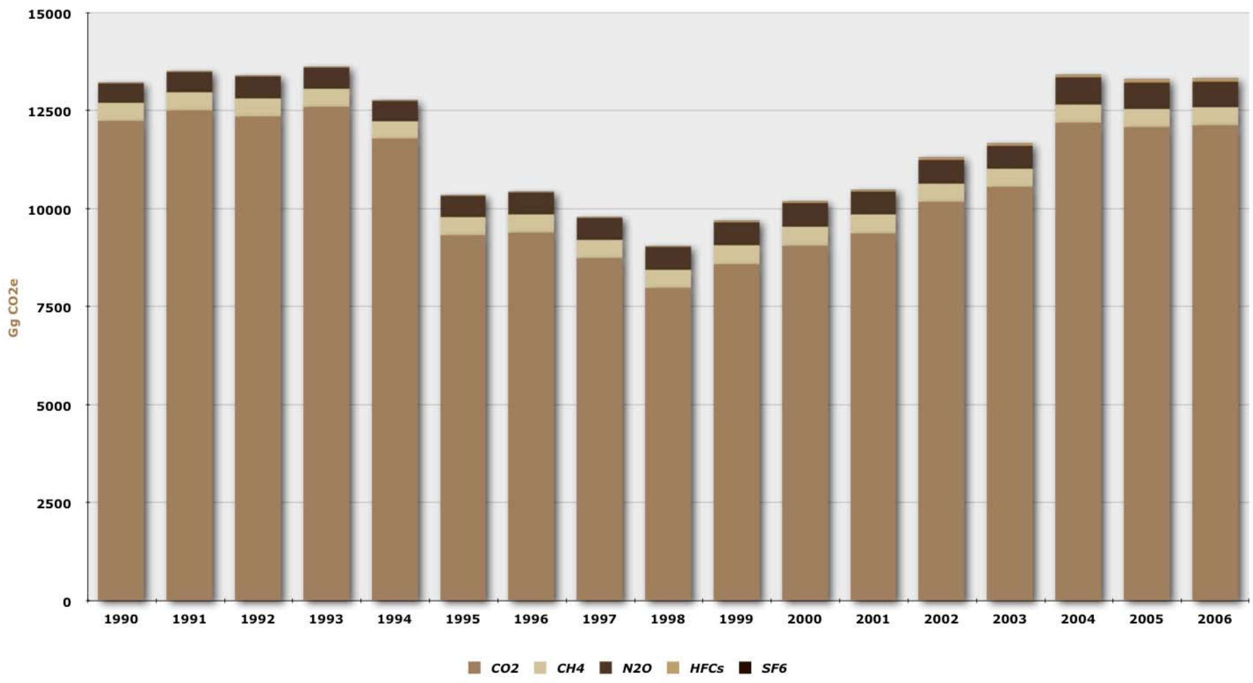
(3) the nitrous oxide emissions are converted in CO_2 equivalents by multiplying the emissions by 310, i.e. the global warming potential (GWP) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

(4) the F-gases are those not covered by the Montreal Protocol, i.e. the HFCs, PFCs and SF6 expressed in CO_2 equivalents using the the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

(5) the land-use change and forestry emissions are based on constant estimates of 294.93 Gg of CO_2 for changes in forest and other woody biomass stocks (CRF 5A).

Figure 2-1 – Luxembourg's GHG emissions and removals (excl. LULUCF) – absolute values: 1990-2006

GHG



CRF Sectors

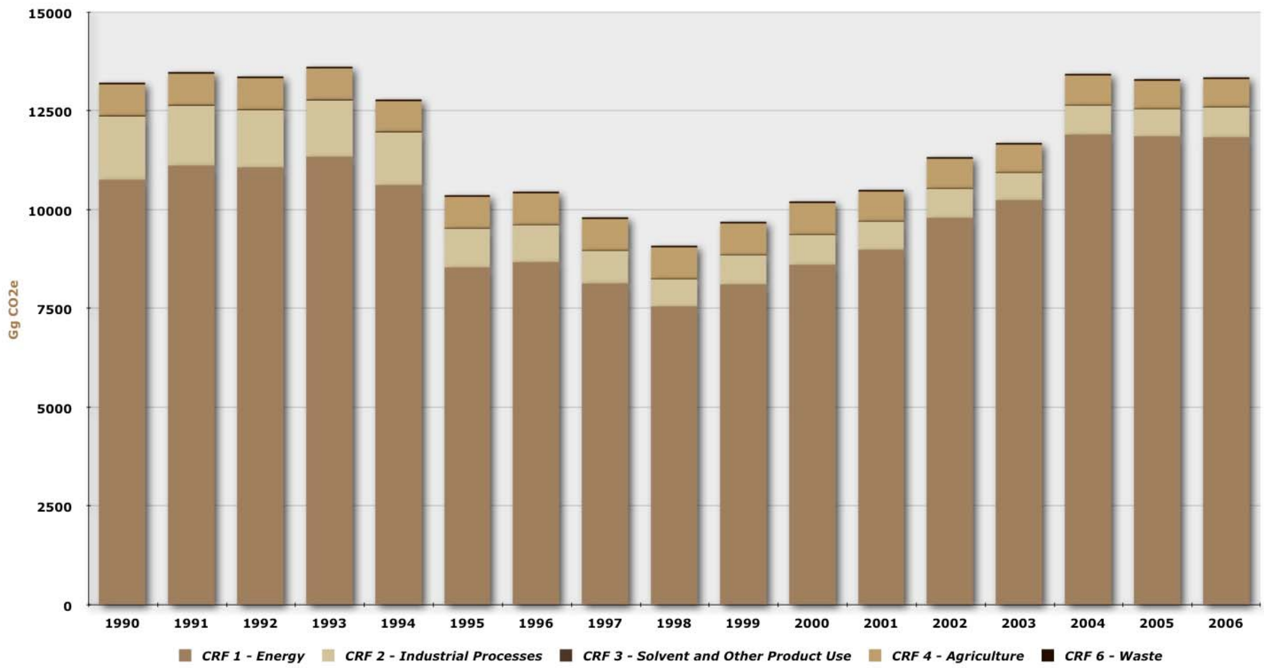
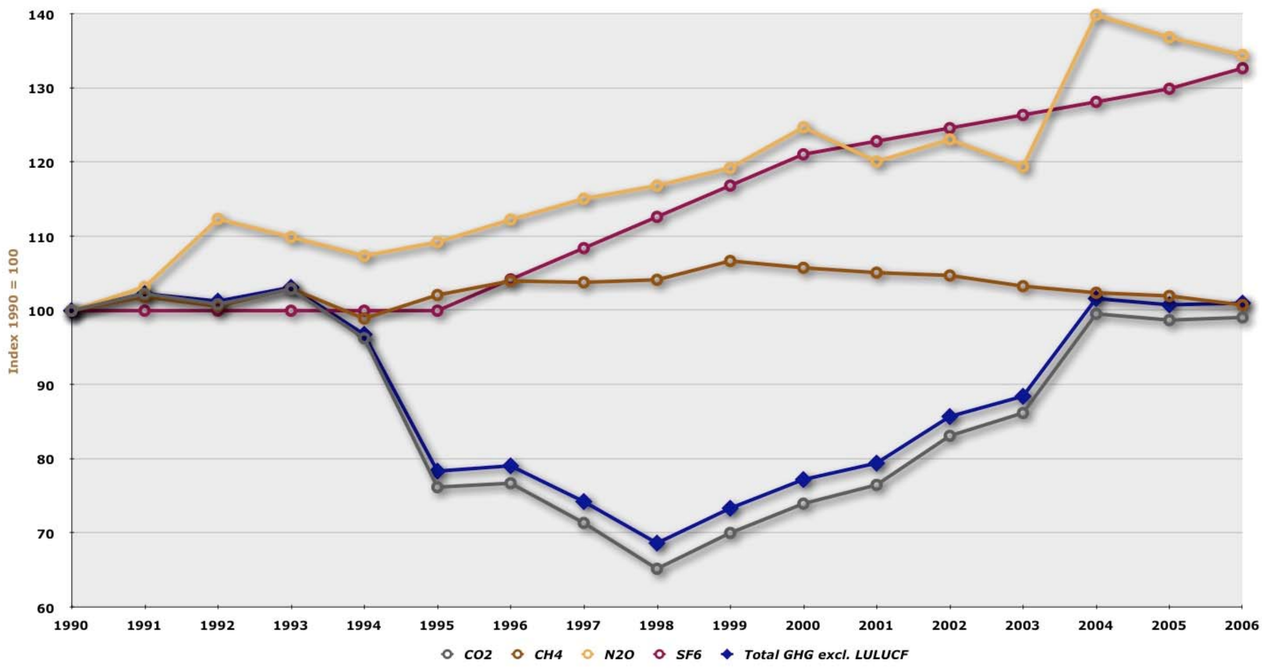


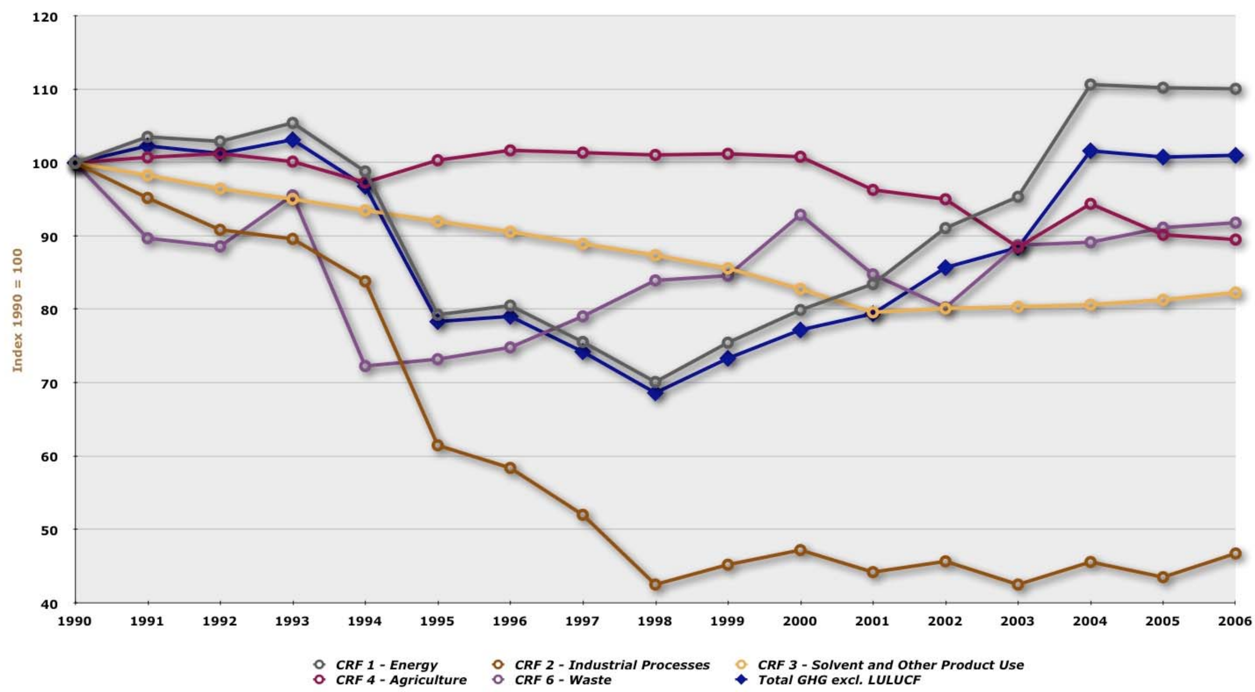
Figure 2-2 – Luxembourg's GHG emissions and removals (excl. LULUCF) – indexes: 1990-2006

GHG



Note: HFcs are not included in this figure for readability reasons (+612.7% between 1990 and 2006).

CRF Sectors



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 is merely justified by increasing energy consumption and fuel sales in the transport sector. The stabilization spotted for the last inventory years (2004 to 2006) is largely the result of a lower use of energy in some manufacturing sectors and a reduction of gasoline sales for road transportation.

More detailed explanations are provided in Sections 2.2.2 (dealing with gases) and 2.2.3 (on CRF Sectors), as well as in the analysis of emission trends for each sector (see the first section of CRF Sectors Chapters 3 to 8).

A fundamental point worth mentioning when analysing Luxembourg's GHG emissions trend and 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 6.9 Mio. t in 1990, CO_2 emissions from industrial processes and fuel combustion in industry accounted for 52% of total GHG emissions. They could eventually be reduced to 2.3 Mio. t in 1998 – i.e. 25% 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, in Esch-sur-Alzette, of a power plant – TWINerg – with a gas vapour turbine with an electrical output of 350 MWel (see also Section 2.1.3.2 above). This plant started its operation in mid-2002 and, by 2006, was responsible of about 1 Mio. t CO_2, i.e. around 8% of the total GHG emissions. These considerations can easily be identified in Table 2-8 that distributes, for each GHG, emissions amongst the main source categories.

2.2.2. GHG trends by gas

For the different GHG, trends over the period 1990-2006 were as follows:

- CO_2: .... -0.91%
- CH_4: .... +0.77%
- N_2O: .... +34.48%
- F-gases: ...... +431,12%

For carbon dioxide, the relatively close values estimated in 1990 and 2006 respectively hide a U-shape evolution over the period as well as important changes in the sources of CO_2 emissions: declining emissions in industrial and thermal power plant combustion, increasing emissions from transport and for natural gas fired power plants – as underlined in the previous section. Methane emissions have increased by less than a percent over the period.

Table 2-8 – Luxembourg's GHG emissions and removals – details by main gases: 1990-2006

Gg (1000 t.) CO_2 equivalent	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2	12219.20	12498.00	12326.14	12571.85	11766.55	9312.46	9377.07	8723.05	7968.03	8558.01	9040.46	9349.65	10157.90	10534.19	12167.49	12064.29	12108.29
	92.66%	*92.65%*	*92.28%*	*92.43%*	*92.18%*	*90.11%*	*89.91%*	*89.07%*	*88.00%*	*88.46%*	*88.76%*	*89.24%*	*89.85%*	*90.31%*	*90.78%*	*90.77%*	*90.89%*
of which																	
CRF 1 - Energy	10614.59	10970.44	10868.54	11134.20	10421.94	8328.14	8448.24	7903.07	7307.05	7859.33	8315.66	8681.46	9473.94	9909.11	11500.78	11438.90	11435.38
	80.50%	*81.33%*	*81.37%*	*81.86%*	*81.64%*	*80.58%*	*81.01%*	*80.70%*	*80.70%*	*81.24%*	*81.65%*	*82.87%*	*83.80%*	*84.95%*	*85.81%*	*86.07%*	*85.84%*
CRF 1A1 - Fuel Combustion from	1301.82	1245.90	1142.90	1231.20	1029.62	817.46	707.94	431.76	122.68	164.93	315.40	325.94	1167.34	1154.01	1454.57	1415.16	1461.98
Energy Industries	*9.87%*	*9.24%*	*8.56%*	*9.05%*	*8.07%*	*7.91%*	*6.79%*	*4.41%*	*1.35%*	*1.70%*	*3.10%*	*3.11%*	*10.33%*	*9.89%*	*10.85%*	*10.65%*	*10.97%*
CRF 1A2 - Fuel Combustion from	5302.69	4796.00	4583.83	4669.24	4351.26	2677.12	2681.79	2172.12	1613.66	1827.24	1783.21	1714.83	1470.60	1398.13	1699.27	1520.49	1664.58
Manuf. Industries & Construction	*40.21%*	*35.55%*	*34.32%*	*34.33%*	*34.09%*	*25.90%*	*25.72%*	*22.18%*	*17.82%*	*18.89%*	*17.51%*	*16.37%*	*13.01%*	*11.99%*	*12.68%*	*11.44%*	*12.50%*
CRF 1A3 - Fuel Combustion from	2719.76	3308.95	3569.43	3626.58	3658.49	3445.56	3528.81	3802.17	3981.37	4339.73	4936.21	5201.48	5433.34	5983.72	6983.40	7181.11	6997.18
Transport	*20.63%*	*24.53%*	*26.72%*	*26.66%*	*28.66%*	*33.34%*	*33.84%*	*38.82%*	*43.97%*	*44.86%*	*48.47%*	*49.65%*	*48.06%*	*51.30%*	*52.11%*	*54.03%*	*52.52%*
of which, road fuel export(1):																	
share in transport sector	67.26%	73.62%	66.70%	67.26%	67.00%	65.04%	65.55%	67.15%	68.16%	69.31%	71.40%	71.49%	71.42%	74.82%	78.22%	79.13%	79.43%
estimated CO_2 emissions	1829.23	2436.21	2380.73	2439.26	2451.33	2241.09	2313.15	2553.18	2713.88	3007.79	3524.59	3718.80	3880.46	4477.10	5462.11	5682.49	5557.84
	13.87%	*18.06%*	*17.82%*	*17.93%*	*19.20%*	*21.68%*	*22.18%*	*26.07%*	*29.97%*	*31.09%*	*34.61%*	*35.50%*	*34.32%*	*38.38%*	*40.75%*	*42.76%*	*41.72%*
CRF 1A4 - Fuel Combustion from	1290.33	1619.60	1572.39	1607.18	1382.56	1387.99	1529.70	1497.03	1589.33	1527.43	1280.84	1439.20	1402.66	1373.25	1363.54	1322.15	1311.63
Other Sectors	*9.79%*	*12.01%*	*11.77%*	*11.82%*	*10.83%*	*13.43%*	*14.67%*	*15.29%*	*17.55%*	*15.79%*	*12.58%*	*13.74%*	*12.41%*	*11.77%*	*10.17%*	*9.95%*	*9.85%*
CRF 2 - Industrial Processes	1595.57	1518.48	1448.49	1428.47	1335.39	975.05	919.47	810.58	651.52	689.19	715.45	659.03	674.75	615.86	657.49	616.11	663.57
	12.10%	*11.26%*	*10.84%*	*10.50%*	*10.46%*	*9.43%*	*8.82%*	*8.28%*	*7.20%*	*7.12%*	*7.02%*	*6.29%*	*5.97%*	*5.28%*	*4.91%*	*4.64%*	*4.98%*
Other Sources (2)	9.05	9.08	9.11	9.18	9.22	9.28	9.36	9.40	9.46	9.49	9.35	9.16	9.21	9.21	9.22	9.28	9.34
	0.07%	*0.07%*	*0.07%*	*0.07%*	*0.07%*	*0.09%*	*0.09%*	*0.10%*	*0.10%*	*0.10%*	*0.09%*	*0.09%*	*0.08%*	*0.08%*	*0.07%*	*0.07%*	*0.07%*
CH_4 (3)	460.04	468.61	462.73	473.77	455.18	469.75	478.48	477.62	479.22	490.89	486.64	483.63	481.88	475.25	471.17	469.18	463.56
	3.49%	*3.47%*	*3.46%*	*3.48%*	*3.57%*	*4.55%*	*4.59%*	*4.88%*	*5.29%*	*5.07%*	*4.78%*	*4.62%*	*4.26%*	*4.07%*	*3.52%*	*3.53%*	*3.48%*
of which																	
CRF 1 - Energy	60.87	68.63	73.89	77.09	72.73	75.21	79.12	79.76	79.21	80.93	83.11	84.75	95.55	96.78	97.49	91.57	90.84
	0.46%	*0.51%*	*0.55%*	*0.57%*	*0.57%*	*0.73%*	*0.76%*	*0.81%*	*0.87%*	*0.84%*	*0.82%*	*0.81%*	*0.85%*	*0.83%*	*0.73%*	*0.69%*	*0.68%*
CRF 4A+4B - Enteric Fermentation and	356.49	362.49	352.03	357.08	354.57	366.32	369.97	367.31	368.15	378.01	369.66	368.87	358.97	348.48	343.41	346.92	342.68
Manure Management	*2.70%*	*2.69%*	*2.64%*	*2.63%*	*2.78%*	*3.54%*	*3.55%*	*3.75%*	*4.07%*	*3.91%*	*3.63%*	*3.52%*	*3.18%*	*2.99%*	*2.56%*	*2.61%*	*2.57%*
Other Sources (4)	42.68	37.48	36.81	39.60	27.87	28.22	29.39	30.55	31.86	31.94	33.87	30.01	27.36	29.99	30.27	30.70	30.05
	0.32%	*0.28%*	*0.28%*	*0.29%*	*0.22%*	*0.27%*	*0.28%*	*0.31%*	*0.35%*	*0.33%*	*0.33%*	*0.29%*	*0.24%*	*0.26%*	*0.23%*	*0.23%*	*0.23%*
N_2O (5)	490.15	505.83	550.77	538.77	526.38	535.48	550.34	564.13	572.79	584.50	611.33	588.73	603.28	585.27	685.53	670.83	659.15
	3.72%	*3.75%*	*4.12%*	*3.96%*	*4.12%*	*5.18%*	*5.28%*	*5.76%*	*6.33%*	*6.04%*	*6.00%*	*5.62%*	*5.34%*	*5.02%*	*5.11%*	*5.05%*	*4.95%*
of which																	
CRF 1 - Energy	54.59	70.70	101.37	102.59	109.79	107.40	116.22	129.18	140.37	160.84	180.61	192.78	206.90	227.56	276.86	297.75	285.79
	0.41%	*0.52%*	*0.76%*	*0.75%*	*0.86%*	*1.04%*	*1.11%*	*1.32%*	*1.55%*	*1.66%*	*1.77%*	*1.84%*	*1.83%*	*1.95%*	*2.07%*	*2.24%*	*2.15%*
CRF 4D - Agricultural Soils	378.84	384.36	402.02	388.92	370.77	381.50	387.85	389.31	387.60	383.47	389.30	355.11	356.21	315.58	366.68	331.10	331.34
	2.87%	*2.85%*	*3.01%*	*2.86%*	*2.90%*	*3.69%*	*3.72%*	*3.98%*	*4.28%*	*3.96%*	*3.82%*	*3.39%*	*3.15%*	*2.71%*	*2.74%*	*2.49%*	*2.49%*
Other Sources (6)	56.72	50.76	47.38	47.26	45.82	46.57	46.27	45.63	44.82	40.19	41.42	40.84	40.17	42.14	41.98	41.98	42.01
	0.43%	*0.38%*	*0.35%*	*0.35%*	*0.36%*	*0.45%*	*0.44%*	*0.47%*	*0.49%*	*0.42%*	*0.41%*	*0.39%*	*0.36%*	*0.36%*	*0.31%*	*0.32%*	*0.32%*
F-gases (7)	17.12	17.12	17.12	17.12	17.12	17.12	23.00	28.88	34.77	40.65	46.53	54.49	62.45	70.40	78.36	86.32	90.90
	0.13%	*0.13%*	*0.13%*	*0.13%*	*0.13%*	*0.17%*	*0.22%*	*0.29%*	*0.38%*	*0.42%*	*0.46%*	*0.52%*	*0.55%*	*0.60%*	*0.58%*	*0.65%*	*0.68%*
Total GHG excluding LULUCF	13186.51	13489.55	13356.75	13601.50	12765.21	10334.81	10428.89	9793.68	9054.81	9674.04	10184.97	10476.50	11305.50	11665.12	13402.55	13290.61	13321.90
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*
LULUCF (8)	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93	-294.93

Source: Environment Agency and Ministry of the Environment.

Notes:

(1) estimation done using COPERT III and the quantities of road fuels sold in Luxembourg: see Section 3.5.4.

(2) the other CO_2 sources are emissions from solvent and other product use (CRF 3).

(3) the methane emissions are converted in CO_2 equivalents 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.

(4) the other CH_4 sources are emissions from waste (CRF 6).

(5) the nitrous oxide emissions are converted in CO_2 equivalents 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.

(6) the other N_2O sources are emissions from anasthesiae (CRF 3D), manure management (CRF 4B), waste water handling (CRF 6B) and composting (CRF 6D).

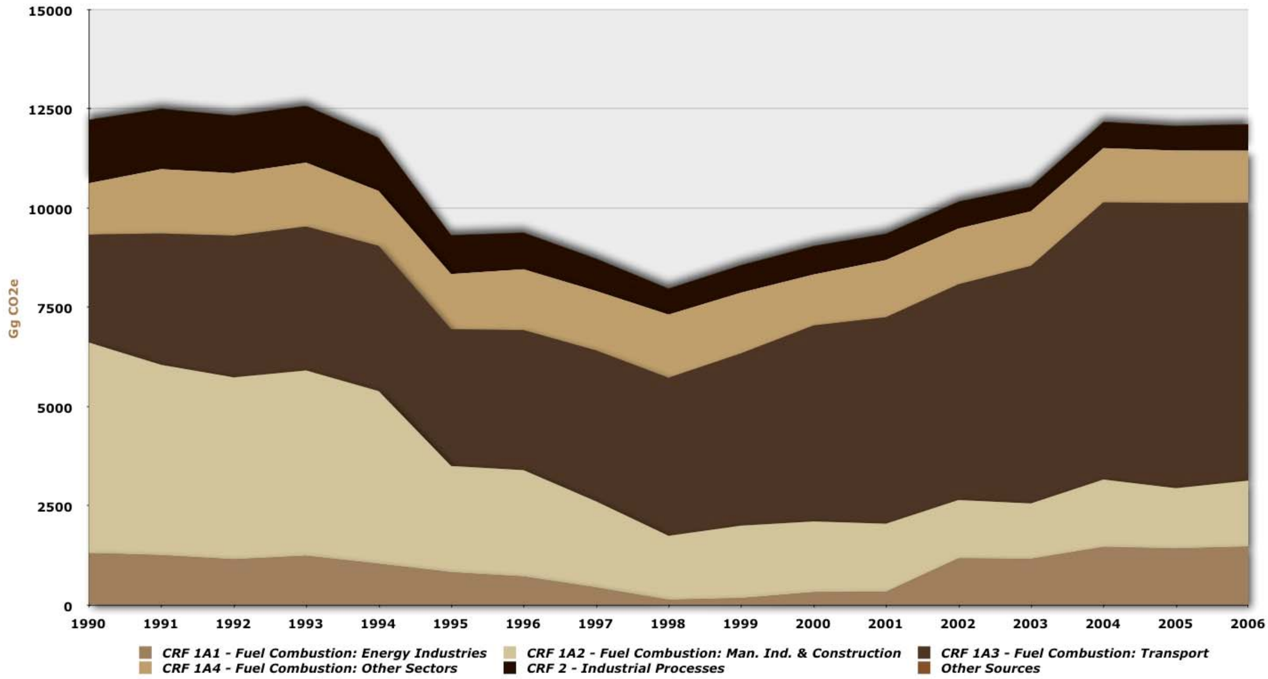
(7) the F-gases are those not covered by the Montreal Protocol, i.e. the HFCs, PFCs and SF6 expressed in CO_2 equivalents using the the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

(8) the land-use, land-use change and forestry emissions are based on constant estimates of 294.93 Gg of CO_2 for changes in forest and other woody biomass stocks (CRF 5A).

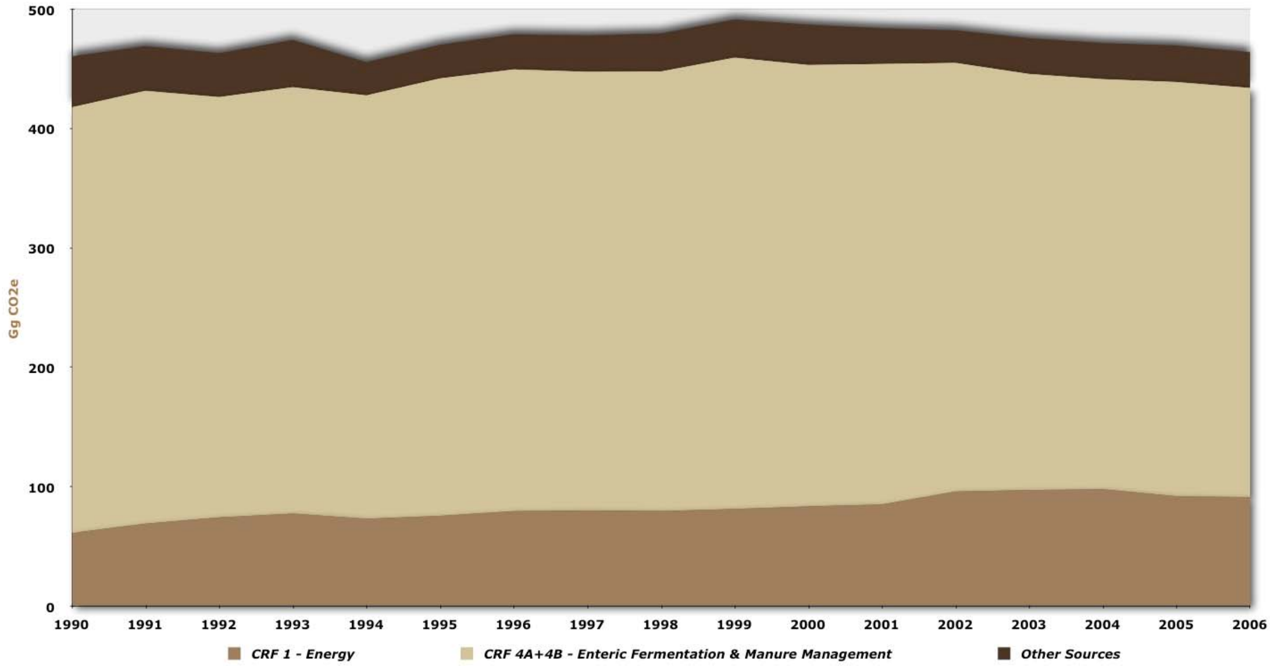
This result is the conjunction of reduced methane emissions in agriculture (-4%) and in waste management (-30%) with growing emissions in energy use (+49%), the latter being mainly due to an increase in road transport emissions and to an upward trend for fugitive emissions from natural gas distribution and use. Nitrous oxide emissions development is closely linked an increase of road transportation emissions that could not be balanced by declining emissions from the agriculture sector. Finally, with regard to F-gases, HFCs emissions were 6 times higher in 2006 than in the base year, whereas SF_6 emissions showed a 33% increase: see Table 2-8, Figure 2-3 and Figure 2-4.

Figure 2-3 – Luxembourg's GHG emissions and removals (excl. F-gases & LULUCF) – details by main gases: 1990-2006

<u>CO_2</u>

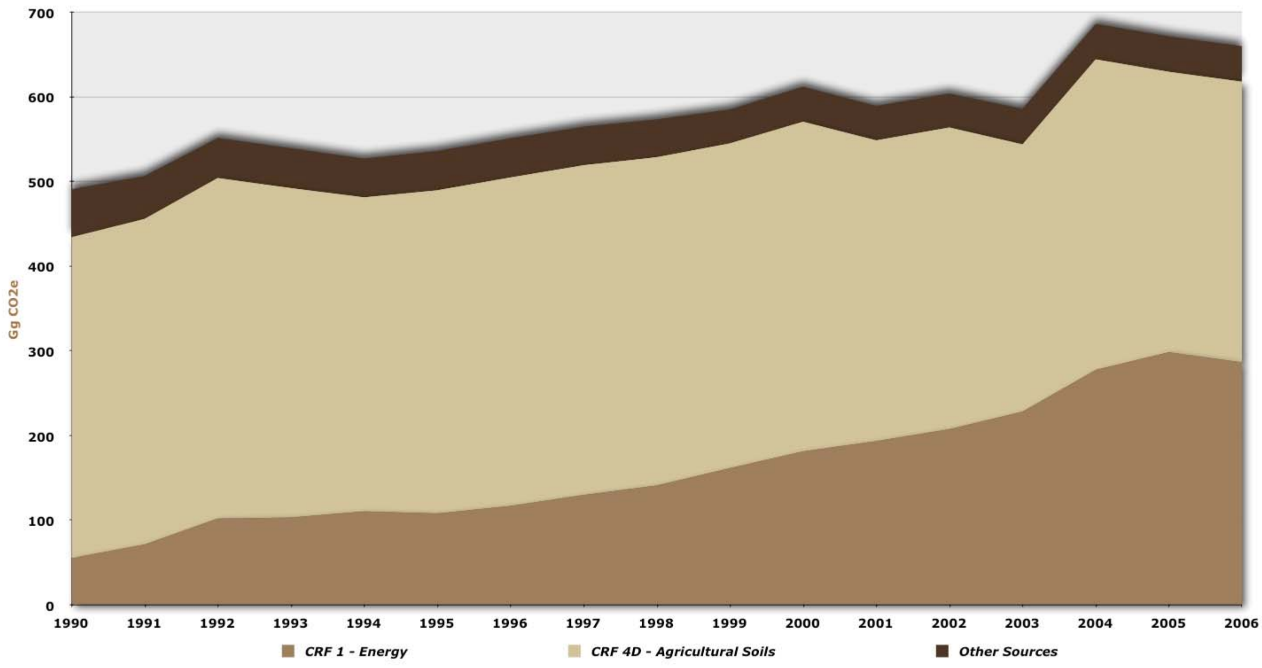


CH_4



Gg CO2e
500
400
300
200
100
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
CRF 1 - Energy
CRF 4A+4B - Enteric Fermentation & Manure Management
Other Sources

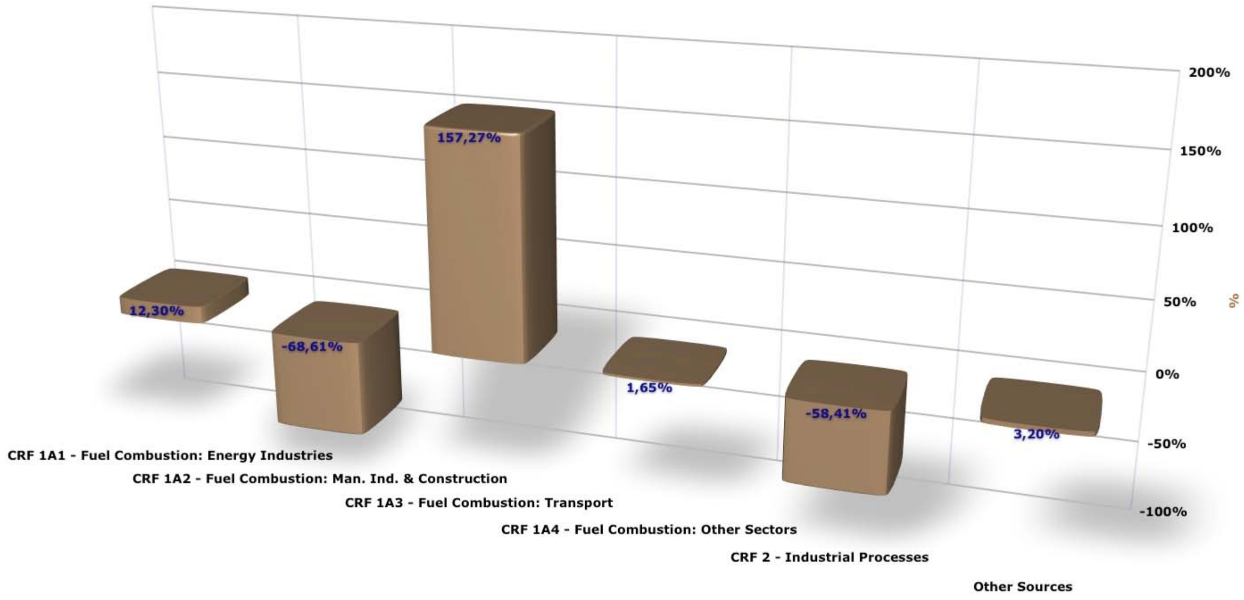
N_2O



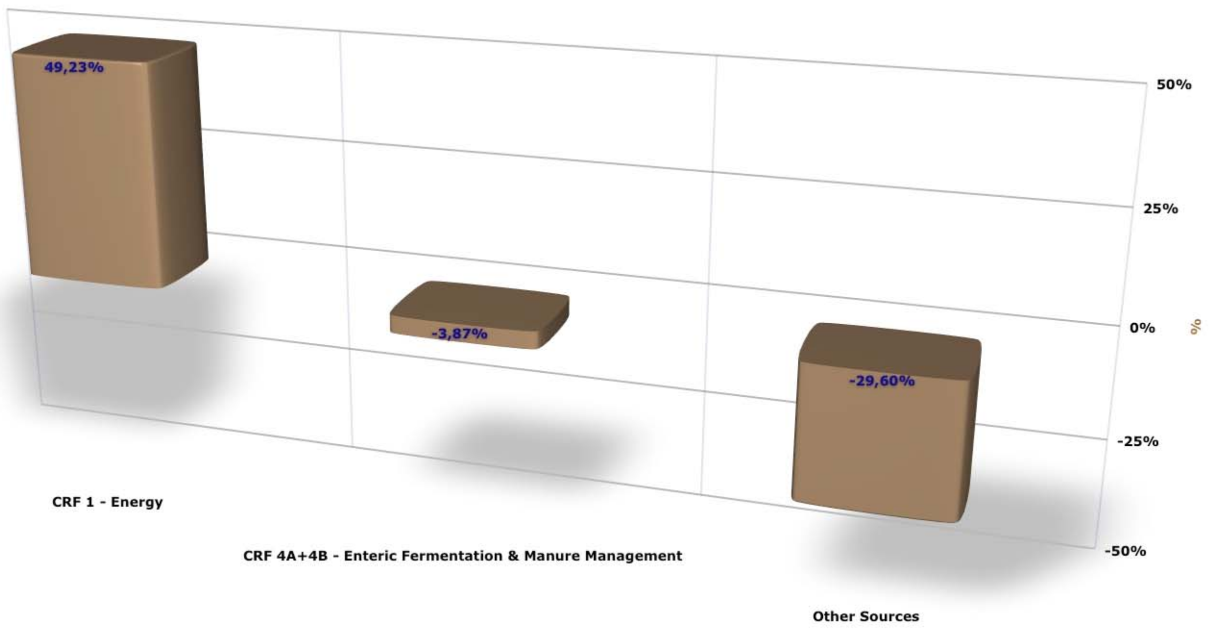
Gg CO2e
700
600
500
400
300
200
100
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
CRF 1 - Energy
CRF 4D - Agricultural Soils
Other Sources

Figure 2-4 – Luxembourg's GHG emission and removal trends in % (excl. LULUCF) – details by main gases 1990-2006

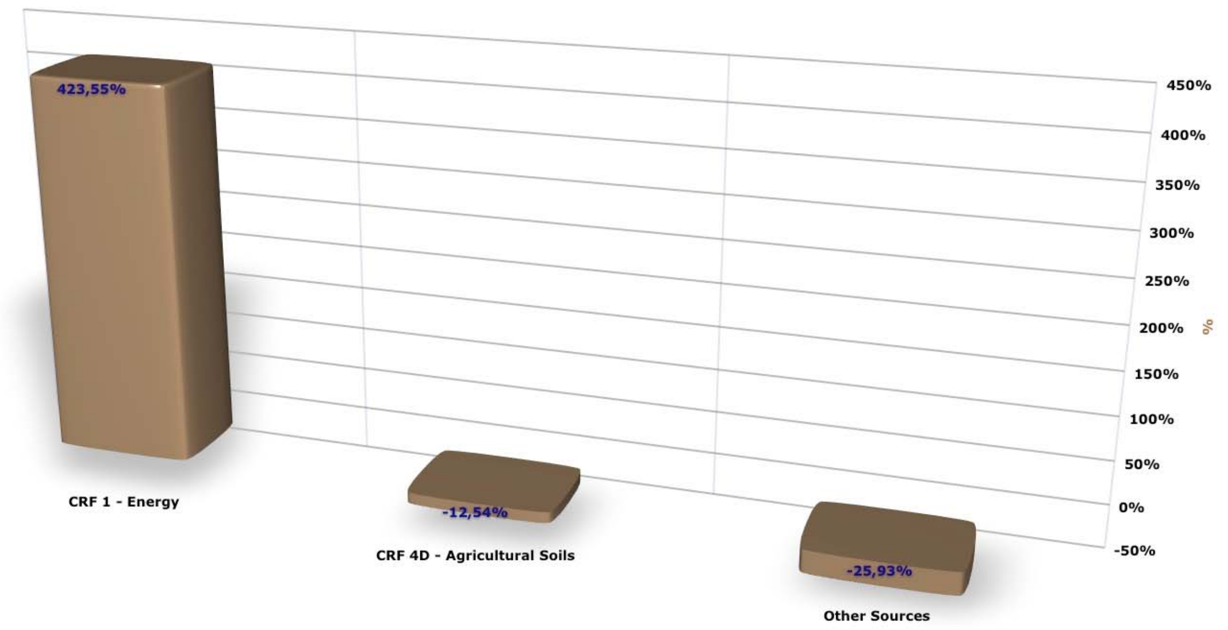
<u>CO_2</u>



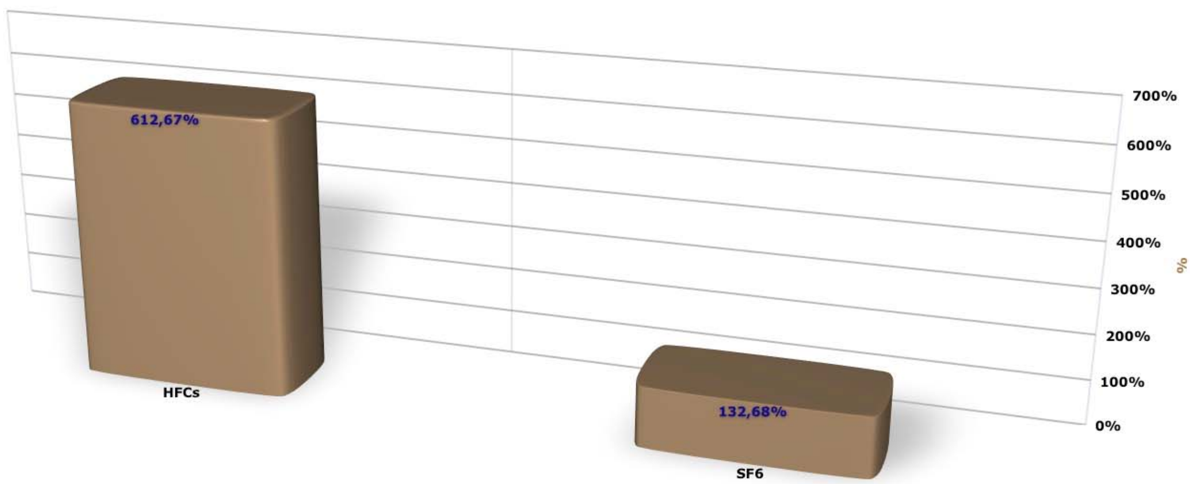
<u>CH_4</u>



N_2O



F-gases



From Table 2-8, and its associated Figures 2-3 and 2-4, emission trends for each of the gases can be analyzed further.

2.2.2.1. Carbon dioxide – CO_2

Throughout the period 1990-2006, the main GHG has remained carbon dioxide, which accounted between 88% and 93% of the total GHG emissions. However, the structure of CO_2 emissions has evolved with an increase in fuel combustion, which accounted for 80.5% of total GHG emissions for the base year (1990) and climbed up to 85.8% in 2006.

Road transport, and more precisely road fuel export, is, with electricity production, one of the culprits for this development. Indeed, in 1990, fuel combustion from the transport sector accounted for 20.6% of total GHG emissions. Then, with 7 Mio. t CO_2, this percentage reached 52.5% in 2006. CO_2 emissions due solely to road fuel export amounted to about 1.8 Mio. t in 1990 and reached 5.6 Mio. t in 2006, i.e. roughly a threefold increase (the same comparison shows only a twofold increase for road fuel consumed by the national vehicle fleet). In 2006, road fuel export represented 79.5% of CO_2 emissions of the transport sector and almost 42% of the total GHG emissions. In 1990, these percentages were, respectively, 67.3% and 13.9%.

Another important source of CO_2 is industrial processes, i.e., in the case of Luxembourg, 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.

2.2.2.2. Methane – CH_4

Methane emissions originate above all from the agricultural sector, and more precisely from enteric fermentation and from manure production and management. As these emissions have been rather stable over the period 1990-2006, total methane emissions have not varied very much.

For the other methane emitting source categories, the increase observed for fuel combustion is mainly due to electricity production related emissions. The decrease noted for waste is the result of reduced methane emissions from waste landfill sites.

2.2.2.3. Nitrous oxide – N_2O

A large part of nitrous oxide emissions is caused by agricultural soils. Another important source, which has generated increasing N_2O emissions since 1990, is road transport, where incomplete NO_X reduction in catalytic converters of gasoline motor vehicles leads to N_2O emissions.

2.2.2.4. Hydrofluorocarbons – HFCs and sulphur hexafluoride – SF_6

A first estimation of the emissions of fluorinated GHG types (HFCs, PFCs and SF_6) was done at the end of 1999 by the Environment Agency and Luxembourg's *Centre de Ressources des Technologies pour l'Environnement* (*CRTE*). It indicated that there are some HFCs and SF_6 emissions in Luxembourg, but no emissions of PFCs.

The increase in HFC emissions between 1990 and 2006 is explained by a more wide spread use of mobile and stationary cooling equipments as well as of aerosols.

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

2.2.3. GHG trends by sector

In 2006, the energy sector accounted for almost 89% of the total CO_2e GHG emissions. Two sectors represent between 5 and 6% of the total emissions: industrial processes (5.7%) and agriculture (5.2%). The remaining sectors[43] (solvent and other product use, waste[44]) were not even reaching 1% of the total GHG emitted in Luxembourg in 2006: see Table 2-7.

For the different sectors, trends over the period 1990-2006 were as follows:

- Energy: .... +10.08%
- Industrial Processes: .... -53.22%
- Solvent and Other Product Use: .... -17.66%
- Agriculture: .... -10.45%
- Waste: .... -8.15%

Emission reductions observed in all sectors but one could not balance the growth of energy use and production related emissions whose contribution to total GHG emissions ranged from 80 to 90% over the period 1990 to 2006. Within the energy sector, the fastest growing sub-sector was transport (1A3): +162% between 1990 and 2006 with, as a result, a share in the total energy related GHG emissions rising from 26% to 62%. For the other sub-sectors, the observed trends between 1990 and 2006 are +13% for energy industries (1A1), -69% for manufacturing industries (1A2), +1% for the other sectors (1A4) and +116% for fugitive emissions from fuels (1B).[45]

The second largest sector in Luxembourg with regard to GHG emissions, i.e. industrial processes, 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). As indicated above, this industry moved from blast to electric arc furnaces between 1994 and 1998. As a consequence, emissions in CO_2e decreased by 83% since 1990.

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43 The sector “other” is not reported for Luxembourg.

44 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).

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

Trends in agriculture were also favourable between 1990 and 2006: declining GHG emissions were observed for the 3 categories for which emissions are recorded in Luxembourg: enteric fermentation (4A: -12%), manure management (4B: -1%) and agricultural soils (4D: -13%).

In the waste sector, the main source of GHG was solid waste disposal on land (6A), but its weight decreased over the period 1990-2006 due to the combination of reduced amounts of landfilled waste and of increased emissions arising from composting activities (6D). However, GHG emission reduction for solid waste disposal on land (-47% between 1990 and 2006) still drove a reduction for the overall waste sector despite composting and wastewater handling (6B) rising emissions (+11% for category 6B following the important population and commuter growths Luxembourg faced over the period).

Finally, the fact that the iron and steel industry has abandoned blast furnaces between 1994 and 1998, and that fossil fuel consumption as well as road fuel sales have continued to increase after 1998, 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.

2.2.4. Indirect GHG and SO_2

Some indirect GHG – NOx, CO, NMVOCs – and SO_2 emissions are recorded in the inventory. Nevertheless, they need to be re-evaluated in the light of the revision of the inventories Luxembourg is compiling for the UNECE CLRTAP. Consequently, these emissions will not be discussed in this NIR and generating better emission estimates for these gases are part of our planned improvements.

2.2.5. Additional information

This section provides some additional information allowing to better assess GHG emissions, trends and configuration in Luxembourg.

Firstly, Table 2-9 assembles CRF source categories in such a way that GHG emission sources are distributed between main emitters – such as energy production, industry, road transportation – and other categories. Data presented in Table 2-9 are complemented by Figure 2-5.

Secondly, a set of tables and figures focus on primary and final energy consumption in Luxembourg. It is complemented by an energy balance for electric power.

2.2.5.1. GHG trend by source categories – alternative distribution

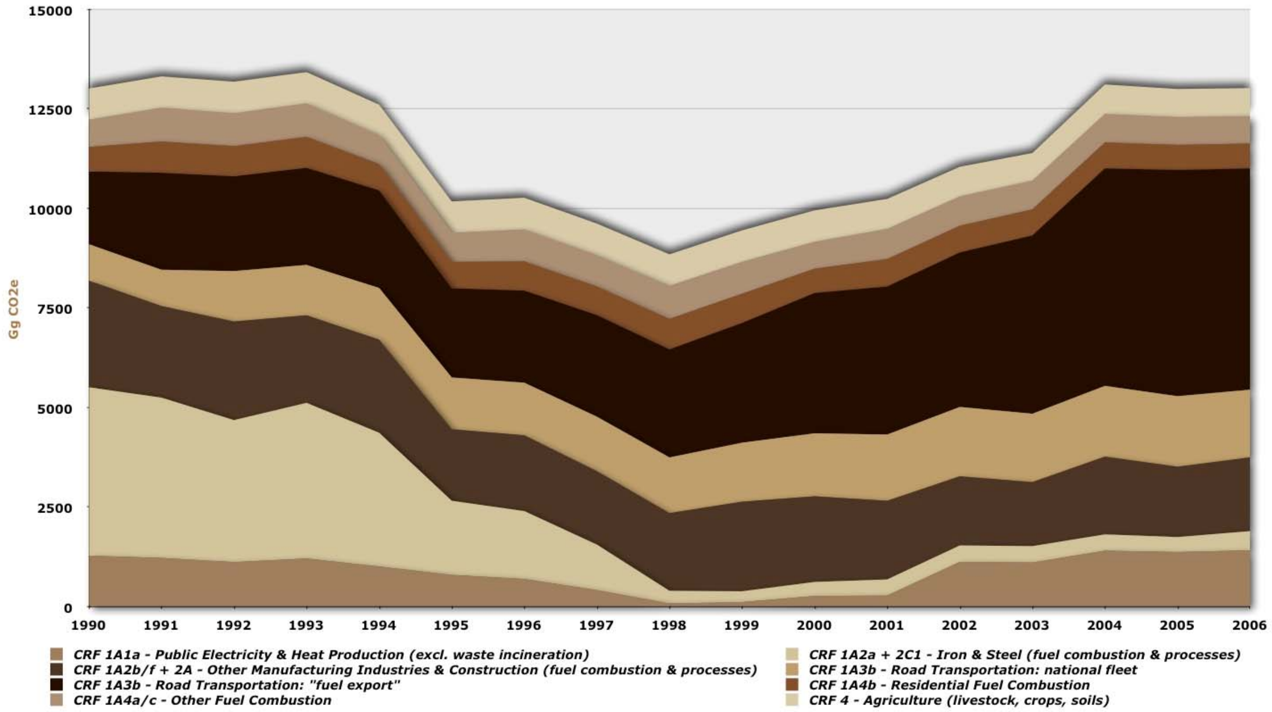
Table 2-9 – Luxembourg's GHG emissions and removals (excl. LULUCF) – alternative presentation: 1990-2006

Gg (1000 t.) CO_2 equivalent	CRF Categories	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Main Emitting Source Categories																		
Public Electricity & Heat Production	*1A1a*	1268.83	1212.21	1108.50	1198.49	997.83	787.09	684.53	403.88	69.17	104.01	256.94	268.30	1112.82	1098.10	1395.25	1361.19	1404.92
(excl. waste incineration)		*9.62%*	*8.99%*	*8.30%*	*8.81%*	*7.82%*	*7.62%*	*6.56%*	*4.12%*	*0.76%*	*1.08%*	*2.52%*	*2.56%*	*9.84%*	*9.41%*	*10.41%*	*10.24%*	*10.55%*
Iron & Steel (fuel combustion	*1A2a + 2C1*	4229.55	4026.13	3565.24	3908.38	3358.08	1861.17	1704.15	1143.28	317.07	270.39	352.00	404.43	413.56	410.10	408.95	375.63	480.74
& processes)		*32.07%*	*29.85%*	*26.69%*	*28.73%*	*26.31%*	*18.01%*	*16.34%*	*11.67%*	*3.50%*	*2.79%*	*3.46%*	*3.86%*	*3.66%*	*3.52%*	*3.05%*	*2.83%*	*3.61%*
Other Manufacturing Industries &	*1A2b/f + 2A*	2680.84	2300.03	2478.27	2200.31	2339.64	1798.55	1905.11	1845.76	1953.10	2251.74	2152.51	1975.61	1736.95	1608.85	1954.22	1766.52	1853.08
Construction (fuel combustion & processes)		*20.33%*	*17.05%*	*18.55%*	*16.18%*	*18.33%*	*17.40%*	*18.27%*	*18.85%*	*21.57%*	*23.28%*	*21.13%*	*18.86%*	*15.36%*	*13.79%*	*14.58%*	*13.29%*	*13.91%*
Road Transportation - national fleet	*1A3b*	912.36	912.23	1264.14	1264.20	1296.75	1298.20	1318.99	1366.91	1397.17	1480.24	1580.82	1663.20	1741.08	1716.80	1775.77	1771.10	1699.03
		6.92%	*6.76%*	*9.46%*	*9.29%*	*10.16%*	*12.56%*	*12.65%*	*13.96%*	*15.43%*	*15.30%*	*15.52%*	*15.88%*	*15.40%*	*14.72%*	*13.25%*	*13.33%*	*12.75%*
Road Transportation - fuel export (1)	*1A3b*	1829.23	2436.21	2380.73	2439.26	2451.33	2241.09	2313.15	2553.18	2713.88	3007.79	3524.59	3718.80	3880.46	4477.10	5462.11	5682.49	5557.84
		13.87%	*18.06%*	*17.82%*	*17.93%*	*19.20%*	*21.68%*	*22.18%*	*26.07%*	*29.97%*	*31.09%*	*34.61%*	*35.50%*	*34.32%*	*38.38%*	*40.75%*	*42.76%*	*41.72%*
Residential Fuel Combustion	*1A4b*	615.36	783.71	759.25	778.46	661.00	663.01	735.76	718.96	764.78	733.50	609.72	689.27	670.35	655.48	650.65	629.97	625.13
		4.67%	*5.81%*	*5.68%*	*5.72%*	*5.18%*	*6.42%*	*7.06%*	*7.34%*	*8.45%*	*7.58%*	*5.99%*	*6.58%*	*5.93%*	*5.62%*	*4.85%*	*4.74%*	*4.69%*
Other Fuel Combustion	*1A4a/c*	688.81	854.31	830.55	848.07	735.09	737.75	807.46	791.07	837.41	806.36	682.57	762.06	743.68	728.81	723.98	703.21	697.28
		5.22%	*6.33%*	*6.22%*	*6.24%*	*5.76%*	*7.14%*	*7.74%*	*8.08%*	*9.25%*	*8.34%*	*6.70%*	*7.27%*	*6.58%*	*6.25%*	*5.40%*	*5.29%*	*5.23%*
Agriculture (livestock, crops, soils)	*4*	775.94	781.73	785.78	777.29	755.31	778.76	789.17	786.73	784.28	785.50	782.40	747.40	737.47	686.70	732.61	699.92	694.86
		5.88%	*5.80%*	*5.88%*	*5.71%*	*5.92%*	*7.54%*	*7.57%*	*8.03%*	*8.66%*	*8.12%*	*7.68%*	*7.13%*	*6.52%*	*5.89%*	*5.47%*	*5.27%*	*5.22%*
Other Source Categories																		
Municipal Waste Incineration	*1A1a (6C)*	36.16	36.95	37.72	35.89	35.11	33.53	25.94	30.73	56.47	64.40	62.81	62.02	62.97	64.28	69.47	63.68	67.12
(with energy & heat recovery)		*0.27%*	*0.27%*	*0.28%*	*0.26%*	*0.28%*	*0.32%*	*0.25%*	*0.31%*	*0.62%*	*0.67%*	*0.62%*	*0.59%*	*0.56%*	*0.55%*	*0.52%*	*0.48%*	*0.50%*
Other Transport	*1A3a/c/d*	36.96	37.08	37.23	37.38	33.73	28.66	28.69	28.70	28.58	28.59	28.56	28.55	31.10	31.21	31.11	31.11	31.00
		0.28%	*0.27%*	*0.28%*	*0.27%*	*0.26%*	*0.28%*	*0.28%*	*0.29%*	*0.32%*	*0.30%*	*0.28%*	*0.27%*	*0.28%*	*0.27%*	*0.23%*	*0.23%*	*0.23%*
Fugitive Emissions from Fuels	*1B2b*	27.51	29.40	30.66	31.92	31.29	36.75	39.27	40.11	40.53	43.26	44.31	45.78	58.17	58.59	61.11	59.43	59.43
		0.21%	*0.22%*	*0.23%*	*0.23%*	*0.25%*	*0.36%*	*0.38%*	*0.41%*	*0.45%*	*0.45%*	*0.44%*	*0.44%*	*0.51%*	*0.50%*	*0.46%*	*0.45%*	*0.45%*
F-gases	*2F*	17.12	17.12	17.12	17.12	17.12	17.12	23.00	28.88	34.77	40.65	46.53	54.49	62.45	70.40	78.36	86.32	90.90
		0.13%	*0.13%*	*0.13%*	*0.13%*	*0.13%*	*0.17%*	*0.22%*	*0.29%*	*0.38%*	*0.42%*	*0.46%*	*0.52%*	*0.55%*	*0.60%*	*0.58%*	*0.65%*	*0.68%*
Solvent & Other Product Use	*3*	18.31	18.00	17.67	17.41	17.13	16.86	16.59	16.29	16.01	15.68	15.17	14.59	14.68	14.72	14.78	14.90	15.08
		0.14%	*0.13%*	*0.13%*	*0.13%*	*0.13%*	*0.16%*	*0.16%*	*0.17%*	*0.18%*	*0.16%*	*0.15%*	*0.14%*	*0.13%*	*0.13%*	*0.11%*	*0.11%*	*0.11%*
Municipal Waste Disposal on Land	*6A*	42.67	37.47	36.80	39.11	27.30	27.51	28.77	29.19	29.61	29.61	29.40	25.83	22.26	23.52	23.94	23.94	22.42
		0.32%	*0.28%*	*0.28%*	*0.29%*	*0.21%*	*0.27%*	*0.28%*	*0.30%*	*0.33%*	*0.31%*	*0.29%*	*0.25%*	*0.20%*	*0.20%*	*0.18%*	*0.18%*	*0.17%*
Domestic & Commercial Waste Water	*6B2*	6.86	6.97	7.09	7.20	7.32	7.28	7.00	7.13	7.26	7.39	7.52	7.67	7.18	7.26	7.35	7.46	7.63
Handling		*0.05%*	*0.05%*	*0.05%*	*0.05%*	*0.06%*	*0.07%*	*0.07%*	*0.07%*	*0.08%*	*0.08%*	*0.07%*	*0.07%*	*0.06%*	*0.06%*	*0.05%*	*0.06%*	*0.06%*
Composting	*6D*	NO	NO	NO	1.03	1.19	1.49	1.30	2.85	4.72	4.91	9.11	8.50	10.32	13.19	12.88	13.75	15.44
		NA	*NA*	*NA*	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.03%*	*0.05%*	*0.05%*	*0.09%*	*0.08%*	*0.09%*	*0.11%*	*0.10%*	*0.10%*	*0.12%*
Total GHG excluding LULUCF		13186.51	13489.55	13356.75	13601.50	12765.21	10334.81	10428.89	9793.68	9054.81	9674.04	10184.97	10476.50	11305.50	11665.12	13402.55	13290.61	13321.90
		100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*
Memo Items																		
International Bunkers - Aviation		403.85	420.65	409.68	406.30	515.79	584.79	635.62	729.55	921.84	1040.13	991.30	1072.18	1161.65	1210.16	1316.92	1337.92	1252.08
		NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
CO_2 Emissions from Biomass		79.41	79.41	79.41	79.41	79.41	79.32	79.94	79.94	79.94	79.94	79.94	79.94	79.94	79.94	79.94	82.60	82.60
		NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*

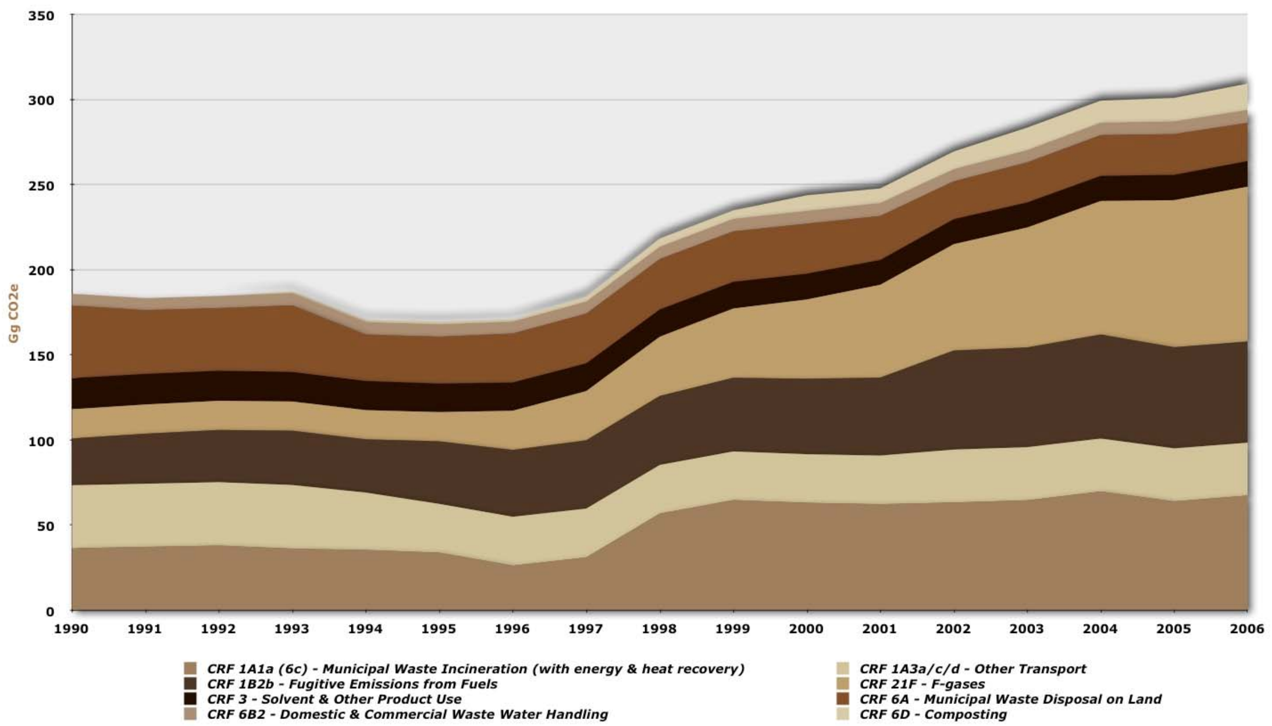
Source: Environment Agency and Ministry for Environment.
Note:
(1) road fuel export estimates only cover CO_2 emissions.

Figure 2-5 – Luxembourg's GHG emissions and removals (excl. LULUCF) – alternative presentation: 1990-2006

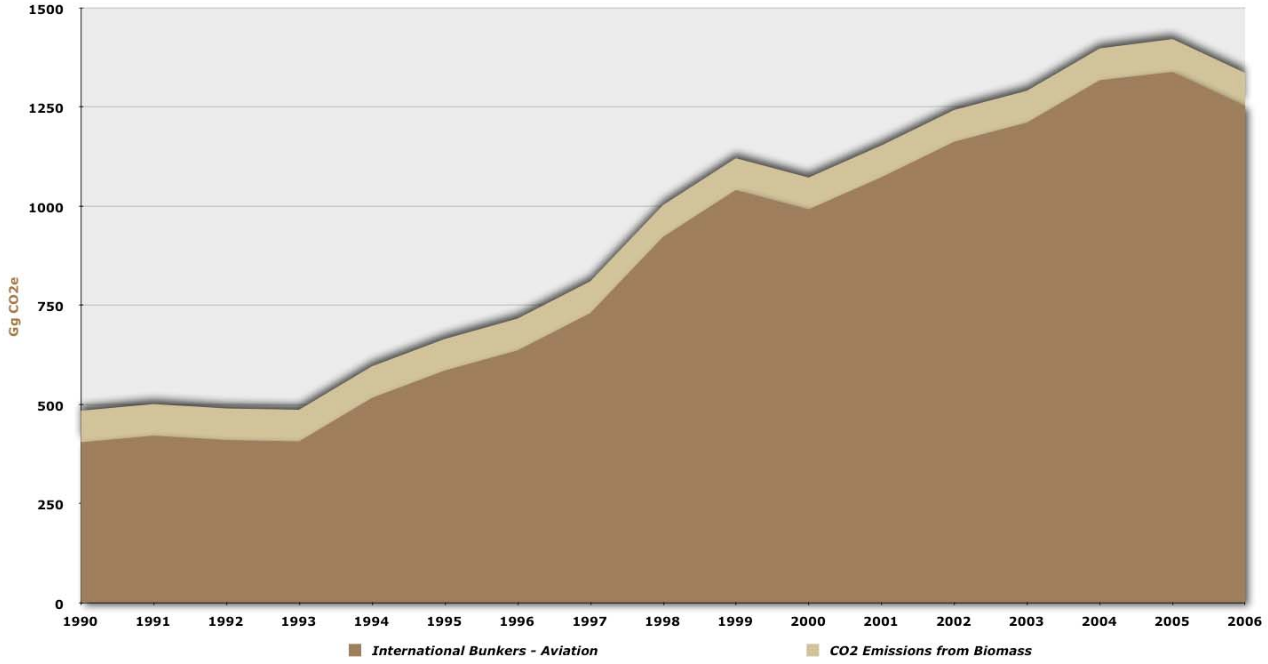
Main emitting source categories



Other source categories



Memo Items



2.2.5.2. Energy consumption and balance

Figure 2-6 – Primary energy consumption (excl. air transport): 1990-2006

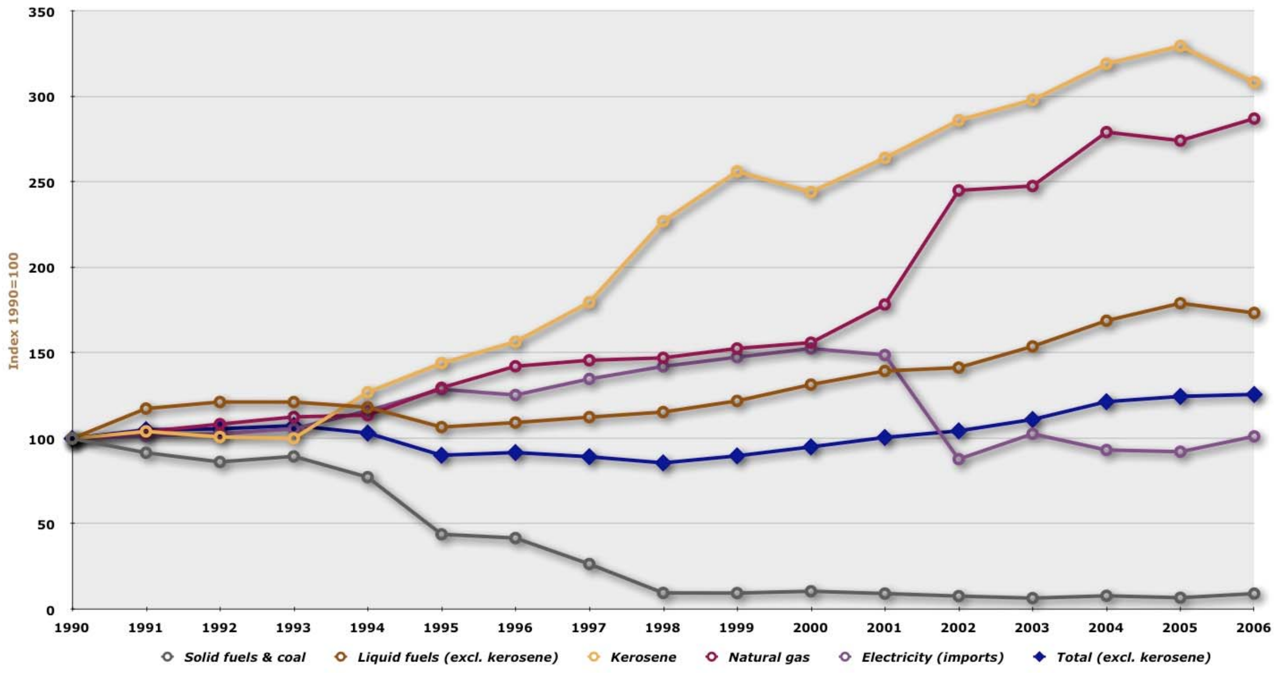


Table 2-10 – Primary energy consumption (excl. air transport): 1990-2006

1000 toe	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Solid fuels & coal	1198.61	1099.27	1034.88	1073.87	928.05	527.59	501.20	319.20	116.62	115.50	128.26	112.03	94.10	79.94	96.22	82.89	111.53
	34.32%	*29.92%*	*28.04%*	*28.58%*	*25.74%*	*16.74%*	*15.63%*	*10.23%*	*3.89%*	*3.68%*	*3.86%*	*3.19%*	*2.58%*	*2.06%*	*2.27%*	*1.90%*	*2.54%*
Liquid fuels (excl. kerosene)	1456.42	1711.93	1768.12	1767.28	1723.27	1554.27	1592.53	1638.96	1682.32	1777.20	1916.19	2032.22	2060.74	2241.71	2460.46	2609.28	2526.84
	41.70%	*46.60%*	*47.90%*	*47.03%*	*47.80%*	*49.32%*	*49.66%*	*52.50%*	*56.15%*	*56.62%*	*57.67%*	*57.81%*	*56.46%*	*57.74%*	*57.95%*	*59.93%*	*57.51%*
Kerosene	127.60	132.97	128.79	127.72	162.15	183.86	199.82	229.35	289.80	326.99	311.64	337.06	365.19	380.44	407.36	420.60	393.62
Natural gas	477.55	496.86	517.89	537.96	542.83	619.38	679.47	696.24	703.01	729.21	745.47	852.06	1170.77	1183.02	1333.47	1309.80	1371.31
	13.67%	*13.53%*	*14.03%*	*14.32%*	*15.06%*	*19.66%*	*21.19%*	*22.30%*	*23.47%*	*23.23%*	*22.43%*	*24.24%*	*32.08%*	*30.47%*	*31.41%*	*30.08%*	*31.21%*
Electricity (imports)	318.22	322.65	327.21	336.34	370.05	409.85	399.29	429.16	452.41	469.72	485.74	473.73	279.92	327.01	296.91	293.72	322.28
	9.11%	*8.78%*	*8.86%*	*8.95%*	*10.26%*	*13.01%*	*12.45%*	*13.75%*	*15.10%*	*14.96%*	*14.62%*	*13.48%*	*7.67%*	*8.42%*	*6.99%*	*6.75%*	*7.33%*
Waste incineration (with heat	26.84	27.92	28.16	26.94	26.34	25.15	19.40	23.14	26.41	31.62	30.77	28.15	26.72	31.42	38.19	35.79	38.17
recovery)	*0.77%*	*0.76%*	*0.76%*	*0.72%*	*0.73%*	*0.80%*	*0.60%*	*0.74%*	*0.88%*	*1.01%*	*0.93%*	*0.80%*	*0.73%*	*0.81%*	*0.90%*	*0.82%*	*0.87%*
Biomass (1)	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.40	15.40	15.40	15.40	15.40	15.40	15.97	15.94
	0.43%	*0.41%*	*0.41%*	*0.40%*	*0.42%*	*0.48%*	*0.47%*	*0.48%*	*0.50%*	*0.49%*	*0.46%*	*0.44%*	*0.42%*	*0.40%*	*0.36%*	*0.37%*	*0.36%*
Biogas	NO	NO	NO	NO	NO	NO	NO	NO	0.13	0.29	1.12	2.02	2.28	3.72	5.00	6.69	8.01
	NA	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0.00%*	*0.01%*	*0.03%*	*0.06%*	*0.06%*	*0.10%*	*0.12%*	*0.15%*	*0.18%*
Total (excl. kerosene)	3492.64	3673.63	3691.26	3757.39	3605.54	3151.24	3206.89	3121.70	2995.90	3138.94	3322.95	3515.61	3649.93	3882.22	4245.65	4354.14	4394.08

Source: Ministry of Economic Affairs and External Trade, Energy Department and FiFo Köln
Note:
(1) wood only up to 2004 included, wood and biofuel in 2005 and 2006.
data prepared in February 2008 (subject to changes since that date)

Table 2-11 – Final energy consumption (excl. air transport): 1990-2006

1000 toe	1990 (base year)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Solid fuels & coal, blast furnaces gas	1021.28	909.03	852.52	888.65	782.74	448.24	434.28	281.20	116.62	115.50	128.26	112.03	94.10	79.94	96.22	82.89	111.53
	30.84%	*26.13%*	*24.43%*	*24.93%*	*22.72%*	*14.79%*	*14.02%*	*9.28%*	*3.96%*	*3.74%*	*3.92%*	*3.31%*	*2.77%*	*2.22%*	*2.45%*	*2.06%*	*2.76%*
solid fuels & coal	819.56	736.47	704.10	733.06	651.29	382.99	374.29	248.93	116.62	115.50	128.26	112.03	94.10	79.94	96.22	82.89	111.53
blast furnaces gas	201.72	172.56	148.42	155.59	131.45	65.25	59.99	32.27	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquid fuels (excl. kerosene)	1453.61	1703.86	1750.48	1755.69	1718.68	1552.32	1585.14	1634.81	1681.99	1776.83	1915.99	2031.88	2060.51	2241.59	2460.36	2609.28	2526.85
	43.89%	*48.98%*	*50.16%*	*49.24%*	*49.89%*	*51.21%*	*51.17%*	*53.96%*	*57.05%*	*57.61%*	*58.58%*	*60.02%*	*60.64%*	*62.26%*	*62.55%*	*64.84%*	*62.58%*
Kerosene	127.60	132.97	128.79	127.72	162.15	183.86	199.82	229.35	289.80	326.99	311.64	337.06	365.19	380.44	407.36	420.60	393.62
Natural gas	464.14	487.02	507.24	527.48	525.22	571.29	627.00	648.61	655.32	679.43	692.52	708.62	703.73	704.09	754.88	726.15	759.97
	14.01%	*14.00%*	*14.53%*	*14.80%*	*15.25%*	*18.85%*	*20.24%*	*21.41%*	*22.23%*	*22.03%*	*21.17%*	*20.93%*	*20.71%*	*19.56%*	*19.19%*	*18.04%*	*18.82%*
Electricity	357.63	363.04	364.75	378.03	400.27	430.70	422.96	435.93	456.15	473.77	491.69	484.32	487.84	517.26	552.15	529.57	559.68
	10.80%	*10.44%*	*10.45%*	*10.60%*	*11.62%*	*14.21%*	*13.65%*	*14.39%*	*15.47%*	*15.36%*	*15.03%*	*14.31%*	*14.36%*	*14.37%*	*14.04%*	*13.16%*	*13.86%*
Heat, cogeneration & biomass	15.40	15.40	15.00	15.40	18.00	28.84	28.47	28.86	38.09	38.96	42.31	48.45	51.90	57.27	69.69	76.36	79.74
	0.46%	*0.44%*	*0.43%*	*0.43%*	*0.52%*	*0.95%*	*0.92%*	*0.95%*	*1.29%*	*1.26%*	*1.29%*	*1.43%*	*1.53%*	*1.59%*	*1.77%*	*1.90%*	*1.97%*
heat & cogeneration	NO	NO	NO	NO	3.00	13.84	13.07	13.46	22.69	23.56	26.91	33.05	36.50	41.87	54.29	60.39	63.80
biomass (1)	15.40	15.40	15.00	15.40	15.00	15.00	15.40	15.40	15.40	15.40	15.40	15.40	15.40	15.40	15.40	15.97	15.94
Total (excl. kerosene)	3312.06	3478.35	3489.99	3565.25	3444.91	3031.39	3097.85	3029.41	2948.17	3084.49	3270.77	3385.30	3398.08	3600.15	3933.30	4024.25	4037.77

Source: Ministry of Economic Affairs and External Trade, Energy Department and FiFo Köln
Note:
(1) wood only up to 2004 included, wood and biofuel in 2005 and 2006.
data prepared in February 2008 (subject to changes since that date)

Table 2-12 – Energy balance for electric power: 1990-2006

GWh		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Imports		4708.28	4713.87	4517.87	4453.75	5026.76	5707.38	5725.89	6040.48	6388.99	6212.79	6465.87	6389.20	6390.70	6562.18	6505.06	6391.00	6824.00
National production		626.24	676.37	662.49	669.79	626.80	537.67	503.77	414.77	343.23	371.12	428.47	842.18	2785.42	2784.39	3372.70	3344.00	3519.00
	cogeneration	NO	NO	NO	NO	30.00	99.84	122.35	124.83	198.03	205.15	227.96	321.41	341.50	382.28	421.44	417.00	438.00
	thermic power stations	558.72	622.11	594.14	607.83	505.96	346.53	307.87	205.38	45.38	52.29	51.74	374.43	2312.42	2285.48	2787.37	2737.00	2866.00
	of which, TWINerg	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*323.03*	*2275.65*	*2237.29*	*2731.06*	*2688.00*	*2774.01*
	hydro-electricity	67.52	54.26	68.35	61.96	90.84	91.30	73.55	81.71	94.75	95.53	119.46	114.39	97.38	73.94	95.64	93.00	103.00
	wind	NO	NO	NO	NO	NO	NO	NO	2.74	4.61	17.14	24.74	23.70	24.73	26.17	39.40	52.00	58.00
	biomass	NO	NO	NO	NO	NO	NO	NO	0.12	0.46	1.01	4.54	8.20	9.30	15.13	20.34	27.00	33.00
	photovoltaic	NO	NO	NO	NO	NO	NO	NO	0.00	0.00	0.00	0.04	0.05	0.08	1.40	8.50	18.00	21.00
Total		5334.52	5390.24	5180.36	5123.54	5653.56	6245.06	6229.66	6455.25	6732.22	6583.91	6894.34	7231.39	9176.12	9346.57	9877.75	9735.00	10343.00
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	2939.92	2799.41	3131.58	3131.00	3267.00
conversion uses and losses		389.32	395.43	334.28	318.06	364.83	434.15	431.95	418.98	428.05	340.97	359.49	414.82	450.53	475.68	428.98	446.00	474.00
net inland consumption		4190.27	4279.65	4303.13	4411.08	4723.16	5066.76	4989.66	5189.31	5380.05	5587.98	5798.00	5749.79	5785.67	6071.48	6317.19	6158.00	6602.00
Total		5334.52	5390.24	5180.36	5123.54	5653.56	6245.06	6229.66	6455.25	6732.22	6583.91	6894.34	7231.39	9176.12	9346.57	9877.75	9735.00	10343.00

Summary in GWh	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2005
Net imports	3953.36	3998.70	3974.92	4059.35	4461.19	4963.24	4917.84	5193.52	5464.86	5557.82	5729.01	5322.42	3450.78	3762.77	3373.47	3260.00	3557.00
Net national production (1)	236.91	280.95	328.21	351.73	261.97	103.52	71.82	-4.21	-84.81	30.15	68.99	427.37	2334.89	2308.71	2943.71	2898.00	3045.00
Net inland consumption	4190.27	4279.65	4303.13	4411.08	4723.16	5066.76	4989.66	5189.31	5380.05	5587.98	5798.00	5749.79	5785.67	6071.48	6317.19	6158.00	6602.00
Net inland consumption in Mio. MJ	15072.91	15394.42	15478.88	15867.20	16989.80	18225.75	17948.41	18666.59	19352.70	20100.64	20856.11	20682.68	20811.76	21839.86	22723.69	22151.08	23748.20
Net inland consumption in 1000 toe	360.01	367.69	369.71	378.98	405.79	435.31	428.69	445.84	462.23	480.10	498.14	494.00	497.08	521.64	542.75	529.07	567.22

Source: Ministry of Economic Affairs and External Trade, Energy Department and FiFo Köln

Note:

(1) the net national production is the difference between the national production and the conversion process uses and losses.

data prepared in February 2008 (subject to changes since that date)

Figure 2-7 – Final energy consumption (excl. air transport): 1990-2006

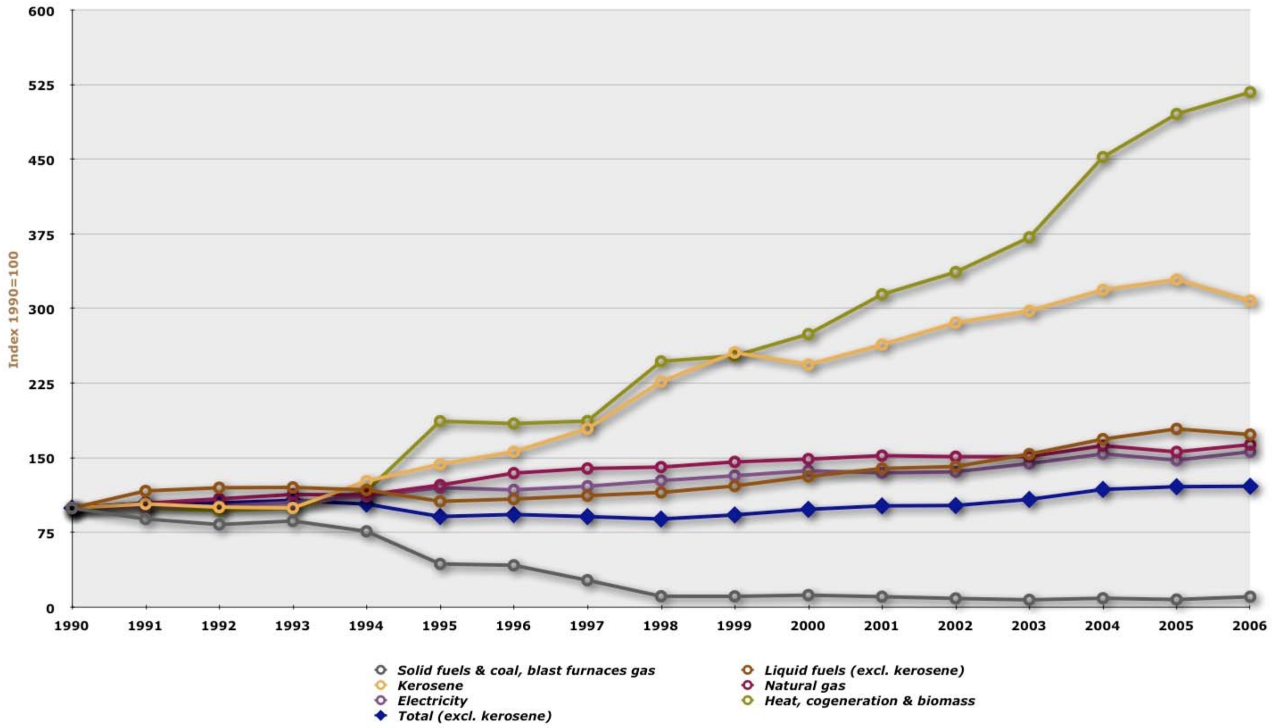
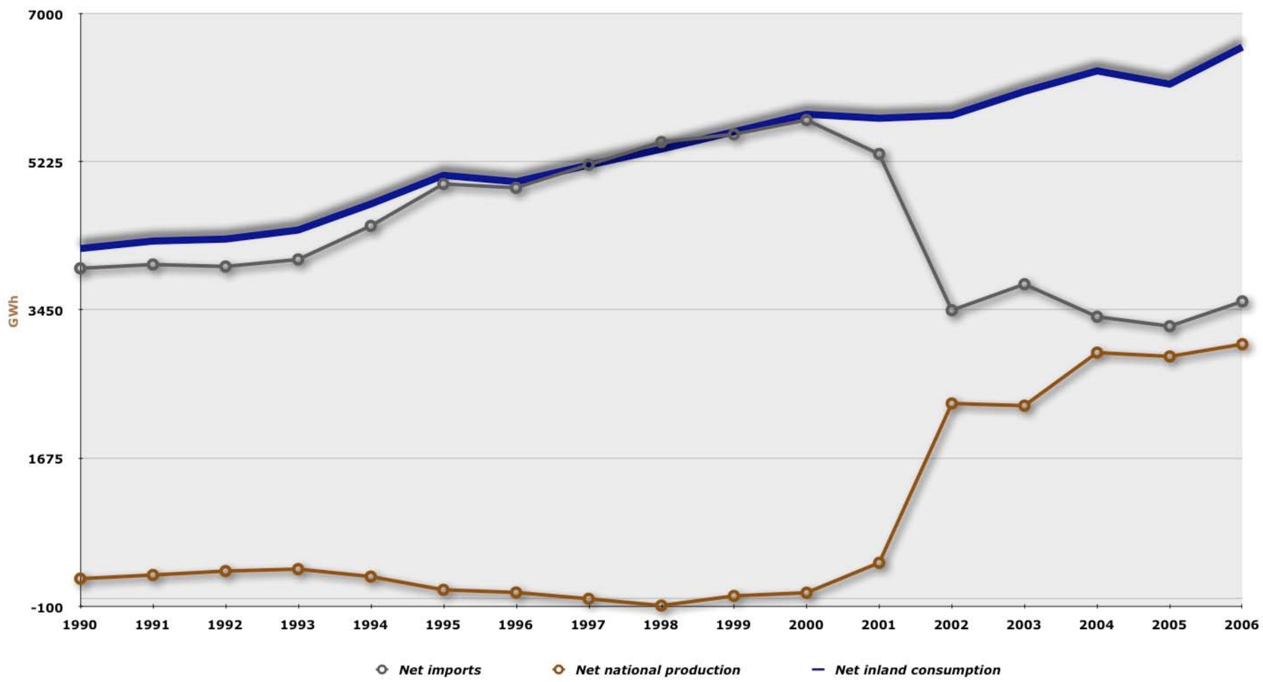


Figure 2-8 – Energy balance for electric power: 1990-2006



For more information on this Chapter, please contact:

Eric DE BRABANTER
Ministère de l'Environnement
18, Montée de la Pétrusse
L-2918 Luxembourg
Tel: (+352) 247-86842
Fax: (+352) 247-86835
E-mail: eric.debrabanter@mev.etat.lu

3. Energy (CRF sector 1)

3.1. Sector Overview

Chapter 3 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 Sectors 1A – Fuel Combustion Activities and 1B – Fugitive Emissions from Fuels for the period 1990 to 2006.

Emissions from this sector comprise emissions from all categories except other fuel combustion activities (1A5) and fugitive emissions from solid fuels (1B1). For more details on categories where emissions are not occurring and categories that are not estimated or included elsewhere, see Table 3-3 below.

Waste incineration related GHG emissions are allocated to IPCC Sub-category 1A1a – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production (see Section 3.3.4) since energy is recovered and injected in the public electric network from waste burned in the sole incinerator of the country.

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

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Section 3.1 is structured as follows:

- overview of the revisions since the ICR of June 2007: submission 2007v2.1 ➔ submission 2007v3.1 ➔ submission 2008v1.2. Submission 2007v2.1 was the version reviewed by the ERT during the ICR, whereas submission 2007v3.1 was the one provided to the ERT after the ICR (see Table 1-1 in Section 1.1). This overview includes therefore information on recalculations;
- completeness analysis of the CRF Sector as reported in submission 2008v1.2. The analysis limits itself to the 6 GHG controlled by the Kyoto Protocol;
- analysis of the emission trends of the CRF Sector, combining source categories and GHG.

Starting with revisions and a completeness analysis is justified by the dramatic improvements the GHG inventory for Luxembourg experienced since the ICR in June 2007.

Other required information, as suggested in Annex I of document FCCC/SBSTA/2006/9, will be presented under each source category review (methodology, AD, EFs, etc.).

3.1.1. Overview of the revisions

Table 3-1 presents the main revisions and recalculations done after the ICR of June 2007 relevant to CRF Sector 1.

Table 3-1 – Changes in GHG inventories: submissions 2007v2.1 and 2007v3.1

GHG source & sink category	Revisions 2007v2.1 ➔ 2007v3.1	Type of revision
1A1a liquid, solid & gaseous fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - truncation issue within CollectER for CH_4 & N_2O emissions - reallocation of the TWINerg power plant (gas-vapour turbine) from 1A2f	- revised EF - error correction - misallocation correction
1A1a biomass	- notation key change: the source category is actually NO	- error correction
1A1a other fuels	- inclusion of the SIDOR emission (waste incinerator with energy recovery) from 6C - revised CO_2 emissions for the SIDOR using IPCC method and default EF (2006 IPCC Guidelines) - calculation of CH_4 & N_2O emissions for the SIDOR using IPCC method and default EF (2006 IPCC Guidelines)	- misallocation correction - revised method - new estimates
1A2a solid & gaseous fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - truncation issue within CollectER for CH_4 & N_2O emissions	- revised EF - error correction
1A2a liquid & other fuels, biomass	- notation key change: the source category is actually NO	- error correction
1A2b liquid fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - truncation issue within CollectER for CH_4 & N_2O emissions	- revised EF - error correction
1A2b all other fuels	- notation key change: the source category is actually NO	- error correction
1A2c all fuels	- notation key change: the source category is actually NO	- error correction
1A2d all fuels	- notation key change: the source category is actually NO	- error correction
1A2e all fuels	- notation key change: the source category is actually NO	- error correction
1A2f liquid, solid & gaseous fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - truncation issue within CollectER for CH_4 & N_2O emissions - reallocation of the TWINerg power plant (gas-vapour turbine) to 1A1a	- revised EF - error correction - misallocation correction
1A2f gaseous fuels	- revised activity data, notably for iron & steel (a SNAP issue forces iron & steel natural gas consumption to be recorded here)	- revised AD & method
1A2f biomass, other fuels	- notation key change: the source category is actually NO	- error correction
1A3a aviation gasoline	- new estimates (source category previously NE)	- new source category
1A3b gasoline, diesel & LPG	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - calculation of CH_4 & N_2O emissions for each fuel type - inclusion of CH_4 emissions for diesel - reallocation of other liquid fuels estimates under LPG - use of IPCC default NCV (2006 IPCC Guidelines) for LPG (following transfer from other liquid fuels to LPG)	- revised EF - refinement - error correction - misallocation correction - revised AD
1A3b gaseous & other fuels, biomass	- notation key change: the source category is actually NO	- error correction
1A3c liquid fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - truncation issue within CollectER for CH_4 & N_2O emissions	- revised EF - error correction
1A3c solid fuels	- notation key change: the source category is actually NO	- error correction

1A3d liquid fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - truncation issue within CollectER for CH_4 & N_2O emissions	- revised EF - error correction
1A3d other fuels	- notation key change: the source category is actually NO	- error correction
1A4a all fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - truncation issue within CollectER for N_2O emissions - notation key change for other fuels: the combination source category/fuels is actually NO	- revised EF - error correction - error correction
1A4b all fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - truncation issue within CollectER for N_2O emissions - notation key change for other fuels: the combination source category/fuels is actually NO	- revised EF - error correction - error correction
1A4c all fuels	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF with the exception of SNAP 080600 - truncation issue within CollectER for CH_4 & N_2O emissions - notation key change for solid & other fuels (all years) and gaseous fuels (from 1996 onwards): the combination source category/fuels is actually NO	- revised EF - error correction - error correction
Memo Items - aviation	- use of IPCC default NCV (2006 IPCC Guidelines) - use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF - calculation of CH_4 & N_2O emissions using IPCC method and default EF (2006 IPCC Guidelines)	- revised AD - revised EF - new estimates
Memo Items biomass	- use of IPCC default EF (2006 IPCC Guidelines) instead of CORINAIR EF for CO_2 emissions (data coming from category 1A4)	- revised EF
Reference Ap-proach	- inclusion of waste incineration as an energy source to ensure accurate comparability between the two approaches (Reference and Sectoral), the latter now including waste incineration emissions as "other fuels" in 1A1a	- new source category

Besides the inclusion of a new source category (waste incineration) in submission 2007v3.1, the Reference Approach, including feedstocks and non-energy use of fuels, is identical to submission 2007v2.1.

Table 3.2 presents the main revisions and recalculations between submissions 2007v3.1 and 2008v1.2 (see also CRF tables 8).

Table 3-2 – Changes in GHG inventories: submissions 2007v3.1 and 2008v1.2

GHG source & sink category	Revisions 2007v3.1 ➔ 2008v1.2	Type of revision
1A1a other fuels	- revised activity data from the operator for the year 2005 - revised emission factors and parameters for the year 2005	- revised AD - revised EF
1A2b liquid & gaseous fuels	- reallocation of emissions in the correct fuel category – from liquid to gaseous fuels – for the years 2002 to 2005	- misallocation correction
1A3b LPG	- corrected emission factor for N2O – diesel for the year 2005 - corrected emission factor for all gases – LPG for the year 2005	- corrected EF - corrected EF
1A4a biomass	- corrected activity data for the years 2002 to 2005	- corrected AD
1A4b biomass	- corrected activity data for the years 2002 to 2005	- corrected AD
Memo Items biomass	- corrected activity data for the years 2002 to 2005	- corrected AD
Reference Ap-proach	- updated data (new extraction from Eurostat's database)	- revised AD

3.1.2. Completeness

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

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

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
1A1a	fuel combustion activities – energy industries – public electricity & heat production	X	X	X
1A1b	fuel combustion activities – energy industries – petroleum refining	NO	NO	NO
1A1c	fuel combustion activities – energy industries – manufacture of solid fuels and other energy industries	NO	NO	NO
1A2a	fuel combustion activities – manufacturing industries & construction – iron & steel	X	X	X
1A2b	fuel combustion activities – manufacturing industries & construction – non-ferrous metals	X	X	X
1A2c	fuel combustion activities – manufacturing industries & construction – chemicals	NO	NO	NO
1A2d	fuel combustion activities – manufacturing industries & construction – pulp, paper & print	NO	NO	NO
1A2e	fuel combustion activities – manufacturing industries & construction – food processing, beverages & tobacco	NO	NO	NO
1A2f	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/fisheries	X	X	X
1A5a	fuel combustion activities – other – stationary	IE	IE	IE
1A5b	fuel combustion activities – other – mobile	IE	IE	IE
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	NE	NE	NO
1B2b	fugitive emissions from fuels – oil & natural gas – natural gas	IE	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	NE	NE	NE
Memo Items	multilateral operations	IE	IE	IE
Memo Items	CO2 emissions from biomass	X		

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.

3.1.3. Emission Trends

This section briefly describes the emission trends from 1990 to 2006 for each of the IPCC Categories under CRF Sector 3 for which GHG emissions are reported. For this analysis, IPCC Category 6C – Waste Incineration is accounted for under IPCC Sub-category 1A1a – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production. Indeed, in the sole incinerator of the country (SIDOR site), energy from waste burning is recovered and injected in the electric public network.

As shown in Table 3-4, energy production and consumption related GHG emissions have increased by 10% between 1990 and 2006. For carbon dioxide, the growth was a bit less than 8%. However, it reached 49% for methane and even 423.5% for nitrous oxide.

Figures 3-1 and 3-2 clearly illustrate that the overall trends observed at the sector level hide very different developments at the IPCC Sub-category level. Indeed, between 1990 and 2006, the 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 IPCC Sub-categories 1A2 – Fuel Combustion Activities – Fuel Combustion from Manufacturing Industries and Construction and 1A3 – Fuel Combustion Activities – Fuel Combustion from Transport demonstrate. There are several industrial sites which have relatively high levels of GHG emissions, and which, therefore, have had a large impact on the national total of those emissions. In the transport sector, road fuel consumption, and even more so road fuel sales,[46] 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 reduce GHG emissions between 1994 and 1997. 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 lead to a rather steep increase of GHG emissions in these sectors and, by extension, of the national total for GHG emissions.

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46 See Section 2.2.2 in Chapter 2.

Table 3-4 – GHG emission trends in CO_2e for CRF Sector 1 – Energy: 1990-2006

Year	CO_2e emissions (Gg) GHG source & sink category															
	1A1 - Energy Industries				1A2 - Manufacturing Industries & Construction				1A3 - Tranport				1A4 - Other Sectors			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	1 304.99	1 301.82	0.88	2.29	5 314.82	5 302.69	3.58	8.56	2 778.54	2 719.76	18.55	40.24	1 304.18	1 290.33	10.35	3.50
1991	1 249.16	1 245.90	0.90	2.36	4 807.68	4 796.00	3.49	8.19	3 385.52	3 308.95	20.84	55.74	1 638.02	1 619.60	14.01	4.41
1992	1 146.22	1 142.90	0.92	2.41	4 595.02	4 583.83	3.29	7.89	3 682.10	3 569.43	25.84	86.84	1 589.80	1 572.39	13.18	4.23
1993	1 234.38	1 231.20	0.88	2.29	4 680.22	4 669.24	3.24	7.74	3 740.84	3 626.58	26.08	88.18	1 626.53	1 607.18	14.96	4.38
1994	1 032.94	1 029.62	0.86	2.47	4 362.33	4 351.26	3.25	7.82	3 781.80	3 658.49	27.40	95.91	1 396.10	1 382.56	9.94	3.60
1995	820.62	817.46	0.81	2.35	2 684.68	2 677.12	2.16	5.40	3 567.94	3 445.56	26.22	96.16	1 400.75	1 387.99	9.27	3.49
1996	710.47	707.94	0.64	1.90	2 689.79	2 681.79	2.27	5.73	3 660.83	3 528.81	27.07	104.94	1 543.22	1 529.70	9.87	3.65
1997	434.62	431.76	0.72	2.14	2 178.47	2 172.12	1.78	4.57	3 948.79	3 802.17	27.75	118.87	1 510.04	1 497.03	9.41	3.60
1998	125.64	122.68	0.83	2.13	1 618.64	1 613.66	1.36	3.62	4 139.63	3 981.37	27.37	130.89	1 602.18	1 589.33	9.12	3.73
1999	168.41	164.93	0.94	2.55	1 832.95	1 827.24	1.80	3.90	4 516.63	4 339.73	26.12	150.77	1 539.86	1 527.43	8.81	3.62
2000	319.75	315.40	1.00	3.35	1 789.06	1 783.21	1.64	4.21	5 133.97	4 936.21	27.97	169.79	1 292.29	1 280.84	8.20	3.25
2001	330.32	325.94	0.99	3.39	1 721.01	1 714.83	1.77	4.40	5 410.55	5 201.48	27.59	181.48	1 451.33	1 439.20	8.62	3.51
2002	1 175.80	1 167.34	1.32	7.14	1 475.76	1 470.60	1.48	3.68	5 652.63	5 433.34	26.59	192.70	1 414.02	1 402.66	7.99	3.38
2003	1 162.38	1 154.01	1.34	7.03	1 403.08	1 398.13	1.41	3.54	6 225.11	5 983.72	27.59	213.80	1 384.29	1 373.25	7.85	3.19
2004	1 464.72	1 454.57	1.53	8.62	1 705.68	1 699.27	1.87	4.53	7 269.00	6 983.40	25.12	260.48	1 374.64	1 363.54	7.86	3.23
2005	1 424.86	1 415.16	1.44	8.27	1 526.04	1 520.49	1.61	3.94	7 484.70	7 181.11	21.21	282.38	1 333.19	1 322.15	7.87	3.16
2006	1 472.04	1 461.98	1.50	8.56	1 670.25	1 664.58	1.62	4.04	7 287.87	6 997.18	20.53	270.16	1 322.41	1 311.63	7.75	3.03
Trend 1990-2006	12.80%	12.30%	70.49%	273.70%	-68.57%	-68.61%	-54.66%	-52.78%	162.29%	157.27%	10.71%	571.36%	1.40%	1.65%	-25.16%	-13.37%

Year	CO_2e emissions (Gg) GHG source & sink category							
	1B2 - Oil & Natural Gas				1 - Total Energy			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	27.51	IE,NA,NE,NO	27.51	NA,NO	10 730.04	10 614.59	60.87	54.59
1991	29.40	IE,NA,NE,NO	29.40	NA,NO	11 109.78	10 970.44	68.63	70.70
1992	30.66	IE,NA,NE,NO	30.66	NA,NO	11 043.81	10 868.54	73.89	101.37
1993	31.92	IE,NA,NE,NO	31.92	NA,NO	11 313.88	11 134.20	77.09	102.59
1994	31.29	IE,NA,NE,NO	31.29	NA,NO	10 604.45	10 421.94	72.73	109.79
1995	36.75	IE,NA,NE,NO	36.75	NA,NO	8 510.75	8 328.14	75.21	107.40
1996	39.27	IE,NA,NE,NO	39.27	NA,NO	8 643.58	8 448.24	79.12	116.22
1997	40.11	IE,NA,NE,NO	40.11	NA,NO	8 112.02	7 903.07	79.76	129.18
1998	40.53	IE,NA,NE,NO	40.53	NA,NO	7 526.63	7 307.05	79.21	140.37
1999	43.26	IE,NA,NE,NO	43.26	NA,NO	8 101.10	7 859.33	80.93	160.84
2000	44.31	IE,NA,NE,NO	44.31	NA,NO	8 579.38	8 315.66	83.11	180.61
2001	45.78	IE,NA,NE,NO	45.78	NA,NO	8 958.99	8 681.46	84.75	192.78
2002	58.17	IE,NA,NE,NO	58.17	NA,NO	9 776.39	9 473.94	95.55	206.90
2003	58.59	IE,NA,NE,NO	58.59	NA,NO	10 233.46	9 909.11	96.78	227.56
2004	61.11	IE,NA,NE,NO	61.11	NA,NO	11 875.14	11 500.78	97.49	276.86
2005	59.43	IE,NA,NE,NO	59.43	NA,NO	11 828.22	11 438.90	91.57	297.75
2006	59.43	IE,NA,NE,NO	59.43	NA,NO	11 812.00	11 435.38	90.84	285.79
Trend 1990-2006	116.03%	NA	116.03%	NA	10.08%	7.73%	49.23%	423.55%

Source: Environment Agency.

Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

Figure 3-1 – GHG emission trends in % for CRF Sector 1 – Energy: 1990-2006

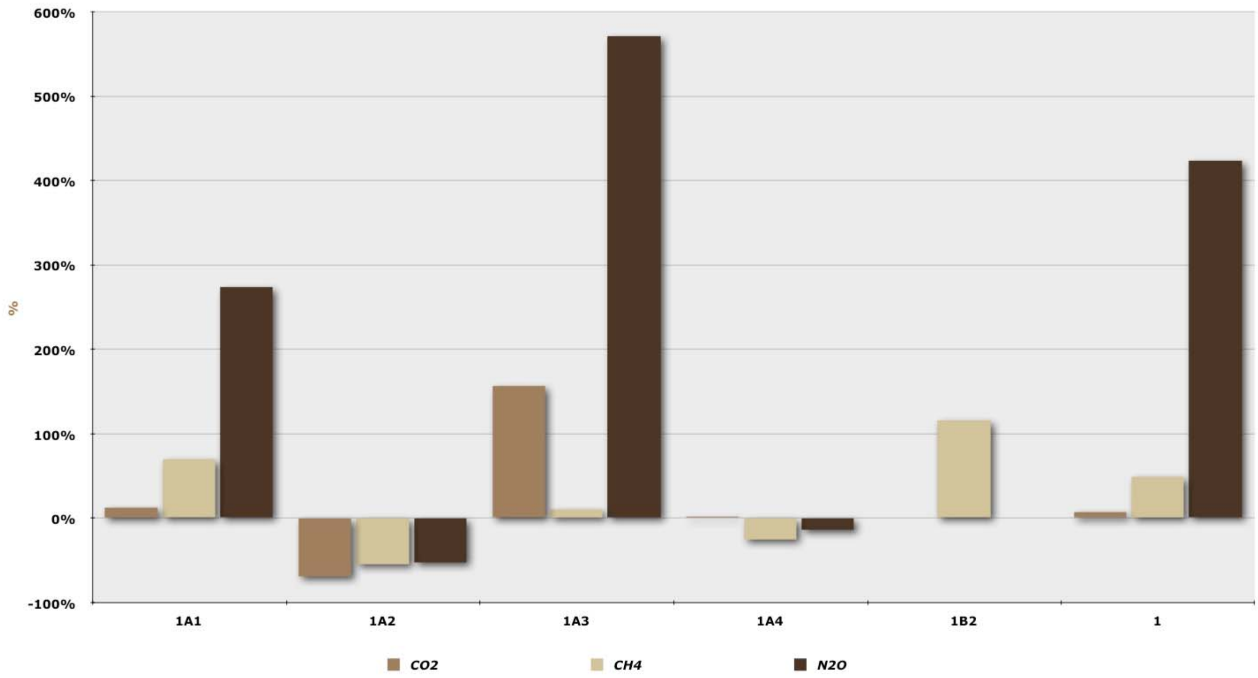
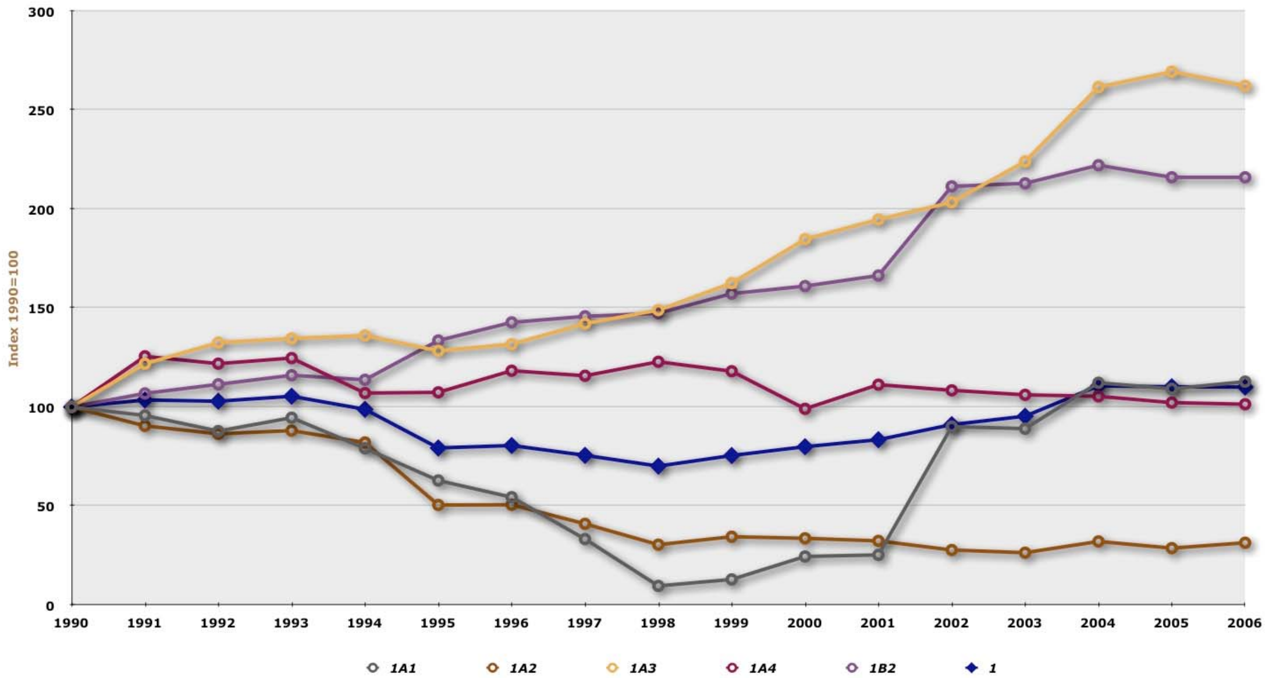


Figure 3-2 – GHG emission trends – indexes – for CRF Sector 1 – Energy: 1990-2006



All the changes briefly presented in the previous paragraphs – as well as in Section 2.2 - completely modified the pattern of the energy related GHG emissions between 1990 and 2006 with regard to IPCC Sub-categories share – see Figure 3-3 – and to the "energy-mix" or fuels usage for energy production and consumption – see Table 3-5.

Figure 3-3 – IPCC Categories weights in GHG emissions for CRF Sector 1 – Energy: 1990 and 2006

1990 *2006*

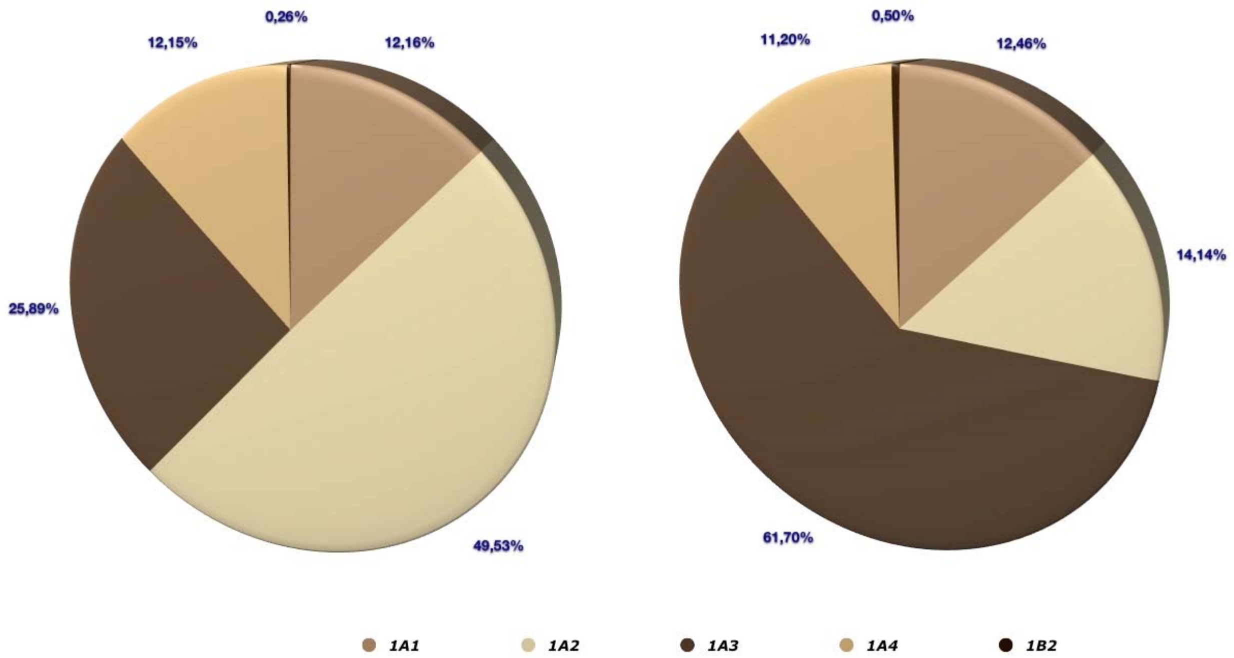


Table 3-5 – Final energy consumption trends: 1970-2006

Year	Total	*Coal*	*Liquid fuels*	*Natural gas*	*Blast furnaces' gas*	*Electricity*	*Heat & cogeneration (1)*	*Wood & biomass (2)*
	1000 toe							
1970	3735.40	*1270.00*	*1230.00*	*10.00*	*1000.00*	*210.00*	*NO*	*15.40*
1980	3422.37	*1341.55*	*1048.95*	*360.15*	*346.15*	*310.17*	*NO*	*15.40*
1990	3439.66	*819.56*	*1581.21*	*464.14*	*201.72*	*357.63*	*NO*	*15.40*
1991	3611.32	*736.47*	*1836.83*	*487.02*	*172.56*	*363.04*	*NO*	*15.40*
1992	3618.78	*704.10*	*1879.27*	*507.24*	*148.42*	*364.75*	*NO*	*15.00*
1993	3692.97	*733.06*	*1883.41*	*527.48*	*155.59*	*378.03*	*NO*	*15.40*
1994	3607.06	*651.29*	*1880.83*	*525.22*	*131.45*	*400.27*	*3.00*	*15.00*
1995	3215.25	*382.99*	*1736.18*	*571.29*	*65.25*	*430.70*	*13.84*	*15.00*
1996	3297.67	*374.29*	*1784.96*	*627.00*	*59.99*	*422.96*	*13.07*	*15.40*
1997	3258.76	*248.93*	*1864.16*	*648.61*	*32.27*	*435.93*	*13.46*	*15.40*
1998	3237.97	*116.62*	*1971.79*	*655.32*	*NO*	*456.15*	*22.69*	*15.40*
1999	3411.48	*115.50*	*2103.82*	*679.43*	*NO*	*473.77*	*23.56*	*15.40*
2000	3582.40	*128.26*	*2227.62*	*692.52*	*NO*	*491.69*	*26.91*	*15.40*
2001	3722.36	*112.03*	*2368.94*	*708.62*	*NO*	*484.32*	*33.05*	*15.40*
2002	3763.27	*94.10*	*2425.70*	*703.73*	*NO*	*487.84*	*36.50*	*15.40*
2003	3980.59	*79.94*	*2622.03*	*704.09*	*NO*	*517.26*	*41.87*	*15.40*
2004	4340.66	*96.22*	*2867.72*	*754.88*	*NO*	*552.15*	*54.29*	*15.40*
2005	4444.85	*82.89*	*3029.88*	*726.15*	*NO*	*529.57*	*60.39*	*15.97*
2006	4431.39	*111.53*	*2920.47*	*759.97*	*NO*	*559.68*	*63.80*	*15.94*
Trend 1990-2006	*28.83%*	*-86.39%*	*84.70%*	*63.74%*	*NA*	*56.50%*	*NA*	*3.51%*
Share 1990	*100.00%*	*23.83%*	*45.97%*	*13.49%*	*5.86%*	*10.40%*	*NA*	*0.45%*
Share 2006	*100.00%*	*2.52%*	*65.90%*	*17.15%*	*NA*	*12.63%*	*1.44%*	*0.36%*

Source: Ministry of Economic Affairs and External Trade, Energy Department and FiFo Köln

Notes:

(1) including heat recovery from waste incineration. There is only one incinerator operating in Luxembourg (SIDOR) and the energy it produces is recovered.

(2) in 2005 and 2006, wood & biomass category includes 0.57 and 0.54 ktoe of biofuels produced in Luxembourg and used by buses of the City of Luxembourg.

data extracted in February 2008 (subject to changes since that date)

Final energy consumption increased by 29% between 1990 and 2006. It has passed through a minimum in 1995. All the energy sources have seen their consumption increase over the period, except coal for which the declining use in the first part of the 1990s was closely linked to the discontinuation of the use of blast furnaces in the steel industry. Table 3-5 also shows the dramatic change in the "energy-mix" used in Luxembourg between 1990 and 2006 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, to a lesser extent, to natural gas and new energy sources such as cogeneration.

In 2006, with 66% 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 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 drivers passing through Luxembourg. Actually, in 2006, almost 80% of road fuels are sold to vehicles registered abroad (see Table 3-36 in Section 3.4.2).

The importance of natural gas has increased constantly and significantly since 1990. In 2006, natural gas consumption ranked second after the consumption of liquid fuels. This development followed the extension of the natural gas network in Luxembourg.

Natural gas has also become the main energy source for the increase of Luxembourg's national electricity production capacity.[47] In 1990, more than 90% of Luxembourg's electric energy consumption was imported and one medium size power plant of some 70 MW was owned by the iron and steel company Arbed.[48] That power plant was run mainly on blast furnace gas, and it 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. A few industrial companies installed gas turbines to produce electricity and heat simultaneously (for example Good Year and Dupont de Nemours). In mid-2002, the TWINerg power plant – a gas turbine – started its operation.[49] Almost all of these plants run on natural gas. Gasoil remains, however, the emergency fuel in case of a natural gas supply disruption.

Table 3-6 summarizes electricity production developments in Luxembourg since 1970.

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47 This cannot be seen in final energy consumption statistics but in the primary energy consumption figures: see Table 2-10 in Section 2.2.5.

48 Later Arcelor-Arbed, then Arcelor-Mittal.

49 See Section 2.1.3.2 above.

Table 3-6 – Electricity production trends: 1970-2006

Year	Electricity production (MWh) Total	*Thermic (1)*	*RES (2)*	*Cogeneration*
1970	1347.50	*1260.98*	*86.52*	*NO*
1980	914.55	*828.31*	*86.24*	*NO*
1990	626.24	*558.72*	*67.52*	*NO*
1991	676.37	*622.11*	*54.26*	*NO*
1992	662.49	*594.14*	*68.35*	*NO*
1993	669.79	*607.83*	*61.96*	*NO*
1994	592.07	*505.96*	*86.11*	*24.00*
1995	527.68	*346.53*	*81.33*	*99.82*
1996	466.07	*306.24*	*53.46*	*106.36*
1997	415.66	*213.96*	*92.14*	*109.56*
1998	396.14	*104.76*	*107.11*	*184.27*
1999	375.28	*51.62*	*133.12*	*190.54*
2000	438.10	*51.50*	*170.12*	*216.48*
2001	864.40	*374.14*	*146.34*	*343.93*
2002	2822.82	*2327.85*	*131.56*	*363.42*
2003	2784.39	*2285.48*	*116.63*	*382.28*
2004	3373.52	*2787.37*	*164.58*	*421.57*
2005	3336.72	*2736.60*	*182.19*	*417.92*
2006	3518.95	*2866.49*	*214.36*	*438.09*
Trend 1990-2006	*461.92%*	*413.05%*	*217.49%*	*NA*
Share 1990	*100.00%*	*89.22%*	*10.78%*	*NA*
Share 2006	*100.00%*	*81.46%*	*6.09%*	*12.45%*

Sources: Ministry of Economic Affairs and External Trade – Energy Division;

ILR (*Institut Luxembourgeois de Régulation*): http://www.ilr.etat.lu/elec/stat/index.htm; and

STATEC, *Statistical Yearbook*, Table C.3506: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1291

Notes:

(1) including the gas-vapour turbine TWINerg since, so far, heat is not yet used (hence, classified as a thermal power plant).

(2) RES = Renewable Energy Sources = small hydro-electric power plant, wind turbines, solar (photovoltaic cells), biogas.

data extracted in February 2008 (subject to changes since that date)

3.2. Fuel Combustion Activities – Energy Industries (IPCC Source Sub-category 1A1)

This section describes GHG emissions resulting from fuel combustion activities in energy industry. In 2006, this source category was responsible for a bit more than 11.8% of GHG emissions from fuel combustion activities (10.6% in 1990) and represented 11% of the total GHG emissions in CO_2e, excluding LULUCF (9.9% in 1990).

In fact, emissions are reported only from public electricity and heat production. Hence, **IPCC Sub-Category 1A1 = IPCC Sub-category 1A1a – Public Electricity and Heat Production**. Within this sub-category, a distinction is made between energy generated from waste burning[50] – waste incineration – and other electricity and heat production facilities.

Table 3-7 summarizes GHG emissions for IPCC Sub-category 1A1.

50 The energy generated during waste incineration is recovered and injected in the electric public network.

Table 3-7 – GHG emission trends in CO_2e for IPCC Sub-category 1A1 – Fuel Combustion Activities – Energy Industries: 1990-2006

Year	*CO_2e emissions (Gg)* GHG source & sink category: 1A1a - Public Electricity & Heat Production excl. Waste Incineration				1A1a - Public Electricity & Heat Production from Waste Incineration				1A1b - Petroleum Refining			
	Total	*CO_2*	*CH_4*	*N_2O*	Total	*CO_2*	*CH_4*	*N_2O*	Total	*CO_2*	*CH_4*	*N_2O*
1990	1 268.83	*1 268.53*	*0.12*	*0.18*	36.16	*33.29*	*0.76*	*2.11*	NO	*NO*	*NO*	*NO*
1991	1 212.21	*1 211.89*	*0.12*	*0.20*	36.95	*34.01*	*0.78*	*2.16*	NO	*NO*	*NO*	*NO*
1992	1 108.50	*1 108.17*	*0.12*	*0.21*	37.72	*34.73*	*0.80*	*2.20*	NO	*NO*	*NO*	*NO*
1993	1 198.49	*1 198.17*	*0.12*	*0.20*	35.89	*33.04*	*0.76*	*2.09*	NO	*NO*	*NO*	*NO*
1994	997.83	*997.29*	*0.11*	*0.42*	35.11	*32.32*	*0.74*	*2.05*	NO	*NO*	*NO*	*NO*
1995	787.09	*786.59*	*0.10*	*0.40*	33.53	*30.87*	*0.71*	*1.95*	NO	*NO*	*NO*	*NO*
1996	684.53	*684.05*	*0.09*	*0.39*	25.94	*23.88*	*0.55*	*1.51*	NO	*NO*	*NO*	*NO*
1997	403.88	*403.47*	*0.07*	*0.35*	30.73	*28.29*	*0.65*	*1.79*	NO	*NO*	*NO*	*NO*
1998	69.17	*68.76*	*0.03*	*0.38*	56.47	*53.92*	*0.80*	*1.76*	NO	*NO*	*NO*	*NO*
1999	104.01	*103.40*	*0.05*	*0.57*	64.40	*61.53*	*0.89*	*1.98*	NO	*NO*	*NO*	*NO*
2000	256.94	*255.43*	*0.11*	*1.40*	62.81	*59.97*	*0.88*	*1.95*	NO	*NO*	*NO*	*NO*
2001	268.30	*266.72*	*0.12*	*1.46*	62.02	*59.21*	*0.87*	*1.93*	NO	*NO*	*NO*	*NO*
2002	1 112.82	*1 107.21*	*0.43*	*5.18*	62.97	*60.13*	*0.89*	*1.96*	NO	*NO*	*NO*	*NO*
2003	1 098.10	*1 092.56*	*0.43*	*5.11*	64.28	*61.45*	*0.92*	*1.92*	NO	*NO*	*NO*	*NO*
2004	1 395.25	*1 388.16*	*0.54*	*6.54*	69.47	*66.40*	*0.99*	*2.07*	NO	*NO*	*NO*	*NO*
2005	1 361.19	*1 354.29*	*0.53*	*6.37*	63.68	*60.87*	*0.91*	*1.90*	NO	*NO*	*NO*	*NO*
2006	1 404.92	*1 397.82*	*0.55*	*6.56*	67.12	*64.16*	*0.96*	*2.01*	NO	*NO*	*NO*	*NO*
Trend 1990-2006	*10.73%*	*10.19%*	*366.16%*	*3464.58%*	*85.63%*	*92.75%*	*25.14%*	*-4.83%*	*NA*	*NA*	*NA*	*NA*

Year	*CO_2e emissions (Gg)* GHG source & sink category: 1A1c - Manuf. of Solid Fuels & Other Energy Industries				1A1 - Energy Industries			
	Total	*CO_2*	*CH_4*	*N_2O*	Total	*CO_2*	*CH_4*	*N_2O*
1990	NO	*NO*	*NO*	*NO*	1 304.99	*1 301.82*	*0.88*	*2.29*
1991	NO	*NO*	*NO*	*NO*	1 249.16	*1 245.90*	*0.90*	*2.36*
1992	NO	*NO*	*NO*	*NO*	1 146.22	*1 142.90*	*0.92*	*2.41*
1993	NO	*NO*	*NO*	*NO*	1 234.38	*1 231.20*	*0.88*	*2.29*
1994	NO	*NO*	*NO*	*NO*	1 032.94	*1 029.62*	*0.86*	*2.47*
1995	NO	*NO*	*NO*	*NO*	820.62	*817.46*	*0.81*	*2.35*
1996	NO	*NO*	*NO*	*NO*	710.47	*707.94*	*0.64*	*1.90*
1997	NO	*NO*	*NO*	*NO*	434.62	*431.76*	*0.72*	*2.14*
1998	NO	*NO*	*NO*	*NO*	125.64	*122.68*	*0.83*	*2.13*
1999	NO	*NO*	*NO*	*NO*	168.41	*164.93*	*0.94*	*2.55*
2000	NO	*NO*	*NO*	*NO*	319.75	*315.40*	*1.00*	*3.35*
2001	NO	*NO*	*NO*	*NO*	330.32	*325.94*	*0.99*	*3.39*
2002	NO	*NO*	*NO*	*NO*	1 175.80	*1 167.34*	*1.32*	*7.14*
2003	NO	*NO*	*NO*	*NO*	1 162.38	*1 154.01*	*1.34*	*7.03*
2004	NO	*NO*	*NO*	*NO*	1 464.72	*1 454.57*	*1.53*	*8.62*
2005	NO	*NO*	*NO*	*NO*	1 424.86	*1 415.16*	*1.44*	*8.27*
2006	NO	*NO*	*NO*	*NO*	1 472.04	*1 461.98*	*1.50*	*8.56*
Trend 1990-2006	*NA*	*NA*	*NA*	*NA*	*12.80%*	*12.30%*	*70.49%*	*273.70%*

Source: Environment Agency.

Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.2.1. IPCC Sub-Category 1A1a – Public Electricity and Heat Production without waste incineration

In 2006, public electricity and heat production, excluding energy production from waste incineration, was responsible for 11.3% of GHG emissions from fuel combustion activities (10.3% in 1990) and represented 10.55% of the total GHG emissions in CO_2e, excluding LULUCF (9.6% in 1990).

3.2.1.1. Key source

Public electricity and heat production is a key source with regard to CO_2 emissions. It has been a key source for solid fuels between 1990 and 1997 and a key source for gaseous fuels from 1994 onwards: see Tables 1-6 and 1-7 in Section 1.5.1.

3.2.1.2. Source category description

This source category includes:

- a power plant operated until 1997 by the steel industry (SNAP 010102);
- combined heat and power (*CHP*) installations (SNAP 010103);
- CHP gas turbines (SNAP 010104).

<u>SNAP 010102 Public power, combustion plants, 50 - 300 MW (boilers)</u>

One power station operated by the steel industry existed in Luxembourg until 1997, in a site called *Terres Rouges*. Between 1990 and 1997, it was fed with blast furnace gas, natural gas and residual oil. The activity rates are based on information received from the plant operator (Arbed[51] at the time) and from TÜV (1990).

<u>SNAP 010103 - Public power, combustion plants < 50 MW</u>

This source type includes 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. The activity rates have been estimated by the Environment Agency based on the available information on the installed electrical power of these installations and based on a typical annual fuel consumption for this type of installations.

<u>SNAP 010104 - Gas turbines</u>

In this activity group CHP gas turbines are included. The major gas vapour turbine - TWINerg – has started heat and electric energy production in 2002. It is operated with natural gas. Since heat is not yet recovered, this unit is counted as a thermal power plant and not a cogeneration one in

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[51] Later Arcelor-Arbed, and now Arcelor-Mittal.

official statistics. However, this classification issue has no impact on the GHG emission estimates since it is the fuel(s) used and the technology(ies) that matter.

3.2.1.3. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

The activity data of SNAP 010102 are based on consumption data of the iron and steel industry, provided by the plant operator, and on statistical data published by STATEC (Statistical Yearbook, Tables C.3001, C.3400 and C.3450 to C.3458). Beside that, estimations of the Environment Agency were necessary to determine more detailed energy consumption data of the CHP installations (internal study). For SNAP activity 010103, fuels 204A and 301A, the activity data were estimated on the basis of an internal study.

Table 3-8 – Activity data for IPCC Sub-category 1A1a – Public Electricity and Heat Production (excl. waste incineration): 1990-2006

SNAP	010102				010103	
Activity	Combustion plants >= 50 MW, <300 MW				Combustion plants < 50MW (CHP)	
Fuel	203A		301A	305A	204A	301A
Unit	[t]	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]
1990		117000	448000	4784265	0	0
1991	6931	284171	356133	4534554	0	0
1992	9671	396511	384803	4092601	0	0
1993	6750	276750	382216	4477919	0	0
1994	1805	74005	626600	3510531	21755	874913
1995	1755	71955	756250	2666289	21755	874913
1996	1129	46289	980706	2227745	21755	874913
1997	1327	54407	803967	1176200	21755	874913
1998	0	0	0	0	29510	1186762
1999	0	0	0	0	44372	1784475
2000	0	0	0	0	109619	4408346
2001	0	0	0	0	114466	4603252
2002	0	0	0	0	114466	4603252
2003	0	0	0	0	114466	4603252
2004	0	0	0	0	164785	6626812
2005	0	0	0	0	164785	6146368
2006	0	0	0	0	164785	6146368
Sources	1990: TÜV (1990); 1991-1998: ARBED: Chaudière HP (PA-EB)		1990-1998: ARBED: Chaudière HP (PA-EB)		internal study (see above)	

SNAP	010104			
Activity		Gas turbines		Gas vapour turbine (TWINerg.)
Fuel	Total	204a	301a	301
Unit	[GJ]	[GJ]	[GJ]	[GJ]
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	359 201	641	358 560	0
1995	602 664	664	602 000	0
1996	902 995	995	902 000	0
1997	902 995	995	902 000	0
1998	1 385 526	1 526	1 384 000	0
1999	1 385 526	1 526	1 384 000	0
2000	1 385 526	1 526	1 384 000	0
2001	3 809 967	1 526	3 808 441	0
2002	18 720 152	4 410	3 733 742	14 982 000
2003	18 458 912	4 410	3 733 742	14 720 760
2004	21 077 827	992	3 176 835	17 900 000
2005	20 498 984	2 289	2 720 058	17 776 637
2006	21 142 195	2 289	2 587 404	18 552 502
Source	STATEC: national statistics; emission measurement reports			

Table 3-9 – Conversion factors for various fuel types

Fuel type	Conversion factor LHV	Unit	Source
203A, residual oil	41.00	GJ/t	CORINAIR Guidebook (1996): Combustion in Energy & transformation industries-ps010101 Activities 010101– 010105, Tab. 21, B111-42.
204A gas oil	42.70	GJ/t	
301A natural gas	37.35	GJ/1000m3	Inquiry Service du Gaz, Ville de Luxembourg

* LHV = lower heat value

Emission factors

Table 3-10 – Emission factors for IPCC Sub-category 1A1a – Public Electricity and Heat Production (excl. waste incineration)

IPCC Category	Source Categories	SNAP	Fuel		Emission factor [kg/GJ]		Source
1A1a	Combustion plants < 50 MW (boilers)	010103	204A	Gas oil	CO_2	74.1	2006 IPCC Guidelines
					CH_4	0.6	2006 IPCC Guidelines
					N_20	1.0	2006 IPCC Guidelines
			301A	Natural gas	CO_2	56.1	2006 IPCC Guidelines
					CH_4	1.2	2006 IPCC Guidelines
					N_20	0.1	2006 IPCC Guidelines
	Combustion plants ≥ 50 MW, <300 MW	010102	203A	Residual oil	CO_2	77.4	2006 IPCC Guidelines
					CH_4	3.0	2006 IPCC Guidelines
					N_20	0.6	2006 IPCC Guidelines
			301A	Natural gas	CO_2	56.1	2006 IPCC Guidelines
					CH_4	1.0	2006 IPCC Guidelines
					N_20	0.1	2006 IPCC Guidelines
			305A	Blast furnace gas	CO_2	258.0	internal study
					CH_4	1.0	2006 IPCC Guidelines
					N_20	0.1	2006 IPCC Guidelines

IPCC Category	Source Categories	SNAP	Fuel		Emission factor [kg/GJ]	Source
1A1a	Gas turbines / Gas turbines (LPS)	010104	204A	Gas oil	74.1	2006 IPCC Guidelines
			301A	Natural gas	56.1	

3.2.2. IPCC Sub-Category 1A1a – Public Electricity and Heat Production – Waste Incineration

In 2006, energy production from waste incineration was responsible for 0.5% of GHG emissions from fuel combustion activities (0.3% in 1990) and represented 0.5% of the total GHG emissions in CO_2e, excluding LULUCF (0.3% in 1990)

3.2.2.1. Key source

Energy production from waste incineration is not a key source.

3.2.2.2. Source category description

In this category CO_2 emissions from waste incineration are included as well as CO_2, CH_4 and N_2O emissions from municipal waste incineration with energy recovery.

In general, municipal waste is combusted for energy recovery in district heating plants or at industrial sites and therefore the emissions are reported as fuel combustion emissions.

No industrial and hazardous waste is incinerated because it is exported. Waste is not pre-treated before combustion. The high calorific waste from SIDEC is sewed out and incinerated at the waste incinerator SIDOR.[52]

3.2.2.3. Methodological issues

Activity data

Activity data are taken from the following studies and for the years in-between an interpolation has been carried out:

- Waste Division of the Environment Agency, *Restabfallanalyse 2004/05 im Großherzogtum Luxemburg, Band 1: Kompendium*, Luxembourg, 2005;
- Waste Division of the Environment Agency, *Restabfallanalyse 2001 im SIDOR*, Luxembourg, 2002;
- Waste Division of the Environment Agency, *Restabfallanalyse 1992/1994*, Luxembourg, 2002.

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

Table 3-11 – MSW components of incinerated waste in tonnes: 1990-2006

	Paper/ cardboard	Textiles	Food waste	Wood	Garden & Park waste	Nappies	Rubber & Leather	Plastics	multilayer composite material	Metal	Glass	Other, Inert waste	Total
							[t]						
1990	29.97	3.27	56.73	1.21	0.00	4.79	0.00	1.76	10.88	3.68	10.73	12.95	135.97
1991	30.62	3.35	57.95	1.24	0.00	4.89	0.00	1.80	11.12	3.76	10.96	13.23	138.91
1992	31.27	3.42	59.18	1.26	0.00	4.99	0.00	1.84	11.35	3.84	11.19	13.51	141.85
1993	29.75	3.25	56.30	1.20	0.00	4.75	0.00	1.75	10.80	3.65	10.65	12.85	134.95
1994	29.11	3.18	55.08	1.17	0.00	4.65	0.00	1.71	10.57	3.57	10.42	12.57	132.03
1995	27.80	3.04	52.60	1.12	0.00	4.44	0.00	1.64	10.09	3.41	9.95	12.01	126.09
1996	21.51	2.35	40.70	0.87	0.00	3.43	0.00	1.27	7.81	2.64	7.70	9.29	97.55
1997	25.48	2.78	48.21	1.03	0.00	4.07	0.00	1.50	9.25	3.13	9.12	11.00	115.56
1998	20.16	3.69	41.67	0.00	0.00	5.02	0.00	3.37	18.31	3.02	4.63	13.41	113.28
1999	23.08	4.22	47.70	0.00	0.00	5.74	0.00	1.80	20.96	3.46	5.31	15.35	127.64
2000	22.42	4.10	46.34	0.00	0.00	5.58	0.00	3.75	20.37	3.36	5.15	14.91	125.99
2001	22.14	4.05	45.76	0.00	0.00	5.51	0.00	3.70	20.11	3.32	5.09	14.73	124.40
2002	22.48	4.11	46.46	0.00	0.00	5.59	0.00	3.76	20.42	3.37	5.17	14.95	126.32
2003	31.51	3.04	32.69	1.10	4.53	5.65	0.65	2.57	21.01	4.02	4.96	12.12	123.83
2004	34.05	3.28	35.32	1.19	4.89	6.11	0.70	2.77	22.70	4.35	5.36	13.09	133.82
2005	31.21	3.01	32.38	1.09	4.49	5.60	0.64	2.54	20.81	3.99	4.91	12.00	122.66
2006	32.90	3.17	34.13	1.15	4.73	5.9.	0.67	2.68	21.94	4.20	5.17	12.65	129.31

Table 3-12 – MSW components of incinerated waste in TJ: 1990-2006

	Paper/ cardboard	Textiles	Food waste	Wood	Garden & Park waste	Nappies	Rubber & Leather	Plastics	multilayer composite material	Metal	Glass	Other, Inert waste	Total
							[TJ]						
1990	389.67	42.57	283.63	6.05		47.86		26.45	326.45			90.63	1213.29
1991	398.10	43.49	289.76	6.18		48.89		27.02	333.51			92.59	1239.54
1992	406.53	44.41	295.90	6.31		49.93		27.59	340.57			94.55	1265.78
1993	386.74	42.25	281.49	6.00		47.50		26.25	323.99			89.95	1204.17
1994	378.38	41.34	275.41	5.87		46.47		25.68	316.99			88.00	1178.14
1995	361.36	39.48	263.02	5.61		44.38		24.53	302.73			84.05	1125.15
1996	279.57	30.54	203.49	4.34		34.34		18.98	234.21			65.02	870.49
1997	331.18	36.18	241.05	5.14		40.67		22.48	277.44			77.03	1031.17
1998	262.08	47.97	208.33	0.00		50.17		50.56	549.33			93.87	1262.31
1999	300.06	54.92	238.51	0.00		57.44		27.02	628.92			107.47	1414.34
2000	291.49	53.35	231.70	0.00		55.80		56.24	610.97			104.40	1403.97
2001	287.81	52.68	228.78	0.00		55.10		55.53	603.26			103.09	1386.25
2002	292.25	53.49	232.30	0.00		55.95		56.38	612.56			104.67	1407.60
2003	409.63	39.47	163.44	5.49	22.64	56.54	3.23	38.48	630.29			84.81	1454.02
2004	442.67	42.65	176.62	5.93	24.47	61.10	3.49	41.59	681.14			91.65	1571.31
2005	405.76	39.10	161.90	5.44	22.43	56.01	3.20	38.12	624.35			84.01	1440.30
2006	427.75	41.21	170.67	5.73	23.64	59.04	3.37	40.19	658.18			88.56	1518.35

CO$_2$ emissions

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

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

with:

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

with:

$$\sum_j WF_j = 1$$

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

Reported CO_2 emissions of waste incineration are only CO_2 emissions from fossil MSW. However the activity data includes biogenic and fossil MSW - as it can be seen in Table 3-11 (for instance, food and garden waste). The reported CO_2 EF is actually an IEF, which is calculated from produced energy and fossil CO_2 emissions.

This means that biogenic CO_2 emissions do not have to be reported under Memo Items, because these emissions are included via the (reduced/corrected) IEF in IPCC Sub-category 1A1a.

Table 3-13 – Default dry matter content, degradable organic carbon (DOC) content, total carbon content and fossil carbon fraction of different MSW components

MSW component	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	
	Default	Default	Range	Default	Range	Default	Range	Default	Range
Paper/ cardboard	90	40	36 - 45	44	40 - 50	46	42 - 50	1	0 - 5
Textiles	80	24	20 - 40	30	25 - 50	50	25 - 50	20	0 - 50
Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50		-
Wood	85	43	39 - 46	50	46 - 54	50	46 - 54		-
Garden and Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0 -
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10 -
Rubber and Leather	84	39	39		47	67	67	20	20 -
Plastics	100					75	67 - 85	100	95 - 100
Metal	100					NA	NA - NA	NA	NA - NA
Glass	100					NA	NA - NA	NA	NA - NA
Other, Inert waste	90					3	0 - 5	100	50 - 100

Source: 2006 IPCC Guidelines, Table 2.4.

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.[53]

Table 3-14 – Calorific values for MSW components

MSW component	Heating value [GJ/t]
Paper/cardboard	13
Textiles	13
Food waste	5
Wood	5
Garden and Park waste	5
Nappies	10
Rubber and Leather	5
Multilayer composite material	15
Plastics	30
Metal	0
Glass	0
Other, Inert waste	7
Total	12

CH_4 emissions

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

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

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

with:

CH_4 Emissions = CH_4 emissions (kg GHG)

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

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

For CO_2, it includes the carbon oxidation factor, assumed to be 1.

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

N_2O emissions

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

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

with:

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

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

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

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

i = category or type of waste incinerated (MSW)

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

Emission factors

For carbon dioxide, the calculation is based on the carbon content of the waste. CO_2 emissions are calculated by applying the default values listed in Table 3-13 (provided in 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.

A fraction analysis of the typical wet MSW for the years 1992/1994, 2001 and 2004/2005 was performed by the Waste Division of the Environment Agency. The CO_2 EF is converted into t CO_2/TJ by the mean of a heating value of the different MSW components listed in Table 3-14. These EF (valid for the whole time series) are listed in the following table.

Table 3-15 – EF for MSW components of incinerated waste: 1990-2006

	Paper/ cardboard	Textiles	Food waste	Wood	Garden & Park waste	Nappies	Rubber & Leather	Plastics	multilayer composite material	Metal	Glass	Other, Inert waste	Total
	[t CO2/TJ]												
1990	39.76	74.03				62.73		6.60	2081.25			185.17	27.44
1991	35.76	75.49				50.20		6.60	1019.05			187.07	27.44
1992	36.52	77.08				51.26		6.60	1040.63			191.03	27.44
1993	34.74	73.33				48.77		6.60	989.98			181.73	27.44
1994	33.99	71.75				47.71		6.60	968.58			177.80	27.44
1995	32.46	68.52				45.57		6.60	925.01			169.81	27.44
1996	25.11	53.01				35.25		6.60	715.65			131.37	27.44
1997	29.75	62.80				41.76		6.60	847.75			155.62	27.44
1998	23.54	83.26				51.51		6.60	1678.51			189.66	42.72
1999	26.95	95.32				58.98		6.60	1921.71			217.13	43.50
2000	26.18	92.60				57.29		6.60	1866.87			210.94	42.72
2001	25.85	91.43				56.57		6.60	1843.31			208.28	42.72
2002	26.25	92.84				57.44		6.60	1871.70			211.48	42.72
2003	36.79	68.50				58.05	53.34	6.60	1925.89			171.35	42.26
2004	39.76	74.03				62.73	57.64	6.60	2081.25			185.17	42.26
2005	36.45	67.86				57.50	52.83	6.60	1907.73			169.73	42.26
2006	38.42	71.54				60.62	55.70	6.60	2011.0			178.93	42.26

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

The N_2O default emission factor of 50 g N_2O/tMSW for continuous and semi-continuous incinerators is applied (2006 IPCC Guidelines).

3.2.3. IPCC Sub-category 1A1b – Petroleum Refining

This source category does not exist in Luxembourg.

3.2.4. IPCC Sub-category 1A1c – Manufacture of Solid Fuels and Other Energy Industries

This source category does not exist in Luxembourg.

3.2.5. Recalculations

See Tables 3-1 and 3-2 above.

3.2.6. Category specific QA/QC procedures

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

3.2.7. 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 3-16 will be explored.

Table 3-16 – Planned improvements for IPCC Sub-category 1A1 – Fuel Combustion Activities – Energy Industries

GHG source & sink category	Planned improvement
1A1a - Public Electricity and Heat Production	revise activity data taking into account EU ETS reported information as well as operating permits related information.
1A1a - Public Electricity and Heat Production	investigate how reported emissions under the EU-ETS regulation could be included in the GHG inventory.
1A1a - Public Electricity and Heat Production	conversion factors: use of factors for various fuel types provided by IEA in its Energy Statistics Manual or of country/plant-specific values?
1A1a - Public Electricity and Heat Production	provide more information on estimation methods used in internal studies.
1A1a/6C - Public Electricity and Heat Production	waste incineration with energy recovery: validate the biogenic vs. non-biogenic breakdown and related emissions estimation method.
1A1a - Public Electricity and Heat Production	investigate emissions allocation between IPCC Sub-category 1A1 and 1A2: public electricity and heat production relates to energy going into the public network. What about autoproducers for their own needs or only if a fraction of the energy produced finally ends in the public network? (e.g. the power plant operated by the iron and steel industry up to 1997 or CHP directly linked to a plant)

3.3. Fuel Combustion Activities – Manufacturing Industries and Construction (IPCC Source Sub-category 1A2)

This section describes GHG emissions resulting from fuel combustion activities in manufacturing industries and construction. In 2006, this source category was responsible for a bit more than 14% of GHG emissions from fuel combustion activities (this share was almost 50% in 1990) and represented 12.5% of the total GHG emissions in CO_2e, excluding LULUCF (40.3% in 1990).

The GHG inventory, so far, does not record GHG emissions for the IPCC Sub-categories 1A2c – Chemicals, 1A2d – Pulp, Paper and Print and 1A2e – Food Processing, Beverages and Tobacco.

Table 3-17 summarizes GHG emissions for IPCC Sub-category 1A2.

Table 3-17 – GHG emission trends in CO_2e for IPCC Sub-category 1A2 – Fuel Combustion Activities – Manufacturing Industries and Construction: 1990-2006

Year	CO_2e emissions (Gg) – GHG source & sink category															
	1A2a - Iron & Steel				1A2b - Non-Ferrous Metals				1A2c - Chemicals				1A2d - Pulp, Paper & Print			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	3 244.64	3 238.00	2.12	4.52	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1991	3 088.39	3 081.36	2.24	4.79	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1992	2 711.95	2 706.19	1.84	3.92	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1993	2 985.19	2 978.87	2.02	4.30	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1994	2 587.25	2 582.02	1.67	3.55	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1995	1 395.79	1 392.99	0.90	1.90	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1996	1 287.55	1 284.98	0.83	1.74	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1997	849.18	847.66	0.50	1.02	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1998	176.38	176.21	0.07	0.10	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
1999	122.69	122.57	0.05	0.07	38.49	38.46	0.01	0.02	NO	NO	NO	NO	NO	NO	NO	NO
2000	205.96	205.76	0.08	0.12	53.17	53.13	0.02	0.03	NO	NO	NO	NO	NO	NO	NO	NO
2001	249.67	249.43	0.10	0.14	53.17	53.13	0.02	0.03	NO	NO	NO	NO	NO	NO	NO	NO
2002	258.16	257.91	0.10	0.15	44.07	44.03	0.02	0.02	NO	NO	NO	NO	NO	NO	NO	NO
2003	258.16	257.91	0.10	0.15	45.82	45.78	0.02	0.03	NO	NO	NO	NO	NO	NO	NO	NO
2004	256.50	256.25	0.10	0.15	52.13	52.08	0.02	0.03	NO	NO	NO	NO	NO	NO	NO	NO
2005	256.50	256.25	0.10	0.15	50.61	50.57	0.02	0.03	NO	NO	NO	NO	NO	NO	NO	NO
2006	310.25	309.96	0.12	0.18	55.67	55.62	0.02	0.03	NO	NO	NO	NO	NO	NO	NO	NO
Trend 1990-2006	-90.44%	-90.43%	-94.43%	-96.10%	44.64%	44.63%	62.67%	62.67%	NA	NA	NA	NA	NA	NA	NA	NA

Year	CO_2e emissions (Gg) – GHG source & sink category											
	1A2e - Food Processing, Beverages & Tobacco				1A2f - Other				1A2 - Manufacturing Industries & Construction			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	NO	NO	NO	NO	2 031.70	2 026.23	1.45	4.02	5 314.82	5 302.69	3.58	8.56
1991	NO	NO	NO	NO	1 680.80	1 676.18	1.24	3.38	4 807.68	4 796.00	3.49	8.19
1992	NO	NO	NO	NO	1 844.58	1 839.19	1.44	3.95	4 595.02	4 583.83	3.29	7.89
1993	NO	NO	NO	NO	1 656.54	1 651.91	1.21	3.42	4 680.22	4 669.24	3.24	7.74
1994	NO	NO	NO	NO	1 736.59	1 730.78	1.56	4.24	4 362.33	4 351.26	3.25	7.82
1995	NO	NO	NO	NO	1 250.40	1 245.67	1.24	3.49	2 684.68	2 677.12	2.16	5.40
1996	NO	NO	NO	NO	1 363.75	1 358.35	1.43	3.97	2 689.79	2 681.79	2.27	5.73
1997	NO	NO	NO	NO	1 290.80	1 286.00	1.27	3.53	2 178.47	2 172.12	1.78	4.57
1998	NO	NO	NO	NO	1 403.78	1 399.00	1.28	3.50	1 618.64	1 613.66	1.36	3.62
1999	NO	NO	NO	NO	1 671.77	1 666.22	1.74	3.81	1 832.95	1 827.24	1.80	3.90
2000	NO	NO	NO	NO	1 529.93	1 524.32	1.54	4.07	1 789.06	1 783.21	1.64	4.21
2001	NO	NO	NO	NO	1 418.17	1 412.28	1.66	4.23	1 721.01	1 714.83	1.77	4.40
2002	NO	NO	NO	NO	1 173.54	1 168.66	1.37	3.51	1 475.76	1 470.60	1.48	3.68
2003	NO	NO	NO	NO	1 099.10	1 094.44	1.30	3.37	1 403.08	1 398.13	1.41	3.54
2004	NO	NO	NO	NO	1 397.05	1 390.94	1.76	4.35	1 705.68	1 699.27	1.87	4.53
2005	NO	NO	NO	NO	1 218.93	1 213.67	1.49	3.77	1 526.04	1 520.49	1.61	3.94
2006	NO	NO	NO	NO	1 304.33	1 299.01	1.48	3.83	1 670.25	1 664.58	1.62	4.04
Trend 1990-2006	NA	NA	NA	NA	-35.80%	-35.89%	2.53%	-4.59%	-68.57%	-68.61%	-54.66%	-52.78%

Source: Environment Agency.

Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.3.1. IPCC Sub-category 1A2a – Iron and Steel

In 2006, fuel combustion in iron and steel was responsible for 2.6% of GHG emissions from fuel combustion activities (this share was 30.2% in 1990) and represented 2.3% of the total GHG emissions in CO_2e, excluding LULUCF (24.6% in 1990).

3.3.1.1. Key source

Iron and steel fuel combustion is a key source with regard to CO_2 emissions. It has been a key source for solid fuels between 1990 and 1997 and a key source for gaseous fuels without interruption since 1990: see Tables 1-6 and 1-7 in Section 1.5.1.

3.3.1.2. Source category description

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 value added. 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, of course, led to big changes in air emissions due to iron and steel activities. Today, the iron and steel industry has a specific energy consumption which is much lower than it was in 1990 but it is still a relatively high consumption at Luxembourg's scale, hence the presence of this activity amongst the key sources.

Emissions from fuel combustion in iron and steel industry are accounted for under IPCC Sub-category 1A2a. CO_2 process related emissions are included under IPCC Sub-category 2C1: see Section 4.4.1 in Chapter 4.

Blast furnace gas is a side product of iron produced in blast furnaces. It can be used as gaseous fuel. That was the case in Luxembourg up to 1997 when the last blast furnace was stopped. Blast furnace gas was used by the iron and steel industry for heating purposes and for electricity production.

In CORINAIR, solid fuels, coke in particular, do not appear as fuel of blast furnaces and blast furnace gas is seen as gaseous fuel. Hence, as solid fuels of the iron and steel industry do not appear explicitly in the inventory compilation, those fuels are not included in the energy balance for the emission inventories. Instead of solid fuels, blast furnace gas appears in this balance (see also Section 4.4.1.3 in the next chapter). This has to be taken into account when comparing common energy balances with those resulting from the emission inventories.

Table 3-18 indicates which SNAP Categories are included for estimating GHG emissions pertaining from IPCC Sub-category 1A2a.

Table 3-18 – SNAP Categories for iron and steel industry included in the GHG inventory

SNAP code	Description
030203	Blast furnace cowpers
030301	Sinter and pelletizing plants
030302	Reheating furnaces steel and iron
030303	Grey iron foundries
040207	Electric furnace steel plants

SNAP 030203 - 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.

SNAP 030301 - Sinter and pelletizing plants

The sinter plant has been used until 1997. Its activity data, i.e. fuel consumption 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 estimated based on the data of 1990 and on the production of sintered ore of 1990 and of the respective years.

SNAP 030302 - Reheating furnaces steel and iron

The reheating furnaces have been used during the whole period 1990 - 2006. Their operation is directly related to steel rolling. Their activity data (fuel combustion data) were received from the operator.

SNAP 030303 - Grey iron foundries

The activity data of those foundries have been estimated in the early 1990s, and no new data have been received since. The activity data and the emission factors were established at that time. According to the TÜV study, the activity data included in the inventory are based on personal information received orally from the operators. Those values in the inventories have been kept rather constant over the time period.

SNAP 040207 - Electric furnace steel plants

The first electric furnace steel plant has appeared in 1994. Beside electric energy, natural gas is used for the reduction of iron oxides to iron. The related fuel consumption data were received directly from the operator.

3.3.1.3. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied. The sinter production site is considered as Large Point Source (*LPS*).

Activity data

Fuel consumption data were received from the operator.

Table 3-19 – Activity data for IPCC Sub-category 1A2a – Iron and Steel – blast furnace cowpers: 1990-2006

SNAP code	030203	
Activity	Blast furnace cowpers	
Fuel	301a	305a
Unit	[GJ]	[GJ]
1990	1658 234	5 207 600
1991	1683 837	4 674 985
1992	1457 697	4 044 813
1993	1400 749	4 518 372
1994	928 413	3 930 783
1995	564 130	1 944 721
1996	482 460	1 744 102
1997	292 469	968 417
1998 - 2006	production shut down	
Source	plant specific	

Emission factors

Table 3-20 – Emission factors for IPCC Sub-category 1A2a – Iron and Steel

IPCC Category	Source Categories	SNAP	Fuel		CO_2 Emission factor [kg/GJ]	Source
1A2a	Blast furnace cowpers	030203	305A	Blast furnace gas	258.0	internal study
	Sinter and pelletizing plants	030301	107A	Coke oven coke	97.1	TÜV 1990
			301A	Natural gas	56.1	IPCC Guidelines (1996, 2006)
			305A	Blast furnace gas	258.0	internal study
	Reheating furnaces steel and iron	030302	301A	Natural gas	56.1	CORINAIR, B111-55, Tab 29
			305A	Blast furnace gas	258.0	internal study
	Grey iron foundries	030303	101A	Coking coal	152.0	TÜV 1990
	Electr. furnace steel pl.	040207	301A	Natural gas	56.1	IPCC guidelines (1996, 2006)

3.3.2. IPCC Sub-category 1A2b – Non-Ferrous Metals

In 2006, fuel combustion due to non-ferrous metal processing or production was responsible for 0.47% of GHG emissions from fuel combustion activities (0.36% in 1990) and represented 0.42% of the total GHG emissions in CO_2e, excluding LULUCF (0.29% in 1990). In Luxembourg, non-ferrous metals activities cover basically secondary aluminium production from aluminium leftovers.

3.3.2.1. Key source

Fuel combustion from non-ferrous metal processing or production is not a key source.

3.3.2.2. Source category description

Liquefied petrol gas (*LPG*) is an important fuel used in secondary aluminium production. For some years, the fuel consumption data have been transmitted to the Environment Agency by the operator.

3.3.2.3. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

The activity data for secondary aluminium production are listed in Table 3-21.

Table 3-21 – Activity data for IPCC Sub-category 1A2b – Non-Ferrous Metals – secondary aluminium production: 1990-2006

SNAP code	030310
Activity	Secondary aluminium production
Fuel	LPG
Unit	[GJ]
1990	609 450
1991	609 450
1992	609 450
1993	609 450
1994	609 450
1995	609 450
1996	609 450
1997	609 450
1998	609 450
1999	609 450
2000	841 950
2001	841 950
2002	841 950
2003	841 950
2004	656 987
2005	not available
2006	not available
Sources	1990-1999: (TÜV 1990); 2000-2004: plant specific data

Emission factors

A default EF has been applied for CO_2: see Table 3-22.

Table 3-22 – Emission factors for Sub-category 1A2b – Non-Ferrous Metals – secondary aluminium production

IPCC Category	Source Categories	SNAP	Fuel		CO_2 Emission factor [kg/GJ]	Source
1A2b	Secondary aluminium production	030310	303A	Liquefied petroleum gas	63.1	2006 IPCC Guidelines

3.3.3. IPCC Sub-category 1A2c – Chemicals

On the basis of the information used so far for realizing the GHG inventory, this source category does not exist in Luxembourg.

3.3.4. IPCC Sub-category 1A2d – Pulp, Paper and Print

On the basis of the information used so far for realizing the GHG inventory, this source category does not exist in Luxembourg.

3.3.5. IPCC Sub-category 1A2e – Food Processing, Beverages and Tobacco

For the moment GHG emissions from this source category are included elsewhere. They will need to be re-allocated in the right sector now that information is transmitted under the EU-ETS scheme.

3.3.6. IPCC Sub-category 1A2f – Other

In 2006, fuel combustion emissions reported under other manufacturing industries and construction was responsible for 11% of GHG emissions from fuel combustion activities (this share was 18.9% in 1990) and represented 9.8% of the total GHG emissions in CO_2e, excluding LULUCF (15.4% in 1990).

Under other manufacturing industries and construction, the following activities have been classified:

Table 3-23 – SNAP Categories for other manufacturing industries and construction included in the GHG inventory

SNAP code	Description
030102	Combustion in boilers, combustion plants, 50 - 300 MW
030103	Combustion in boilers, < 50 MW
030311	Clinker
030314	Flat glass
030320	Fine ceramic materials

3.3.6.1. Key source

Fuel combustion emissions reported under other manufacturing industries and construction are a key source, with regard to CO_2 emissions, for the 3 main energy carriers – gaseous, liquid and solid fuels – without interruption since 1990: see Tables 1-6 and 1-7 in Section 1.5.1.

3.3.6.2. Source category description – combustion in boilers

SNAP 030102 - Combustion in boilers, combustion plants, 50 - 300 MW

Under this SNAP code, larger industrial boilers are included. They have used residual oil or natural gas as fuel. The information about the fuel combustion in these boilers was received directly from the operator.

SNAP 030103 - Combustion in boilers, < 50 MW

This source includes smaller combustion installations. As the number of this kind of boilers is quite important, they have not been treated individually.

3.3.6.3. Methodological issues – combustion in boilers

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

Activity data are listed in Tables 3-24 and 3-25.

Table 3-24 – Activity data for IPCC Sub-category 1A2f – Other – combustion plants 50 MW – 300 MW: 1990-2006

SNAP	030102	
Activity	Combustion Plants, 50 MW – 300 MW	
Fuel	203A	301A
Unit	[GJ]	[GJ]
1990	1 280 000	952 000
1991	1 757 178	1 120 000
1992	1 302 324	1 138 777
1993	1 335 026	1 094 055
1994	1 276 412	1 047 838
1995	1 156 364	1 107 755
1996	842 714	1 044 469
1997	0	1 190 306
1998	0	1 187 072
1999	0	1 233 554
2000	0	1 147 017
2001	0	965 035
2002	0	1 006 519
2003	0	1 006 519
2004	0	1 080 592
2005	0	861 747
2006	0	781220
Sources	1990: TÜV (1991); 1991– 2006 : plant specific data	

Table 3-25 – Activity data for IPCC Sub-category 1A2f – Other – combustion in boilers < 50MW: 1990-2006

SNAP	030103							
Activity	Combustion Plants, < 50 MW							
Fuel	Total	101A	104A	203A	204A	301A	303A	305A
Unit	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]
1990	9 284 066	273 686	43 024	400 000	3 509 623	1 549 733	588 000	2 920 000
1991	6 968 126	266 893	0	605 734	2 166 860	841 212	496 500	2 590 927
1992	9 447 945	301 073	443 223	653 499	3 711 684	1 362 376	471 950	2 504 140
1993	7 766 635	213 037	416 117	665 471	2 382 749	1 332 734	337 300	2 419 227
1994	9 454 763	432 225	1 190 475	427 179	3 168 761	2 260 773	207 400	1 767 950
1995	7 622 312	211 140	327 272	371 132	2 399 223	4 020 738	163 050	129 757
1996	8 991 933	343 026	792 740	280 317	4 023 800	3 250 868	233 550	67 632
1997	8 669 550	304 654	0	216 193	3 497 719	4 463 504	160 550	26 930
1998	10 744 650	244 861	57 110	185 976	4 703 184	4 791 469	762 050	0
1999	10 510 414	294 892	1 227 505	139 318	1 594 763	6 389 999	863 937	0
2000	10 088 529	275 471	434 772	172 843	3 557 941	5 095 352	552 150	0
2001	5 138 699	176 349	690 750	212 610	2 226 494	1 015 265	817 231	0
2002	4 281 587	182 178	702 834	195 541	1 248 109	1 952 925	0	0
2003	4 326 458	196 533	0	160 061	2 122 128	1 666 036	181 700	0
2004	7 372 299	192 386	1 006 077	61 418	3 221 322	2 891 096	0	0
2005	5 728 513	832 040	0	21 279	2 159 225	2 167 369	548 600	0
2006	7 697 761	177 451	1 016 926	0	1 878 454	4 207 830	417 100	0
Sources	STATEC: national statistics and energy balance; plant specific data							

Emission factors

Default EFs have been applied: see Table 3-26.

Table 3-26 – Emission factors for IPCC Sub-category 1A2f – Other – combustion in boilers

IPCC Category	Source Categories	SNAP	Fuel		Emission factor [kg/GJ]		Source
1A2f	Combustion in boilers, 50 - 300 MW	030102	301A	Natural gas	CO_2	65.1	IPCC Guidelines (1996, 2006)
					CH_4	1.0	
					N_2O	0.1	
			203A	Residual oil	CO_2	77.4	
					CH_4	3.0	
					N_2O	0.6	
	Combustion in boilers, < 50 MW	030103	101A	Coking coal	CO_2	94.6	
					CH_4	10.0	
					N_2O	1.5	
			104A	Patent fuels	CO_2	97.5	
					CH_4	10.0	
					N_2O	1.5	
			203A	Residual oil	CO_2	77.4	
					CH_4	3.0	
					N_2O	0.6	
			204A	Gas oil	CO_2	74.4	
					CH_4	3.0	
					N_2O	0.6	
			301A	Natural gas	CO_2	56.1	
					CH_4	1.0	
					N_2O	0.1	

			303A	Liquefied petroleum gas	CO_2	63.1	
					CH_4	1.0	
					N_2O	0.1	

3.3.6.4. Source category description – clinker

SNAP 030311 - Clinker (LPS)

One industrial site produces clinker in Luxembourg. It is included in the inventory as a large point source (*LPS*). Its major fuel has been hard coal, but use is also made of residual oil, natural gas and special types of waste, for example shredded tyres. The consumption data of these fuels are transmitted annually to the Environment Agency by the operator. Its production has decreased from 1048 kt clinker in 1990 to 826 kt in 2006. Hard coal consumption was 3.6 PJ in 1990 and 1.8 PJ in 2006.

3.3.6.5. Methodological issues – clinker

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

Activity data are listed in Table 3-27.

Table 3-27 – Activity data for IPCC Sub-category 1A2f – Other – clinker: 1990-2006

SNAP	030311					
Activity	Cement production (LPS)					
Fuel		Total (except other solid fuel)	104	203	301	other solid fuel
Unit	[t product]	[GJ]	[GJ]	[GJ]	[GJ]	[t]
1990	1 048 000	3 748 254	3 561 653	186 601	0	0
1991	1 048 000	3 484 135	3 391 352	92 783	0	0
1992	1 013 452	3 528 827	3 442 128	86 699	0	0
1993	1 013 452	2 967 660	2 844 970	122 690	0	0
1994	950 854	3 428 448	3 317 450	110 998	0	0
1995	848 455	3 190 899	3 083 719	107 180	0	0
1996	837 518	3 139 224	3 042 623	96 601	0	0
1997	865 659	3 522 487	3 369 318	144 047	9 122	0
1998	870 053	3 043 354	2 941 888	92 425	9 041	0
1999	913 265	3 231 779	3 150 721	72 819	8 239	6 212
2000	965 369	3 253 732	3 152 003	92 386	9 343	9 527
2001	843 608	2 230 315	2 149 050	73 390	7 875	20 716
2002	874 577	2 214 134	2 144 750	61 459	7 925	24 440
2003	769 754	2 217 324	1 513 321	72 501	8 385	22 112
2004	847 389	2 101 924	2 001 550	91 676	8 698	23 942
2005	833 798	2 219 249	2 140 725	69 618	8 906	25 640
2006	826 131	1 919 772	1 842 825	68 880	8 067	25 100
Source	Plant specific data & internal estimation					

Emission factors

CO_2 emission factors for solid fuels are plant specific data, others are default EFS: see Table 3-28.

Table 3-28 – Emission factors for IPCC Sub-category 1A2f – Other – clinker

IPCC Category	Source Categories	SNAP	Fuel		CO2 Emission factor [kg/GJ]	Source
1A2f	Cement	030311	104A	Patent fuels	99.46	plant specific
			121B	Other solid fuel	102.6	plant specific
			203A	Residual oil	77.4	2006 IPCC Guidelines
			301A	Natural gas	56.1	

3.3.6.6. Source category description – flat glass

SNAP 030314 - Flat glass (LPS)

There are two flat glass plants in Luxembourg. Their main fuel is natural gas, and some quantities of LPG are used too. Natural gas consumption increased from 2,76 PJ in 1990 to about 2,94 PJ in 2006, at the same time production increased from 377 Gg to 436 Gg.

3.3.6.7. Methodological issues – flat glass

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

Activity data are listed in Table 3-29.

Table 3-29 – Activity data for IPCC Sub-category 1A2f – Other – flat glass: 1990-2006

Activity	Flatglass	Flatglass I (LPS)	Flatglass II LPS
Fuel	Total	301	301
Unit	[GJ]	[GJ]	[GJ]
1990	2 759 860	1 263 244	1 496 616
1991	2 512 530	986 043	1 526 487
1992	2 889 257	1 393 642	1 495 615
1993	3 045 064	1 482 307	1 562 757
1994	3 179 583	1 544 938	1 634 645
1995	3 206 512	1 567 629	1 638 883
1996	3 251 215	1 608 504	1 642 711
1997	3 251 215	1 608 504	1 642 711
1998	2 775 598	1 608 504	1 167 094
1999	3 177 204	1 608 504	1 568 700
2000	3 177 204	1 608 504	1 568 700
2001	3 040 969	1 608 504	1 432 465
2002	3 131 301	1 645 075	1 486 226
2003	3 131 301	1 645 075	1 486 226
2004	2 971 153	1 412 876	1 558 277
2005	2 997 278	1 456 275	1 541 003
2006	2 941 761	1 431 364	1 510 397
Source	Plant specific data		

Emission factors

A default EF has been applied for CO_2: see Table 3-30.

Table 3-30 – Emission factors for IPCC Sub-category 1A2f – Other – flat glass

IPCC Category	Source Categories	SNAP	Fuel		CO_2 Emission factor [kg/GJ]	Source
1A2f	Flat glass	030314	301A	Natural gas	56.1	IPCC Guidelines (1996, 2006)

3.3.6.8. Source category description – fine ceramic materials

SNAP 030320 - Fine ceramic materials

One major production site of ceramic materials exists in Luxembourg and it uses natural gas as fuel.

3.3.6.9. Methodological issues – fine ceramic materials

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

Activity data are listed in Table 3-31.

Table 3-31 – Activity data for IPCC Sub-category 1A2f – Other – fine ceramic materials: 1990-2006

SNAP code	030320
Activity	Fine ceramic materials
Fuel	301A
Unit	[GJ]
1990 - 2006	198 124
Source	plant specific data

Emission factors

A default EF has been applied for CO_2: see Table 3-32.

Table 3-32 – Emission factors for IPCC Sub-category 1A2f – Other – fine ceramic materials

IPCC Category	Source Categories	SNAP	Fuel		CO_2 Emission factor [kg/GJ]	Source
1A2f	Fine ceramic materi-als	030320	301A	Natural gas	56.1	IPCC Guidelines (1996, 2006)

3.3.7. Recalculations

See Tables 3-1 and 3-2 above.

3.3.8. Category specific QA / QC procedures

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

3.3.9. 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 3-33 will be explored.

Table 3-33 – Planned improvements for IPCC Sub-category 1A2 – Fuel Combustion Activities – Manufacturing Industries and Construction

GHG source & sink category	Planned improvement
1A2 – Manufacturing Industries and Construction	revise activity data taking into account EU ETS reported information as well as operating permits related information.
1A2 – Manufacturing Industries and Construction	investigate how reported emissions under the EU-ETS regulation could be included in the GHG inventory.
1A2 – Manufacturing Industries and Construction	conversion factors: use of factors for various fuel types provided by IEA in its Energy Statistics Manual or of country/plant-specific values?
1A2a – Iron and Steel	revise activity data used for estimating GHG emissions. Revise the CO_2 emission factor for 101A (coking coal) since it appears to be too high – the IPCC default factor is 94,6 kg/GJ (25,8 t C/TJ coal).
1A2a – Iron and Steel	investigate whether another production unit – Primorec, a plant recycling iron from slag and collected dust (direct reduction furnace) – should be included in Sub-category 1A2a.
1A2b – Non-Ferrous Metals	revise activity data used for estimating GHG emissions.
1A2b – Non-Ferrous Metals	include other non-ferrous activities if relevant.
1A2c – Chemicals	investigate further whether this category is effectively NA or NO in Luxembourg.
1A2d – Pulp, Paper and Print	investigate further whether this category is effectively NA or NO in Luxembourg.
1A2e – Food Processing, Beverages and Tobacco	re-allocate emissions in this source category, notably using information transmitted under the EU-ETS scheme.
1A2f – Other	revise activity data used for estimating GHG emissions and re-allocate emissions in the right source categories if relevant.

3.4. Transport (IPCC Source Sub-category 1A3)

This section describes GHG emissions resulting from transport fuel combustion. In 2006, this source category was responsible for a bit more than 61.7% of GHG emissions from fuel combustion activities (this share was only 25.9% in 1990) and represented 54.7% of the total GHG emissions in CO_2e, excluding LULUCF (coming from 21.1% in 1990).

Table 3-34 summarizes GHG emissions for IPCC Sub-category 1A3.

Table 3-34 – GHG emission trends in CO_2e for IPCC Sub-category 1A3 – Fuel Combustion Activities – Transport: 1990-2006

Year	*CO_2 e emissions (Gg)* GHG source & sink category 1A3a - Civil Aviation				1A3b - Road Transportation				1A3c - Railways				1A3d - Navigation			
	Total	*CO_2*	*CH_4*	*N_2O*	Total	*CO_2*	*CH_4*	*N_2O*	Total	*CO_2*	*CH_4*	*N_2O*	Total	*CO_2*	*CH_4*	*N_2O*
1990	0.24	*0.24*	*0.00*	*0.00*	2 741.58	*2 686.17*	*18.50*	*36.91*	30.73	*27.42*	*0.03*	*3.28*	5.99	*5.93*	*0.01*	*0.05*
1991	0.36	*0.36*	*0.00*	*0.00*	3 348.44	*3 275.24*	*20.79*	*52.40*	30.73	*27.42*	*0.03*	*3.28*	5.99	*5.93*	*0.01*	*0.05*
1992	0.51	*0.51*	*0.00*	*0.00*	3 644.87	*3 535.57*	*25.80*	*83.50*	30.73	*27.42*	*0.03*	*3.28*	5.99	*5.93*	*0.01*	*0.05*
1993	0.66	*0.66*	*0.00*	*0.01*	3 703.46	*3 592.57*	*26.04*	*84.84*	30.73	*27.42*	*0.03*	*3.28*	5.99	*5.93*	*0.01*	*0.05*
1994	0.78	*0.78*	*0.00*	*0.01*	3 748.07	*3 627.74*	*27.36*	*92.97*	26.96	*24.05*	*0.03*	*2.88*	5.99	*5.93*	*0.01*	*0.05*
1995	0.84	*0.84*	*0.00*	*0.01*	3 539.28	*3 419.32*	*26.18*	*93.78*	21.83	*19.47*	*0.02*	*2.33*	5.99	*5.93*	*0.01*	*0.05*
1996	0.87	*0.86*	*0.00*	*0.01*	3 632.14	*3 502.55*	*27.04*	*102.56*	21.83	*19.47*	*0.02*	*2.33*	5.99	*5.93*	*0.01*	*0.05*
1997	0.88	*0.88*	*0.00*	*0.01*	3 920.09	*3 775.89*	*27.71*	*116.48*	21.83	*19.47*	*0.02*	*2.33*	5.99	*5.93*	*0.01*	*0.05*
1998	0.76	*0.75*	*0.00*	*0.01*	4 111.05	*3 955.21*	*27.34*	*128.51*	21.83	*19.47*	*0.02*	*2.33*	5.99	*5.93*	*0.01*	*0.05*
1999	0.78	*0.77*	*0.00*	*0.01*	4 488.03	*4 313.56*	*26.09*	*148.38*	21.83	*19.47*	*0.02*	*2.33*	5.99	*5.93*	*0.01*	*0.05*
2000	0.74	*0.74*	*0.00*	*0.01*	5 105.41	*4 910.07*	*27.94*	*167.41*	21.83	*19.47*	*0.02*	*2.33*	5.99	*5.93*	*0.01*	*0.05*
2001	0.74	*0.73*	*0.00*	*0.01*	5 381.99	*5 175.35*	*27.56*	*179.09*	21.83	*19.47*	*0.02*	*2.33*	5.99	*5.93*	*0.01*	*0.05*
2002	0.68	*0.68*	*0.00*	*0.01*	5 621.53	*5 404.94*	*26.55*	*190.04*	24.43	*21.79*	*0.03*	*2.61*	5.99	*5.93*	*0.01*	*0.05*
2003	0.79	*0.79*	*0.00*	*0.01*	6 193.90	*5 955.21*	*27.55*	*211.13*	24.43	*21.79*	*0.03*	*2.61*	5.99	*5.93*	*0.01*	*0.05*
2004	0.70	*0.69*	*0.00*	*0.01*	7 237.88	*6 954.99*	*25.08*	*257.82*	24.43	*21.79*	*0.03*	*2.61*	5.99	*5.93*	*0.01*	*0.05*
2005	0.69	*0.68*	*0.00*	*0.01*	7 453.59	*7 152.70*	*21.18*	*279.71*	24.43	*21.79*	*0.03*	*2.61*	5.99	*5.93*	*0.01*	*0.05*
2006	0.59	*0.58*	*0.00*	*0.01*	7 256.87	*6 968.88*	*20.50*	*267.49*	24.43	*21.79*	*0.03*	*2.61*	5.99	*5.93*	*0.01*	*0.05*
Trend 1990-2006	*146.47%*	*146.47%*	*146.47%*	*146.47%*	*164.70%*	*159.44%*	*10.77%*	*624.76%*	*-20.51%*	*-20.51%*	*-20.51%*	*-20.51%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

Year	*CO_2 e emissions (Gg)* GHG source & sink category 1A3e - Other Transportation				1A3 - Transport			
	Total	*CO_2*	*CH_4*	*N_2O*	Total	*CO_2*	*CH_4*	*N_2O*
1990	NA	*NA*	*NA*	*NA*	2 778.54	*2 719.76*	*18.55*	*40.24*
1991	NA	*NA*	*NA*	*NA*	3 385.52	*3 308.95*	*20.84*	*55.74*
1992	NA	*NA*	*NA*	*NA*	3 682.10	*3 569.43*	*25.84*	*86.84*
1993	NA	*NA*	*NA*	*NA*	3 740.84	*3 626.58*	*26.08*	*88.18*
1994	NA	*NA*	*NA*	*NA*	3 781.80	*3 658.49*	*27.40*	*95.91*
1995	NA	*NA*	*NA*	*NA*	3 567.94	*3 445.56*	*26.22*	*96.16*
1996	NA	*NA*	*NA*	*NA*	3 660.83	*3 528.81*	*27.07*	*104.94*
1997	NA	*NA*	*NA*	*NA*	3 948.79	*3 802.17*	*27.75*	*118.87*
1998	NA	*NA*	*NA*	*NA*	4 139.63	*3 981.37*	*27.37*	*130.89*
1999	NA	*NA*	*NA*	*NA*	4 516.63	*4 339.73*	*26.12*	*150.77*
2000	NA	*NA*	*NA*	*NA*	5 133.97	*4 936.21*	*27.97*	*169.79*
2001	NA	*NA*	*NA*	*NA*	5 410.55	*5 201.48*	*27.59*	*181.48*
2002	NA	*NA*	*NA*	*NA*	5 652.63	*5 433.34*	*26.59*	*192.70*
2003	NA	*NA*	*NA*	*NA*	6 225.11	*5 983.72*	*27.59*	*213.80*
2004	NA	*NA*	*NA*	*NA*	7 269.00	*6 983.40*	*25.12*	*260.48*
2005	NA	*NA*	*NA*	*NA*	7 484.70	*7 181.11*	*21.21*	*282.38*
2006	NA	*NA*	*NA*	*NA*	7 287.87	*6 997.18*	*20.53*	*270.16*
Trend 1990-2006	*NA*	*NA*	*NA*	*NA*	*162.29%*	*157.27%*	*10.71%*	*571.36%*

Source: Environment Agency.

Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.4.1. IPCC Sub-category 1A3a – Civil Aviation

In Luxembourg, civil aviation, excluding international flights, is a very narrow activity. This is therefore reflected in GHG emission estimates. In 2006, civil aviation fuel consumption was responsible for 0.005% of GHG emissions from fuel combustion activities (0.002% in 1990) and represented 0.004% of the total GHG emissions in CO_2e, excluding LULUCF (0.002% in 1990).

3.4.1.1. Key source

Fuel consumption from civil aviation is not a key source.

3.4.1.2. Source category description

There is only one airport for commercial aviation in Luxembourg (Findel). Therefore all flights, either coming to Luxembourg or going out from Luxembourg, are international flights. For that reason, emissions of kerosene consumption are not included in the national total of Luxembourg, but under international bunkers as a memo item. It exists, however, private flights with Luxembourg as a start and return point. These are mainly leisure or urgency (medical, police) flights made with small-sized propellers planes or helicopters using aviation gasoline.

As there is only one company selling aviation fuels in Luxembourg, calculations are straightforward. Expert judgement has been made for determining the share of aviation gasoline sold by this company that is being exported – outbound flights - and the share that is addressed to the domestic consumption –inbound flights. It has been assumed that 90 % of aviation gasoline sales directed towards inbound flights.

3.4.1.3. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied.

<u>Activity data</u>

Activity data are listed in Table 3-35.

<u>Emission factors</u>

Default EFs for aviation gasoline have been used:

- CO_2 aviation gasoline.............. 69300 kg/TJ
- CH_4 default.................................... 0.5 kg/TJ
- N_2O default.................................... 2.0 kg/TJ

The 2006 IPCC Guidelines NCV of 44.1 TJ/Gg has been applied for converting activity data.

Table 3-35 – Activity data for IPCC Sub-category 1A3a – Civil Aviation: 1990-2006

Year	*Aviation gasoline*
	TJ
1990	3.41
1991	5.18
1992	7.31
1993	9.46
1994	11.19
1995	12.05
1996	12.42
1997	12.64
1998	10.89
1999	11.12
2000	10.61
2001	10.54
2002	9.77
2003	11.37
2004	9.97
2005	9.86
2006	8.40
Trend 1990-2006	*146.33%*

Source: expert judgement based on aviation gasoline sales in Luxembourg.

3.4.2. IPCC Sub-Category 1A3b – Road Transportation

In 2006, road transportation was responsible for 61.44% of GHG emissions from fuel combustion activities (this share was only 25.55% in 1990) and represented 54.5% of the total GHG emissions in CO_2e, excluding LULUCF (but no more than 20.8% in 1990). This evolution has already been depicted in previous sections of the NIR – see, for example, Sections 2.1.3, 2.2.2 or 2.2.5 – and is explained by a twofold increase for road fuel consumed by the national vehicle fleet and by almost a threefold increase for road fuel export.

3.4.2.1. Key source

With 54.5% of the total GHG emissions from Luxembourg, road transportation is the major key source. With regard to CO_2, it has been a key source for both diesel oil and gasoline without interruption since 1990. For N_2O, the picture is a bit different: diesel oil is a key source since 1995 and gasoline has been identified as a key source only in 1998 and in 2001: see Tables 1-6 and 1-7 in Section 1.5.1.

3.4.2.2. Source category description

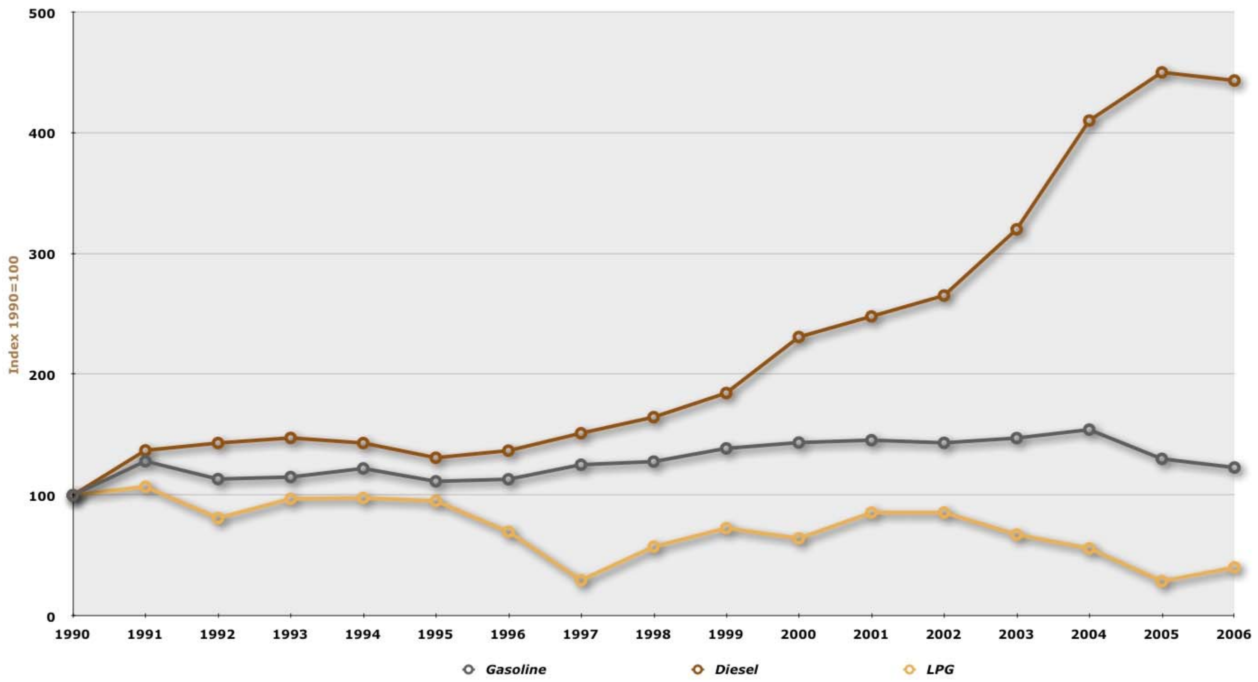
As indicated above, road transportation has already been discussed in details in previous sections of the NIR. Table 3-36 and Figure 3-4 focus on road fuel export, the main driver and the main part of road transportation related emissions.

Table 3-36 – CO_2 emission trends from road fuel export for IPCC Sub-category 1A3b – Road Transportation: 1990-2006

	CO_2 emissions (Gg)					%
	road fuel export				1A3b	road fuel
Year	Total	*Gasoline*	*Diesel*	*LPG*	Total	export share
1990	1829.23	*785.40*	*1034.29*	*9.53*	2686.17	68.10%
1991	2436.21	*1007.00*	*1419.00*	*10.21*	3275.24	74.38%
1992	2380.73	*891.00*	*1482.00*	*7.73*	3535.57	67.34%
1993	2439.26	*904.00*	*1526.00*	*9.26*	3592.57	67.90%
1994	2451.33	*960.00*	*1482.00*	*9.33*	3627.74	67.57%
1995	2241.09	*876.00*	*1356.00*	*9.09*	3419.32	65.54%
1996	2313.15	*889.69*	*1416.80*	*6.66*	3502.55	66.04%
1997	2553.18	*984.22*	*1566.13*	*2.83*	3775.89	67.62%
1998	2713.88	*1004.65*	*1703.76*	*5.47*	3955.21	68.62%
1999	3007.79	*1090.53*	*1910.32*	*6.94*	4313.56	69.73%
2000	3524.59	*1128.23*	*2390.23*	*6.13*	4910.07	71.78%
2001	3718.80	*1143.82*	*2566.81*	*8.17*	5175.35	71.86%
2002	3880.46	*1126.68*	*2745.61*	*8.18*	5404.94	71.79%
2003	4477.10	*1157.65*	*3313.02*	*6.43*	5955.21	75.18%
2004	5462.11	*1212.38*	*4244.39*	*5.34*	6954.99	78.54%
2005	5682.49	*1022.27*	*4657.47*	*2.75*	7152.70	79.45%
2006	5557.84	*966.00*	*4588.00*	*3.84*	6968.88	79.75%
Trend 1990-2006	*203.84%*	*22.99%*	*343.59%*	*-59.72%*	*159.44%*	
Share 1990	*100.00%*	*42.94%*	*56.54%*	*0.52%*		
Share 2006	*100.00%*	*17.38%*	*82.55%*	*0.07%*		

Source: Environment Agency.

Figure 3-4 – CO_2 emission trends – indexes - from road fuel export for IPCC Sub-category 1A3b – Road Transportation: 1990-2006



3.4.2.3. Methodological issues

Road transportation GHG emissions are estimated in two steps:

1	COPERT III: estimation of the annual fuel consumption of the vehicle fleet registered in Luxembourg	• EF: default data from the COPERT III • AD (1990–2006): fleet statistic provided by SNCT (*Société Nationale de Controle Technique*)
2	CO_2 Emission for road fuel export which is the difference between: • CO_2 Emission estimated by COPERT III, and • CO_2 Emission derived from the energy balance for total road transportion	• Ministry of Economic Affairs and External Trade, Energy Directorate • Environment Agency

Road traffic emissions have been calculated using COPERT III, which is referred in IPCC Guidelines as a Tier 3 method. The input data were based on car fleet statistics on registered vehicles in Luxembourg (SNCT 1990- 2006). Emission factors are default data from COPERT III.[54] With this information it is thus possible to estimate annual fuel consumptions for the national vehicle fleet. This fuel consumption estimate is lower than total road fuel sales in Luxembourg, the difference being, therefore, road fuel export (see Table 3-36).

So, air emissions of road traffic calculated with COPERT III reflect Luxembourg's vehicle fleet. Consequently, CO_2, CH_4 and N_2O emissions of road traffic have been adjusted to take into account road fuel export using total road fuel sales in Luxembourg as a basis. Inventory values for the other air pollutants to be reported in CRF tables – NOx, CO, NMVOC and SO_2 – could not be updated that way, hence being marked as "not estimated".

Total emission estimates have been calculated combining default emission factors of COPERT III, total fuel sales and annual vehicle kilometres estimates of the national vehicle fleet.

Emission types[55]

$$E_{TOTAL} = E_{HOT} + E_{COLD} + E_{EVAP}$$

with:

- E_{TOTAL}: total emissions of any pollutant for the spatial and temporal resolution of the application
- E_{HOT}: emissions during stabilised (hot) engine operation
- E_{COLD}: emissions during transient thermal engine operation (cold start)
- E_{EVAP}: emissions from fuel evaporation. Emissions from evaporation are only relevant for NMVOC species from gasoline powered vehicles.

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54 Chariton Kouridis, Leonidas Ntziachristos and Zissis Samaras, *COPERT III - Computer programme to calculate emissions from road transport - user manual (version 2.1)*.Technical Report N°50, European Environment Agency, Copenhagen, 2000.

55 Ntziachristos, L. & Samaras, Z. (2000) p. 13.

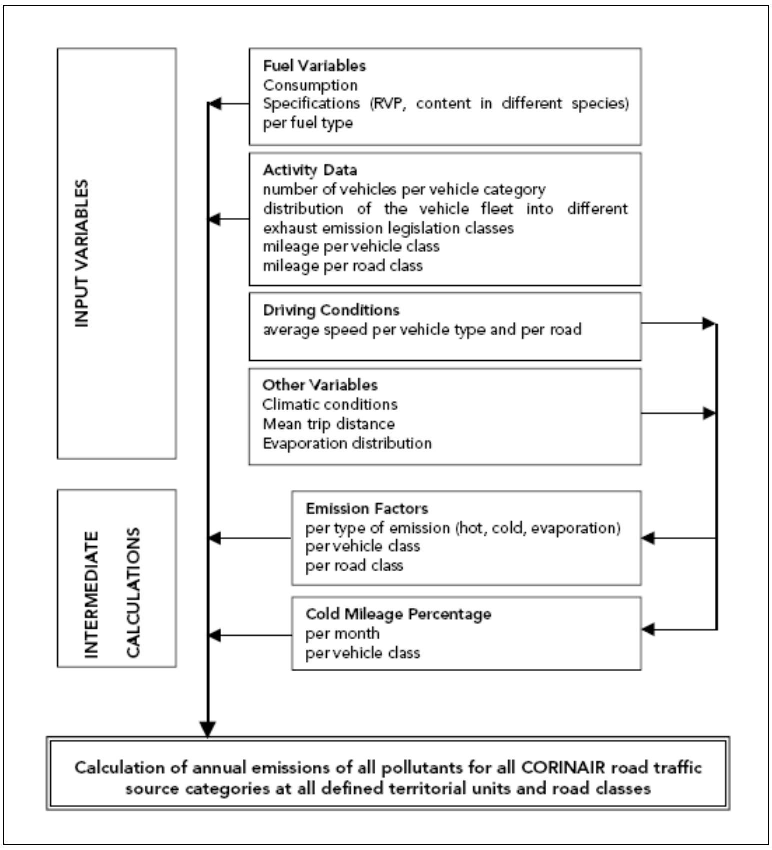
Emissions under different driving conditions[56]

$$E_{TOTAL} = E_{URBAN} + E_{RURAL} + E_{HIGHWAY}$$

with:

- E_{URBAN}, E_{RURAL}, $E_{HIGHWAY}$: total emissions of any pollutant for the respective driving situation.

Illustration 3-1 – Flow chart of the application of the baseline methodology in COPERT III



Activity data

The main COPERT III categories can be allocated to the UNECE classification as follows:

- Passenger Cars M1
- Light Duty Vehicles N1
- Heavy Duty Vehicles N2, N3
- Urban Buses & Coaches.................M2, M3
- Two Wheelers (motorcycles) L1, L2, L3, L4, L5

Activity data – vehicles numbers and fuel sold – are listed in the tables on the next pages. For the national vehicle fleet, source is SNCT; for road fuel sales, source is the Ministry of Economic Affairs and External Trade, Energy Directorate and the Environment Agency.

56 Ntziachristos, L. & Samaras, Z. (2000) p. 14.

Table 3-37 – Passengers cars (M1) – gasoline: 1990-2006

gasoline, cyl. < 1,4 litres										
	Pré ECE	ECE 15/00 et 15/01	ECE 15/02	ECE 15/03	ECE 15/04	b. fermée (91/441/CEE et 88/76/CEE)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL
1990	335	629	2089	17 017	49 784	1 516	0	0	-	71 370
1991	335	629	2089	17 017	49 784	1 516	0	0	-	71 370
1992	478	838	1973	15 366	45 476	28 182	0	0	-	92 313
1993	478	838	1973	15 366	45 476	28 182	0	0	-	92 313
1994	472	648	1260	12 430	42 070	32 243	0	0	-	89 123
1995	453	490	764	9 644	38 264	35 602	0	0	-	85 217
1996	470	400	489	7 322	34 361	38 727	0	0	-	81 769
1997	449	337	331	5 482	30 746	35 559	6 617	0	-	79 521
1998	437	284	229	3 954	26 982	32 360	13 171	0	-	77 417
1999	453	258	168	2 748	23 461	29 252	19 677	0	-	76 017
2000	463	246	129	1 904	19 830	26 243	25 503	0	-	74 318
2001	457	245	105	1 250	16 233	23 133	29 199	0	-	70 622
2002	475	257	90	872	12 973	20 189	31 494	0	-	66 350
2003	522	261	84	625	10 008	17 421	23 520	10 626	-	63 067
2004	483	272	80	474	7 676	14 836	20 892	13 912	-	58 625
2005	478	251	66	350	5 332	11 624	17 951	16 309	-	52 361
2006	505	256	71	319	4 126	9711	15 815	14 737	4032	49 572
Trend - %	*51*	*-59*	*-97*	*-98*	*-92*	*548*	-	-	-	*-31*

gasoline, cyl. 1,4 - 2,0 litres										
	Pré ECE	ECE 15/00 et 15/01	ECE 15/02	ECE 15/03	ECE 15/04	b. fermée (91/441/CEE et 88/76/CEE)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL
1990	343	692	1 974	13 626	50 348	5 479	0	0	-	72 462
1991	343	692	1 974	13 626	50 348	5 479	0	0	-	72 462
1992	517	929	2 093	12 938	59 771	42 033	0	0	-	118 281
1993	517	929	2 093	12 938	59 771	42 033	0	0	-	118 281
1994	504	758	1 466	10 808	55 945	49 409	0	0	-	118 890
1995	494	625	993	8 622	51 342	56 064	0	0	-	118 140
1996	487	534	720	6 775	46 398	62 269	0	0	-	117 183
1997	460	458	549	5 167	41 544	57 854	9 150	0	-	115 182
1998	438	399	427	3 873	36 392	52 835	18 458	0	-	112 822
1999	452	377	354	2 885	31 617	42 412	27 824	0	-	105 921
2000	477	376	319	2 160	27 400	43 437	35 054	0	-	109 223
2001	501	371	273	1 526	22 652	38 166	40 014	0	-	103 503
2002	528	394	257	1 112	18 585	33 480	44 358	0	-	98 714
2003	551	390	235	848	15133	29125	33154	14392	-	93 828
2004	509	410	257	703	12404	25161	29345	19397	-	88 186
2005	518	392	237	535	9 115	19 891	25 146	22 720	-	78 554
2006	534	412	238	485	7 425	16 672	22 080	21 017	4323	73 186
Trend - %	*56*	*-40*	*-88*	*-96*	*-85*	*204*	-	-	-	*1*

	gasoline, cyl. > 2,0 litres									
	Pré ECE	ECE 15/00 et 15/01	ECE 15/02	ECE 15/03	ECE 15/04	b. fermée (91/441/CEE et 88/76/CEE)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL
1990	388	411	977	4 253	10 216	4 280	0	0	-	20 525
1991	388	411	977	4 253	10 216	4 280	0	0	-	20 525
1992	603	735	1351	4 262	18 806	14 534	0	0	-	40 291
1993	603	735	1351	4 262	18 806	14 534	0	0	-	40 291
1994	634	649	1059	3 839	18 352	18 154	0	0	-	42 687
1995	610	557	805	3 307	17 348	21 071	0	0	-	43 698
1996	611	498	637	2 825	16 233	23 632	0	0	-	44 436
1997	593	440	508	2 378	14 953	22 519	3 928	0	-	45 319
1998	592	394	406	1 923	13 393	20 826	8 216	0	-	45 750
1999	617	379	351	1 514	11 826	18 675	12 644	0	-	46 006
2000	633	369	303	1 257	10 309	16 700	15 829	0	-	45 400
2001	655	364	257	992	8 685	14 499	18 093	0	-	43 545
2002	662	367	241	846	7 400	12 756	19 975	0	-	42 247
2003	673	360	225	736	6 312	11 204	14 945	6 782	-	41 237
2004	584	381	254	714	5 533	9 995	13 218	9 187	-	39 866
2005	592	372	236	604	4 389	8 163	11 220	11 168	-	36 744
2006	610	394	262	578	3 852	7 006	9 950	10 530	2533	35 715
Trend - %	*57*	*-4*	*-73*	*-86*	*-62*	*64*	-	-	-	*74*

Table 3-38 – Passengers cars (M1) – diesel: 1990-2006

	Diesel, cyl. < 2,0 litres						Diesel, cyl. > 2,0 litres					
	Pré 91/441/CEE	91/441/CEE (Euro I)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL	Pré 91/441/CEE	91/441/CEE (Euro I)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL
1990	16 926	0	0	0	-	16 926	8 320	0	0	0	-	8 320
1991	16 926	0	0	0	-	16 926	8 320	0	0	0	-	8 320
1992	20 121	3 995	0	0	-	24 116	9 276	1 164	0	0	-	10 440
1993	20 121	3 995	0	0	-	24 116	9 276	1 164	0	0	-	10 440
1994	18 026	8 382	0	0	-	26 408	8 423	2 712	0	0	-	11 135
1995	15 928	12 713	0	0	-	28 641	7 601	4 758	0	0	-	12 359
1996	13 974	17 861	0	0	-	31 835	6 871	7 095	0	0	-	13 966
1997	12 280	16 284	7 114	0	-	35 678	6 163	6 709	3 027	0	-	15 899
1998	10 516	14 412	15 353	0	-	40 281	5 392	6 067	6 516	0	-	17 975
1999	8 963	12 395	25 257	0	-	46 615	4 624	5 351	10 094	0	-	20 069
2000	7 640	10 770	36 296	0	-	54 706	3 898	4 683	13 944	0	-	22 525
2001	6 445	9 269	48 087	0	-	63 801	3 236	4 092	18 124	0	-	25 452
2002	5 193	8 014	59 729	0	-	72 936	2 686	3 566	22 727	0	-	28 979
2003	4 125	6 931	33 804	37 172	-	82 032	2 191	3 110	13 513	15 510	-	34 324
2004	3 334	6 014	28 500	56 296	-	94 144	1 887	2 837	11 515	23 131	-	39 370
2005	2 470	4 940	23 985	75 236	-	106 631	1 510	2 400	9 756	28 954	-	42 620
2006	1 932	4 216	20 809	67 440	27208	121 605	1 264	2 059	8 647	26 708	9267	47 945
Trend - %	*-89*	-	-	-	-	*618*	*-85*	-	-	-	-	*476*

Table 3-39 – Passengers cars (M1) – LPG: 1990-2006

	LPG					
	Pré 91/441/ CEE	91/441/ CEE (Euro I)	94/12/ CEE (Euro II)	98/69/ CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL
1990	564	0	0	0	-	564
1991	564	0	0	0	-	564
1992	377	13	0	0	-	390
1993	377	13	0	0	-	390
1994	304	25	0	0	-	329
1995	250	42	0	0	-	292
1996	221	65	0	0	-	286
1997	193	60	17	0	-	270
1998	174	58	38	0	-	270
1999	149	60	66	0	-	275
2000	131	60	94	0	-	285
2001	97	48	98	0	-	243
2002	74	53	89	0	-	216
2003	67	44	99	20	-	230
2004	52	50	90	26	-	218
2005	36	39	80	29	-	184
2006	37	35	83	40	18	213
Trend - %	*-93*	-	-	-	-	*-62*

Table 3-40 – Light duty vehicles (N1): 1990-2006

	gasoline						diesel					
	Pré 91/542/CEE Stage I	91/542/CEE Stage I (Euro I)	91/542/CEE Stage II (Euro II)	Standards 2000 (Euro III)	Standards 2005 (Euro IV)	TOTAL	Pré 91/441/CEE	91/441/CEE (Euro I)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL
1990	6 495	0	0	0	-	6 495	5 677	0	0	0	-	5 677
1991	6 495	0	0	0	-	6 495	5 677	0	0	0	-	5 677
1992	4 323	0	0	0	-	4 323	7 047	0	0	0	-	7 047
1993	4 323	0	0	0	-	4 323	7 047	0	0	0	-	7 047
1994	4 097	24	0	0	-	4 121	7 314	261	0	0	-	7 575
1995	3 733	156	0	0	-	3 889	6 816	1 417	0	0	-	8 233
1996	3 331	156	0	0	-	3 487	6 356	2 583	0	0	-	8 939
1997	2 962	410	0	0	-	3 372	5 817	3 921	0	0	-	9 738
1998	2 595	539	35	0	-	3 169	5 264	5 345	393	0	-	11 002
1999	2 322	651	162	0	-	3 135	4 744	7 064	2 455	0	-	14 263
2000	2 007	752	262	0	-	3 021	4 287	8 822	4 502	0	-	17 611
2001	1 685	797	322	0	-	2 804	3 709	10 752	6 843	0	-	21 304
2002	1 447	838	370	0	-	2 655	3 234	12 380	8 766	0	-	24 380
2003	1 219	871	303	121	-	2 514	2 734	13 635	5 372	5 083	-	26 824
2004	1 057	427	296	154	-	1 934	2 357	3 007	4 913	7 077	-	17 354
2005	805	366	285	194	-	1 650	1 803	2 579	4 456	9 266	-	18 104
2006	699	356	273	245	0	1 573	1 540	2 292	4 131	11 385	0	20 921
Trend - %	*-89*	-	-	-	-	*-76*	*-73*	-	-	-	-	*269*

Table 3-41 – Heavy duty vehicles (N2, N3): 1990-2006

	gasoline	diesel, PTMA: 3,5 - 7,5 t						diesel, PTMA: 7,5 - 16 t					
	Pré 91/441/CEE	Pré 91/542/CEE Stage I	91/542/CEE Stage I (Euro I)	91/542/CEE Stage II (Euro II)	Standards 2000 (Euro III)	Standards 2005 (Euro IV)	TOTAL	Pré 91/441/CEE	91/441/CEE (Euro I)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL
1990	68	796	0	0	0	-	796	750	0	0	0	-	750
1991	68	796	0	0	0	-	796	750	0	0	0	-	750
1992	51	696	7	0	0	-	703	1 597	9	0	0	-	1 606
1993	51	696	7	0	0	-	703	1 597	9	0	0	-	1 606
1994	51	664	49	0	0	-	713	1 463	70	0	0	-	1 533
1995	49	629	78	0	0	-	707	1 355	147	0	0	-	1 502
1996	45	584	99	9	0	-	692	1 254	209	23	0	-	1 486
1997	43	542	95	40	0	-	677	1 144	207	122	0	-	1 473
1998	43	493	95	69	0	-	657	1 052	211	230	0	-	1 493
1999	41	440	101	111	0	-	652	980	218	384	0	-	1 582
2000	37	395	98	147	0	-	640	873	216	520	0	-	1 609
2001	35	351	93	212	0	-	656	784	199	458	0	-	1 441
2002	35	304	88	261	0	-	653	679	189	523	0	-	1 391
2003	35	277	82	196	110	-	665	621	181	428	195	-	1 425
2004	18	257	77	194	153	-	681	552	168	415	263	-	1 398
2005	17	212	70	190	153	-	625	464	155	394	368	-	1 381
2006	18	190	66	176	244	0	676	413	156	378	440	0	1 387
Trend - %	*-74*	*-76*	-	-	-	-	*-15*	*-45*	-	-	-	-	*85*

	diesel, PTMA: 16 -32 t						diesel, PTMA: > 32 t					
	Pré 91/441/CEE	91/441/CEE (Euro I)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL	Pré 91/441/CEE	91/441/CEE (Euro I)	94/12/CEE (Euro II)	98/69/CE Stage 2000 (Euro III)	98/69/CE Stage 2005 (Euro IV)	TOTAL
1990	4 087	0	0	0	-	4 087	12	0	0	0	-	12
1991	4 087	0	0	0	-	4 087	12	0	0	0	-	12
1992	4 523	75	0	0	-	4 598	14	1	0	0	-	15
1993	4 523	75	0	0	-	4 598	14	1	0	0	-	15
1994	4 190	430	0	0	-	4 620	14	2	0	0	-	16
1995	3 643	1 003	0	0	-	4 646	15	7	0	0	-	22
1996	3 238	1 423	136	0	-	4 797	14	8	1	0	-	23
1997	2 863	1 357	874	0	-	5 094	14	8	5	0	-	27
1998	2 532	1 191	1 930	0	-	5 653	16	8	9	0	-	33
1999	2 246	1 066	3 144	0	-	6 456	15	9	13	0	-	37
2000	1 952	961	4 678	0	-	7 591	14	9	15	0	-	38
2001	1 635	821	5 507	0	-	7 963	20	13	9	0	-	42
2002	1 415	702	5 631	0	-	7 748	29	7	9	0	-	45
2003	1 242	616	3 775	2 466	-	8 099	32	6	15	16	-	69
2004	1 053	507	2 937	3 400	-	7 897	4	8	14	21	-	47
2005	852	399	2 307	3 400	-	6 958	2	8	14	30	-	54
2006	767	354	1 930	5 299	0	8 350	1	6	12	49	0	68
Trend - %	*-81*	-	-	-	-	*104*	*-92*	-	-	-	-	*467*

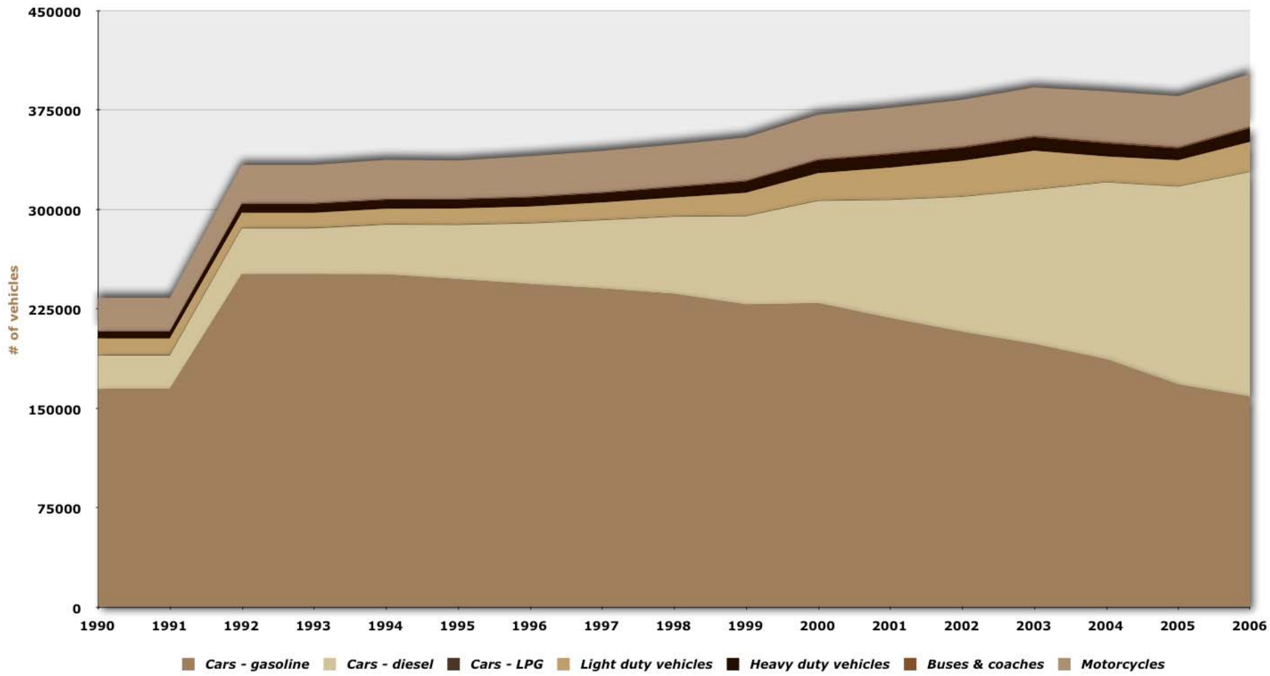
Table 3-42 – Urban busses and coaches (M2, M3): 1990-2006

	Urban busses						Coaches					
	Pré 91/542/CEE Stage I	91/542/CEE Stage I (Euro I)	91/542/CEE Stage II (Euro II)	Standards 2000 (Euro III)	Standards 2005 (Euro IV)	TOTAL	Pré 91/542/CEE Stage I	91/542/CEE Stage I (Euro I)	91/542/CEE Stage II (Euro II)	Standards 2000 (Euro III)	Standards 2005 (Euro IV)	TOTAL
1990	375	0	0	0	-	375	375	0	0	0	-	375
1991	375	0	0	0	-	375	375	0	0	0	-	375
1992	45	3	0	0	-	48	798	5	0	0	-	803
1993	45	3	0	0	-	48	798	5	0	0	-	803
1994	40	7	0	0	-	47	755	44	0	0	-	799
1995	33	8	0	0	-	41	691	150	0	0	-	841
1996	32	9	3	0	-	44	643	222	9	0	-	874
1997	28	9	7	0	-	44	575	220	108	0	-	903
1998	20	9	16	0	-	45	492	212	203	0	-	907
1999	17	9	19	0	-	45	426	198	320	0	-	944
2000	16	9	34	0	-	59	378	192	432	0	-	1 002
2001	14	9	48	0	-	71	317	177	561	0	-	1 055
2002	9	9	57	0	-	76	276	175	653	0	-	1 105
2003	6	11	44	20	-	81	229	157	544	222	-	1 152
2004	4	8	42	27	-	81	194	142	524	345	-	1 205
2005	2	6	39	40	-	87	154	110	494	495	-	1 253
2006	0	5	32	47	0	84	121	85	443	660	0	1 309
Trend - %	*-100*	-	-	-	-	*-78*	*-68*	-	-	-	-	*248*

Table 3-43 – Two wheelers/motorcycles (L1, L2, L3, L4, L5)

	motorcycles				
	Cyl. < 50 cm3, all 2 stroke engines	Cyl. < 250 cm3, 4 stroke engines	Cyl. 250 - 750 cm3, 4 stroke engines	Cyl. > 750 cm3, 4 stroke engines	TOTAL
1990	19 312	1 002	2 356	1 634	24 304
1991	19 312	1 002	2 356	1 634	24 304
1992	19 806	1 711	4 025	2 792	28 334
1993	19 806	1 711	4 025	2 792	28 334
1994	19 962	1 665	4 261	3 237	29 125
1995	20 130	1 564	4 308	2 405	28 407
1996	20 287	1 513	4 365	3 961	30 126
1997	20 494	1 464	4 469	4 281	30 708
1998	20 755	1 408	4 437	4 622	31 222
1999	21 073	1 377	4 535	5 053	32 038
2000	21 451	1 437	4 805	5 549	33 242
2001	21 793	1 416	4 849	5 730	33 788
2002	22 231	1 481	5 016	6 219	34 947
2003	22 818	1 518	5 204	6 691	36 231
2004	23 340	1 653	5 558	7 289	37 840
2005	23 790	1 633	5 319	7 258	38 000
2006	24 407	1 763	5 563	7 726	39 459
Trend - %	*26*	*76*	*136*	*373*	*62*

Figure 3-5 – National vehicle fleet: 1990-2006



Source: SNCT.

Table 3-44 – Total fuel sold for road transport – inland consumption and road fuel export: 1990-2006

	TOTAL			Gasoline		
	Total fuel sold road transport	fuel consumption in LU	road fuel export'	Total fuel sold road transport	fuel consumption in LU	road fuel export'
	[t]	[t]	[t]	[t]	[t]	[t]
1990	855 750	264 500	583 250	412 000	160 000	252 000
1991	1 040 980	264 500	776 480	483 000	160 000	323 000
1992	1 125 970	367 334	758 636	523 000	237 000	286 000
1993	1 144 490	367 334	777 156	527 000	237 000	290 000
1994	1 152 460	371 281	781 179	545 000	237 000	308 000
1995	1 087 340	373 247	714 097	514 000	233 000	281 000
1996	1 114 930	377 895	737 035	514 830	229 367	285 463
1997	1 199 520	386 105	813 415	542 030	226 237	315 793
1998	1 262 910	398 392	864 518	544 570	222 222	322 348
1999	958 079	414 981	958 079	349 904	217 126	349 904
2000	1 573 320	451 230	1 122 090	582 000	220 000	362 000
2001	1 651 980	468 196	1 183 784	572 000	205 000	367 000
2002	1 715 160	480 173	1 234 987	557 500	196 000	361 500
2003	1 904 445	480 173	1 424 272	567 438	196 000	371 438
2004	1 904 445	480 173	1 736 821	565 000	176 000	389 000
2005	2 273 082	467 145	1 805 937	486 000	158 000	328 000
2006	2 216 463	450 154	1 766 309	450 000	140 000	310 000

	Diesel			LPG		
	Total fuel sold road transport	fuel consumption in LU	road fuel export'	Total fuel sold road transport	fuel consumption in LU	road fuel export'
	[t]	[t]	[t]	[t]	[t]	[t]
1990	432 000	104 000	328 000	3 750	500	3 250
1991	554 000	104 000	450 000	3 980	500	3 480
1992	600 000	130 000	470 000	2 970	334	2 636
1993	614 000	130 000	484 000	3 490	334	3 156
1994	604 000	134 000	470 000	3 460	281	3 179
1995	570 000	140 000	430 000	3 340	247	3 097
1996	597 590	148 288	449 302	2 510	240	2 270
1997	656 300	159 643	496 657	1 190	225	965
1998	716 250	175 946	540 304	2 090	224	1 866
1999	605 810	197 630	605 810	2 365	225	2 365
2000	989 000	231 000	758 000	2 320	230	2 090
2001	1 077 000	263 000	814 000	2 980	196	2 784
2002	1 154 700	284 000	870 700	2 960	173	2 787
2003	1 334 641	284 000	1 050 641	2 366	173	2 193
2004	1 645 000	299 000	1 346 000	1 994	173	1 821
2005	1 786 000	309 000	1 477 000	1 082	145	937
2006	1 765 000	310 000	1 455 000	1 463	154	1 309

3.4.3. IPCC Sub-category 1A3c – Railways

In 2006, railways fuel consumption was responsible for 0.21% of GHG emissions from fuel combustion activities (0.29% in 1990) and represented 0.18% of the total GHG emissions in CO_2e, excluding LULUCF (0.23% in 1990).

3.4.3.1. Key source

Fuel consumption from railways is not a key source.

3.4.3.2. Source category description

As indicated above, railways GHG related emissions are quite low in Luxembourg. The reason stems from the fact that Luxembourg's national railways company, *CFL (Chemins de Fer Luxembourgeois*), use, almost exclusively, locomotives powered by electricity.

3.4.3.3. Methodology

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

Activity data are listed in Table 3-45.

Table 3-45 – Activity data for IPCC Sub-category 1A3c – Railways: 1990-2006

SNAP	80200
Activity	Railways
Fuel	204a
Unit	[GJ]
1990	370 000
1991	370 000
1992	370 000
1993	370 000
1994	324 584
1995	262 817
1996	262 817
1997	262 817
1998	262 817
1999	262 817
2000	262 817
2001	262 817
2002	294 118
2003	294 118
2004	294 118
2005	294 118
2006	294 118
Source	CFL

Emission factors

Default EFs have been applied: see Table 3-46.

Table 3-46 – Emission factors for IPCC Sub-category 1A3c – Railways

IPCC Category	Source Categories	SNAP	Fuel		Emission factor [g/GJ, CO_2 kg/GJ]	Source
1A3c	Railways	080200	204A	Gas oil	CO_2: 74.1	2006 IPCC Guidelines
					CH_4: 4.15	
					N_2O: 28.6	

3.4.4. IPCC Sub-category 1A3d – Navigation

In 2006, fuel consumption in navigation was responsible for 0.05% of GHG emissions from fuel combustion activities (0.06% in 1990) and represented 0.04% of the total GHG emissions in CO_2e, excluding LULUCF (0.05% in 1990).

3.4.4.1. Key source

Navigation related fuel consumption is not a key source.

3.4.4.2. Source category description

As Luxembourg has no direct access to the sea, there are no maritime activities taking place. Similarly, Luxembourg has no domestic shipping activities, but only some shipping activities on the

Moselle River, a border river with Germany. These can also be seen as international movements. Nevertheless, the related emissions are of minor importance, as underlined above.

3.4.4.3. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

Activity data are listed in Table 3-47.

Table 3-47 – Activity data for IPCC Sub-category 1A3d – Navigation: 1990-2006

SNAP code	80300
Activity	Inland waterways
Fuel	204a
Unit	[GJ]
1990 - 2006	80 000
Source	TÜV 1990

Emission factors

Default EFs have been applied: see Table 3-48.

Table 3-48 – Emission factors for IPCC Sub-category 1A3d – Navigation

IPCC Category	Source Categories	SNAP	Fuel		Emission factor [g/GJ, CO_2 kg/GJ]	Reference
1A3d	Navigation	080300	205A	Diesel Oil	CO_2: 74.1	2006 IPCC Guidelines
					CH_4: 7.0	
					N_2O: 2.0	

3.4.5. IPCC Sub-Category 1A3e – Other Transportation

No activities that could go under this source category have been identified for Luxembourg.

3.4.6. Recalculations

See Tables 3-1 and 3-2 above.

3.4.7. Category specific QA/QC procedures

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

3.4.8. 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 3-49 will be explored.

Table 3-49 – Planned improvements for IPCC Sub-category 1A3 – Fuel Combustion Activities – Transport

GHG source & sink category	Planned improvement
1A3a – Civil Aviation	refine activity data that are based, for the moment, on an expert judgement.
1A3b – Road Transportation	investigate the possible use of COPERT IV instead of COPERT III.
1A3b – Road Transportation	it has recently been identified a source of biofuels for urban busses: the inventory should be corrected by moving related emissions from IPCC Sub-category 1A4 – where it is recorded for the moment – to 1A3b.
1A3c – Railways	refine activity data and revise EFs on the basis of possible new information from CFL.
1A3d – Navigation	revise and expand the present activity data.

3.5. Other Sectors (IPCC Source Sub-category 1A4)

This section describes GHG emissions resulting from fuel combustion activities in the "other sectors" sub-category. "Other sectors" covers the activities presented in Table 3-50.

Table 3-50 – Activities for IPCC Sub-category 1A4 – Other Sectors

SNAP code	Description
020103	Non-industrial commercial and institutional combustion plants <50 MW
020202	Non-industrial residential combustion plants < 50 MW
020302	Non-industrial combustion plants in agriculture, forestry and aquaculture

In 2006, IPCC Sub-category 1A4 was responsible for 11.2% of GHG emissions from fuel combustion activities (this share was 12.15% in 1990) and represented around 9.9% of the total GHG emissions in CO_2e, excluding LULUCF (the same weight – 9.9% - was recorded for the year 1990).

This sub-category is, for the moment, the only one for which CO_2 emissions from biomass are recorded. That will, however, change in the future as Tables 3-49 and 3-59 indicate.

Table 3-51 summarizes GHG emissions for IPCC Sub-category 1A4.

3.5.1. IPCC Sub-category 1A4a – Commercial / Institutional

In 2006, fuel combustion from the commercial and institutional sectors was responsible for 5.3% of GHG emissions from fuel combustion activities (this share was 5.7% in 1990). With regard to total GHG emissions in CO_2e, excluding LULUCF and excluding CO_2 emissions from biomass, percentages were 4.66% in 2006 and 4.63% in 1990.

Table 3-51 – GHG emission trends in CO_2e for IPCC Sub-category 1A4 – Fuel Combustion Activities – Other Sectors: 1990-2006

Year	1A4a - Commercial/Institutional				1A4b - Residential				1A4c - Agriculture/Forestry/Fisheries				1A4 - Other Sectors			
	CO_2e emissions (Gg) — GHG source & sink category															
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	610.18	605.05	3.51	1.62	615.36	607.35	6.40	1.62	78.64	77.93	0.43	0.27	1 304.18	1 290.33	10.35	3.50
1991	775.67	769.68	3.92	2.07	783.71	771.98	9.65	2.07	78.64	77.93	0.43	0.27	1 638.02	1 619.60	14.01	4.41
1992	751.92	746.08	3.86	1.98	759.25	748.38	8.89	1.98	78.64	77.93	0.43	0.27	1 589.80	1 572.39	13.18	4.23
1993	769.43	763.50	3.87	2.06	778.46	765.75	10.66	2.06	78.64	77.93	0.43	0.27	1 626.53	1 607.18	14.96	4.38
1994	656.46	651.16	3.63	1.66	661.00	653.46	5.87	1.66	78.64	77.93	0.43	0.27	1 396.10	1 382.56	9.94	3.60
1995	659.11	653.88	3.62	1.61	663.01	656.18	5.22	1.61	78.64	77.93	0.43	0.27	1 400.75	1 387.99	9.27	3.49
1996	731.59	726.14	3.77	1.69	735.76	728.44	5.63	1.69	75.87	75.13	0.46	0.27	1 543.22	1 529.70	9.87	3.65
1997	715.21	709.80	3.74	1.66	718.96	712.10	5.20	1.66	75.87	75.13	0.46	0.27	1 510.04	1 497.03	9.41	3.60
1998	761.54	755.95	3.86	1.73	764.78	758.25	4.80	1.73	75.87	75.13	0.46	0.28	1 602.18	1 589.33	9.12	3.73
1999	730.49	725.02	3.79	1.67	733.50	727.27	4.56	1.67	75.87	75.13	0.46	0.28	1 539.86	1 527.43	8.81	3.62
2000	606.70	601.71	3.50	1.49	609.72	604.01	4.23	1.49	75.87	75.13	0.46	0.27	1 292.29	1 280.84	8.20	3.25
2001	686.20	680.89	3.69	1.62	689.27	683.19	4.47	1.62	75.87	75.13	0.46	0.27	1 451.33	1 439.20	8.62	3.51
2002	667.81	662.61	3.65	1.55	670.35	664.91	3.88	1.55	75.87	75.13	0.46	0.27	1 414.02	1 402.66	7.99	3.38
2003	652.95	647.91	3.58	1.46	655.48	650.21	3.81	1.46	75.87	75.13	0.46	0.27	1 384.29	1 373.25	7.85	3.19
2004	648.12	643.06	3.58	1.48	650.65	645.36	3.82	1.48	75.87	75.13	0.46	0.27	1 374.64	1 363.54	7.86	3.23
2005	627.35	622.31	3.60	1.44	629.97	624.71	3.82	1.45	75.87	75.13	0.46	0.28	1 333.19	1 322.15	7.87	3.16
2006	621.41	616.48	3.56	1.38	625.13	620.03	3.72	1.38	75.87	75.13	0.46	0.28	1 322.41	1 311.63	7.75	3.03
Trend 1990-2006	*1.84%*	*1.89%*	*1.28%*	*-14.69%*	*1.59%*	*2.09%*	*-41.83%*	*-14.69%*	*-3.52%*	*-3.60%*	*6.85%*	*2.45%*	*1.40%*	*1.65%*	*-25.16%*	*-13.37%*

Source: Environment Agency.

Notes:

CO_2 emissions does not include CO2 emissions from biomass which are reported under Memo Items.

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GW*P) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3.5.1.1. Key source

Commercial and institutional fuel combustion is a key source with regard to CO_2 emissions. It has been a key source for solid fuels only for the years 1991, 1992 and 1993, and a key source for both liquid and gaseous fuels without interruption since 1990: see Tables 1-6 and 1-7 in Section 1.5.1.

3.5.1.2. Source category description

SNAP 020103 - Non-industrial commercial and institutional combustion plants <50 MW

The consumption of hard coal, lignite, wood, gasoil and natural gas in the so-called "*secteur domestique*" is documented in STATEC's Statistical Yearbook as well as in yearly activity reports from the Ministry of Economic Affairs and External Trade. Nevertheless, in official statistics the "*secteur domestique*" covers commercial and institutional consumption as well as residential combustion. Consequently, data had to be distributed arbitrarily, i.e. 50% did go under "commercial/institutional" and 50% under "residential".

3.5.1.3. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

Activity data are listed in Table 3-52.

Table 3-52 – Activity data for IPCC Sub-category 1A4a – Commercial/Institutional – combustion plants < 50 MW

SNAP code	020103					
Activity	Commercial / institutional Combustion Plants, < 50 MW					
Fuel	104a	106a	111a	204a	301a	Total
Unit	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]
1990	366 250	108 098	322 300	4 732 000	3 710 464	9 239 112
1991	761 800	179 902	322 300	5 918 600	4 265 573	11 448 175
1992	673 900	152 756	322 300	5 713 500	4 315 658	11 178 114
1993	966 900	147 160	322 300	5 361 900	4 591 125	11 389 385
1994	297 395	71 355	322 300	5 186 100	4 116 245	9 993 395
1995	209 000	53 215	321 860	5 099 600	4 464 058	10 147 733
1996	250 173	56 019	321 860	5 249 349	5 477 815	11 355 216
1997	187 473	51 888	321 860	5 343 608	5 178 233	11 083 062
1998	115 368	38 401	321 860	5 836 116	5 499 148	11 810 893
1999	92 796	33 165	321 860	5 663 900	5 223 680	11 335 401
2000	93 841	25 286	321 860	4 869 700	4 086 405	9 397 092
2001	103 246	23 849	321 860	5 434 000	4 738 598	10 621 553
2002	22 990	15 457	184 030	5 308 600	4 732 569	10 263 646
2003	22 990	14 844	184 030	4 723 400	5 244 549	10 189 813
2004	20 900	17 507	184 030	4 890 600	4 936 155	10 049 192
2005	20 900	13 979	334 400	4 598 000	4 958 966	9 926 245
2006	20 900	6352	184030	4221800	5365124	9777306
Trend 1990-2006	*-95*	*-94*	*-43*	*-11*	*45*	*6*
Source	STATEC Statistical Yearbook, Tables C.3502, C.3503 & C.3516					

Emission factors

Default EFs have been applied: see Table 3-53.

Table 3-53 – Emission factors for IPCC Sub-category 1A4a – Commercial/Institutional – combustion plants < 50 MW

IPCC Category	Source Categories	SNAP	Fuel		Emission factor [kg/GJ]		Reference
1A4a	Commercial/ Institutional	020103	104A	Patent fuels	CO_2	97.5	2006 IPCC Guidelines
					CH_4	10.0	
			106A	Lignite	CO_2	97.5	
					CH_4	10.0	
			111A	Wood	CO_2	112.0	
					CH_4	300.0	
			204A	Gas oil	CO_2	74.1	
					CH_4	10.0	
			301A	Natural gas	CO_2	56.1	
					CH_4	5.0	

3.5.2. IPCC Sub-category 1A4b – Residential

In 2006, fuel combustion from the residential sector was responsible for 5.3% of GHG emissions from fuel combustion activities (this share was 5.7% in 1990). With regard to total GHG emissions in CO_2e, excluding LULUCF and excluding CO_2 emissions from biomass, percentages were 4.69% in 2006 and 4.67% in 1990.

3.5.2.1. Key source

Residential fuel combustion is a key source with regard to CO_2 emissions. It has been a key source for solid fuels only for the years 1992 and 1993, and a key source for both liquid and gaseous fuels without interruption since 1990: see Tables 1-6 and 1-7 in Section 1.5.1.

3.5.2.2. Source category description

SNAP 020202 - Non-industrial residential combustion plants < 50 MW

Same comment as in Section 3.5.1.2.

3.5.2.3. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied.

Activity data

Activity data are listed in Table 3-54.

Table 3-54 – Activity data for IPCC Sub-category 1A4b – Residential – combustion plants < 50 MW: 1990-2006

SNAP code	020102					
Activity	Residential combustion Plants, < 50 MW					
Fuel	104a	106a	111a	204a	301a	Total
Unit	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]
1990	366 250	108 098	322 300	4 732 000	3 710 464	9 239 112
1991	761 800	179 902	322 300	5 918 600	4 265 573	11 448 175
1992	673 900	152 756	322 300	5 713 500	4 315 658	11 178 114
1993	966 900	147 160	322 300	5 361 900	4 591 125	11 389 385
1994	297 395	71 355	322 300	5 186 100	4 116 245	9 993 395
1995	209 000	53 215	321 860	5 099 600	4 464 058	10 147 733
1996	250 173	56 019	321 860	5 249 349	5 477 815	11 355 216
1997	187 473	51 888	321 860	5 343 608	5 178 233	11 083 062
1998	115 368	38 401	321 860	5 836 116	5 499 148	11 810 893
1999	92 796	33 165	321 860	5 663 200	5 223 680	11 334 701
2000	93 841	25 286	321 860	4 869 700	4 086 405	9 397 092
2001	103 246	23 849	321 860	5 434 000	4 738 598	10 621 553
2002	22 990	15 457	184 030	5 308 600	4 732 569	10 263 646
2003	22 990	14 844	184 030	4 723 400	5 244 549	10 189 813
2004	20 900	17 507	184 030	4 890 600	4 936 155	10 049 192
2005	20 900	13 979	33 4400	4 598 000	4 958 966	9 926 245
2006	20 900	6 352	184 030	4 221 800	5 365 124	9 777 306
Trend 1990-2006	*-95*	*-94*	*-43*	*-11*	*45*	*6*
Source	STATEC Statistical Yearbook, Tables C.3502, C.3503 & C.3516					

Emission factors

Default EFs have been applied: see Table 3-55.

Table 3-55 – Emission factors for IPCC Sub-category 1A4b – Residential – combustion plants < 50 MW

IPCC Category	Source Categories	SNAP	Fuel	Emission factor [kg/GJ]			Reference
1A4b	Commercial/ Institutional	020102	104A	Patent fuels	CO_2	97.5	2006 IPCC Guidelines
					CH_4	10.0	
			106A	Lignite	CO_2	97.5	
					CH_4	10.0	
			111A	Wood	CO_2	112.0	
					CH_4	300.0	
			204A	Gas oil	CO_2	74.1	
					CH_4	10.0	
			301A	Natural gas	CO_2	56.1	
					CH_4	5.0	

3.5.3. IPCC Sub-Category 1A4c – Agriculture / Forestry / Fisheries

In 2006, fuel combustion in agriculture, as well as in forestry and fisheries activities, was responsible for 0.64% of GHG emissions from fuel combustion activities (this share was 0.73% in 1990). With regard to total GHG emissions in CO_2e, excluding LULUCF and excluding CO_2 emissions from biomass, percentages were 0.57% in 2006 and 0.6% in 1990.

3.5.3.1. Key source

Fuel combustion related to agriculture/forestry/fisheries has been a key source with regard to CO_2 emissions and liquid fuels between the years 1995 and 2003 included: see Tables 1-6 and 1-7 in Section 1.5.1.

3.5.3.2. Source category description

<u>SNAP 020302 - Non-industrial combustion plants in agriculture, forestry and aquaculture</u>

The consumption data of this activity group is a first estimation. It is of minor importance, as the energy consumption – mainly wood – for this source category is rather low.

<u>SNAP 080600 – Tractors and harvesters used in agriculture</u>

This category includes emissions from tractors and harvesters used in agriculture.

3.5.3.3. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied.

<u>Activity data</u>

Activity data are listed in Tables 3-56 and 3-57.

Table 3-56 – Activity data for IPCC Sub-category 1A4c – Agriculture/Forestry/Fisheries – combustion plants, < 50 MW: 1990-2006

SNAP code	020203		
Activity	Agriculture/forestry – combustion Plants, < 50 MW		
Fuel	111A	301A	TOTAL
Unit	[GJ]	[GJ]	[GJ]
1990	64 460	50000	114460
1991	64 460	50000	114460
1992	64 460	50000	114460
1993	64 460	50000	114460
1994	64 460	50000	114460
1995	64 460	50000	114460
1996	70 000	0	70000
1997	70 000	0	70000
1998	70 000	0	70000
1999	70 000	0	70000
2000	70 000	0	70000
2001	70 000	0	70000
2002	70 000	0	70000
2003	70 000	0	70000
2004	70 000	0	70000
2005	70 000	0	70000
2006	70 000	0	70000
Trend 1990-2006	*9%*	*-100%*	*-39%*
Source	CITEPA		

Table 3-57 – Activity data for IPCC Sub-category 1A4c – Agriculture/Forestry/Fisheries – tractors & harvesters used in agriculture

SNAP code	080600	
Activity	080600/N09 Tractors used in agriculture	080600/N10 Harvesters used in agriculture
Fuel	205A	205A
Unit	[GJ]	[GJ]
1990 - 2006	427 435	551 026
Source	TÜV 1990	TÜV 1990

Emission factors

Default EFs have been applied: see Table 3-58.

Table 3-58 – Emission factors for IPCC Sub-category 1A4c – Agriculture/Forestry/Fisheries

IPCC Category	Source Categories	SNAP	Fuel		Emission factor [kg/GJ]		Reference
1A4c	Agriculture/ forestry	020302	111A	Wood	CO_2	112.0	2006 IPCC Guidelines
					CH_4	300.0	
			301A	Natural gas	CO_2	56.1	
					CH_4	5.0	
		080600	205A	Diesel	CO_2	73.8	CORINAIR, B111-52

3.5.4. Recalculations

See Tables 3-1 and 3-2 above.

3.5.5. Category specific QA / QC procedures

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

3.5.6. 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 3-59 will be explored.

Table 3-59 – Planned improvements for IPCC Sub-category 1A4 – Fuel Combustion Activities – Other Sectors

GHG source & sink category	Planned improvement
1A4 – Other Sectors	revise thoroughly all the activity data.
1A4 – Other Sectors	it has recently been identified a source of biofuels for urban busses: the inventory should be corrected by moving related emissions from IPCC Sub-category 1A4 – where it is recorded for the moment – to 1A3b.
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.
1A4a – Commercial/Institutional	investigate whether it would be possible to move away from default EFs to more specific/accurate ones.
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.
1A4b – Residential	investigate whether it would be possible to move away from default EFs to more specific/accurate ones.
1A4c – Agriculture/Forestry/Fisheries	investigate whether it would be possible to move away from default EFs to more specific/accurate ones.

3.6. Other (IPCC Source Sub-category 1A5)

Emissions pertaining to this source category are supposedly recorded elsewhere. This will need to be investigated further in the future improvements of Luxembourg's inventory. So far, the following explanations have been provided in the documentation box of CRF table 1:

- 1A5a – Stationary – Building and Plant Site Fuel Powered Machinery: it is not possible to distinguish liquid fuel use for stationary machinery from the data used to estimate emissions from gasoline and diesel oil since the share of these specific activities is not estimated for the moment (that would require getting information directly from the operators). Consequently, the notation key IE has been used;
- 1A5b – Mobile – Off-road Vehicles and Other Machinery, Airport and Military Vehicles: it is not possible to distinguish liquid fuel use for specific activities (military activities, ground transportation at the airport, etc.) from the data used to estimate emissions from gasoline and diesel oil since the share of these specific activities is not estimated for the moment (that would require getting information directly from the operators). Consequently, the notation key IE has been used.

3.7. Comparison of the Sectoral Approach with the Reference Approach

The following explanations have been provided in the documentation box of CRF table 1.A(b) and 1.A(c):

- data for the Reference Approach are coming from Eurostat databases on energy. The data have been extracted from Eurostat's web site on 14 January 2008;
- the unit for the conversion factor is Eurostat's default since we use Eurostat's default factors;
- the unit for the fraction of carbon oxidized is the default one too;

- municipal solid waste (garbage): in order to have accurate comparisons in table 1.A(c), this energy source has to be recorded under one of the three main fuels of the Reference Approach (i.e. Liquid, Solid and Gaseous). If not, the total for the Reference Approach would not include municipal waste incineration on the contrary of the Sectoral Approach, hence leading to incomplete comparisons. The source "Other Solid Fossil Fuels" has been selected for recording municipal waste incineration data.

This latter explanation is one of the main reason explaining differences recorded between the Sectoral and the Reference Approaches (CRF table 1.A(c)). Since the CRF table for the Reference Approach does not provide a line "other" independently from a fuel type (liquid, solid or gaseous), we had to arbitrarily choose a fuel type for incorporating energy production from municipal solid waste.

Hence, differences between the two approaches are justified by:

- Eurostat's default factors used for the Reference Approach vs. country specific, plant specific or IPCC default EFs for the Sectoral Approach;[57]
- the inclusion of municipal solid waste as an "other solid fossil fuel";
- in some rare cases, an allocation of certain fuels in a fuel type category for the Sectoral Approach and in another type category for the Reference Approach.

3.8. Feedstocks

Non-energy use of fuels is considered in the national energy balance. For the data recorded, please refer to the delivery available on the Central Data Repository of the EIONET of the EEA: http://cdr.eionet.europa.eu/lu/eu/ghgmm/envsa9e_q.

3.9. Fugitive Emissions from Fuels – Solid Fuels (IPCC Source Sub-category 1B1)

This source category does not exist in Luxembourg.

57 It is worth noting that a recent exercise made by the Ministry of the Environment with Eurostat showed lower differences in percentage points when the newest Eurostat's default factors are applied. Indeed, these new defaults factors are harmonized with those of the International Energy Agency (*IEA*) and are, therefore, also closer to those reported in the 2006 IPCC Guidelines.

3.10. Fugitive Emissions from Fuels – Oil and Natural Gas (IPCC Source Sub-category 1B2)

This section describes GHG fugitive emissions from oil and natural gas in distribution and transmission, i.e. the sole sub-categories for which emissions might occur since there are no exploration and production of oil and natural gas in Luxembourg.

In 2006, this source category was responsible for 0.5% of GHG emissions from the energy sector (0.45% in 1990) and represented 0.26% of the total GHG emissions in CO_2e, excluding LULUCF (0.21% in 1990).

Table 3-60 summarizes GHG emissions for IPCC Sub-category 1B2.

3.10.1. Key source

Fugitive emissions from oil and natural gas distribution and transmission is not a key source.

3.10.2. Source category description

In Luxembourg, fugitive emissions could only occur from oil distribution (IPCC Sub-category 1B2a.v) and from natural gas transmission, distribution and leakages (IPCC Sub-categories 1B2b.iii/iv and v). Other fugitive emissions – because they are closely linked to production, processing or exploration – are not occurring in Luxembourg.

Fugitive emissions from the distribution of oil products have not yet been estimated, hence the NE notation key reported in the CRF tables.

As regards natural gas, methane emissions from distribution have been re-estimated in 2006 and included in the inventories. These emissions are due to leaks or to accidental events. There is, however, no distinction being made between transmission and distribution, and since leakages could only happen during these phases, **IPCC Sub-Category 1B2b.iii – Natural Gas – Transmission reports CH_4 emissions due to leaks or to accidental events in gas transmission and distribution**. It includes therefore IPCC Sub-Category 1B2b.iv and v.

3.10.3. Methodological issues

3.10.3.1. Activity data

Activity data are listed in Table 3-61.

Table 3-60 – GHG emission trends in CO_2e for IPCC Sub-category 1B2 – Fugitive Emissions from Fuels – Oil and Natural Gas: 1990-2006

Year	*CO_2e emissions (Gg)* GHG source & sink category																			
	1B2a - Oil				1B2b - Natural Gas				1B2c - Venting & Flaring				1B2d - Other				1B2 - Oil & Natural Gas			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	NE,NO	NE,NO	NE,NO	NO	27.51	IE,NO	27.51	NA	NO	NO	NO	NO	NA	NA	NA	NA	27.51	IE,NA,NE,NO	27.51	NA,NO
1991	NE,NO	NE,NO	NE,NO	NO	29.40	IE,NO	29.40	NA	NO	NO	NO	NO	NA	NA	NA	NA	29.40	IE,NA,NE,NO	29.40	NA,NO
1992	NE,NO	NE,NO	NE,NO	NO	30.66	IE,NO	30.66	NA	NO	NO	NO	NO	NA	NA	NA	NA	30.66	IE,NA,NE,NO	30.66	NA,NO
1993	NE,NO	NE,NO	NE,NO	NO	31.92	IE,NO	31.92	NA	NO	NO	NO	NO	NA	NA	NA	NA	31.92	IE,NA,NE,NO	31.92	NA,NO
1994	NE,NO	NE,NO	NE,NO	NO	31.29	IE,NO	31.29	NA	NO	NO	NO	NO	NA	NA	NA	NA	31.29	IE,NA,NE,NO	31.29	NA,NO
1995	NE,NO	NE,NO	NE,NO	NO	36.75	IE,NO	36.75	NA	NO	NO	NO	NO	NA	NA	NA	NA	36.75	IE,NA,NE,NO	36.75	NA,NO
1996	NE,NO	NE,NO	NE,NO	NO	39.27	IE,NO	39.27	NA	NO	NO	NO	NO	NA	NA	NA	NA	39.27	IE,NA,NE,NO	39.27	NA,NO
1997	NE,NO	NE,NO	NE,NO	NO	40.11	IE,NO	40.11	NA	NO	NO	NO	NO	NA	NA	NA	NA	40.11	IE,NA,NE,NO	40.11	NA,NO
1998	NE,NO	NE,NO	NE,NO	NO	40.53	IE,NO	40.53	NA	NO	NO	NO	NO	NA	NA	NA	NA	40.53	IE,NA,NE,NO	40.53	NA,NO
1999	NE,NO	NE,NO	NE,NO	NO	43.26	IE,NO	43.26	NA	NO	NO	NO	NO	NA	NA	NA	NA	43.26	IE,NA,NE,NO	43.26	NA,NO
2000	NE,NO	NE,NO	NE,NO	NO	44.31	IE,NO	44.31	NA	NO	NO	NO	NO	NA	NA	NA	NA	44.31	IE,NA,NE,NO	44.31	NA,NO
2001	NE,NO	NE,NO	NE,NO	NO	45.78	IE,NO	45.78	NA	NO	NO	NO	NO	NA	NA	NA	NA	45.78	IE,NA,NE,NO	45.78	NA,NO
2002	NE,NO	NE,NO	NE,NO	NO	58.17	IE,NO	58.17	NA	NO	NO	NO	NO	NA	NA	NA	NA	58.17	IE,NA,NE,NO	58.17	NA,NO
2003	NE,NO	NE,NO	NE,NO	NO	58.59	IE,NO	58.59	NA	NO	NO	NO	NO	NA	NA	NA	NA	58.59	IE,NA,NE,NO	58.59	NA,NO
2004	NE,NO	NE,NO	NE,NO	NO	61.11	IE,NO	61.11	NA	NO	NO	NO	NO	NA	NA	NA	NA	61.11	IE,NA,NE,NO	61.11	NA,NO
2005	NE,NO	NE,NO	NE,NO	NO	59.43	IE,NO	59.43	NA	NO	NO	NO	NO	NA	NA	NA	NA	59.43	IE,NA,NE,NO	59.43	NA,NO
2006	NE,NO	NE,NO	NE,NO	NO	59.43	IE,NO	59.43	NA	NO	NO	NO	NO	NA	NA	NA	NA	59.43	IE,NA,NE,NO	59.43	NA,NO
Trend 1990-2006	*NA*	*NA*	*NA*	*NA*	*116.03%*	*NA*	*116.03%*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*116.03%*	*NA*	*116.03%*	*NA*

Source: Environment Agency.

Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

Table 3-61 – Activity data trend for IPCC Sub-category 1B2 – Fugitive Emissions from Fuels – Oil and Natural Gas: 1990-2006

SNAP	50402	50502	50503	50601	50603
Activity	Other handling and storage	Transport and depots	Service stations (+ refuelling of cars)	Gas distribution networks pipelines	Distribution networks
Unit	[GJ]	[GJ]	[GJ]	[GJ]	[GJ]
1990	33 008 893	18 247 913	18 228 158	19 394 216	19 394 216
1991	39 032 241	21 224 333	21 191 847	20 800 000	20 800 000
1992	42 123 806	22 973 309	22 945 213	21 680 000	21 680 000
1993	40 708 259	23 133 105	23 117 301	22 520 000	22 520 000
1994	40 650 912	23 935 597	23 920 671	22 080 000	22 080 000
1995	38 221 624	22 580 404	22 566 356	25 920 000	25 920 000
1996	41 654 021	22 613 329	22 601 037	27 640 000	27 640 000
1997	43 312 830	23 808 726	23 795 117	28 320 000	28 320 000
1998	48 006 372	23 930 329	23 906 623	28 600 000	28 600 000
1999	49 478 625	24 903 592	24 892 617	30 520 000	30 520 000
2000	55 086 843	25 552 873	25 541 459	31 191 000	31 191 000
2001	60 461 449	25 117 824	25 108 166	32 311 000	32 311 000
2002	63 665 188	24 476 445	24 476 445	48 986 000	33 000 000
2003	75 014 591	24 910 528	24 910 528	49 498 000	33 000 000
2004	83 797 725	24 188 900	24 188 900	55 794 000	34 197 000
2005	88 950 932	21 359 106	21 352 741	50 854 000	33 077 000
2006	88 154 620	19 779 364	19 772 164	53 242 210	34 689 708
Trend 1990-2006	*167*	*8*	*8*	*175*	*79*
Sources	STATEC, Statistical Yearbook, Table C3517	STATEC, Statistical Yearbook, Table C3517	Ministry of Economic Affairs and External Trade, Activity Reports, fuel imports (gasoline)	Ministry of Economic Affairs and External Trade, Activity Reports, natural gas imports; STATEC, Table C3513	Ministry of Economic Affairs and External Trade, Activity Reports, natural gas imports

3.10.4. Recalculations

See Tables 3-1 and 3-2 above.

3.10.5. Category specific QA / QC procedures

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

3.10.6. 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 3-62 will be explored.

Table 3-62 – Planned improvements for IPCC Sub-category 1B2 – Fugitive Emissions from Fuels – Oil and Natural Gas

GHG source & sink category	Planned improvement
1B2 – Fugitive Emissions from Fuels – Oil and Natural Gas	revise thoroughly all the activity data and provide more background information by contacting oil and gas distributors in Luxembourg.

3.11. Memo Items

Under Memo Items, Parties should report GHG emissions from international aviation, from marine bunkers, from multilateral operations and from CO_2 emitted from biomass.

3.11.1. Aviation Bunkers

3.11.1.1. Source category description

As indicated in Section 3.4.1, there is only one airport for commercial aviation in Luxembourg (Findel). Therefore all flights, either coming to Luxembourg or going out from Luxembourg, are international flights. Domestic flights are mainly leisure or urgency (medical, police) flights made with small-sized propellers planes or helicopters using aviation gasoline. Consequently, all kerosene sales and related emissions are allocated to international bunkers.

3.11.1.2. Methodological issues

The 2006 IPCC Guidelines Tier 1 approach has been applied.

<u>Activity data</u>

Activity data, as well as emission estimates, are listed in Table 3-63.

<u>Emission factors</u>

Default EFs for kerosene have been used:

- CO_2 aviation gasoline.............. 71500 kg/TJ
- CH_4 default.................................... 0.5 kg/TJ
- N_2O default.................................... 2.0 kg/TJ

The 2006 IPCC Guidelines NCV of 44.1 TJ/Gg has been applied for converting activity data.

Table 3-63 – Activity data and GHG emissions for International Bunkers – Aviation: 1990-2006

Year	Fuel: Kerosene (tonnes)	Fuel: Kerosene (TJ)	GHG Emissions: CO_2 (Gg)	CH_4 (Mg)	N_2O (Mg)	Total (Gg)
1990	126960.00	5598.94	400.32	2.80	11.20	403.85
1991	132240.00	5831.78	416.97	2.92	11.66	420.65
1992	128790.00	5679.64	406.09	2.84	11.36	409.68
1993	127730.00	5632.89	402.75	2.82	11.27	406.30
1994	162150.00	7150.82	511.28	3.58	14.30	515.79
1995	183840.00	8107.34	579.68	4.05	16.21	584.79
1996	199820.00	8812.06	630.06	4.41	17.62	635.62
1997	229350.00	10114.34	723.17	5.06	20.23	729.55
1998	289800.00	12780.18	913.78	6.39	25.56	921.84
1999	326986.00	14420.08	1031.04	7.21	28.84	1040.13
2000	311635.00	13743.10	982.63	6.87	27.49	991.30
2001	337061.00	14864.39	1062.80	7.43	29.73	1072.18
2002	365190.00	16104.88	1151.50	8.05	32.21	1161.65
2003	380438.00	16777.32	1199.58	8.39	33.55	1210.16
2004	414000.00	18257.40	1305.40	9.13	36.51	1316.92
2005	420603.00	18548.59	1326.22	9.27	37.10	1337.92
2006	393619.00	17358.60	1241.14	8.68	34.72	1252.08
Trend 1990-2006	*210.03%*	*210.03%*	*210.03%*	*210.03%*	*210.03%*	*210.03%*

Sources: Kerosene: Ministry of Economic Affairs and External Trade, Energy Directorate.
Emissions: Environment Agency.

3.11.2. Marine Bunkers

This source category is not yet estimated for Luxembourg. It should, however, be investigated if it should be counted or not since if there are some sea ships under a Luxembourg licence, there is no coastline, hence no harbour, in Luxembourg.

3.11.3. Multilateral Operations

It is supposed that related emissions are appearing under other CRF Sector 1 source categories, hence the IE notation keys in the CRF tables.

3.11.4. CO_2 Emissions from Biomass

This category is automatically filled in CRF tables by gathering CO_2 emissions – and only carbon dioxide emissions – estimated for biomass used as a fuel.

3.11.5. 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 3-64 will be explored.

Table 3-64 – Planned improvements for International Bunkers – Aviation

GHG source & sink category	Planned improvement
Memo Items – International Bunkers - Aviation	re-estimate emissions taking into account LTO and plane types (CORINAIR Guidebook methodology).
Memo Items – International Bunkers - Marine	investigate whether emissions should be reported for this source category and, if yes, how to calculate them.
Memo Items – Multilateral Operations	investigate whether emissions could be identified for this source category and, if yes, how to calculate them.
Memo Items – CO_2 Emissions from Biomass	it has recently been identified a source of biofuels for urban busses: the inventory should be corrected by moving related emissions from IPCC Sub-category 1A4 – where it is recorded for the moment – to 1A3b. This will change slightly emission estimates since ad-hoc EFs will be used for the part moved to 1A3b.

3.12. Selected references

ARBED (1990 – 1998): Annual communications from the operator to the Environment Agency Luxembourg. Luxembourg.

CITEPA (1990): Estimation of emissions from biogenic sources. Paris.

CORINAIR Guidebook (1996): Combustion in Energy & transformation industries - ps010101 Activities 010101 – 010105 - Table 21: Selection of relevant fuels from NAPFUE and lower heating values for boilers, gas turbines and stationary engines.

EMEP/CORINAIR Emission Inventory Guidebook, 3rd edition (2006). European Environment Agency (EEA), Copenhagen.

EMEP/CORINAIR Guidebook (1996): Atmospheric Emission Inventory Guidebook. Prepared by the EMEP Task Force on Emission Inventories. Edited by Stephen Richardson, Task Force Secretary.

ETS Emission Trading Scheme Guidelines 2004 – Commission Decision of 29 January 2004 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (May 2000).

Kouridis, C.; Ntziachristos, L. & Samaras, Z. (2000): COPERT III – Computer programme to calculate emissions from road transport – User Manual (Version 2.1). Technical report No 50, European Environment Agency (EEA). Copenhagen.

Ministère de l'Economie et du Commerce Extérieur, Direction de l'Energie (1990 – 2007): Rapports d'Activité. Luxembourg.

Ministère de l'Environnement, L'Environnement en Chiffres 2002-2003 (2003).

Ntziachristos, L. & Samaras, Z. (2000): COPERT III – Computer programme to calculate emissions from road transport – Methodology and Emission Factors (Version 2.1). Technical report No 49, European Environment Agency (EEA). Copenhagen.

Pulles, T., Marecková, K.; Skákala, J.; Svetlik, J.; Linek, M. & Nagy, C. & Vatral, M. (1999): Redesigning the CORINAIR System – Basics Of The EstimatER Tool. European Environment Agency (EEA). Copenhagen.

Pulles, T., Marecková, K.; Svetlik, J.; Linek, M. & Skákala, J. (1999): CollectER – Installation and User Guide. Technical Report No 31. European Environment Agency (EEA). Copenhagen.

Pulles, T., Marecková, K.; Svetlik, J. & Skákala, J. (1999): TrainerER – Compiling a National Emission Inventory using the CollectER and ReportER software system. Technical Report No 33. European Environment Agency (EEA). Copenhagen.

Pulles, T., Skákala , J. & Svetlik, J. (1999): ReportER. User Manual. Technical Report No 32. European Environment Agency (EEA). Copenhagen.

Pulles, T.; Svetlik, J.; Linek, M. & Skákala, J. (2002): ReportER Auxiliary Database – Technical description of the ReportER auxiliary database format. European Environment Agency (EEA). Copenhagen.

Société Nationale de Contrôle Technique (SNCT) (1990-2006) : Stock of passenger cars, light duty vehicle, heavy duty vehicle, busses, motor cycles. Sandweiler, Luxembourg.

Société Nationale des Chemins de Fer Luxembourgeois (CFL) (1996): Fuel consumption. Luxembourg.

Société Nationale des Chemins de Fer Luxembourgeois (CFL) (2003): Fuel consumption. Luxembourg.

STATEC 1990 – 2007. Annuaires statistiques. Luxembourg.

TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln.

TÜV Rheinland (1992-1993) Impaktstudien für die ARBED-Werke Esch/Belval, Differdange und Esch-Schifflange für das Jahr 1990.

For more information on this Chapter, please contact:

All sectors except Transport and Waste Incineration
Frank THEWES
Administration de l'Environnement
16, rue Eugène Ruppert
L-2453 Luxembourg
Tel: (+352) 40 56 56 646
Fax: (+352) 48 50 78
E-mail: frank.thewes@aev.etat.lu

Transport
Georges BLASEN
Administration de l'Environnement
16, rue Eugène Ruppert
L-2453 Luxembourg
Tel: (+352) 40 56 56 556
Fax: (+352) 48 50 78
E-mail: georges.blasen@aev.etat.lu

Waste Incineration
Serge LESS
Administration de l'Environnement
16, rue Eugène Ruppert
L-2453 Luxembourg
Tel: (+352) 40 56 56 522
Fax: (+352) 49 62 56
E-mail: serge.less@aev.etat.lu

4. Industrial Processes (CRF sector 2)

4.1. Sector Overview

Chapter 4 includes information on and description of methodologies used for estimating GHG emissions as well as references to activity data and emission factors reported under CRF Sector 2 – Industrial Processes for the period 1990 to 2006.

Emissions from this sector comprise emissions from the following categories: mineral products (2A), metal production (2C) and consumption of halocarbons and SF_6 (2F). 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 below.

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).

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Section 4.1 is structured as follows:

- overview of the revisions since the ICR of June 2007: submission 2007v2.1 ➔ submission 2007v3.1 ➔ submission 2008v1.2. Submission 2007v2.1 was the version reviewed by the ERT during the ICR, whereas submission 2007v3.1 was the one provided to the ERT after the ICR (see Table 1-1 in Section 1.1). This overview includes therefore information on recalculations;
- completeness analysis of the CRF Sector as reported in submission 2008v1.2. The analysis limits itself to the 6 GHG controlled by the Kyoto Protocol;
- analysis of the emission trends of the CRF Sector, combining source categories and GHG.

Starting with revisions and a completeness analysis is justified by the dramatic improvements the GHG inventory for Luxembourg experienced since the ICR in June 2007.

Other required information, as suggested in Annex I of document FCCC/SBSTA/2006/9, will be presented under each source category review (methodology, AD, EFs, etc.).

4.1.1. Overview of the revisions

Table 4-1 presents the main revisions and recalculations done after the ICR of June 2007 relevant to CRF Sector 2.

Table 4-1 – Changes in GHG inventories: submissions 2007v2.1 and 2007v3.1

GHG source & sink category	Revisions 2007v2.1 → 2007v3.1	Type of revision
2A1	- use of a Tier 2 method instead of a Tier 1 - revised activity data from the operator - revised EF on the basis of information from the operator	- revised method - revised AD - revised EF
2A3	- notation key change: the source category is actually IE	- error correction
2A4	- notation key change: the source category is actually IE	- error correction
2A5	- notation key change: the source category is actually NO	- error correction
2A6	- notation key change: the source category is actually NO	- error correction
2A7	- revised activity data from the operator - revised EF on the basis of information from the operator	- revised AD - revised EF
2B5	- new estimates for NMVOC (category previously NE)	- new category
2C1	- use of a Tier 2 method instead of a Tier 1 - revised activity data mixing information from the operator and STATEC - revised EF on the basis of information from the operator and internal calculations	- revised method - revised AD - revised EF
2C3	- notation key change: the source category is actually NO	- error correction
2C5	- notation key change: the source category is actually NO (removing of the activity indicated, i.e. copper processing)	- error correction
2D2	- deletion of this source category	- error correction
2F	- allocation of activity data in the detailed HFCs categories - revised AD estimates using an interpolation approach - revised methodology for EF and emission estimates	- refinement - revised AD - revised method

There have been no recalculations between submissions 2007v3.1 and 2008v1.2 (see also CRF tables 8).

4.1.2. Completeness

Table 4-2 gives an overview of the IPCC categories included under CRF Sector 2 and provides information on the status of emission estimates of all subcategories.

Table 4-2 – Overview of subcategories of CRF Sector 2 – Industrial Processes: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
2A1	mineral products - cement production	X		
2A2	mineral products - lime production	NO		
2A3	mineral products - limestone and dolomite use	IE		
2A4	mineral products - soda ash production and use	IE		
2A5	mineral products - asphalt roofing	NO		
2A6	mineral products - road paving with asphalt	NO		
2A7	mineral products - other: glass production	X	NO	NO
2B1	chemical industry - ammonia production	NO	NO	NO

2B2	chemical industry - nitric acid production			NO
2B3	chemical industry - adipic acid production	NO		NO
2B4	chemical industry - carbide production	NO	NO	
2B5	chemical industry - other	NO	NO	NO
2C1	metal production - iron and steel production	X	NO	
2C2	metal production - ferroalloys production	NO	NO	
2C3	metal production - aluminium production	NO	NO	
2C4	metal production - SF_6 used in aluminium and magnesium foundries			
2C5	metal production - other	NA	NA	NA
2D1	other production - pulp and paper			
2D2	other production - food and drink	NO		
2G	other	NA	NA	NA

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 4-3 – Overview of subcategories of CRF Sector 2 – Industrial Processes: status of emission estimates for halocarbons and SF_6

GHG source & sink category	Description	Status		
		HFCs - actual	PFCs - actual	SF_6 - actual
2E1	production of halocarbons and SF_6 - by-products emissions	NO	NA	NA
2E2	production of halocarbons and SF_6 - fugitive emissions	NO	NO	NO
2E3	production of halocarbons and SF_6 - other	NA	NA	NA
2F1	consumption of halocarbons and SF_6 - refrigeration and air conditioning equipment	X	NO	NO
2F2	consumption of halocarbons and SF_6 - foam blowing	X	NO	NO
2F3	consumption of halocarbons and SF_6 - fire extinguishers	NE	NO	NO
2F4	consumption of halocarbons and SF_6 - aerosols/metered dose inhalers	X	NO	NO
2F5	consumption of halocarbons and SF_6 - solvents	NE	NO	NO
2F6	consumption of halocarbons and SF_6 - other applications using ODS substitutes	NE	NO	NO
2F7	consumption of halocarbons and SF_6 - semiconductor manufacture	NE	NO	NO
2F8	consumption of halocarbons and SF_6 - electrical equipment	NA	NO	X
2F9	consumption of halocarbons and SF_6 - other: noise reduction window	NO	NO	X
G	other	NA	NA	NA

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.

4.1.3. Emission Trends

This section briefly describes the emission trends from 1990 to 2006 for each of the IPCC Categories under CRF Sector 2 for which GHG emissions are reported – i.e. categories 2A, 2C and 2F.

Industrial process emissions include emissions from industrial installations and from consumption of halocarbons and SF_6 (the fluorinated gases or F-gases).[58] 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.

[58] No PFC application and emissions have been identified in Luxembourg so far (see Section 4.7).

As shown in Table 4-4, emissions of GHG due to industrial processes have decreased by about 53% between 1990 and 2006 (-58% for carbon dioxide but +431% for F-gases). It is for IPCC Category 2C – Metal Production that CO_2 emissions have decreased the most over the period: -82.7%. For IPCC Category 2A – Mineral Products the decline is limited to -19.25% for CO_2 emissions. In fact, only 3 companies and their various production installations are part of CRF Sector 2 (excluding F-gases):

- IPCC Category 2A: one cement works unit and one flat glass manufacturing company;
- IPCC Category 2C: the iron and steel manufacturing company Arcelor-Mittal, as already mentioned in previous chapters.

The trend observed for the iron and steel production units of Arcelor-Mittal 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., Section 2.2.1) and will not be detailed once again here.

F-gases striking increasing emissions are the consequences of supposedly growing use in the country, but also of the hypothesis made for their estimation: see Section 4.7.

Figures 4-1 and 4-2 provide a quick overview on industrial processes related emission trends between 1990 and 2006. More explanations are presented in the subsequent sections detailing each of the sector source categories.

Figure 4-1 – GHG emission trends in % for CRF Sector 2 – Industrial Processes: 1990-2006

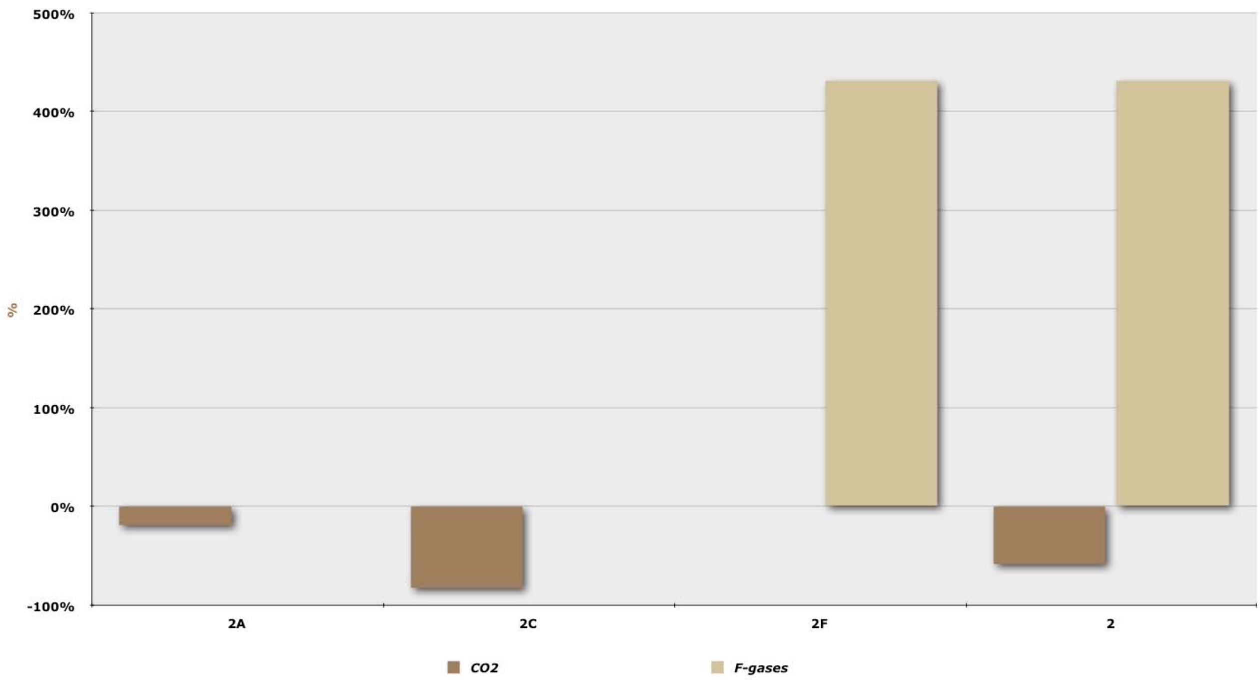


Table 4-4 – GHG emission trends in CO_2e for CRF Sector 2 – Industrial Processes: 1990-2006

Year	*CO_2e emissions (Gg)* GHG source & sink category																
	2A - Mineral Products				2C - Metal Production				2F - Consumption of Halocarbons & SF_6				2 - Industrial Processes				
	Total	*CO_2*	*CH_4*	*N_2O*	Total	*CO_2*	*CH_4*	*N_2O*	Total	*HFCs*	*PFCs*	*SF_6*	Total	*CO_2*	*CH_4*	*N_2O*	*F-gases*
1990	610.65	*610.65*	*NO*	*NO*	984.91	*984.91*	*NO*	*NO*	17.12	*14.21*	*NO*	*2.91*	1 612.68	*1 595.57*	*NO*	*NO*	*17.12*
1991	580.73	*580.73*	*NO*	*NO*	937.74	*937.74*	*NO*	*NO*	17.12	*14.21*	*NO*	*2.91*	1 535.59	*1 518.48*	*NO*	*NO*	*17.12*
1992	595.20	*595.20*	*NO*	*NO*	853.29	*853.29*	*NO*	*NO*	17.12	*14.21*	*NO*	*2.91*	1 465.61	*1 448.49*	*NO*	*NO*	*17.12*
1993	505.28	*505.28*	*NO*	*NO*	923.19	*923.19*	*NO*	*NO*	17.12	*14.21*	*NO*	*2.91*	1 445.58	*1 428.47*	*NO*	*NO*	*17.12*
1994	564.56	*564.56*	*NO*	*NO*	770.83	*770.83*	*NO*	*NO*	17.12	*14.21*	*NO*	*2.91*	1 352.51	*1 335.39*	*NO*	*NO*	*17.12*
1995	509.66	*509.66*	*NO*	*NO*	465.38	*465.38*	*NO*	*NO*	17.12	*14.21*	*NO*	*2.91*	992.16	*975.05*	*NO*	*NO*	*17.12*
1996	502.87	*502.87*	*NO*	*NO*	416.60	*416.60*	*NO*	*NO*	23.00	*19.97*	*NO*	*3.03*	942.47	*919.47*	*NO*	*NO*	*23.00*
1997	516.48	*516.48*	*NO*	*NO*	294.10	*294.10*	*NO*	*NO*	28.88	*25.73*	*NO*	*3.15*	839.46	*810.58*	*NO*	*NO*	*28.88*
1998	510.84	*510.84*	*NO*	*NO*	140.69	*140.69*	*NO*	*NO*	34.77	*31.49*	*NO*	*3.28*	686.29	*651.52*	*NO*	*NO*	*34.77*
1999	541.49	*541.49*	*NO*	*NO*	147.70	*147.70*	*NO*	*NO*	40.65	*37.25*	*NO*	*3.40*	729.84	*689.19*	*NO*	*NO*	*40.65*
2000	569.40	*569.40*	*NO*	*NO*	146.05	*146.05*	*NO*	*NO*	46.53	*43.01*	*NO*	*3.52*	761.99	*715.45*	*NO*	*NO*	*46.53*
2001	504.27	*504.27*	*NO*	*NO*	154.76	*154.76*	*NO*	*NO*	54.49	*50.92*	*NO*	*3.57*	713.53	*659.03*	*NO*	*NO*	*54.49*
2002	519.34	*519.34*	*NO*	*NO*	155.40	*155.40*	*NO*	*NO*	62.45	*58.82*	*NO*	*3.62*	737.19	*674.75*	*NO*	*NO*	*62.45*
2003	463.92	*463.92*	*NO*	*NO*	151.94	*151.94*	*NO*	*NO*	70.40	*66.73*	*NO*	*3.68*	686.27	*615.86*	*NO*	*NO*	*70.40*
2004	505.04	*505.04*	*NO*	*NO*	152.45	*152.45*	*NO*	*NO*	78.36	*74.63*	*NO*	*3.73*	735.85	*657.49*	*NO*	*NO*	*78.36*
2005	496.98	*496.98*	*NO*	*NO*	119.13	*119.13*	*NO*	*NO*	86.32	*82.54*	*NO*	*3.78*	702.42	*616.11*	*NO*	*NO*	*86.32*
2006	493.08	*493.08*	*NO*	*NO*	170.49	*170.49*	*NO*	*NO*	90.90	*87.04*	*NO*	*3.86*	754.48	*663.57*	*NO*	*NO*	*90.90*
Trend 1990-2006	*-19.25%*	*-19.25%*	*NA*	*NA*	*-82.69%*	*-82.69%*	*NA*	*NA*	*431.12%*	*512.67%*	*NA*	*32.68%*	*-53.22%*	*-58.41%*	*NA*	*NA*	*431.12%*

Source: Environment Agency.

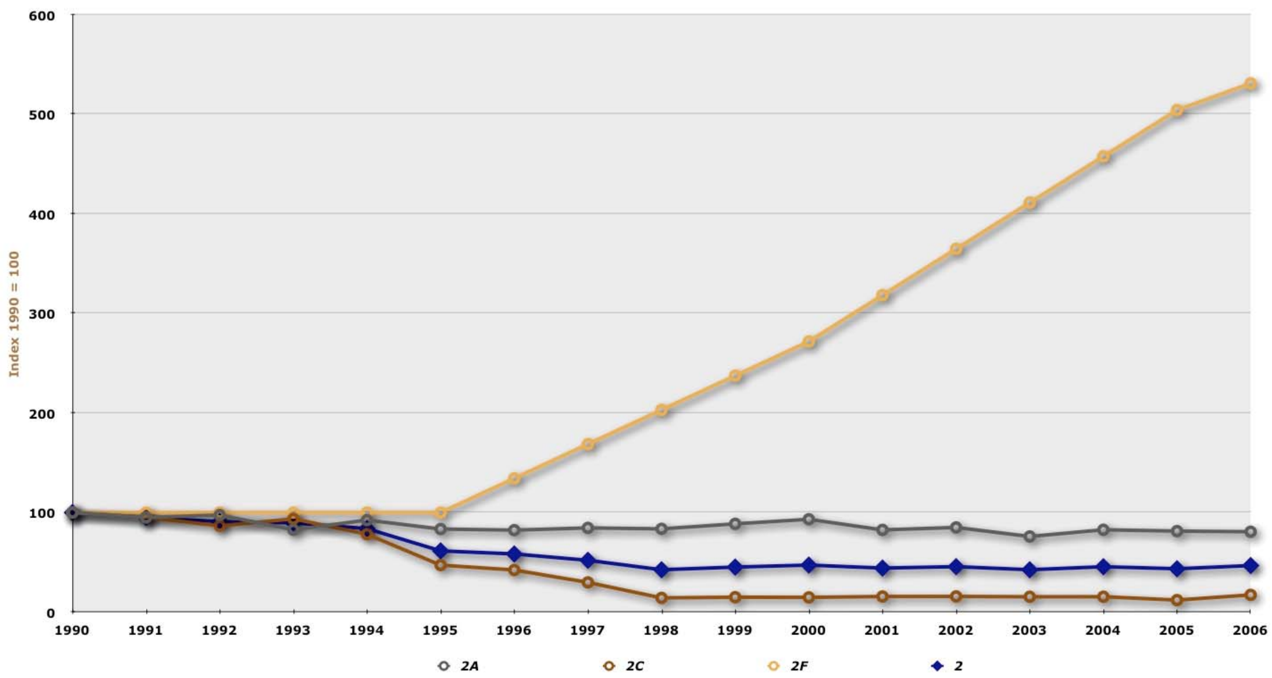
Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GW*P) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

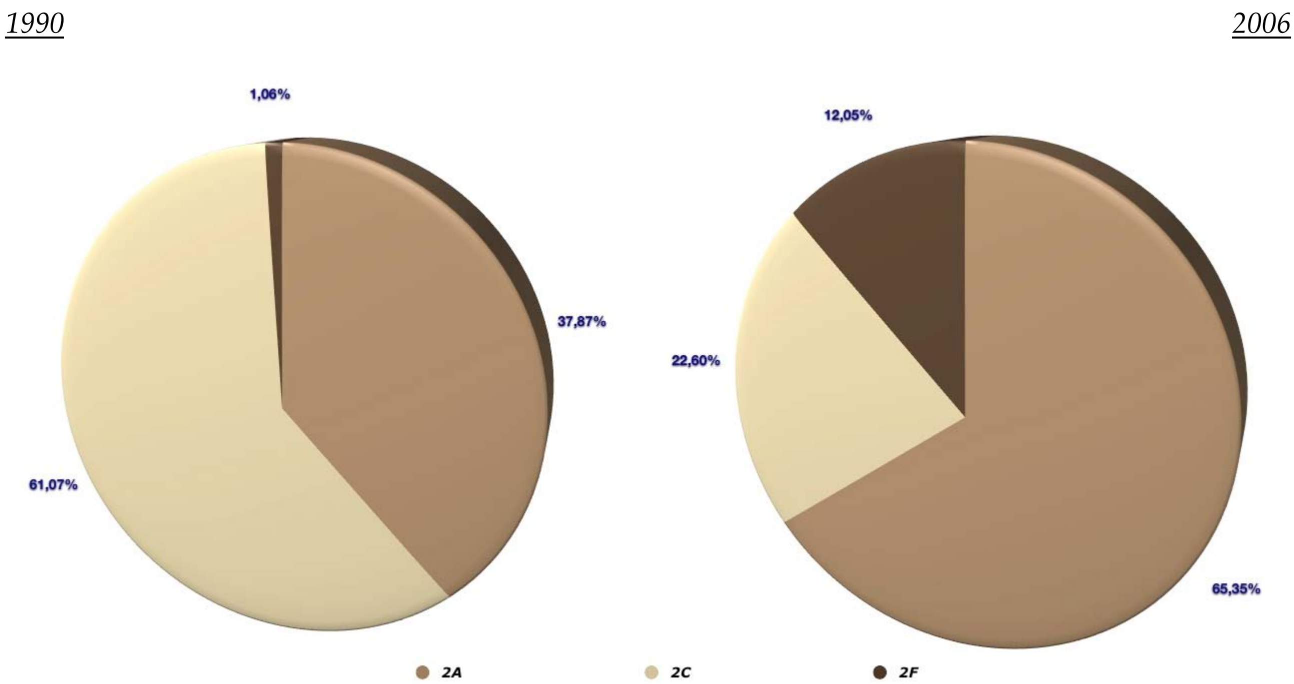
The F-gases are those not covered by the Montreal Protocol, i.e. HFCs, PFCs and SF_6 expressed in CO_2e using the global warming potential (GWP) values based on the effects of GHG over a 100-year time horizon.

Figure 4-2 – GHG emission trends – indexes – for CRF Sector 2 – Industrial Processes: 1990-2006



The emission trends briefly described above led to a significant change in the composition of industrial processes' GHG emissions, as shown in Figure 4-3.

Figure 4-3 – IPCC Categories weights in GHG emissions for CRF Sector 2 – Industrial Processes: 1990 and 2006



4.2. *Mineral Products (IPCC Source Category 2A)*

This section describes the estimation of carbon dioxide emissions resulting from industrial processes used in cement works and flat glass installations. In 2006, this source category was responsible for 74.3% of CO_2 emissions from industrial processes – but only 38.3% in 1990 – and for 4.1% of the total CO_2 emissions estimated for Luxembourg. It represented 3.7% of the total GHG emissions in CO_2e (excluding LULUCF).

4.2.1. IPCC Sub-category 2A1 – Cement Production

In 2006, cement production was responsible for 65% of CO_2 emissions from industrial processes – but only 34.9% in 1990 – and for 3.56% of the total CO_2 emissions estimated for Luxembourg. It represented 3.24% of the total GHG emissions in CO_2e (excluding LULUCF).

4.2.1.1. Key source

With 3.24% of the total GHG emissions in CO_2e (excluding LULUCF) in 2006, carbon dioxide emissions from cement production is a key source. It has been a key source without interruption since 1990.

4.2.1.2. Source category description

In Luxembourg, one clinker production plant is operating. During the production of clinker, limestone, which is mainly calcium carbonate ($CaCO_3$), is calcined to produce lime (CaO) and CO_2 as a by-product.

4.2.1.3. Methodological issues

For the estimation of CO_2 emissions, the Tier 2 method of 2000 IPCC-GPG using clinker production data is applied:

$$CO_2 \text{ Emissions} = EF_{clinker} \bullet \text{Clinker Production} \bullet \text{CKD Correction Factor}$$

According to the operator of the plant, there is no calcined Cement Kiln Dust (*CKD*) to be lost from the system. Hence, the CKD Correction Factor equals 1.00.

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

Table 4-5 – CO_2 emissions trend, activity data and IEFs for IPCC Sub-category 2A1 – Cement Production: 1990-2006

Year	2A1 - Cement Production		
	Emissions	AD	IEF
	CO_2e	*kt*	*kg CO_2/t*
1990	557.09	1 048.00	531.57
1991	532.06	1 001.64	531.19
1992	537.93	1 013.45	530.79
1993	447.03	842.86	530.38
1994	503.92	950.85	529.97
1995	449.31	848.46	529.56
1996	443.12	837.52	529.09
1997	457.60	865.66	528.62
1998	459.52	870.05	528.15
1999	481.91	913.27	527.68
2000	508.95	965.37	527.21
2001	443.87	843.61	526.15
2002	459.24	874.58	525.10
2003	403.39	769.75	524.05
2004	443.18	847.39	523.00
2005	435.20	833.80	521.95
2006	431.20	826.13	521.95
Trend 1990-2006	*-22.60%*	*-21.17%*	*-1.81%*

Sources: CO_2 emissions and IEF: Environment Agency.
AD: plant operator.

Emission factors

According to 2000 IPCC-GPG Tier 2 method, the emission factor is based on the CaO content of the clinker:

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

It is assumed that all the CaO is from carbonate source (e.g. $CaCO_3$ in limestone). Plant-specific CaO contents are available on a five-yearly basis (chemical analysis done by the plant operator). These contents are provided in Table 4.6.

Table 4-6 – CaO contents in %

Year	CaO Content *weight %*
1990	67.72%
1995	67.46%
2000	67.16%
2005	66.49%

Source: plant operator (Intermoselle).

The CaO contents for the years for which no CaO contents are on hand are estimated by a linear interpolation. The CaO content for the year 2006 is set equal to the CaO content of the year 2005: see Table 4-7.

Table 4-7 – Effective and interpolated CaO content in % and EFs: 1990-2006

Year	CaO (%) *operator*	CaO (%) *interpolation*	EF *kg CO_2/ t clinker*
1990	67.72	67.72	531.57
1991		67.67	531.19
1992		67.62	530.79
1993		67.56	530.38
1994		67.51	529.97
1995	67.46	67.46	529.56
1996		67.40	529.09
1997		67.34	528.62
1998		67.28	528.15
1999		67.22	527.68
2000	67.16	67.16	527.21
2001		67.03	526.15
2002		66.89	525.10
2003		66.76	524.05
2004		66.62	523.00
2005	66.49	66.49	521.95
2006		66.49	521.95

Sources: plant operator (Intermoselle) and Environment Agency.

The calculated plant-specific EFs are consistent with the 2004 ETS Tier 1 Guidelines default EF of 525 kg CO_2/t clinker.

4.2.2. IPCC Sub-category 2A2 – Lime Production

This source category does not exist in Luxembourg.

4.2.3. IPCC Sub-category 2A3 – Limestone and Dolomite Use

The use of limestone and dolomite is accounted for in IPCC Sub-categories 2A1 – Cement Production and 2A7 – Other – Glass Production.

4.2.4. IPCC Sub-category 2A4 – Soda Ash Production and Use

The use of soda ash is accounted for in IPCC Sub-category 2A7 – Other – Glass Production.

4.2.5. IPCC Sub-category 2A5 – Asphalt Roofing

It should be investigated further whether this category is effectively NA or NO in Luxembourg.

4.2.6. IPCC Sub-category 2A6 – Road Paving with Asphalt

It should be investigated further whether this category is effectively NA or NO in Luxembourg.

4.2.7. IPCC Sub-category 2A7 – Other – Glass Production

In 2006, glass production was responsible for 9.3% of CO_2 emissions from industrial processes – but only 3.4% in 1990 – and for 0.51% of the total CO_2 emissions estimated for Luxembourg. It represented 0.46% of the total GHG emissions in CO_2e (excluding LULUCF).

4.2.7.1. Key source

Glass production is not a key source.

4.2.7.2. Source category description

In Luxembourg, one company runs two flat glass production plants. CO_2 is released during melting in the kiln, from carbonates contained in mineral input materials (limestone, dolomite and soda ash).

4.2.7.3. Methodological issues

A country specific methodology is applied:

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

Estimates from the CS method, as well as activity data and IEFs, are summarized in Table 4-8.

Table 4-8 – CO_2 emissions trend, activity data and IEFs for IPCC Sub-category 2A7 – Other – Glass Production: 1990-2006

Year	2A7 - Other - Glass Production		
	Emissions	AD	IEF
	CO_2e	*kt*	*kg CO_2/t*
1990	53.57	377.24	142.00
1991	48.67	342.75	142.00
1992	57.27	403.33	142.00
1993	58.24	410.18	142.00
1994	60.63	426.99	142.00
1995	60.35	425.03	142.00
1996	59.75	420.75	142.00
1997	58.88	414.62	142.00
1998	51.32	361.40	142.00
1999	59.58	419.58	142.00
2000	60.46	425.75	142.00
2001	60.41	425.39	142.00
2002	60.10	423.24	142.00
2003	60.53	426.30	142.00
2004	61.85	435.60	142.00
2005	61.78	435.07	142.00
2006	61.88	435.81	142.00
Trend 1990-2006	*15.52%*	*15.52%*	*NA*

Sources: CO_2 emissions: Environment Agency.
AD and IEF: plant operator.

Emission factors

The emission factor is based on the loss of ignition of the batch composition. The background data and the calculation of the emission factor are provided by the operator. 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.

$$EF_{glass} = 142 \ kg \ CO_2 / t \ glass$$

The calculated plant-specific EF is consistent with the calculated value for 2005 according to the 2004 ETS Guidelines carbonates method. For 2005, an EF of 140 kg CO_2/t glass was determined based on the carbonates contents in the raw materials and the activity data.

4.2.8. Recalculations

See Table 4-1 of Section 4.1.1.

4.2.9. Category specific QA / QC procedures

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

4.2.10. 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 4-9 will be explored.

Table 4-9 – Planned improvements for IPCC Category 2A – Mineral Products

GHG source & sink category	Planned improvement
2A1 – Cement Production	streamlining with the new 2006 IPCC Guidelines and the new 2007 ETS Guidelines.
2A5 – Asphalt Roofing	investigate further whether this category is effectively NA or NO in Luxembourg.
2A6 – Road Paving with Asphalt	investigate further whether this category is effectively NA or NO in Luxembourg.
2A7 – Other – Glass Production	streamlining with the new 2006 IPCC Guidelines and the new 2007 ETS Guidelines.

4.3. Chemical Industry (IPCC Source Category 2B)

This activity only results in process and by-product NMVOC emissions (e.g. methanol) and is therefore not reported in the GHG inventory. It is, however, requested to report these emissions in other reporting schemes (e.g. EC NEC Directive and UNECE LRTAP).

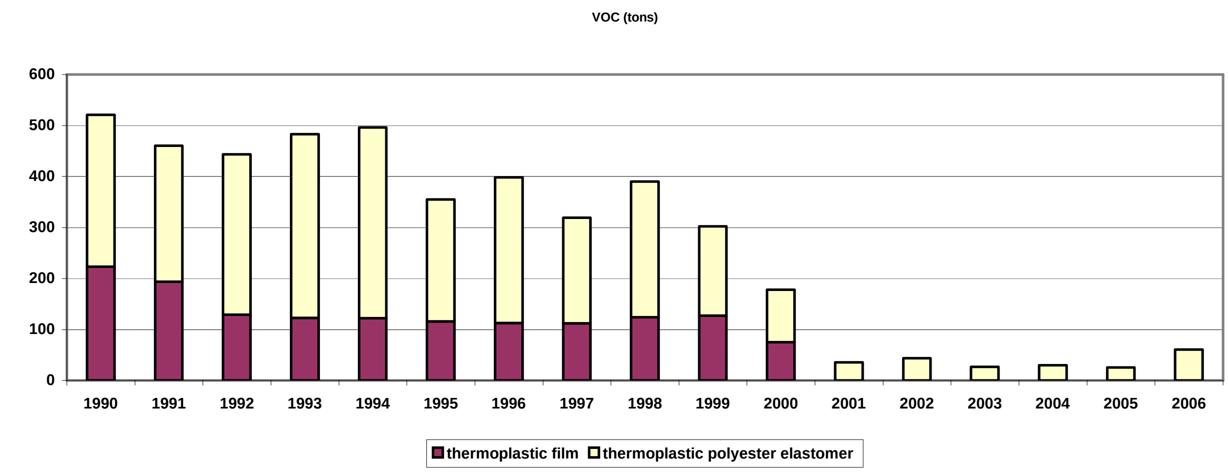
NMVOC emissions are the result of the production of:

- a thermoplastic polyester elastomer, a copolymer consisting of polybutylene terephthalate and long-chain glycols, and
- a thermoplastic film, made from ethylene glycol and dimethyl terephthalate (DMT) release process emissions at the cooling towers of one chemical processing facility. The emitted VOC's are mainly methanol, ethanol, ethylenglycol and tetrahydrofuran.

The emissions related to these activities have been considerably reduced between 1994 and 2001 due to changes in the process (decoupling of cooling tower circuit and polymerisation circuit, vacuum pumps instead instead of water-jet): see Figure 4-4.

The data on VOC emissions are directly collected from the operator based on measurements.

Figure 4-4 – NMVOC emissions from thermoplastic polymer and film production: 1990-2006



Source: plant operator data based on measurements.

4.4. Metal Production (IPCC Source Category 2C)

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 combine 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**[59] (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**.

59 Accounted for under IPCC Category 1A – Fuel Combustion Activities. See also Section 4.4.1.3 below.

4.4.1. IPCC Sub-category 2C1 – Iron and Steel Production

In 2006, iron and steel production was responsible for 25.7% of CO_2 emissions from industrial processes – but 61.7% in 1990 – and for 1.4% of the total CO_2 emissions estimated for Luxembourg. It represented 1.28% of the total GHG emissions in CO_2e (excluding LULUCF).

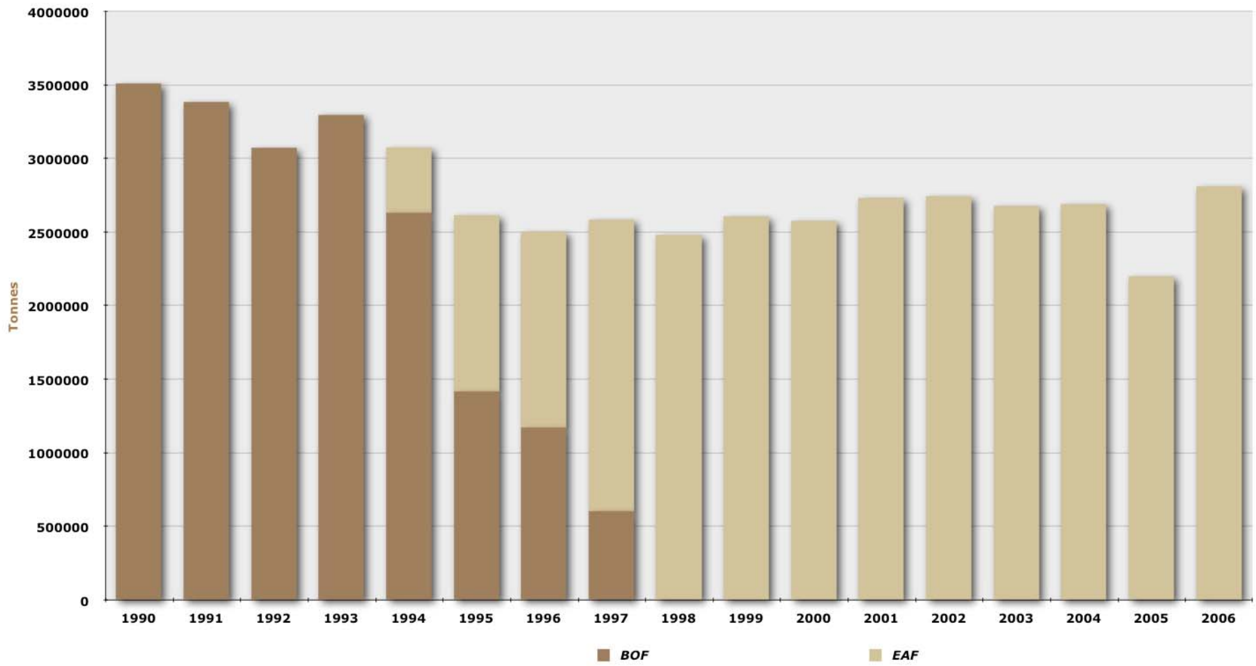
4.4.1.1. Key source

With 1.28% of the total GHG emissions in CO_2e (excluding LULUCF) in 2006, carbon dioxide emissions from cement production is a key source. It has been a key source without interruption since 1990.

4.4.1.2. Source category description

One sinter plant, two blast furnaces and three basic oxygen furnace steel plants (*BOF*) were operated in Luxembourg in 1990. In 2006, only three electric arc furnaces (*EAF*) remained. The shift from BOF to the EAF occurred between 1993 and 1997 (see Figure 4-5).

Figure 4-5 – Steel production according to BOF and EAF: 1990-2006



Sources: plant operator (Arcelor-Mittal)

STATEC, *Statistical Yearbook*, Table C.3400: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1268 and Table C.3451: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1273

data extracted on 14 December 2007 (subject to changes since that date)

Sinter Plant (*SP*)

In the sinter plant iron ore and other iron-containing materials are agglomerated prior to the introduction into the blast furnace. Process emissions occur from the oxidation of the carbonates in the iron ore.

Blast furnace (*BF*)

Mainly sinter (iron oxides), coke and other fuels are supplied to the blast furnace. CO_2 process emissions are associated with the use of carbon to convert iron oxide to pig iron. Coke and other fuels serve not only as reducing agent but also to produce blast furnace gas as energy source which is recovered and used as fuel within the plant and in other steel industry processes and in a power station.

An energy balance serves to exclude double-counting of carbon from the consumption as reducing agent if this is already accounted for as fuel consumption in IPCC category 1A – Fuel Combustion Activities.

Basic oxygen furnace steel production (*BOF*)

In the basic oxygen furnace, pig iron (4% C) is transformed to steel (0.13% C). During the process, the reduced carbon is released as CO_2.

Electric arc furnace steel production (*EAF*)

In the electric arc furnaces anthracite and carbon, including the consumption of the electrodes, are used as reducing agent with the result of CO_2 process emissions. The consumption of natural gas in the EAF is accounted for as energy consumption and, consequently, reported under IPCC Sub-category 1A2a – Iron and Steel.

4.4.1.3. Methodological issue

Activity data

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 break-down between BOF & EAF between 1993 and 1997.

The production data for the steel production in 1990 (*BOF*) was corrected based on detailed information from the TÜV Rheinland 1992-1993 study. It is assumed that the 1990 value of 3 560 290 tonnes for BOF in STATEC's Statistical Yearbook is a typing error.

Table 4-10 summarizes iron and steel production by process.

Table 4-10 – Iron and steel production by process: 1990-2006

Year	Steel production (tonnes) SP	BF	BOF	EAF
1990	4 804 000	2 645 200	3 506 230**	NO
1991	4 567 000	2 463 000	3 379 440	NO
1992	4 152 000	2 255 200	3 068 463	NO
1993	4 561 000	2 412 000	3 288 847	4 095
1994	3 747 000	1 926 890	2 627 278	445 990
1995	1 977 700	1 028 230	1 410 469	1 202 668
1996	1 810 970	829 010	1 168 070	1 333 758
1997	1 002 815	438 030	597 814	1 982 405
1998	NO	NO	NO	2 476 909
1999	NO	NO	NO	2 600 324
2000	NO	NO	NO	2 571 243
2001	NO	NO	NO	2 724 679
2002	NO	NO	NO	2 736 000
2003	NO	NO	NO	2 675 000
2004	NO	NO	NO	2 684 000
2005	NO	NO	NO	2 194 485
2006	NO	NO	NO	2 802 049

Sources: SP, BOF and EAF: plant operator (Arcelor-Mittal)

BF, BOF and EAF: STATEC, *Statistical Yearbook*, Table C.3400: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1268 and Table C.3451: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1273

Note: STATEC's 1990 value for BOF replaced by TÜV Rheinland 1992-1993 study reported value.

data extracted on 14 December 2007 (subject to changes since that date)

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_2 emissions – Sinter Plant

Raw material	Tonnes (dry)	% C	Gg CO_2
Minettes calcaires	2 043 408	4.38	328.16
Minettes silicieuses	908 957	1.57	52.27
Total	2 952365	NA	380.43

A **country specific methodology** has been applied for the years **1991 to 1997** based on the emission factor determined for the year 1990:

$$CO_2\ Emissions_{SP} = EF_{SP} \bullet Sinter\ Production$$

Blast furnace (*BF*) and basic oxygen furnace steel production (*BOF*)

The 2000 IPCC-GPG Tier 2 methodology is applied for calculating the emissions in **1990**.

The emissions from iron production in BF and from steel production in BOF are calculated separately based on a carbon balance over the production processes.

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

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

With $C_{Reducing\ Agent}$ = *carbon serving as reducing agent: calculated from the energy balance over the iron and steel production, see below*

C_{Ore} = *additional C-input from Iron ore and Iron scrap into the BF: 3 841 t iron ore (1.57% C, plant specific) + 6 222 t iron scrap (4% C, IPCC default)*

C_{Iron} = *2 645 200 t Iron (4% C, IPCC default)*

C_{Scrap} = *1 296 470 t Steel Scrap (0.4%, ETS default)*

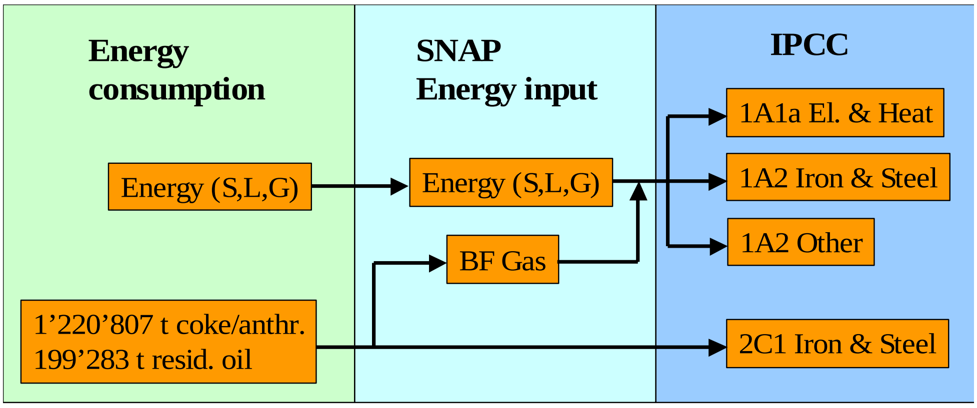
C_{AddBOF} = *Additional C-input in BOF: 19 532 t Ferromangan (4% C, plant specific), 1 688 t Carbon 95 (95% C, plant specific), 2 671 t Carbon 98 (98% C, plant specific)*

C_{Steel} = *5 506 230 t Steel (0.13% C, plant specific)*

Activity data indicated above are collected from the operator [TÜV Rheinland, 1992-1993].

The carbon accounted for reducing agent ($C_{Reducing\ Agent}$) in the blast furnace is determined from the energy balance over the iron and steel industry.

Illustration 4-1 – 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 1A1a, 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 CO2/ GJ	kg C/ GJ	Gg C
BFGas	15 851 000	258.00	70.36	1115.33

	Gg C
C Reducing Agent	160.05

Therefore, the resulting carbon dioxide emissions for the iron and steel production in 1990 equal:

$$CO_2\ Emissions_{BF} = 200.00\ Gg\ CO_2$$

$$CO_2\ Emissions_{BOF} = 404.48\ Gg\ CO_2$$

For the subsequent years (**1991 to 1997**), a **country specific methodology** has been applied based on the emission factor determined for the year 1990:

$$CO_2\ Emissions_{BF} = EF_{BF} \bullet Pig\ Iron\ Production$$

$$CO_2\ Emissions_{BOF} = EF_{BOF} \bullet Steel\ Production$$

Electric arc furnace steel production (*EAF*)

The 2000 IPCC-GPG Tier 2 methodology has been applied for calculating the emissions from **the year 2004 onward**.

The emissions are calculated based on a carbon balance over the production process.

$$E_{Steel} = (C_{Scrap} + C_{Electrodes} + C_{Carbon} + C_{Anthracite} - C_{Steel}) \bullet 44/12$$

It is assumed that C_{Scrap} equals C_{Steel}.

The activity data are collected from the individual EAF (consumption of electrodes, carbon and anthracite with their respective carbon contents).

The resulting emissions for the steel production are:

$$2004 - CO_2\ Emissions_{EAF} = 152.45\ Gg\ CO_2$$

$$2005 - CO_2\ Emissions_{EAF} = 119.13\ Gg\ CO_2$$

$$2006 - CO_2\ Emissions_{EAF} = 170.49\ Gg\ CO_2$$

For the previous years (**1993 to 2003**), a **country specific methodology** has been applied based on the emission factor determined for the years 2004 to 2006:

$$CO_2\ Emissions_{EAF} = EF_{EAF} \bullet Steel\ Production$$

<u>Emission factors summary</u>

For **SP, BF and BOF**, EFs are calculated from the determined CO_2 emissions and the production data in 1990. The EF is kept constant for the subsequent years 1991 to 1997: see Table 4-13.

Table 4-13 – EFs for SP, BF and BOF

Production (1990)	Emissions (1990)	EF
4 804 000 t sinter	380.44 Gg CO_2	EF_{SP} = 79.19 kg CO_2 / t sinter
2 645 200 t iron	200.00 Gg CO_2	EF_{BF} = 75.61 kg CO_2 / t iron
3 506 230 t steel	404.48 Gg CO_2	EF_{BOF} = 115.36 kg CO_2 / t steel

For **EAF**, the EF is calculated from the determined CO_2 emissions and the production data.

For the period from 1993 to 2004, the EF is equal to the one determined for the year 2004. For the years 2005 and 2006, EFs are recalculated for each year: see Table 4-14.

Table 4-14 – EFs for EAF

Production (2004)	Emissions (2004)	EF
2 684 000 t steel	152.45 Gg CO_2	EF_{EAF} = 56.80 kg CO_2 / t steel
Production	Emissions	EF_{EAF} *(kg CO_2 / t steel)*
2005 – 2 194 485 t steel	2005 – 119.13 Gg CO_2	54.29
2006 – 2 802 049 t steel	2006 – 170.49 Gg CO_2	60.85

The calculated plant-specific emission factor for steel production in 2004 (EF_{EAF} = 56.80 kg CO_2 / t steel) is consistent with the calculated emission factors according to the 2004 ETS Guidelines for the three EAF for the years 2005 (EF_{EAF} = 54.29 kg CO_2 / t steel) and 2006 (60.85 kg CO_2 / t steel).

4.4.1.4. Overall summary

A complete overview of the iron and steel related CO_2 emissions is provided in Table 4-15.

Table 4-15 – CO_2 emissions trend, activity data and IEFs for IPCC Sub-category 2C1 – Iron and Steel Production: 1990-2006

Year	GHG source & sink category 2C1 - Iron & Steel Production				
	Emissions CO_2e	*BOF* *kt*	*EAF* *kt*	Total *kt*	IEF *kg CO_2/t*
1990	984.91	*3 506.23*	*NO*	3 506.23	113.61
1991	937.74	*3 379.44*	*NO*	3 379.44	115.36
1992	853.29	*3 068.46*	*NO*	3 068.46	115.36
1993	923.19	*3 288.85*	*4.10*	3 292.94	115.29
1994	770.83	*2 627.28*	*445.99*	3 073.27	106.86
1995	465.38	*1 410.47*	*1 202.67*	2 613.14	88.41
1996	416.60	*1 168.07*	*1 333.76*	2 501.49	84.15
1997	294.10	*597.81*	*1 982.41*	2 580.22	70.37
1998	140.69	*NO*	*2 476.91*	2 476.91	56.80
1999	147.70	*NO*	*2 600.32*	2 600.32	56.80
2000	146.05	*NO*	*2 571.24*	2 571.24	56.80
2001	154.76	*NO*	*2 724.68*	2 724.68	56.80
2002	155.40	*NO*	*2 736.00*	2 736.00	56.80
2003	151.94	*NO*	*2 675.00*	2 675.00	56.80
2004	152.45	*NO*	*2 684.00*	2 684.00	56.80
2005	119.13	*NO*	*2 194.49*	2 194.49	54.29
2006	170.49	*NO*	*2 802.05*	2 802.05	60.85
Trend 1990-2006	*-82.69%*	*NA*	*NA*	*-20.08%*	*-46.44%*

Sources: CO_2 emissions and IEF: Environment Agency.

BOF and EAF: plant operator (Arcelor-Mittal)

STATEC, *Statistical Yearbook*, Table C.3400: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1268 and Table C.3451: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1273

data extracted on 14 December 2007 (subject to changes since that date)

4.4.2. IPCC Sub-category 2C2 – Ferroalloys Production

There are no dedicated plants for producing ferroalloys in Luxembourg.

4.4.3. IPCC Sub-category 2C3 – Aluminium Production

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 1A2b – Non-Ferrous Metals.

4.4.4. Recalculations

See Table 4-1 of Section 4.1.1.

4.4.5. Category specific QA / QC procedures

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.

Consistency and completeness checks have been performed using the tools embedded in CRF Reporter.

4.4.6. 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 4-16 will be explored.

Table 4-16 – Planned improvements for IPCC Category 2C – Metal Production

GHG source & sink category	Planned improvement
2C1 – Iron and Steel Production	application of the mass balance approach according to the ETS guidelines.
2C1 – Iron and Steel Production	inclusion of another production unit – Primorec – a plant recuperating iron from slag and collected dust (direct reduction furnace).

4.5. Other Production (IPCC Source Category 2D)

There are no emissions to be reported for the food and drink industry for Luxembourg.

4.6. Production of Halocarbons and SF_6 (IPCC Source Category 2E)

This source category does not exist in Luxembourg.

4.7. Consumption of Halocarbons and SF_6 (IPCC Source Category 2F)

This section describes the estimation of F-gases emissions resulting from industrial processes (production, consumption). In 2006, F-gases represented 0.7% of the total GHG emissions in CO_2e (excluding LULUCF). This percentage was only 0.13% in 1990. As shown by Figure 4-2 in Section 4.1.3, F-gases related emissions experienced a major increase between 1990 and 2006.

4.7.1. Key source

F-gases related emissions are not a key source.

4.7.2. Source category description

A first estimation of the emissions of fluorinated GHG types (HFCs, PFCs and SF_6) has been undertaken end 1999 by the Environment Agency and Luxembourg's *Centre de Ressources des Technologies pour l'Environnement* (*CRTE*). The study tried to establish F-gas emissions for the years 1995, 2000, 2005 and 2010. F-gas emission estimates presented in Table 4-17 are the result of that work.

The following sources have been identified:

2(I) F	Consumption of Halocarbons and SF_6;
2(I) F1	Refrigeration and Air Conditioning Equipment;
2(I) F 2	Foam Blowing;
2(I) F 4	Aerosols/Metered Dose Inhalers;
2(I) F 7	Electrical Equipment;
2(I) F 8	Other (windows containing SF_6).

Neither PFC applications nor PFC emission sources have been identified in Luxembourg so far.

Finally, Luxembourg has chosen 1995 as the base year for HFCs, PFCs and SF_6.

Table 4-17 – Estimated emissions of HFCs and SF_6: 1995-2010

Application	IPCC Category	1995	2000	2005	2010
		Mg CO_2e			
Stationary cooling installations	2(I) F1	2 088	12 670	33 720	46 810
Mobile cooling installations		4 160	21 388	39 006	48 762
High voltage electrical equipments	2(I) F8	576	956	956	1 076
Vaporizers (medical applications)	2(I) F4	4	2 737	3 650	3 650
Filling of car tires		0	0	0	0
Noise reduction windows	2(I) F9	2 332	2 565	2 822	3 104
Foam blowing	2(I) F2	7 366	6 266	6 266	6 266
Sum	2(I) F	16 526	46 582	86 420	109 668

Source: Environment Agency and CRTE analysis.

4.7.3. Methodological issues

Emission estimates for the years 1996 to 1999, 2001 to 2004 and 2006 have been calculated with the respective trends 1995-2000, 2000-2005 and 2005-2010. The emissions from 1990 to 1994 are assumed to be equal to 1995 emissions since trend calculations are not possible for those years (it would actually lead to negative values).

A re-evaluation of the emission sources and the emissions of HFCs, PFCs and SF_6, taking into account the 2000 IPCC-GPG Guidelines as well as country specific considerations, is ongoing. In the meantime, the following approaches and hypothesis have been made:

F1 – Refrigeration and Air Conditioning Equipment

The stationary refrigeration and the mobile air conditioning are estimated using reported emissions by Germany expressed per capita with the relative population in Luxembourg.

F2 – Foam Blowing

The PU spray emissions are estimated using reported emissions by Germany expressed per capita with the relative population in Luxembourg.

F4 – Aerosols / Metered Dose Inhalers (MDI)

The MDI emissions are estimated from the reported MDI emissions by Germany per capita with the relative population in Luxembourg. Other aerosols have not been considered. In the new study, the other aerosol emissions account for about 1.5 Gg CO_2e.

F7 – Electrical Equipment

A country specific methodology is applied:

$$Emissions = EF \bullet AR$$

The activity rate (*AR*) is the estimated installed capacity with the total nameplate capacity from the largest operator in Luxembourg.

The yearly emissions are assumed to be 1% of the activity rate, i.e. EF=0.01.

F8 – Noise reduction windows

A country specific methodology is applied:

$$Emissions = EF \bullet AR$$

The activity rate (*AR*) is the calculated SF_6 stock on the basis of the estimated installed noise reduction windows.

The yearly emissions are assumed to be 1% of the activity rate, i.e. EF=0.01.

4.7.4. Recalculations

See Table 4-1 of Section 4.1.1.

4.7.5. Category specific QA/QC procedures

Preliminary results from the new study confirm that the levels of emissions reported for 1995 are reasonable.

4.7.6. Planned improvements

Table 4-18 – Planned improvements for IPCC Category 2F – Consumption of Halocarbons and SF_6

GHG source & sink category	Planned improvement
2F – Consumption of Halocarbons & SF_6	complete re-evaluation including the results of the new study.
2F – Consumption of Halocarbons & SF6	different GWPs are provided by IPCC for the different HFCs categories: should they be used instead of a generic GWP for HFCs?

4.8. Selected references

ARBED (1990 – 1998): Annual communications from the operator to the Environment Agency Luxembourg. Luxembourg.

CORINAIR Guidebook (1996): Combustion in Energy & transformation industries - ps010101 Activities 010101 – 010105 - Table 21: Selection of relevant fuels from NAPFUE and lower heating values for boilers, gas turbines and stationary engines.

EMEP/CORINAIR Emission Inventory Guidebook, 3rd edition (2006). European Environment Agency (EEA), Copenhagen.

EMEP/CORINAIR Guidebook (1996): Atmospheric Emission Inventory Guidebook. Prepared by the EMEP Task Force on Emission Inventories. Edited by Stephen Richardson, Task Force Secretary.

ETS Emission Trading Scheme Guidelines 2004 – Commission Decision of 29 January 2004 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

INTERMOSELLE (1990 – 2005): Statistics on production and fuel consumption. Rumelange, Luxembourg.

IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (May 2000).

Luxguard (1990 – 2005): Operation permits for Luxguard I and II. Luxembourg.

Ministère de l'Economie et du Commerce Extérieur, Direction de l'Energie (1990 – 2007): Rapports d'Activité. Luxembourg.

Ministère de l'Environnement, L'Environnement en Chiffres 2002-2003 (2003).

STATEC 1990 – 2007. Annuaires statistiques. Luxembourg.

TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln.

TÜV Rheinland (1992-1993) Impaktstudien für die ARBED-Werke Esch/Belval, Differdange und Esch-Schifflange für das Jahr 1990.

For more information on Chapter 4, please contact:

Pierre DORNSEIFFER
Administration de l'Environnement
16, rue Eugène Ruppert
L-2453 Luxembourg
Tel: (+352) 40 56 56 648
Fax: (+352) 48 50 78
E-mail: pierre.dornseiffer@aev.etat.lu

5. Solvent and Other Product Use (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 – Solvent and Other Product Use for the period 1990 to 2006.

Solvents are chemical compounds, which are mainly used to dissolve substances such as paint, glues, ink, rubber, plastic, pesticides or for cleaning purposes (degreasing). After application of these substances or other procedures of solvent use most of the solvents are released into the atmosphere. Because solvents consist mainly of volatile organic compounds (*NMVOC* – non-methane volatile organic compounds), solvent use is a major source for anthropogenic NMVOC emissions in Luxembourg. Once released into the atmosphere, NMVOCs react with reactive molecules (mainly HO-radicals) or high energetic light to finally form CO_2.

Estimations for N_2O emissions from other product use (such as anaesthesia e.g.) are also addressed in this chapter. For more details on categories where emissions are not occurring and categories that are not estimated or included elsewhere, see Table 5-2 below.

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Section 5.1 is structured as follows:

- overview of the revisions since the ICR of June 2007: submission 2007v2.1 ➔ submission 2007v3.1 ➔ submission 2008v1.2. Submission 2007v2.1 was the version reviewed by the ERT during the ICR, whereas submission 2007v3.1 was the one provided to the ERT after the ICR (see Table 1-1 in Section 1.1). This overview includes therefore information on recalculations;
- completeness analysis of the CRF Sector as reported in submission 2008v1.2. The analysis limits itself to the 6 GHG controlled by the Kyoto Protocol;
- analysis of the emission trends of the CRF Sector, combining source categories and GHG.
- planned improvements for this CRF sector.

Starting with revisions and a completeness analysis is justified by the dramatic improvements the GHG inventory for Luxembourg experienced since the ICR in June 2007.

Other required information, as suggested in Annex I of document FCCC/SBSTA/2006/9, will be presented under each source category review (methodology, AD, EFs, etc.).

5.1.1. Overview of the revisions

Table 5-1 presents the main revisions and recalculations done after the ICR of June 2007 relevant to CRF Sector 3.

Table 5-1 – Changes in GHG inventories: submissions 2007v2.1 and 2007v3.1

GHG source & sink category	Revisions 2007v2.1 ➔ 2007v3.1	Type of revision
3D1	- new estimates (source category previously NE)	- new source category

There have been no recalculations between submissions 2007v3.1 and 2008v1.2 (see also CRF tables 8).

5.1.2. Completeness

Table 5-2 gives an overview of the IPCC categories included under CRF Sector 3 and provides information on the status of emission estimates of all subcategories.

Table 5-2 – Overview of subcategories of CRF Sector 3 – Solvent and Other Product Use: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
3A	paint application	X		
3B	degreasing & dry cleaning	X		NE
3C	chemical products, manufacture & processing	IE		
3D1	other – use of N2O for anaesthesia			X
3D2	other – N2O from fire extinguishers			NE
3D3	other – N2O from aerosol cans			NE
3D4	other – other use of N2O			NO
3D5	other – other	X		NE

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.

5.1.3. Emission Trends

Solvent and other product use share of the total GHG emissions (excluding LULUCF) has remained fairly stable between 1990 and 2006: it evolved between 0.11% and 0.18%.

Table 5-3 as well as Figures 5-1 to 5-3 present the main trends for CRF Sector 3. NMVOC emissions are indicated since they are, when appropriate, converted in CO_2e for the purpose of estimating GHG emissions.

It should however be mentioned that actual emission estimates for CRF Sector 3 are very rough and will need to be improved. This is actually on-going through developments and analyses with the aim of improving EC NEC Directive and UNECE LRTAP reporting for Luxembourg (see Section 5.2.6).

Table 5-3 – GHG emission trends in CO_2e for CRF Sector 3 – Solvent and Other Product Use: 1990-2006

Year	CO_2e emissions (Gg) – GHG source & sink category: 3A - Paint Application				3B - Degreasing & Dry Cleaning				3D - Other				3 - Solvent & Other Product Use			
	Total	CO_2	N_2O	NMVOC	Total	CO_2	N_2O	NMVOC	Total	CO_2	N_2O	NMVOC	Total	CO_2	N_2O	NMVOC
1990	4,22	4,22	NA	1,35	0,84	0,84	NE	0,27	13,25	3,99	9,26	1,28	18,31	9,05	9,26	3,75
1991	4,24	4,24	NA	1,36	0,84	0,84	NE	0,27	12,92	4,00	8,92	1,28	18,00	9,08	8,92	3,76
1992	4,24	4,24	NA	1,36	0,84	0,84	NE	0,27	12,59	4,03	8,56	1,29	17,67	9,11	8,56	3,77
1993	4,26	4,26	NA	1,37	0,84	0,84	NE	0,27	12,31	4,08	8,23	1,31	17,41	9,18	8,23	3,80
1994	4,28	4,28	NA	1,37	0,84	0,84	NE	0,27	12,01	4,10	7,91	1,32	17,13	9,22	7,91	3,76
1995	4,29	4,29	NA	1,38	0,84	0,84	NE	0,27	11,73	4,15	7,58	1,33	16,86	9,28	7,58	3,76
1996	4,31	4,31	NA	1,38	0,84	0,84	NE	0,27	11,44	4,21	7,23	1,35	16,59	9,36	7,23	3,78
1997	4,33	4,33	NA	1,39	0,84	0,84	NE	0,27	11,12	4,23	6,89	1,36	16,29	9,40	6,89	3,79
1998	4,34	4,34	NA	1,39	0,84	0,84	NE	0,27	10,83	4,28	6,55	1,37	16,01	9,46	6,55	3,80
1999	4,36	4,36	NA	1,40	0,84	0,84	NE	0,27	10,48	4,29	6,19	1,38	15,68	9,49	6,19	3,14
2000	4,31	4,31	NA	1,38	0,84	0,84	NE	0,27	10,02	4,20	5,82	1,35	15,17	9,35	5,82	3,09
2001	4,26	4,26	NA	1,37	0,84	0,84	NE	0,27	9,49	4,06	5,43	1,30	14,59	9,16	5,43	3,03
2002	4,27	4,27	NA	1,37	0,84	0,84	NE	0,27	9,57	4,10	5,47	1,32	14,68	9,21	5,47	3,05
2003	4,27	4,27	NA	1,37	0,84	0,84	NE	0,27	9,61	4,10	5,51	1,32	14,72	9,21	5,51	3,05
2004	4,28	4,28	NA	1,37	0,84	0,84	NE	0,27	9,66	4,10	5,56	1,32	14,78	9,22	5,56	3,05
2005	4,29	4,29	NA	1,38	0,84	0,84	NE	0,27	9,77	4,15	5,62	1,33	14,90	9,28	5,62	3,07
2006	4,31	4,31	NA	1,38	0,84	0,84	NE	0,27	9,93	4,19	5,74	1,34	15,08	9,34	5,74	3,08
Trend 1990-2006	2,13%	2,13%	NA	2,22%	0,00%	0,00%	NA	0,00%	-19,33%	5,01%	-30,26%	2,29%	-17,66%	3,20%	-38,05%	-17,87%

Source: Environment Agency.

Notes:

3B: N_2O: since there are no methodologies in the IPCC Guidelines for calculating the emissions of this gas and since there is no national methodology to do so, it was not feasible to estimate N_2O emissions.

3C: chemical products data are not yet recorded. However, an estimate of the NMVOC generated by the chemical activities exists.

3D: N_2O emissions only cover anaesthesia related emissions. They are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GW*P) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

3: total NMVOC emissions include NMVOC emissions recorded under IPCC Category 3C – Chemical Products, Manufacture & Processing for which corresponding CO_2 emissions have been reported as IE.

Figure 5-1 – GHG emission trends in % for CRF Sector 3 – Solvent and Other Product Use: 1990-2006

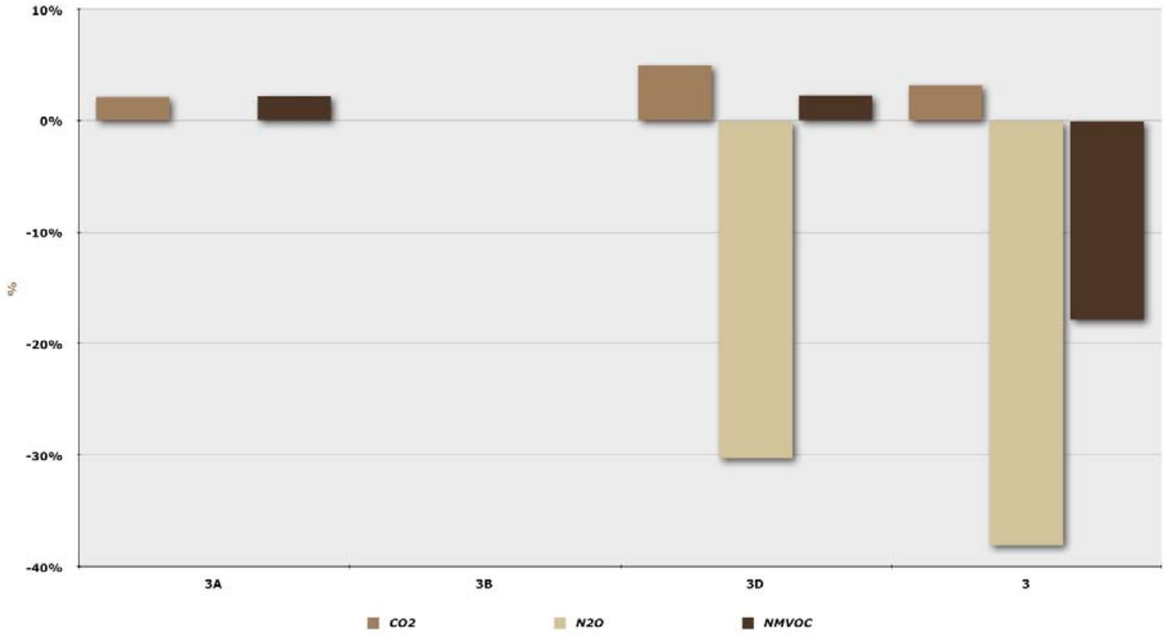


Figure 5-2 – GHG emission trends – indexes – for CRF Sector 3 – Solvent and Other Product Use: 1990-2006

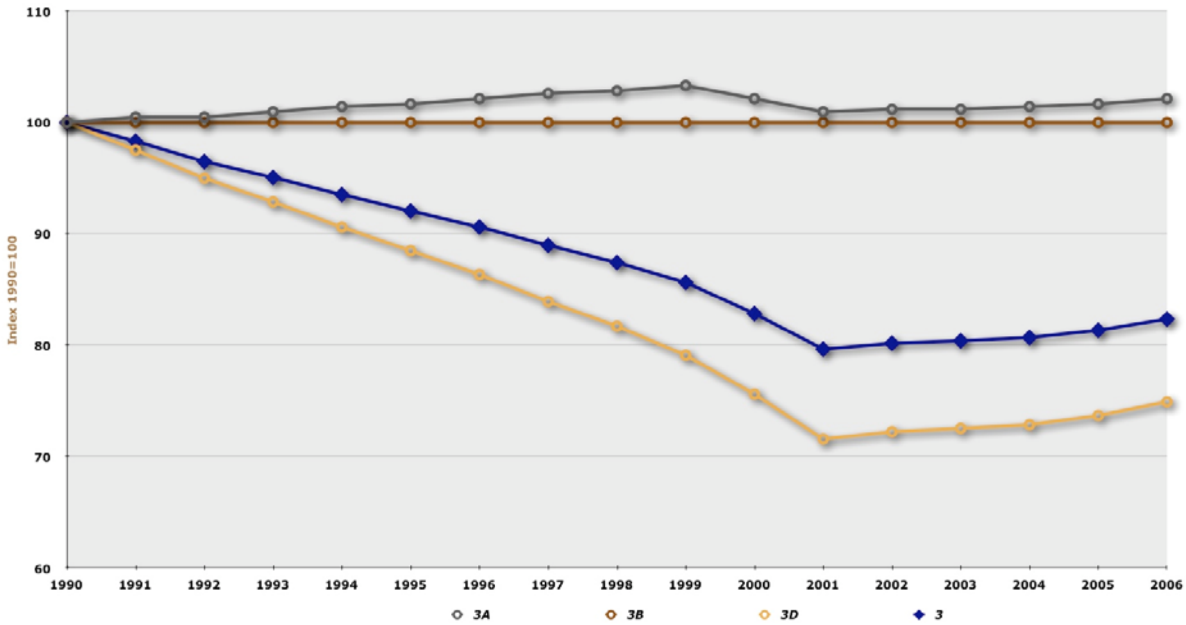
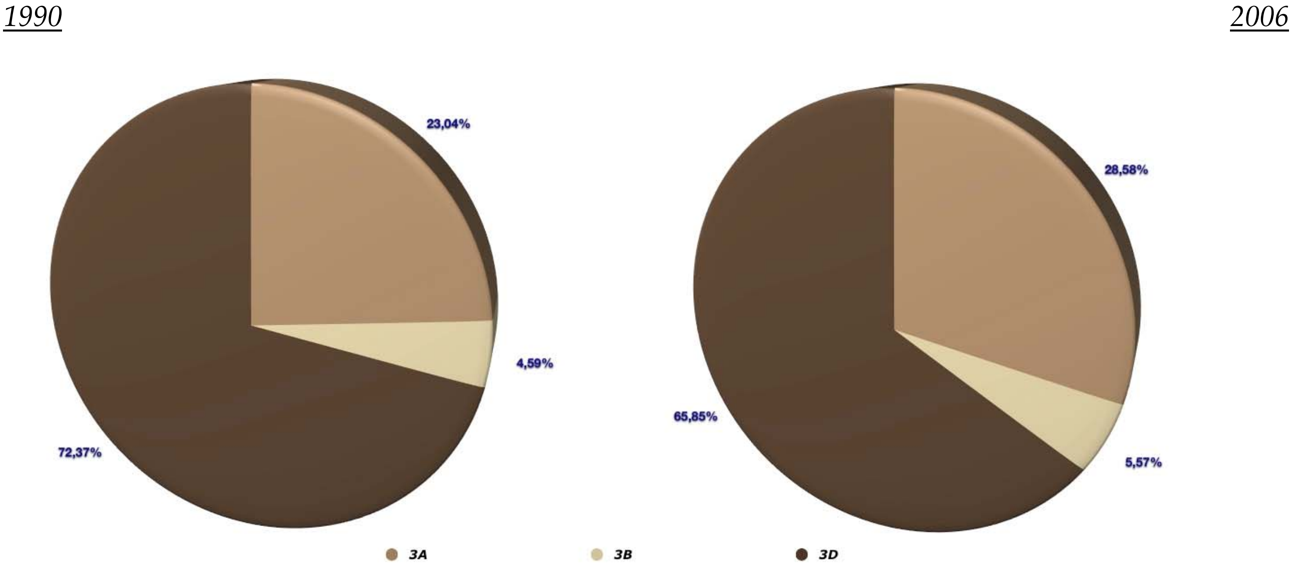


Figure 5-3 – IPCC Categories weights in GHG emissions for CRF Sector 3 – Solvent and Other Product Use: 1990 and 2006



5.2. Solvent, Other Product Use and Anaesthesia (IPCC Categories 3A to 3D)

This section describes briefly the basic method used so far for estimating CRF Sector 3 related GHG emissions – CO_2 and N_2O.

5.2.1. Carbon dioxide emissions

Table 5-4 indicates which SNAP Categories have been included for estimating CO_2 emissions for each IPCC Category under CRF Sector 3. It lists SNAP Categories for which NMVOC emissions are reported, respectively expected.

CO_2 emissions are in fact obtained from NMVOC emissions. It has not yet been estimated how many of the emissions of this sector would have to be counted as CO_2 emissions. A conservative approach is to suppose a complete oxidation of the carbon of the NMVOC emissions to CO_2. By doing so, GHG emission estimates are possibly over-estimated but certainly not under-estimated. This approach leads to CO_2 emissions resulting from oxidation of NMVOC emissions of approximately 9 Gg of CO_2 per year. Hence, carbon dioxide emissions from solvent and other product use have a very limited impact on the total GHG emissions of Luxembourg.

Table 5-4 – Source categories for CRF Sector 3 – Solvent and Other Product Use

IPCC Category		SNAP		
3 A	Paint application	0601		Paint application
			060102	Car repairing
			060103	Construction and buildings
			060104	Domestic use
			060105	Coil coating
			060106	Boat building
			060108	Other industrial paint application
			060109	Other non-industrial paint application
3 B	Degreasing and Dry Cleaning	0602		Degreasing, dry cleaning and electronics
			060201	Metal degreasing
			060202	Dry cleaning
3 C	Chemical Products, Manufacture and Process-ing	0603		Chemical products manufacturing and processing
			060302	Polyvinyle chloride processing
			060305	Rubber processing
			060307	Paints manufacturing
3 D	Other	0604		Other use of solvents and related activities
			060403	Printing industry
			060405	Application of glues and adhesives
			060406	Preservation of wood
			060407	Under seal treatment and conservation of vehicles
			060408	Domestic solvent use (other than paint application)

5.2.1.1. Key source

Solvent and other product use CO_2 emissions are not a key source.

5.2.1.2. Methodological issues

Activity data and emission factors were taken from the 1990 TÜV Rheinland study[60] and were left unchanged in most cases. As the organic solvent concentrations of paints have been reduced in the 1990s, NMVOC emission factors have been somewhat reduced in order to reflect that trend.

Activity data by SNAP Categories are listed in Tables 5-5 to 5.8.

60 TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln.

Table 5-5 – Activity data for IPCC Category 3A – Paint Application

SNAP	60102	60103	60104	60105	60106	60108	60109
Activity	Car repairing	Construction and buildings	Domestic use	Coil coating	Boat building	Other industrial paint application	Other non indus-trial paint appli-cation
Unit	[t paint]	[t paint]	[t paint]	[t paint]	[t paint]	[t paint]	[t paint]
1990	250	1 800	1 566	250	0	250	250
1991	250	1 800	1 598	250	0	250	250
1992	250	1 800	1 620	250	0	250	250
1993	250	1 800	1 644	250	0	250	250
1994	250	1 800	1 667	250	0	250	250
1995	250	1 800	1 692	250	0	250	250
1996	250	1 800	1 715	250	0	250	250
1997	250	1 800	1 737	250	0	250	250
1998	250	1 800	1 760	250	0	250	250
1999	250	1 800	1 786	250	0	250	250
2000	250	1 800	1 809	250	0	250	250
2001	250	1 800	1 820	250	0	250	250
2002	250	1 800	1 837	250	0	250	250
2003	250	1 800	1 837	250	0	250	250
2004	250	1 800	1 851	250	0	250	250
2005	250	1 800	1 872	250	0	250	250
2006	250	1 800	1 872	250	0	250	250

Source: TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln.

Table 5-6 – Activity data for IPCC Category 3B – Degreasing and Dry Cleaning

SNAP	60201	60202
Activity	Metal degreasing	Dry cleaning
Unit	[t solv.]	[t solv.]
1990	200	86
1991	200	86
1992	200	86
1993	200	86
1994	200	86
1995	200	86
1996	200	86
1997	200	86
1998	200	86
1999	200	86
2000	200	86
2001	200	86
2002	200	86
2003	200	86
2004	200	86
2005	200	86
2006	200	86

Source: TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln.

Table 5-7 – Activity data for IPCC Category 3C – Chemical Products, Manufacture and Processing

SNAP	60302	60305	60307
Activity	Polyvinyl chloride processing	Rubber processing	Paints manufacturing
Unit	[t prod.]	[t solv.]	[t solv.]
1990	13 000	711	190
1991	13 000	711	190
1992	13 000	711	190
1993	13 000	711	190
1994	13 000	441	190
1995	13 000	350	190
1996	13 000	310	190
1997	13 000	280	190
1998	13 000	250	190
1999	13 000	250	190
2000	13 000	250	190
2001	13 000	250	190
2002	13 000	250	190
2003	13 000	250	190
2004	13 000	250	190
2005	13 000	250	190
2006	13 000	250	190

Source: TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln.

Table 5-8 – Activity data for IPCC Category 3D – Other

SNAP	60403	60405	60406	60407	60408
Activity	Printing industry	Application of glues and adhesives	Preservation of wood	Under seal treatment of vehicles	Domestic solvent use
Unit	[kg ink]	[t paint]	[t paint]	[t solv.]	[inhab.]
1990	487 000	955	300	3	1 018
1991	487 000	975	300	3	1 040
1992	487 000	988	300	3	1 054
1993	487 000	1 002	300	3	1 069
1994	487 000	1 017	300	3	1 084
1995	487 000	1 032	300	3	1 101
1996	487 000	1 046	300	3	1 115
1997	487 000	1 059	300	3	1 130
1998	487 000	1 073	300	3	1 145
1999	487 000	1 089	300	3	1 162
2000	487 000	1 103	300	3	1 177
2001	487 000	1 110	300	3	1 184
2002	487 000	1 120	300	3	1 195
2003	487 000	1 120	300	3	1 195
2004	487 000	1 120	300	3	1 204
2005	487 000	1 120	300	3	1 217
2006	487 000	1 120	300	3	NE

SNAP	60502	60503	60504	60507	60508
Activity	Refrigeration, air condition. (HFC, SF_6)	Refrigeration, air condition. (NH_3)	Foam blowing (except 060304) (HFC,PFC)	Electrical equipments (SF_6)	Other (NMVOC, N_2O, SF_6, HFC, PFC)
Unit	[t solv.]	[t]	[t solv.]	[t SF_6]	[t]
1990	34	35 000	9	2	10
1991	34	35 000	9	2	10
1992	34	35 000	9	2	10
1993	34	35 000	9	2	10
1994	34	35 000	9	2	10
1995	34	35 000	9	2	10
1996	34	35 000	9	2	10
1997	34	35 000	9	2	10
1998	34	35 000	9	2	10
1999	34	35 000	9	2	10
2000	170	35 000	9	5	11
2001	170	35 000	9	5	11
2002	170	35 000	9	5	11
2003	170	35 000	9	5	11
2004	170	35 000	9	5	11
2005	170	35 000	9	5	11
2006	170	35 000	9	5	11

Sources: TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg, except SNAP 60408: STATEC.

Remark

For IPCC Sub-category 3D5 – Other Use of Solvent and Related Activities, CO_2 emissions relate to both the chemical activities (IPCC Category 3C) and the other use of solvents and related activities (IPCC Sub-category 3D5). They are recorded altogether under IPCC Sub-category 3D5. NMVOC emissions, on the other hand, relate only to the other use of solvents and related activities (IPCC Sub-category 3D5). NMVOC emissions from chemical activities are recorded under IPCC Category 3C.

5.2.2. Nitrous oxide emissions

The only N_2O emissions reported so far under CRF Sector 3 are those generated by the use of anaesthesia.

5.2.2.1. Key source

Anaesthesia usage related N_2O emissions are not a key source.

5.2.2.2. Methodological issues

N_2O emissions from anaesthesia usage are estimated by combining reported emissions in Germany with the relative population in Luxembourg. The reported emissions in Germany remained constant between 2002 and 2005 and the same value for Germany is also applied for 2006 in the estimation calculation for Luxembourg.

5.2.3. Recalculations

See Table 5-1 above.

5.2.4. Category specific QA / QC procedures

No category specific QA/QC procedures have been completed, only the tools embedded in CRF Reporter have been used.

5.2.5. Planned improvements

In March 2008, the Environment Agency contracted the *Institute für Industrielle Ökologie*[61] for elaborating a model for estimating air emissions from solvent and other product use. This study, aiming firstly at helping producing more accurate inventories in the framework of the EC NEC Directive and the UNECE LRTAP, will of course provide the necessary information for improving GHG emission estimates for CRF Sector 3.

Table 5-9 – Planned improvements for CRF Sector 3 – Solvent and Other Product Use

GHG source & sink category	Planned improvement
3 – Solvent and Other Product Use	complete re-evaluation on the basis of the study on air emissions from solvent and other product use.

For more information on this Chapter, please contact:

Frank THEWES — *Pierre DORNSEIFFER*

Administration de l'Environnement
16, rue Eugène Ruppert
L-2453 Luxembourg

Tel: (+352) 40 56 56 646 — *(+352) 40 56 56 648*
Fax: (+352) 48 50 78 — *(+352) 48 50 78*
E-mail: frank.thewes@aev.etat.lu — *pierre.dornseiffer@aev.etat.lu*

61 See http://www.indoek.noe-lak.at/

6. Agriculture (CRF Sector 4)

6.1. Sector Overview

Chapter 6 includes information on and description of methodologies used for estimating GHG emissions as well as references to activity data and emission factors reported under CRF Sector 4 – Agriculture for the period 1990 to 2006.

Emissions from this sector comprise emissions from the following categories: enteric fermentation (4A), manure management (4B) and agricultural soils (4D). 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 whole country of Luxembourg is lying in a **cool climate region**.

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Section 6.1 is structured as follows:

- overview of the revisions since the ICR of June 2007: submission 2007v2.1 ➔ submission 2007v3.1 ➔ submission 2008v1.2. Submission 2007v2.1 was the version reviewed by the ERT during the ICR, whereas submission 2007v3.1 was the one provided to the ERT after the ICR (see Table 1-1 in Section 1.1). This overview includes therefore information on recalculations;
- completeness analysis of the CRF Sector as reported in submission 2008v1.2. The analysis limits itself to the 6 GHG controlled by the Kyoto Protocol;
- analysis of the emission trends of the CRF Sector, combining source categories and GHG.

Starting with revisions and a completeness analysis is justified by the dramatic improvements the GHG inventory for Luxembourg experienced since the ICR in June 2007.

Other required information, as suggested in Annex I of document FCCC/SBSTA/2006/9, will be presented under each source category review (methodology, AD, EFs, etc.).

6.1.1. Overview of the revisions

Table 6-1 presents the main revisions and recalculations done after the ICR of June 2007 relevant to CRF Sector 4.

Table 6-1 – Changes in GHG inventories: submissions 2007v2.1 and 2007v3.1

GHG source & sink category	Revisions 2007v2.1 ➔ 2007v3.1	Type of revision
4A	- updated activity data for the livestock	- revised AD
	- revised activity data for dairy cattle (use of milk yield and fat content of milk for Luxembourg instead of German averages)	- revised AD
	- reallocation of cattle types among option B categories: dairy-cattle, mature non-dairy cattle and young cattle	- refinement
	- revised calculation of Gross Energy Intake for young cattle	- error correction
	- revision of the Digestible Energy parameter for all animal categories	- refinement
4B – CH_4	- updated activity data for the livestock	- revised AD
	- reallocation of cattle types among option B categories dairy-cattle, mature non-dairy cattle and young cattle	- refinement
	- revised calculation of Gross Energy Intake for young cattle	- error correction
	- revision of the Digestible Energy parameter for all animal categories	- refinement
	- revised estimates for the breakdown of manure by AWMS	- error correction
4B – N_2O	- new estimates (source category previously NE)	- new source category
4D	- new estimates (source category previously very roughly and partially estimated)	- new estimates
4F	- updated activity data for the crops	- revised AD

Table 6-2 presents the main revisions and recalculations between submissions 2007v3.1 and 2008v1.2 (see also CRF tables 8).

Table 6-2 – Changes in GHG inventories: submissions 2007v3.1 and 2008v1.2

GHG source & sink category	Revisions 2007v3.1 ➔ 2008v1.2	Type of revision
4A4	- new estimates (source category previously NE) for goats for the years 1997 to 1999	- new estimates
4A7	- reallocation of mules & asses from category 4A6 to 4A7 for the year 2005	- misallocation correction
4A10	- addition of 3 new animals categories (rabbits, other poultry & cervidae species) for the years 1997 to 2005	- new estimates
4B4	- new estimates (source category previously NE) for goats for the years 1997 to 1999	- new estimates
4B7	- reallocation of mules & asses from category 4A6 to 4A7 for the year 2005	- misallocation correction
4B10	- addition of 3 new animals categories (rabbits, other poultry & cervidae species) for the years 1997 to 2005	- new estimates
4D12	- new estimates for goats for the years 1997 to 1999	- updated estimates
	- reallocation of mules & asses from category 4A6 to 4A7 for the year 2005	
	- addition of 3 new animals categories (rabbits, other poultry & cervidae species) for the years 1997 to 2005	
4D13	- reallocation of crops activity data between N-fixing and non N-fixing crops for all the years	- misallocation correction
4D14	- reallocation of crops activity data between N-fixing and non N-fixing crops for all the years	- misallocation correction
4D2	- new estimates for goats for the years 1997 to 1999	- updated estimates
	- reallocation of mules & asses from category 4A6 to 4A7 for the year 2005	
	- addition of 3 new animals categories (rabbits, other poultry & cervidae species) for the years 1997 to 2005	
4D3	- new estimates for goats for the years 1997 to 1999	- updated estimates
	- reallocation of mules & asses from category 4A6 to 4A7 for the year 2005	
	- addition of 3 new animals categories (rabbits, other poultry & cervidae species) for the years 1997 to 2005	

6.1.2. Completeness

Table 6-3 gives an overview of the IPCC categories included under CRF Sector 4 and provides information on the status of emission estimates of all subcategories.

Table 6-3 – Overview of subcategories of CRF Sector 4 – Agriculture: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
4A1 – option B	enteric fermentation – cattle		X	
4A2	enteric fermentation – buffalo		NO	
4A3	enteric fermentation – sheep		X	
4A4	enteric fermentation – goats		NE (1990-1996) X (1997-2006)	
4A5	enteric fermentation – camels & llamas		NO	
4A6	enteric fermentation – horses		X	
4A7	enteric fermentation – mules & asses		IE (1990-2004) * X (2005-2006)	
4A8	enteric fermentation – swine		X	
4A9	enteric fermentation – poultry		X	
4A10	enteric fermentation – other livestock		NE (1990-1996) X (1997-2006)	
4B1 – option B	manure management – cattle		X	
4B2	manure management – buffalo		NO	
4B3	manure management – sheep		X	
4B4	manure management – goats		NE (1990-1996) X (1997-2006)	
4B5	manure management – camels & llamas		NO	
4B6	manure management – horses		X	
4B7	manure management – mules & asses		IE (1990-2004) * X (2005-2006)	
4B8	manure management – swine		X	
4B9	manure management – poultry		X	
4B10	manure management – other livestock		NE (1990-1996) X (1997-2006)	
4B11	manure management – anaerobic lagoons			NO
4B12	manure management – liquid systems			X
4B13	manure management – solid storage & dry lot			X
4B14	manure management – other AWMS			X
4C1	rice cultivation – irrigated		NO	
4C2	rice cultivation – rainfed		NO	
4C3	rice cultivation – deep water		NO	
4C4	rice cultivation – other		NA	
4D1	agricultural soils – direct soil emissions		NE **	X
4D2	agricultural soils – pasture, range & paddock manure			X
4D3	agricultural soils – indirect emissions		NE **	X
4D4	agricultural soils – other		NA	NA
4E	prescribed burning of savannas		NO	NO
4F1	field burning of agricultural residues – cereals		NO	NO
4F2	field burning of agricultural residues – pulses		NO	NO
4F3	field burning of agricultural residues – tubers & roots		NO	NO

4F4	field burning of agricultural residues – sugar cane		NO	NO
4F5	field burning of agricultural residues – other		NO	NO
4G	other		NA	NA

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.

* = the number of mules & asses where recorded together with horses (category 4A6) up to 2004 included.

** = NE but not indicated in the sectoral background data for agriculture table 4D.

IPCC (Sub-)Categories 4A1 – Enteric Fermentation – Cattle and 4D – Agricultural Soils have been identified as key source categories (see Section 1.5).

6.1.3. Emission trends

This section briefly describes the emission trends from 1990 to 2006 for each of the IPCC Categories under CRF Sector 4 for which GHG emissions are reported – i.e. categories 4A, 4B and 4D.

As shown in Table 6-4, emissions of GHG related to agricultural activities have decreased by about 10.5% (-3.8% for methane and -16% for nitrous oxide). Both IPCC Categories 4A – Enteric Fermentation and 4D – Agricultural Soils saw their emissions falling by some 12%. For manure management (IPCC Category 4B), emissions remained quite stable between 1990 and 2006, though opposite variations are observed for the two GHG emitted by this activity: methane increased by 22.4% and nitrous oxide declined by 48.7%.

Figures 6-1 and 6-2 provide a quick overview on agriculture related emission trends between 1990 and 2006. More details and explanations are presented in the subsequent sections detailing each of the sector source categories.

Figure 6-1 – GHG emission trends in % for CRF Sector 4 – Agriculture: 1990-2006

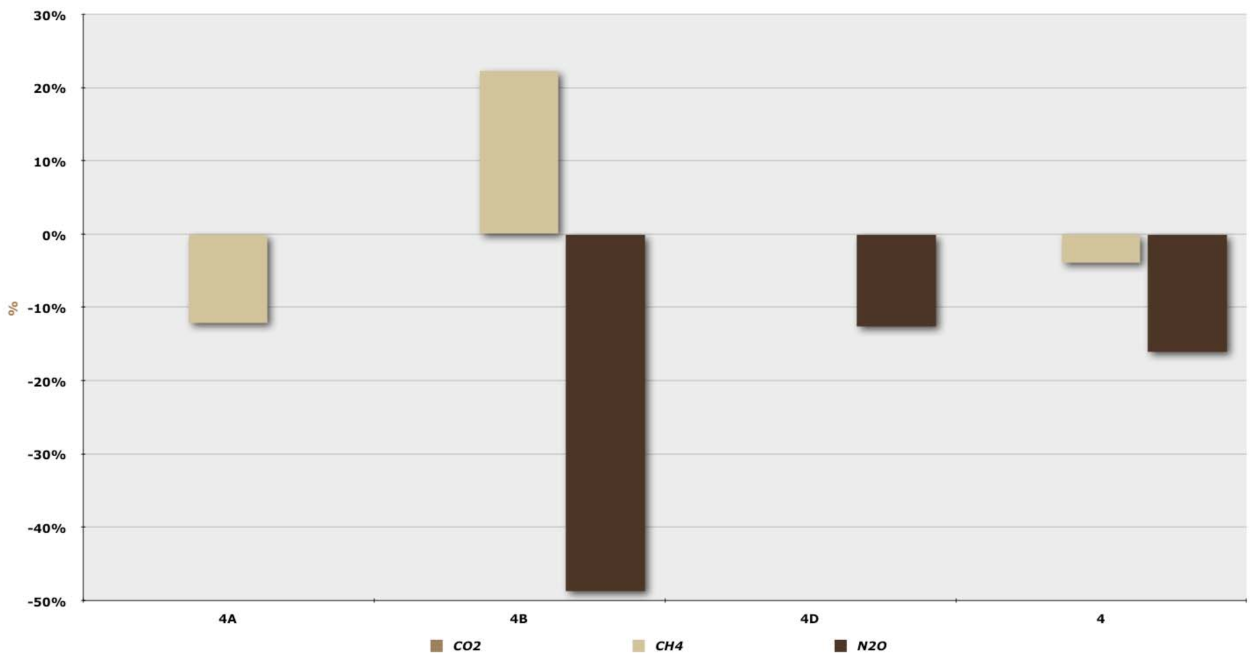


Table 6-4 – GHG emission trends in CO_2e for CRF Sector 4 – Agriculture: 1990-2006

Year	4A - Enteric Fermentation				4B - Manure Management				4D - Agricultural Soils				4 - Agriculture			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	270.93	NA	270.93	NA	126.18	NA	85.57	40.61	378.84	NA	NA	378.84	775.94	NA	356.49	419.45
1991	269.67	NA	269.67	NA	127.69	NA	92.82	34.87	384.36	NA	NA	384.36	781.73	NA	362.49	419.24
1992	258.59	NA	258.59	NA	125.17	NA	93.43	31.74	402.02	NA	NA	402.02	785.78	NA	352.03	433.75
1993	260.60	NA	260.60	NA	127.77	NA	96.49	31.29	388.92	NA	NA	388.92	777.29	NA	357.08	420.21
1994	258.14	NA	258.14	NA	126.40	NA	96.43	29.96	370.77	NA	NA	370.77	755.31	NA	354.57	400.74
1995	265.30	NA	265.30	NA	131.96	NA	101.02	30.94	381.50	NA	NA	381.50	778.76	NA	366.32	412.44
1996	268.41	NA	268.41	NA	132.91	NA	101.56	31.35	387.85	NA	NA	387.85	789.17	NA	369.97	419.20
1997	263.14	NA	263.14	NA	134.29	NA	104.17	30.12	389.31	NA	NA	389.31	786.73	NA	367.31	419.43
1998	260.45	NA	260.45	NA	136.24	NA	107.70	28.53	387.60	NA	NA	387.60	784.28	NA	368.15	416.13
1999	260.10	NA	260.10	NA	141.94	NA	117.91	24.02	383.47	NA	NA	383.47	785.50	NA	378.01	407.49
2000	256.70	NA	256.70	NA	136.40	NA	112.96	23.45	389.30	NA	NA	389.30	782.40	NA	369.66	412.75
2001	257.96	NA	257.96	NA	134.33	NA	110.91	23.42	355.11	NA	NA	355.11	747.40	NA	368.87	378.53
2002	250.79	NA	250.79	NA	130.47	NA	108.18	22.29	356.21	NA	NA	356.21	737.47	NA	358.97	378.50
2003	243.39	NA	243.39	NA	127.74	NA	105.09	22.65	315.58	NA	NA	315.58	686.70	NA	348.48	338.22
2004	240.93	NA	240.93	NA	125.00	NA	102.47	22.53	366.68	NA	NA	366.68	732.61	NA	343.41	389.21
2005	240.62	NA	240.62	NA	128.20	NA	106.29	21.90	331.10	NA	NA	331.10	699.92	NA	346.92	353.00
2006	238.24	NA	238.24	NA	125.53	NA	104.69	20.83	331.34	NA	NA	331.34	695.11	NA	342.93	352.18
Trend 1990-2006	-12.07%	NA	-12.07%	NA	-0.51%	NA	22.35%	-48.70%	-12.54%	NA	NA	-12.54%	-10.42%	NA	-3.80%	-16.04%

CO_2e emissions (Gg) — GHG source & sink category

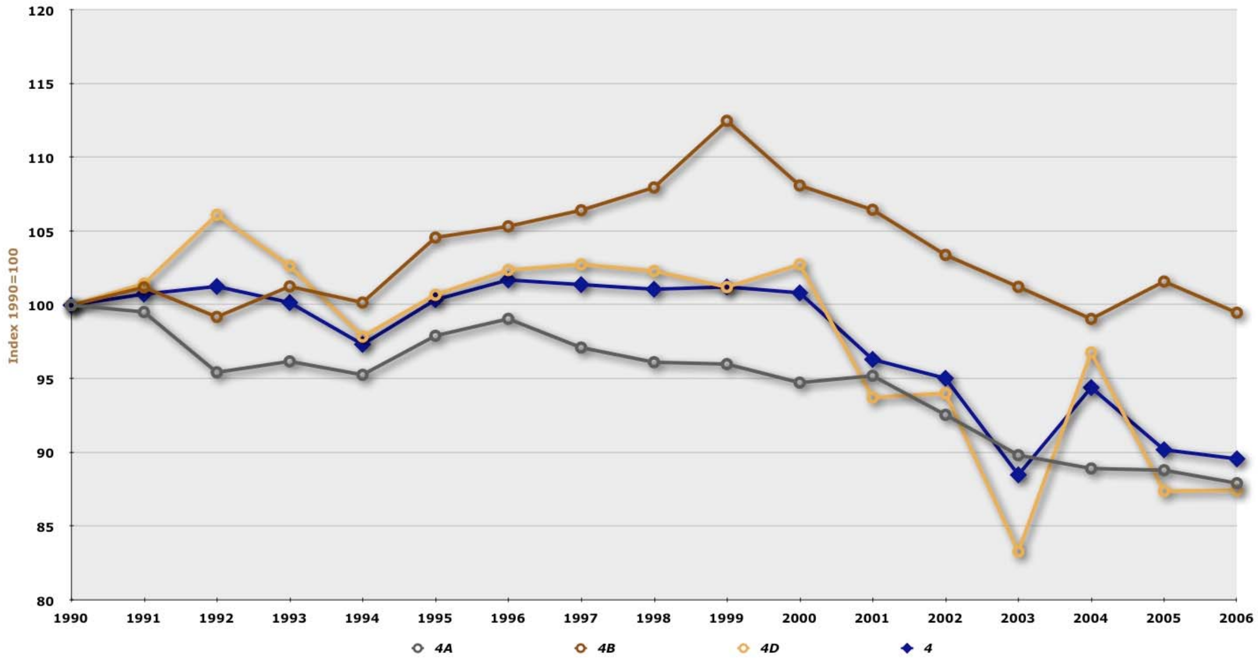
Source: Ministry of the Environment.

Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

Figure 6-2 – GHG emission trends – indexes – for CRF Sector 4 – Agriculture: 1990-2006

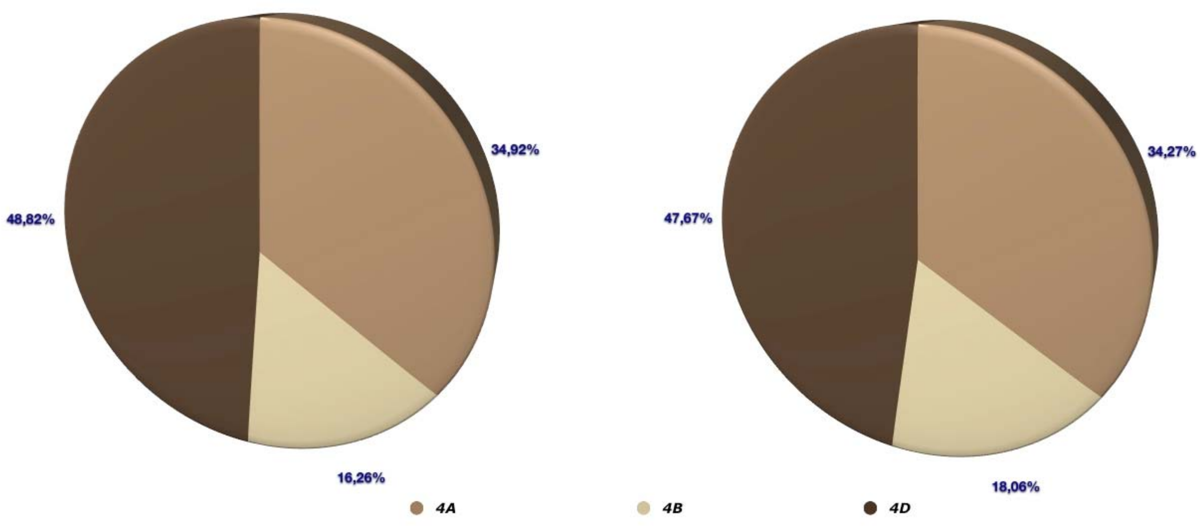


As shown in Figure 6-2, IPCC Category 4D – Agricultural Soils presents an erratic evolution at the end of the period. This is explained mainly by important changes in crops, especially N-fixing crops, as well as in N-fertilizer use which showed a slack in 2003 and a peak in 2004. The lower N-fertilizer use in 2003 was the result of the drought that characterized that year's summer.

The evolution of IPCC Category 4D also shapes the overall agriculture emission pattern. Indeed, as depicted in Figure 6-3, for both the years 1990 and 2006, IPCC Category 4D is the biggest contributor to agriculture related emissions. It is also worth noting that the shares of each IPCC Category under CRF Sector 4 for which GHG emissions are reported have barely changed over the period.

Figure 6-3 – IPCC Categories weights in GHG emissions for CRF Sector 4 – Agriculture: 1990 and 2006

<u>*1990*</u> <u>*2006*</u>



In order to facilitate and complement the explanations provided in Sections 6.2 to 6.8 below, it is highly recommended to explore the Microsoft Excel™ file that has been developed to calculate GHG emissions from the agriculture sector. This file (**Agriculture_GHG Estimates.xls**) details all the calculations and is indicating (activity) data sources, methods, formulas, parameters, coefficients and equations used to estimate CH_4 and N_2O emissions. It is available and downloadable at the following address: http://cdr.eionet.europa.eu/lu/eu/ghgmm/envsa9e_q.

It should also be mentioned that the text, the tables and the figures in this chapter **includes final activity data for fertilizers for 2006** – instead of provisional data as indicated in the Microsoft Excel™ CRF tables 2008v1.2: the difference = +0.25 Gg CO_2e: 695.11 (see Table 6-4) instead of 694.86 Gg CO_2e recorded in the CRF tables submitted in April 2008.

6.2. Enteric Fermentation (IPCC Source Category 4A)

This section describes the estimation of methane emissions resulting from enteric fermentation. In 2006, this source category was responsible for 69.5% of agricultural methane emissions and for 51.4% of the total methane emissions estimated for Luxembourg. It represented 1.8% of the total GHG emissions in CO_2e (excluding LULUCF).

6.2.1. Key source

With 1.74% of the total GHG emissions in CO_2e (excluding LULUCF) in 2006, methane emissions from cattle (IPCC Sub-category 4A1) is a key source. It has been a key source without interruption since 1990.

6.2.2. Source category description

Table 6-5 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 B for cattle. Under other livestock, Luxembourg has included the following animals: other poultry (i.e. ducks, geese, turkeys, guinea fowls and wild poultry), rabbits and cervidae species (mainly deer). Some farm animals recorded in statistics are not yet included in the inventory. It is the case for ostriches and a category labelled "other productive animals". However, in 2006, there were 172 ostriches and only 8 "productive animals" reported.

Looking at animal species, horses have experienced the biggest increase in their population. Nevertheless, as shown in Table 6-6, which recapitulates methane emissions from enteric fermentation for each of the livestock categories, horse related methane emissions are relatively low compared to emissions originating from cattle and swine, the two main methane emitting animal categories with regard to enteric fermentation.

Table 6-5 – Domestic livestock population and trends: 1990-2006

Year	4A1 Cattle - Mature Dairy Cattle	4A1 Non-Dairy Cattle	*4A1 Cattle - Mature Non-Dairy Cattle - Females*	*4A1 Cattle - Mature Non-Dairy Cattle - Males*	*4A1 Cattle - Young Cattle - Calves*	*4A1 Cattle - Young Cattle - Growing Heifers*	4A2 Buffalo	4A3 Sheep	4A4 Goats	4A5 Camels & Llamas	4A6 Horses	4A7 Mules & Asses	4A8 Swine	4A9 Poultry - Chickens	4A10 Other - Other Poultry	4A10 Other - Rabbits	4A10 Other - Cervidae Species
	Population size (heads) Livestock category																
1990	58 840	158 611	*22 048*	*5 442*	*59 553*	*71 568*	NO	7 281	NE	NO	1 722	IE	75 463	69 021	NE	NE	NE
1991	55 604	163 940	*25 319*	*5 624*	*59 254*	*73 743*	NO	7 726	NE	NO	1 829	IE	66 592	63 559	NE	NE	NE
1992	51 110	158 225	*25 713*	*4 728*	*56 214*	*71 570*	NO	6 924	NE	NO	1 835	IE	67 837	60 281	NE	NE	NE
1993	50 182	158 696	*27 314*	*4 714*	*55 747*	*70 921*	NO	6 775	NE	NO	1 925	IE	71 800	63 444	NE	NE	NE
1994	48 978	159 766	*28 884*	*4 247*	*58 026*	*68 609*	NO	7 744	NE	NO	2 123	IE	68 854	60 451	NE	NE	NE
1995	48 599	165 288	*30 732*	*4 936*	*57 582*	*72 038*	NO	7 552	NE	NO	2 164	IE	72 640	55 618	NE	NE	NE
1996	47 953	169 974	*31 989*	*5 064*	*59 094*	*73 827*	NO	7 152	NE	NO	2 198	IE	72 494	61 855	NE	NE	NE
1997	46 305	166 030	*30 847*	*5 576*	*57 000*	*72 607*	NO	8 009	360	NO	2 295	IE	77 149	66 293	1 937	7 240	174
1998	45 952	162 788	*30 696*	*5 270*	*55 319*	*71 503*	NO	8 237	294	NO	2 342	IE	81 392	68 364	1 390	6 773	284
1999	45 102	162 760	*32 097*	*4 812*	*55 384*	*70 467*	NO	8 220	263	NO	2 818	IE	85 830	62 061	982	6 132	333
2000	43 346	161 726	*32 871*	*4 383*	*54 806*	*69 666*	NO	7 971	297	NO	3 154	IE	80 141	71 785	849	6 638	383
2001	42 854	162 339	*33 427*	*4 833*	*54 331*	*69 748*	NO	8 476	311	NO	3 126	IE	78 540	84 317	999	6 542	339
2002	42 076	155 181	*32 782*	*4 188*	*53 723*	*64 488*	NO	9 104	1 103	NO	3 117	IE	79 665	77 968	958	6 993	318
2003	40 599	149 075	*31 499*	*3 820*	*51 325*	*62 431*	NO	9 446	1 878	NO	3 449	IE	84 140	79 288	1 010	6 516	238
2004	39 879	146 846	*31 133*	*3 571*	*50 819*	*61 323*	NO	9 743	2 010	NO	3 686	IE	84 611	73 111	1 082	6 603	285
2005	39 340	145 995	*31 693*	*3 432*	*49 195*	*61 675*	NO	10 277	2 203	NO	4 072	121	90 147	83 407	1 122	6 514	234
2006	38 617	145 023	*31 616*	*3 169*	*49 453*	*60 785*	NO	9 644	1 950	NO	4 161	175	84 151	81 252	1 153	6 840	244
Trend 1990-2006	*-34.37%*	*-8.57%*	*43.40%*	*-41.77%*	*-16.96%*	*-15.07%*	*NA*	*32.45%*	*441.67%*	*NA*	*141.64%*	*44.63%*	*11.51%*	*17.72%*	*-40.47%*	*-5.52%*	*40.23%*

Sources : SER: http://www.ser.public.lu/statistik/agrarstrukturen/statec_15_mai_pluriannuel.pdf and STATEC, *Statistical Yearbook*, Table C.2107: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1220

data extracted on 11 March 2008 (subject to changes since that date)

Table 6-6 – CH_4 emission trends for IPCC Category 4A – Enteric Fermentation: 1990-2006

Year	4A1 Cattle - Mature Dairy Cattle	4A1 Non-Dairy Cattle	*4A1 Cattle - Mature Non-Dairy Cattle - Females*	*4A1 Cattle - Mature Non-Dairy Cattle - Males*	*4A1 Cattle - Young Cattle - Calves*	*4A1 Cattle - Young Cattle - Growing Heifers*	4A2 Buffalo	4A3 Sheep	4A4 Goats	4A5 Camels & Llamas	4A6 Horses	4A7 Mules & Asses	4A8 Swine	4A9 Poultry - Chickens	4A10 Other - Other Poultry	4A10 Other - Rabbits	4A10 Other - Cervidae Species	4A Total
	CH_4 emissions (Mg) Livestock category																	
1990	6 199.52	6 498.55	*1 206.74*	*289.65*	*1 864.07*	*3 138.09*	NO	58.25	NE	NO	31.00	IE	113.19	0.84	NE	NE	NE	12 901.35
1991	5 871.09	6 774.95	*1 385.77*	*299.33*	*1 855.97*	*3 233.89*	NO	61.81	NE	NO	32.92	IE	99.89	0.77	NE	NE	NE	12 841.44
1992	5 562.44	6 560.63	*1 407.33*	*251.64*	*1 762.50*	*3 139.15*	NO	55.39	NE	NO	33.03	IE	101.76	0.73	NE	NE	NE	12 313.97
1993	5 605.88	6 606.15	*1 494.96*	*250.90*	*1 748.80*	*3 111.50*	NO	54.20	NE	NO	34.65	IE	107.70	0.77	NE	NE	NE	12 409.35
1994	5 449.61	6 638.51	*1 580.89*	*226.04*	*1 821.09*	*3 010.49*	NO	61.95	NE	NO	38.21	IE	103.28	0.73	NE	NE	NE	12 292.29
1995	5 510.44	6 914.04	*1 682.03*	*262.71*	*1 807.98*	*3 161.31*	NO	60.42	NE	NO	38.95	IE	108.96	0.67	NE	NE	NE	12 633.47
1996	5 458.24	7 116.77	*1 750.83*	*269.53*	*1 856.20*	*3 240.21*	NO	57.22	NE	NO	39.56	IE	108.74	0.75	NE	NE	NE	12 781.28
1997	5 339.99	6 963.09	*1 688.33*	*296.78*	*1 790.99*	*3 187.00*	NO	64.07	1.80	NO	41.31	IE	115.72	0.80	NE	0.06	3.48	12 530.33
1998	5 326.58	6 837.51	*1 680.06*	*280.49*	*1 738.15*	*3 138.80*	NO	65.90	1.47	NO	42.16	IE	122.09	0.83	NE	0.06	5.68	12 402.27
1999	5 285.25	6 846.40	*1 756.74*	*256.11*	*1 740.22*	*3 093.32*	NO	65.76	1.32	NO	50.72	IE	128.75	0.75	NE	0.05	6.66	12 385.65
2000	5 159.75	6 813.26	*1 799.11*	*233.28*	*1 722.71*	*3 058.17*	NO	63.77	1.49	NO	56.77	IE	120.21	0.87	NE	0.05	7.66	12 223.84
2001	5 175.24	6 857.27	*1 829.54*	*257.23*	*1 708.43*	*3 062.07*	NO	67.81	1.56	NO	56.27	IE	117.81	1.02	NE	0.05	6.78	12 283.80
2002	5 143.05	6 538.16	*1 794.23*	*222.90*	*1 689.60*	*2 831.43*	NO	72.83	5.52	NO	56.11	IE	119.50	0.94	NE	0.06	6.36	11 942.53
2003	5 028.06	6 282.73	*1 724.01*	*203.32*	*1 614.17*	*2 741.24*	NO	75.57	9.39	NO	62.08	IE	126.21	0.96	NE	0.05	4.76	11 589.81
2004	5 000.35	6 184.84	*1 703.98*	*190.06*	*1 598.21*	*2 692.58*	NO	77.94	10.05	NO	66.35	IE	126.92	0.88	NE	0.05	5.70	11 473.09
2005	4 977.09	6 172.51	*1 734.63*	*182.66*	*1 547.20*	*2 708.02*	NO	82.22	11.02	NO	73.30	1.21	135.22	1.01	NE	0.05	4.68	11 458.30
2006	4 925.37	6 123.66	*1 730.42*	*168.67*	*1 555.61*	*2 668.97*	NO	77.15	9.75	NO	74.90	1.75	126.23	0.98	NE	0.06	4.88	11 344.72
Trend 1990-2006	*-20.55%*	*-5.77%*	*43.40%*	*-41.77%*	*-16.55%*	*-14.95%*	*NA*	*32.45%*	*441.67%*	*NA*	*141.64%*	*44.63%*	*11.51%*	*17.72%*	*NA*	*-5.52%*	*40.23%*	*-12.07%*

Source: Ministry of the Environment.

Notes for Tables 6-5 and 6-6:

Livestock population is coming from the yearly agricultural census. The situation is the one on the 15th of May of each year. Thus, the number of heads included in the inventory for a certain year corresponds to the population on May 15.

Accurate data on the population size for certain livestock categories (4A4 and 4A10) is only available since the 1997 census (hence the NE notation key).

Mules & Asses population was reported together with horses population up to the 2004 census included.

Livestock description:

4A1 – Cattle – Mature Dairy Cattle: dairy cows

4A1 – Cattle – Mature Non-Dairy Cattle – Females: suckler cows & other cows

4A1 – Cattle – Mature Non-Dairy Cattle – Males: male cattle over 2 years

4A1 – Cattle – Young Cattle – Calves: calves for slaughtering & other calves

4A1 – Cattle – Young Cattle – Growing Heifers: cattle from 1 to 2 years (males & females), heifers for slaughtering & other heifers

4A3 – Sheep: ovine

4A4 – Goats: caprine

4A6 – Horses: ponies, foals, mares, stallions & geldings; includes farming & horsemanship animals, the latter only for horse clubs registered as farms

4A7 – Mules & Asses: asses (included with horses up to 2004 included)

4A8 – Swine: porcine including piglets, sows, pigs & boars

4A9 – Poultry – Chickens: broiler & layer chickens, roosters & chicks

4A10 – Other – Other Poultry: ducks, geeses, turkeys, guinea-fowls & wild poultry

4A10 – Other – Rabbits: breeding females & other rabbits

4A10 – Other – Cervidae Species: breeding females & other cervidae species

On the whole, methane emissions from enteric fermentation decreased by around 12% over the period 1990-2006. This was mainly the result from declining emissions generated by cattle – -20.6% for dairy cattle and -5.8% for non-dairy cattle – whilst increasing emissions were recorded for the other livestock categories – with +11.5% for swine, +32.4% for sheep and +141.6% for horses, naming only the biggest contributors. It is worth noting that because a Tier 1 method has been applied to estimate methane emissions from enteric fermentation for all animal categories except cattle (see Section 6.2.3), population and methane emission growths are exactly the same.[62]

With regard to cattle, its total population size declined throughout the period 1990-2006. However, a shift did occur within the cattle population with a reduction for dairy cattle (-34.4%) and an increase for female mature non-dairy cattle (+43.4%). 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*). 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). Furthermore, several reductions in the milk quota were decided in the framework of the CAP. Another factor influencing cattle population is, of course, 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.

Finally, if the dairy cattle population decreased by 34.4% between 1990 and 2006, related methane emissions only declined by 20.6%. This is explained by increasing milk yield over the period which, in turn, led to an augmentation of the gross energy intake for dairy cattle.[63]

6.2.3. Methodological issues

The IPCC Tier 1 method has been applied to all farm animal categories with the exception of cattle (IPCC Sub-category 4A1) for which a Tier 2 method has been used together with option B.

6.2.3.1. Activity data

The following activity data have been extracted from national statistics:

- number of animals: see Table 6-5 in Section 6.2.2;
- the milk yield and the fat content of milk for dairy cattle: see Table 6-7.

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62 Actually, even in the case of a Tier 2 method, it would be possible to have an equality between population and emission growth. This occurs when default and invariable values for the components of the gross energy intake are chosen for every inventory year (see Section 6.2.3.2 below).

63 Via an increase of one of the component of the gross energy intake: the net energy for lactation (see Section 6.2.3.2 below).

Milk yield and fat content

Table 6-7 – Milk yield and fat content of milk for dairy cattle: 1990-2006

Year	Milk yield *kg/cow/year*	Fat content of milk *%*
1990	4787	4.09%
1991	4767	4.16%
1992	5095	4.16%
1993	5345	4.22%
1994	5341	4.16%
1995	5527	4.20%
1996	5536	4.25%
1997	5700	4.23%
1998	5745	4.25%
1999	5909	4.20%
2000	6103	4.19%
2001	6293	4.17%
2002	6433	4.18%
2003	6579	4.20%
2004	6734	4.20%
2005	6856	4.19%
2006	6942	4.21%
Trend 1990-2006	*45.02%*	*NA*

Sources : SER: http://www.ser.public.lu/statistik/tier_produktion/milchliefermenge_erzeugerpreis_jahr.pdf

STATEC, *Statistical Yearbook*, Table C.2111: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1224

data extracted on 11 March 2008 (subject to changes since that date)

The milk yield is obtained by dividing the milk production by the number of dairy cows. It is measured in kg per head. 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).

Over the period 1990-2006, the milk yield has increased by a bit more than 45%. At the same time – see Table 6-5 above – the dairy cattle population declined by 34.4%. 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 21% increase since 1990 for the IEF expressed in CH_4/head/year – see Table 6-13 in Section 6.2.3.2.

Live-weight

Live-weight 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 6-8.

Table 6-8 – Live-weight for farm animals reported in the inventory

Livestock category	Live-weight in kg used for estimating enteric fermentation emissions	Comments
4A1 – Cattle – Mature Dairy Cattle	650.00	
4A1 – Cattle – Mature Non-Dairy Cattle – Females	700.00	
4A1 – Cattle – Mature Non-Dairy Cattle – Males	750.00	
4A1 – Cattle – Young Cattle – Calves	110.00	
4A1 – Cattle – Young Cattle – Growing Heifers	350.00	
4A2 – Buffalo	NO	
4A3 – Sheep	45.00	*This is a simple average between the estimated weights of a lamb (30 kg) and of a mature sheep (60 kg).*
4A4 – Goats	40.00	
4A5 – Camels & Llamas	NO	
4A6 – Horses	600.00	
4A7 – Mules & Asses	300.00	
4A8 – Swine	100.00	
4A9 – Poultry – Chickens	2.00	
4A10 – Other – Other Poultry	NE	*Not yet estimated in Luxembourg. Moreover, no default value was found in the literature.*
4A10 – Other – Rabbits	1.60	*Value taken from table 10A-9 of the 2006 IPCC Guidelines. It is obtained from the 2004 GHG inventory of Italy.*
4A10 – Other – Cervidae Species	120.00	*Value taken from table 10.10 of the 2006 IPCC Guidelines. It refers to deer.*

Source: SER, not published (provided on 1st June 2007), otherwise indicated.

6.2.3.2. 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:

$$IEF_i = [GE_i \bullet Ym_i \bullet 365] / 55.65$$

with i = each livestock category

IEF_i expressed in kg CH_4/head/year

the factor 55.65 expressed in MJ/kg of CH_4

➔ see equation 4.14 of the 2000 IPCC-GPG.

For the Tier 1 method, default GE are 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 6-9 indicates, for each animal category, which method has been used to estimate methane emissions as well as the corresponding IEF type.

Table 6-9 – Method and type of EF used in the inventory

Livestock category	Estimation method	IEF	Comments
4A1 – Cattle – Mature Dairy Cattle	T2	CS	*The IEF is CS because GE is obtained by combining national AD, default coefficients/parameters from the IPCC Guidelines and, in some cases, other country values.*
4A1 – Cattle – Mature Non-Dairy Cattle – Females	T2	CS	
4A1 – Cattle – Mature Non-Dairy Cattle – Males	T2	CS	
4A1 – Cattle – Young Cattle – Calves	T2	CS	
4A1 – Cattle – Young Cattle – Growing Heifers	T2	CS	
4A2 – Buffalo	NO	NO	
4A3 – Sheep	T1	D	
4A4 – Goats	T1	D	
4A5 – Camels & Llamas	NO	NO	
4A6 – Horses	T1	D	
4A7 – Mules & Asses	T1	D	
4A8 – Swine	T1	D	
4A9 – Poultry – Chickens	T1	OTH	*GE and Ym values used are obtained from the EC GHG inventory.*
4A10 – Other – Other Poultry	NE	NE	*There are no methods and default values provided in the literature for estimating emissions for this source category.*
4A10 – Other – Rabbits	T1	OTH	*GE and Ym values used are obtained from the 2004 GHG inventory of Italy.*
4A10 – Other – Cervidae Species	T1	D	*Value taken from table 10.10 of the 2006 IPCC Guidelines. It refers to deer in developed countries.*

Source: Ministry of the Environment.

Abbreviations:

T1 = Tier 1 T2 = Tier 2 CS = Country Specific D = IPCC Default OTH = Other

Tier 2 method – cattle

For dairy cattle, the IEF has been calculated by combining the following activity data, coefficients and parameters:

Table 6-10 – 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 & STATEC (updated 070214)	AD (see Table 6-5)
Live Weight	kg	SER, not published (provided 070601)	AD (see Table 6-8), invariable
Live Body Weight	kg	equation 7 – Revised 1996 IPCC Guidelines	calculated, invariable
Daily Weight Gain	kg/day	-	NA
Milk Yield	kg/cow/year	SER (updated 080311)	AD (see Table 6-7)
Daily Milk Production	kg/cow/day	-	calculated using 365.25 days/year
Fat Content of Milk	%	SER (updated 080311)	AD (see Table 6-7)
Digestible Energy	%	German value	invariable
Net Energy for Maintenance	MJ/day	equation 4.1 & table 4.4 – 2000 IPCC-GPG	calculated using the default coefficient for lactating cattle, invariable
Net Energy for Activity	MJ/day	equation 4.2a & table 4.5 – 2000 IPCC-GPG	calculated using the default cattle coefficient for pasture, invariable
Net Energy for Growth	MJ/day	equation 4.3a – 2000 IPCC-GPG	calculated, nil by definition
Net Energy due to Weight Loss	MJ/day	equation 4.4a – 2000 IPCC-GPG	NO
Net Energy for Lactation	MJ/day	equation 4.5a – 2000 IPCC-GPG	calculated using daily milk production
Net Energy for Work	MJ/day	equation 4.6 – 2000 IPCC-GPG	NO

Net Energy for Pregnancy	MJ/day	equation 4.8 & table 4.7 – 2000 IPCC-GPG	calculated using the default pregnancy coefficient for cattle and corrected by a factor of 0.9, invariable
Ratio of Net Energy in a Diet for Maintenance to Digestible Energy Consumed	#	equation 4.9 – 2000 IPCC-GPG	calculated, invariable
Ratio of Net Energy Available for Growth in a Diet to Digestible Energy Consumed	#	equation 4.10 – 2000 IPCC-GPG	calculated, invariable
Gross Energy Intake (average)	MJ/day	equation 4.11 – 2000 IPCC-GPG	calculated
CH_4 Conversion Rate (average)	%	table 4.8 – 2000 IPCC-GPG	default for developed countries

For other cattle sub-categories, the IEF has been calculated by combining the following activity data, coefficients and parameters:

Table 6-11 – Activity data, coefficients and parameters used for IPCC Sub-category 4A1 – Cattle – Non-Dairy Cattle

AD, parameter, coefficient	Unit	Source(s)	Type of value
Livestock (# of heads)	#	SER & STATEC (updated 070214)	AD (see Table 6-5)
Live Weight	kg	SER, not published (provided 070601)	AD (see Table 6-8), invariable
Live Body Weight	kg	equation 7 – Revised 1996 IPCC Guidelines	calculated, invariable for male & female non-dairy cattle, variable for young cattle (weighted averages of young cattle sub-categories default weights)
Daily Weight Gain	kg/day	- mature non-dairy cattle: NA - young cattle: SER, not published (provided 070601)	- NA - AD: 0.8 for calves and 0.6 for growing heifers
Digestible Energy	%	- mature non-dairy cattle: German value - young cattle: table A-2 – Revised 1996 IPCC Guidelines	- invariable - default for Western Europe
Net Energy for Maintenance	MJ/day	equation 4.1 & table 4.4 – 2000 IPCC-GPG	calculated using the default coefficient for non-lactating cattle, invariable
Net Energy for Activity	MJ/day	equation 4.2a & table 4.5 – 2000 IPCC-GPG	calculated using the default cattle coefficient for pasture, invariable
Net Energy for Growth	MJ/day	equation 4.3a – 2000 IPCC-GPG	calculated, nil by definition for mature non-dairy cattle
Net Energy due to Weight Loss	MJ/day	equation 4.4b – 2000 IPCC-GPG	NO
Net Energy for Lactation	MJ/day	equation 4.5a – 2000 IPCC-GPG	NA
Net Energy for Work	MJ/day	equation 4.6 – 2000 IPCC-GPG	NO
Net Energy for Pregnancy	MJ/day	equation 4.8 & table 4.7 – 2000 IPCC-GPG	calculated using the default pregnancy coefficient for female non-dairy cattle and corrected by a factor of 0.9, invariable (NA for male and young cattle)
Ratio of Net Energy in a Diet for Maintenance to Digestible Energy Consumed	#	equation 4.9 – 2000 IPCC-GPG	calculated, invariable
Ratio of Net Energy Available for Growth in a Diet to Digestible Energy Consumed	#	equation 4.10 – 2000 IPCC-GPG	calculated, invariable
Gross Energy Intake (average)	MJ/day	equation 4.11 – 2000 IPCC-GPG	calculated
CH_4 Conversion Rate (average)	%	table 4.8 – 2000 IPCC-GPG	default for developed countries

Note: variable values for live body weight explain why population and methane emission growths presented in Tables 6-5 and 6-6 differ slightly.

Tier 1 method – all farm animal categories except cattle

For farm animals, which are not cattle, the IEF is generally the default enteric fermentation EF for developed countries presented in Table 4-3 of the Revised 1996 IPCC Guidelines. More details are provided in Table 6-12.

Table 6-12 – Activity data, coefficients and parameters used for IPCC Sub-categories 4A3 to 4A10[64]

AD, parameter, coefficient	Unit	Source(s)	Type of value
Livestock (# of heads)	#	SER & STATEC (updated 070214)	AD (see Table 6-5)
Live Weight	kg	- 4A3 to 4A9: SER, not published (provided 070601) - 4A10 – rabbits: table 10A-9 – 2006 IPCC Guidelines (italian value) - 4A10 – cervidae species: table 10.10 – 2006 IPCC Guidelines (deer's value)	AD (see Table 6-8), invariable
Gross Energy Intake (average)	MJ/day	- 4A3 to 4A8: table A-4 – Revised 1996 IPCC Guidelines - 4A9: EC average value - 4A10 – rabbits: Italian reported value	- default for developed countries - invariable - invariable
CH_4 Conversion Rate (average)	%	- 4A3 to 4A8: table A-4 – Revised 1996 IPCC Guidelines - 4A9: EC average value - 4A10 – rabbits: Italian reported value	- default for developed countries - invariable - invariable

Notes:

If an animal category is not indicated, it means that the value is NE for that particular AD, parameter or coefficient.

When default values have been used for both GE and Ym, the IEF calculated equals the enteric fermentation EF provided for developed countries in table 4-3 of the Revised 1996 IPCC Guidelines.

For sub-categories 4A9 & 4A10 – rabbits, equation 4.14 of the 2000 IPCC-GPG has been used to calculate the IEF.

For sub-category 4A10 – cervidae species, the default EF for deer in developed countries presented in table 10.10 of the 2006 IPCC Guidelines has been used.

Methane IEFs for IPCC Category 4A – Enteric Fermentation

Table 6-13 presents the IEFs obtained for each farm animal category using the Tier 1 or Tier 2 methods described above.

For those animal categories for which no accurate data are available in official statistics for the years prior to 1997 (i.e. 4A4 and 4A10), it **has not been attempted** to "backcast" the methane emissions back to the base year, because:

- Not estimated (NE) emissions under- but not overestimate the base year GHG emissions;
- it would not make much sense to devote efforts for estimating the missing years since CH_4 emissions for the concerned animal categories are particularly low and almost negligible.

64 IPCC Sub-categories 4A2 – Buffalo and 4A5 – Camels & Llamas do not exist in Luxembourg.

Table 6-13 – CH_4 IEFs trends for IPCC Category 4A – Enteric Fermentation: 1990-2006

Year	IEF for CH_4 (kg CH_4/head/year) – Livestock category															
	4A1 Cattle - Mature Dairy Cattle	4A1 Non-Dairy Cattle	*4A1 Cattle - Mature Non-Dairy Cattle - Females*	*4A1 Cattle - Mature Non-Dairy Cattle - Males*	*4A1 Cattle - Young Cattle - Calves*	*4A1 Cattle - Young Cattle - Growing Heifers*	4A2 Buffalo	4A3 Sheep	4A4 Goats	4A5 Camels & Llamas	4A6 Horses	4A7 Mules & Asses	4A8 Swine	4A9 Poultry - Chickens	4A10 Other - Other Poultry	4A10 Other - Rabbits	4A10 Other - Cervidae Species
1990	105.36	40.97	*54.73*	*53.22*	*31.30*	*43.85*	NO	8.00	NE	NO	18.00	IE	1.50	0.01	NE	NE	NE
1991	105.59	41.33	*54.73*	*53.22*	*31.32*	*43.85*	NO	8.00	NE	NO	18.00	IE	1.50	0.01	NE	NE	NE
1992	108.83	41.46	*54.73*	*53.22*	*31.35*	*43.86*	NO	8.00	NE	NO	18.00	IE	1.50	0.01	NE	NE	NE
1993	111.71	41.63	*54.73*	*53.22*	*31.37*	*43.87*	NO	8.00	NE	NO	18.00	IE	1.50	0.01	NE	NE	NE
1994	111.27	41.55	*54.73*	*53.22*	*31.38*	*43.88*	NO	8.00	NE	NO	18.00	IE	1.50	0.01	NE	NE	NE
1995	113.39	41.83	*54.73*	*53.22*	*31.40*	*43.88*	NO	8.00	NE	NO	18.00	IE	1.50	0.01	NE	NE	NE
1996	113.82	41.87	*54.73*	*53.22*	*31.41*	*43.89*	NO	8.00	NE	NO	18.00	IE	1.50	0.01	NE	NE	NE
1997	115.32	41.94	*54.73*	*53.22*	*31.42*	*43.89*	NO	8.00	5.00	NO	18.00	IE	1.50	0.01	NE	0.01	20.00
1998	115.92	42.00	*54.73*	*53.22*	*31.42*	*43.90*	NO	8.00	5.00	NO	18.00	IE	1.50	0.01	NE	0.01	20.00
1999	117.18	42.06	*54.73*	*53.22*	*31.42*	*43.90*	NO	8.00	5.00	NO	18.00	IE	1.50	0.01	NE	0.01	20.00
2000	119.04	42.13	*54.73*	*53.22*	*31.43*	*43.90*	NO	8.00	5.00	NO	18.00	IE	1.50	0.01	NE	0.01	20.00
2001	120.76	42.24	*54.73*	*53.22*	*31.44*	*43.90*	NO	8.00	5.00	NO	18.00	IE	1.50	0.01	NE	0.01	20.00
2002	122.23	42.13	*54.73*	*53.22*	*31.45*	*43.91*	NO	8.00	5.00	NO	18.00	IE	1.50	0.01	NE	0.01	20.00
2003	123.85	42.14	*54.73*	*53.22*	*31.45*	*43.91*	NO	8.00	5.00	NO	18.00	IE	1.50	0.01	NE	0.01	20.00
2004	125.39	42.12	*54.73*	*53.22*	*31.45*	*43.91*	NO	8.00	5.00	NO	18.00	IE	1.50	0.01	NE	0.01	20.00
2005	126.51	42.28	*54.73*	*53.22*	*31.45*	*43.91*	NO	8.00	5.00	NO	18.00	10.00	1.50	0.01	NE	0.01	20.00
2006	127.54	42.23	*54.73*	*53.22*	*31.46*	*43.91*	NO	8.00	5.00	NO	18.00	10.00	1.50	0.01	NE	0.01	20.00
Trend 1990-2006	*21.05%*	*3.06%*	*NA*	*NA*	*0.50%*	*0.14%*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
IEF type	*CS*	*CS*	*CS*	*CS*	*CS*	*CS*	*NO*	*D*	*D*	*NO*	*D*	*D*	*D*	*OTH*	*NE*	*OTH*	*D*

Source: Ministry of the Environment.

Notes:

Accurate data on the population size for certain livestock categories (4A4 and 4A10) is only available since the 1997 census (hence the NE notation key).

Mules & asses were recorded together with horses (sub-category 4A6) up to and including 2004.

CS variable IEFs: the result of changing milk yields for dairy cattle and of changing live body weight for young cattle (other constituting parameters and coefficients show constant values).

CS invariable IEFs: the result of the use of constant values for live body weights as well as for other constituting parameters and coefficients.

6.2.4. Recalculations

See Tables 6-1 and 6-2 of Section 6.1.1.

6.2.5. Category specific QA/QC procedures

Consistency and completeness checks have been performed directly within the Microsoft Excel™ file that has been developed by the Ministry of the Environment to calculate 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 extensively discussed between the Ministry of the Environment and the sector experts, SER and ASTA.

6.2.6. Planned improvement

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 6-14 will be explored.

Table 6-14 – Planned improvements for IPCC Category 4A – Enteric Fermentation

GHG source & sink category	Planned improvement
4A – Enteric Fermentation	analyze whether it would be possible to replace some default parameter values – such as GE – by national values.
4A1 – Cattle: net energy for activity	refine the calculation for this parameter taking into account the time spent by animals in stalls and on pastures.
4A3 – Sheep: live-weight	national statistics allow for a breakdown of sheep between lambs and mature animals, hence allow for calculating a more precise live-weight for this animal category since estimated weights are known for both lambs and mature animals.
4A8 – Swine	national statistics allow for a breakdown of swine in various sub-categories for which more precise parameter values could be applied.
4A9 – Poultry – Chickens	national statistics allow for a breakdown of chickens in various sub-categories for which more precise parameter values could be applied.
4A10 – Other	investigate whether it would be worth, straightforward and not time/resources consuming to include the missing farm animals (ostriches, "productive animals").

6.3. Manure Management (IPCC Source Category 4B)

This section describes the estimation of methane and nitrous oxide emissions resulting from manure management. In 2006, this source category was responsible for a bit more than 18% of the total GHG emissions from the agriculture sector and it represented 0.94% of the total GHG emissions in CO_2e (excluding LULUCF). For each of the two gases reported, in 2006:

- CH_4 represented 30.5% of agricultural methane emissions and 22.5% of the total methane emissions estimated for Luxembourg;
- N_2O represented 5.9% of agricultural nitrous oxide emissions and a bit more than 3.15% of the total nitrous oxide emissions estimated for Luxembourg.

6.3.1. Key source

None of the source categories under manure management is a key source.

6.3.2. Source category description

Table 6-5 in Section 6.2.2 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, of course, identical to the population reported for enteric fermentation. Consequently, here too, livestock statistics are detailed enough to go for option B for cattle.

Looking at methane emissions from manure management – Table 6-15 – an increase by more than 22% can be observed for the period 1990-2006. Animals who did contribute the most of these emissions are cattle, swine and, to a lesser extent, chicken. For the other farm animal categories, methane emissions can be considered as negligible. Similarly to enteric fermentation methane related emissions, when a Tier 1 method has been applied to estimate methane emissions from manure management – i.e. for all animal categories except cattle (see Section 6.3.3) – population and methane emission growths are exactly the same.

Looking at nitrous oxide emissions from manure management – Table 6-16 – a decrease of almost 50% is observed for the period 1990-2006. These emissions are mainly due to cattle. However, if cattle were responsible for more than 95% of manure related N_2O emissions in 1990, this share dropped to 84% in 2006. This evolution is the result of a declining cattle population at the same time as other farm animal categories saw their number grow. Here too, for some livestock categories, the observed nitrous oxide emissions developments between 1990 and 2006 are identical to those of their population size: it is the case for all categories except cattle and swine. Since a Tier 1 method has been applied to estimate nitrous oxide emissions from manure management for **all** farm animal categories (see Section 6.3.4), the reason behind disparate growths lies elsewhere. In fact, for cattle, the inventory records varying values for some of the animal waste management systems (*AWMS*) as well as, for some cattle sub-categories, varying values for nitrogen excretion (see Table 6-25 in Section 6.3.4.1). For swine, nitrogen excretion is changing through time.

Actually, with regard to nitrous oxide, the CRF requires reporting emissions by AWMS categories rather than by livestock categories. As shown in Table 6-17, solid storage is the main source of N_2O (96% in 1990, 88% in 2006). In the same time, liquid system share tripled (from 3.9% to 10.2%). Another category is taking more and more importance, even if its share in the total AWMS related N_2O emissions remains modest: anaerobic digesters – recorded under "other AWMS" – for the production of biogas. Finally, anaerobic lagoons, daily spread and dry lots are AWMS that are not or barely existing in Luxembourg, hence the NO notation key.

Table 6-15 – CH_4 emission trends for IPCC Category 4B – Manure Management: 1990-2006

Year	*CH_4 emissions (Mg)* Livestock category																	
	4B1 Cattle - Mature Dairy Cattle	4B1 Non-Dairy Cattle	*4B1 Cattle - Mature Non-Dairy Cattle - Females*	*4B1 Cattle - Mature Non-Dairy Cattle - Males*	*4B1 Cattle - Young Cattle - Calves*	*4B1 Cattle - Young Cattle - Growing Heifers*	4B2 Buffalo	4B3 Sheep	4B4 Goats	4B5 Camels & Llamas	4B6 Horses	4B7 Mules & Asses	4B8 Swine	4B9 Poultry - Chickens	4B10 Other - Other Poultry	4B10 Other - Rabbits	4B10 Other - Cervidae Species	4B Total
1990	1 526.82	1 015.71	*156.04*	*37.45*	*281.20*	*541.02*	NO	1.35	NE	NO	2.39	IE	1 472.97	55.36	NE	NE	NE	4 074.60
1991	1 784.41	1 280.88	*217.47*	*46.97*	*339.80*	*676.65*	NO	1.43	NE	NO	2.53	IE	1 299.81	50.98	NE	NE	NE	4 420.05
1992	1 776.11	1 296.78	*230.99*	*41.30*	*337.50*	*686.99*	NO	1.28	NE	NO	2.54	IE	1 324.11	48.35	NE	NE	NE	4 449.19
1993	1 816.91	1 321.43	*248.96*	*41.78*	*339.78*	*690.90*	NO	1.26	NE	NO	2.67	IE	1 401.47	50.89	NE	NE	NE	4 594.62
1994	1 829.10	1 366.16	*271.82*	*38.87*	*365.31*	*690.17*	NO	1.44	NE	NO	2.94	IE	1 343.97	48.49	NE	NE	NE	4 592.09
1995	1 891.87	1 451.60	*295.27*	*46.12*	*370.28*	*739.93*	NO	1.40	NE	NO	3.00	IE	1 417.86	44.61	NE	NE	NE	4 810.35
1996	1 873.95	1 493.21	*307.35*	*47.31*	*380.15*	*758.40*	NO	1.33	NE	NO	3.05	IE	1 415.01	49.62	NE	NE	NE	4 836.17
1997	1 889.79	1 506.20	*305.50*	*53.70*	*378.09*	*768.91*	NO	1.48	0.04	NO	3.18	IE	1 505.88	53.18	0.15	0.58	0.04	4 960.52
1998	1 951.59	1 528.06	*314.09*	*52.44*	*379.11*	*782.42*	NO	1.53	0.03	NO	3.25	IE	1 588.70	54.84	0.11	0.54	0.06	5 128.70
1999	2 180.20	1 703.53	*366.41*	*53.42*	*423.46*	*860.24*	NO	1.52	0.03	NO	3.90	IE	1 675.32	49.78	0.08	0.49	0.07	5 614.93
2000	2 092.42	1 658.15	*367.40*	*47.64*	*410.43*	*832.68*	NO	1.48	0.03	NO	4.37	IE	1 564.28	57.58	0.07	0.53	0.08	5 378.99
2001	2 052.64	1 621.51	*363.43*	*51.10*	*395.94*	*811.04*	NO	1.57	0.04	NO	4.33	IE	1 533.03	67.63	0.08	0.52	0.07	5 281.42
2002	2 013.87	1 513.02	*349.67*	*43.44*	*384.16*	*735.75*	NO	1.69	0.13	NO	4.32	IE	1 554.99	62.54	0.07	0.56	0.07	5 151.25
2003	1 899.93	1 390.99	*321.22*	*37.88*	*350.88*	*681.00*	NO	1.75	0.22	NO	4.78	IE	1 642.33	63.60	0.08	0.52	0.05	5 004.25
2004	1 837.75	1 323.94	*306.99*	*34.24*	*335.92*	*646.79*	NO	1.81	0.23	NO	5.11	IE	1 651.53	58.64	0.08	0.53	0.06	4 879.68
2005	1 874.63	1 351.94	*319.80*	*33.68*	*332.79*	*665.68*	NO	1.90	0.26	NO	5.64	0.09	1 759.58	66.90	0.09	0.52	0.05	5 061.61
2006	1 897.74	1 371.36	*326.30*	*31.80*	*342.22*	*671.04*	NO	1.79	0.23	NO	5.77	0.13	1 642.55	65.17	0.09	0.55	0.05	4 985.43
Trend 1990-2006	*24.29%*	*35.01%*	*109.12%*	*-15.08%*	*21.70%*	*24.03%*	*NA*	*32.45%*	*441.67%*	*NA*	*141.64%*	*44.63%*	*11.51%*	*17.72%*	*-40.47%*	*-5.52%*	*40.23%*	*22.35%*

Table 6-16 – N_2O emission trends for IPCC Category 4B – Manure Management: 1990-2006 by livestock category

Year	*N_2O emissions (Mg)* Livestock category																	
	4B1 Cattle - Mature Dairy Cattle	4B1 Non-Dairy Cattle	*4B1 Cattle - Mature Non-Dairy Cattle - Females*	*4B1 Cattle - Mature Non-Dairy Cattle - Males*	*4B1 Cattle - Young Cattle - Calves*	*4B1 Cattle - Young Cattle - Growing Heifers*	4B2 Buffalo	4B3 Sheep	4B4 Goats	4B5 Camels & Llamas	4B6 Horses	4B7 Mules & Asses	4B8 Swine	4B9 Poultry - Chickens	4B10 Other - Other Poultry	4B10 Other - Rabbits	4B10 Other - Cervidae Species	4B Total
1990	52.11	73.14	*15.10*	*3.73*	*17.60*	*36.72*	NO	1.56	NE	NO	1.16	NE	2.35	0.68	NE	NE	NE	131.00
1991	40.77	66.11	*14.98*	*3.33*	*15.05*	*32.75*	NO	1.65	NE	NO	1.23	NE	2.10	0.63	NE	NE	NE	112.49
1992	35.40	61.49	*14.58*	*2.68*	*13.74*	*30.49*	NO	1.48	NE	NO	1.24	NE	2.17	0.60	NE	NE	NE	102.38
1993	34.12	61.15	*15.27*	*2.63*	*13.43*	*29.82*	NO	1.45	NE	NO	1.30	NE	2.28	0.63	NE	NE	NE	100.93
1994	31.81	58.97	*15.62*	*2.30*	*13.48*	*27.58*	NO	1.66	NE	NO	1.43	NE	2.18	0.60	NE	NE	NE	96.66
1995	33.64	60.23	*16.24*	*2.61*	*13.06*	*28.31*	NO	1.61	NE	NO	1.46	NE	2.31	0.55	NE	NE	NE	99.80
1996	33.19	62.08	*16.91*	*2.68*	*13.41*	*29.08*	NO	1.53	NE	NO	1.48	NE	2.25	0.61	NE	NE	NE	101.14
1997	30.63	58.20	*15.74*	*2.85*	*12.21*	*27.41*	NO	1.71	0.08	NO	1.55	NE	2.40	0.66	0.07	1.84	0.02	97.15
1998	28.73	54.99	*15.04*	*2.58*	*11.41*	*25.95*	NO	1.76	0.06	NO	1.58	NE	2.44	0.68	0.05	1.72	0.03	92.04
1999	22.15	46.81	*13.38*	*2.01*	*9.61*	*21.82*	NO	1.76	0.06	NO	1.90	NE	2.57	0.61	0.03	1.56	0.04	77.50
2000	20.93	45.91	*13.50*	*1.80*	*9.38*	*21.23*	NO	1.70	0.06	NO	2.13	NE	2.43	0.71	0.03	1.69	0.04	75.63
2001	20.57	45.97	*13.66*	*1.98*	*9.17*	*21.16*	NO	1.81	0.07	NO	2.11	NE	2.45	0.83	0.03	1.67	0.04	75.55
2002	19.61	42.94	*13.13*	*1.68*	*8.89*	*19.23*	NO	1.95	0.24	NO	2.10	NE	2.45	0.77	0.03	1.78	0.04	71.91
2003	21.14	42.10	*12.87*	*1.56*	*8.76*	*18.91*	NO	2.02	0.40	NO	2.33	NE	2.57	0.78	0.03	1.66	0.03	73.06
2004	20.82	41.38	*12.72*	*1.46*	*8.61*	*18.58*	NO	2.08	0.43	NO	2.49	NE	2.99	0.72	0.04	1.68	0.03	72.66
2005	19.40	40.04	*12.50*	*1.35*	*8.19*	*17.99*	NO	2.20	0.47	NO	2.75	0.06	3.18	0.83	0.04	1.66	0.03	70.65
2006	17.99	38.25	*12.02*	*1.21*	*7.99*	*17.04*	NO	2.06	0.42	NO	2.81	0.09	2.97	0.80	0.04	1.74	0.03	67.21
Trend 1990-2006	*-65.48%*	*-47.70%*	*-20.37%*	*-67.66%*	*-54.61%*	*-53.60%*	*NA*	*32.45%*	*441.67%*	*NA*	*141.64%*	*44.63%*	*26.39%*	*17.72%*	*-40.47%*	*-5.52%*	*40.23%*	*-48.70%*

Source for Tables 6-15 and 6-16: Ministry of the Environment.

Notes for Tables 6-15 and 6-16:
Accurate data on the population size for certain livestock categories (4B4 and 4B10) is only available since the 1997 census (hence the NE notation key).

Mules & asses were recorded together with horses (sub-category 4B6) up to and including 2004.

N_2O emissions by livestock category excludes emissions from pasture, range & paddock (*PRP*) since they have to be accounted for in IPCC Sub-category 4D2 – Emissions from PRP Manure.

Table 6-17 – N_2O emission trends for IPCC Category 4B – Manure Management: 1990-2006 per AWMS

Year	N_2O emissions (Mg) AWMS category: Anaerobic Lagoon	Liquid System	Daily Spread	Solid Storage	Dry Lot	*Pasture, Range & Paddock (PRP)*	Other AWMS (anaerobic digester)	Total (excl. PRP)
1990	NO	5.07	NO	125.86	NO	*188.94*	0.08	131.00
1991	NO	5.94	NO	106.48	NO	*190.61*	0.07	112.49
1992	NO	5.97	NO	96.34	NO	*181.38*	0.07	102.38
1993	NO	6.08	NO	94.77	NO	*181.35*	0.07	100.93
1994	NO	6.16	NO	90.42	NO	*180.06*	0.07	96.66
1995	NO	6.68	NO	93.05	NO	*190.65*	0.07	99.80
1996	NO	6.72	NO	94.35	NO	*193.44*	0.07	101.14
1997	NO	6.80	NO	90.27	NO	*188.30*	0.08	97.15
1998	NO	6.96	NO	85.00	NO	*186.09*	0.08	92.04
1999	NO	7.72	NO	69.69	NO	*185.55*	0.08	77.50
2000	NO	7.41	NO	67.96	NO	*182.98*	0.26	75.63
2001	NO	7.25	NO	67.85	NO	*183.17*	0.45	75.55
2002	NO	6.94	NO	64.36	NO	*176.91*	0.61	71.91
2003	NO	6.73	NO	65.54	NO	*176.00*	0.79	73.06
2004	NO	6.66	NO	65.05	NO	*173.50*	0.95	72.66
2005	NO	6.86	NO	62.83	NO	*173.65*	0.96	70.65
2006	NO	6.82	NO	59.44	NO	*171.50*	0.94	67.21
Trend 1990-2006	*NA*	*34.71%*	*NA*	*-52.77%*	*NA*	*-8.92%*	*1122.72%*	*-48.70%*

Source: Ministry of the Environment.

Note: N_2O emissions from pasture, range & paddock (*PRP*) are excluded from the total N_2O emissions in IPCC Category 4B since they have to be accounted for in IPCC Sub-category 4D2 – Emissions from PRP Manure.

Combining both gases – CH_4 and N_2O – manure management related emissions, expressed in CO_2e, remained fairly stable between 1990 and 2006: 125.28 Gg CO_2e in 2006, i.e. 0.51% lower than the value obtained for the base year (126.18 Gg CO_2e) – see Table 6-18. Beside livestock population developments, the methane emission increase is mainly driven by the changes in the AWMS for cattle: the liquid system share in AWMS went from 23% to about 38% for dairy cattle and from 18.9% to 28.9% for non-dairy cattle.[65] Now, liquid system is the AWMS that has the highest methane conversion factor: 39%. This explains why, despite a decreasing cattle population, related CH_4 emissions did rise over the period 1990-2006. Nevertheless, at the end of the day, the higher variation in absolute terms recorded for nitrous oxide between 1990 and 2006 counterbalanced the increasing methane emissions from manure management (|48.70%| for N_2O and |22.35%| for CH_4), leading to a, nowadays, fairly stable emission trend for manure management.[66]

65 See also above: liquid system share in AWMS tripled over the period.

66 A peak was reached in 1999 with regard to manure management GHG related emissions (see also Figure 6-2 in Section 6.1.3 above).

Table 6-18 – CH_4 & N_2O emission trends for IPCC Category 4B – Manure Management: 1990-2006

Year	*CO_2e emissions (Gg)* 4B - Manure Management		
	CH_4	N_2O	Total
1990	85.57	40.61	126.18
1991	92.82	34.87	127.69
1992	93.43	31.74	125.17
1993	96.49	31.29	127.77
1994	96.43	29.96	126.40
1995	101.02	30.94	131.96
1996	101.56	31.35	132.91
1997	104.17	30.12	134.29
1998	107.70	28.53	136.24
1999	117.91	24.02	141.94
2000	112.96	23.45	136.40
2001	110.91	23.42	134.33
2002	108.18	22.29	130.47
2003	105.09	22.65	127.74
2004	102.47	22.53	125.00
2005	106.29	21.90	128.20
2006	104.69	20.83	125.53
Trend 1990-2006	*22.35%*	*-48.70%*	*-0.51%*

Source: Ministry of the Environment.

Note: N_2O emissions from pasture, range & paddock (*PRP*) are excluded from the total N_2O emissions in IPCC Category 4B since they have to be accounted for in IPCC Sub-category 4D2 – Emissions from PRP Manure.

6.3.3. Methodological issues – methane emissions

The IPCC Tier 1 method has been applied to all farm animal categories with the exception of cattle (IPCC Sub-category 4B1) for which a Tier 2 method has been used together with option B. It should be underlined that, essentially, the same calculation method characterizes both tiers. What distinguishes one tier from the other is the fact that, for cattle, 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 6.2.3.2).

6.3.3.1. Activity data

The only activity data that have been extracted from national statistics are those relating to the livestock population: see Table 6-5 in Section 6.2.2.

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 6-8 in Section 6.2.3.1) 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 Tables 6-22 and 6-23 on activity data, parameters and coefficients used).

ASTA provided an expert judgement 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 various information and its knowledge on agricultural practices in Luxembourg. These percentages are presented in the Table 6-19.

Table 6-19 – AWMS per livestock category: estimates for the year 2004

Livestock category	AWMS						
	Anaerobic Lagoon	Liquid System	Daily Spread	Solid Storage	Dry Lot	PRP	Other: Anaerobic Digester
4B1 – Cattle – Mature Dairy Cattle	NO	35.75%	NO	14.25%	NO	45.00%	5.00%
4B1 – Cattle – Mature Non-Dairy Cattle – Females	NO	27.50%	NO	17.50%	NO	50.00%	5.00%
4B1 – Cattle – Mature Non-Dairy Cattle – Males	NO	27.50%	NO	17.50%	NO	50.00%	5.00%
4B1 – Cattle – Young Cattle – Calves	NO	27.50%	NO	17.50%	NO	50.00%	5.00%
4B1 – Cattle – Young Cattle – Growing Heifers	NO	27.50%	NO	17.50%	NO	50.00%	5.00%
4B2 – Buffalo	NO	NO	NO	NO	NO	NO	NO
4B3 – Sheep	NO	NO	NO	40.00%	NO	60.00%	NO
4B4 – Goats	NO	NO	NO	40.00%	NO	60.00%	NO
4B5 – Camels & Llamas	NO	NO	NO	NO	NO	NO	NO
4B6 – Horses	NO	NO	NO	40.00%	NO	60.00%	NO
4B7 – Mules & Asses	NO	NO	NO	40.00%	NO	60.00%	NO
4B8 – Swine	NO	90.00%	NO	5.00%	NO	NO	5.00%
4B9 – Poultry – Chickens	NO	25.00%	NO	50.00%	NO	NO	25.00%
4B10 – Other – Other Poultry	NO	NO	NO	100.00%	NO	NO	NO
4B10 – Other – Rabbits	NO	NO	NO	100.00%	NO	NO	NO
4B10 – Other – Cervidae Species	NO	NO	NO	10.00%	NO	90.00%	NO

Source: ASTA expert judgement (not published): prepared on 7 June 2007.

Note: for the other livestock categories (4B10), percentages are first expert judgements discussed between the SER and the Ministry of the Environment.

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;
- PRP: this system is present around 6 months/year when the animals are grazing (summer season);
- anaerobic digester: biogas installations are more and more frequent at farms (and/or manure is more regularly collected to supply municipal or private biomethanization units). Hence, if the percentages presented in Table 6-19 could be seen as reasonable for the latest years, this would not be the case for the early 1990s. However, the choice of the methane conversion factor for anaerobic digester solves that issue (see Tables 6-22 and 6-23).[67]

67 Most of the installations producing biogas from manure are operating in Luxembourg since around the year 2000. Consequently, being new, they are usually very efficient and a gas tight coverage is present (expert judgement). Therefore emissions to be accounted for in CRF Sector 4 (leakages, as well as emissions due to storage in the digester) are very low (the methane produced should be recorded under the energy sector). Hence, it has been decided to use a methane conversion factor of 0% for anaerobic digester. It is a conservative estimate reducing/limiting our emissions for the base year.

Consequently, due to the uncertainty going along with the first AWMS expert judgement, ASTA and SER decided to improve the AWMS breakdown for the main emitting animal category, i.e. cattle.[68] The result of this exercise is presented in Table 6-20.

Table 6-20 – Revised AWMS for cattle

Year	AWMS			
	Liquid System	Solid Storage	PRP	Other: Anaerobic Digester
4B1 – Cattle – Mature Dairy Cattle				
1990	23.00%	32.00%	45.00%	0.00%
1991	29.00%	26.00%	45.00%	0.00%
1992	30.60%	24.40%	45.00%	0.00%
1993	31.10%	23.90%	45.00%	0.00%
1994	32.30%	22.70%	45.00%	0.00%
1995	33.10%	21.90%	45.00%	0.00%
1996	33.10%	21.90%	45.00%	0.00%
1997	34.20%	20.80%	45.00%	0.00%
1998	35.50%	19.50%	45.00%	0.00%
1999	40.30%	14.70%	45.00%	0.00%
2000	39.60%	14.40%	45.00%	1.00%
2001	38.70%	14.30%	45.00%	2.00%
2002	38.20%	13.80%	45.00%	3.00%
2003	36.80%	14.20%	45.00%	4.00%
2004	35.75%	14.25%	45.00%	5.00%
2005	36.70%	13.30%	45.00%	5.00%
2006	37.60%	12.40%	45.00%	5.00%
4B1 – Cattle – Mature Non-Dairy Cattle				
1990	18.90%	31.10%	50.00%	0.00%
1991	23.50%	26.50%	50.00%	0.00%
1992	24.70%	25.30%	50.00%	0.00%
1993	25.10%	24.90%	50.00%	0.00%
1994	26.00%	24.00%	50.00%	0.00%
1995	26.60%	23.40%	50.00%	0.00%
1996	26.60%	23.40%	50.00%	0.00%
1997	27.50%	22.50%	50.00%	0.00%
1998	28.50%	21.50%	50.00%	0.00%
1999	32.10%	17.90%	50.00%	0.00%
2000	31.40%	17.60%	50.00%	1.00%
2001	30.50%	17.50%	50.00%	2.00%
2002	29.90%	17.10%	50.00%	3.00%
2003	28.50%	17.50%	50.00%	4.00%
2004	27.50%	17.50%	50.00%	5.00%
2005	28.20%	16.80%	50.00%	5.00%
2006	28.90%	16.10%	50.00%	5.00%

68 Another livestock category which is responsible for relatively high methane emissions is sub-category 4B8 – Swine. However, it has not yet been possible to perform an exercise similar to the one for cattle for this sub-category.

4B1 – Cattle – Young Cattle				
1990	18.90%	31.10%	50.00%	0.00%
1991	23.50%	26.50%	50.00%	0.00%
1992	24.70%	25.30%	50.00%	0.00%
1993	25.10%	24.90%	50.00%	0.00%
1994	26.00%	24.00%	50.00%	0.00%
1995	26.60%	23.40%	50.00%	0.00%
1996	26.60%	23.40%	50.00%	0.00%
1997	27.50%	22.50%	50.00%	0.00%
1998	28.50%	21.50%	50.00%	0.00%
1999	32.10%	17.90%	50.00%	0.00%
2000	31.40%	17.60%	50.00%	1.00%
2001	30.50%	17.50%	50.00%	2.00%
2002	29.90%	17.10%	50.00%	3.00%
2003	28.50%	17.50%	50.00%	4.00%
2004	27.50%	17.50%	50.00%	5.00%
2005	28.20%	16.80%	50.00%	5.00%
2006	28.90%	16.10%	50.00%	5.00%

Source: SER & ASTA calculations (not published): prepared on 19 June 2007.

These revised AWMS shares for cattle were produced by SER using information collected in the framework of the yearly agricultural census.[69] Cowshed numbers and capacity (in number of heads) are known for various types of cowsheds. On this basis, an estimated share of the liquid system was possible. For PRP, the first expert judgement formulated by ASTA has been kept (Table 6-19). For anaerobic digesters, the hypothesis has been made that specific manure collection started around the year 2000 and has been increasing since then to reach the first expert judgement value of 5%. Finally, solid storage has been deduced from the other three AWMS estimates.

As a result, the following AWMS shares are reported in Luxembourg's GHG inventory:

- for IPCC Sub-category 4B1: shares recorded in Table 6-20 (with the same percentages for both females and males mature non-dairy cattle, on the one hand, and the same percentages for both calves and growing heifers, on the other hand);
- for the other IPCC Sub-categories (4B3 to 4B10): first expert judgement recorded in Table 6-19.

6.3.3.2. 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^3CH_4/kg of VS) and the sum of the fractions of animals by AWMS (in %) multiplied by their corresponding methane conversion factor (*MCF* in %):

69 See http://www.ser.public.lu/statistik/agrarstrukturen/statec_15_mai_pluriannuel.pdf, section 3.2.

$$IEF_i = VS_i \bullet 365 \bullet Bo_i \bullet 0.67 \bullet [\sum_j MCF_j \bullet AWMS_{ij}]$$

with j = the various AWMS identified for each livestock category i

IEF_i expressed in kg CH_4/head/year

the factor 0.67 expressed in kg/m^3

➔ see equation 4.17 of the 2000 IPCC-GPG.

For most of the farm animal categories, VS is calculated using equation 4.16 of the 2000 IPCC-GPG 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 6-21 indicates, for each animal category, which method has been used to estimate methane emissions as well as the corresponding IEF type.

Table 6-21 – Method and type of EF used in the inventory

Livestock category	Estimation method	IEF	Comments
4B1 – Cattle – Mature Dairy Cattle	T2	CS	*The IEF is CS because GE and DE are obtained by combining national AD, default coefficients/parameters from the IPCC Guidelines and, in some cases, other country values.*
4B1 – Cattle – Mature Non-Dairy Cattle – Females	T2	CS	
4B1 – Cattle – Mature Non-Dairy Cattle – Males	T2	CS	
4B1 – Cattle – Young Cattle – Calves	T2	CS	
4B1 – Cattle – Young Cattle – Growing Heifers	T2	CS	
4B2 – Buffalo	NO	NO	
4B3 – Sheep	T1	D	*VS calculated but equal to the default value provided for developed countries in table B-7 of the Revised 1996 IPCC Guidelines.*
4B4 – Goats	T1	D	
4B5 – Camels & Llamas	NO	NO	
4B6 – Horses	T1	D	*VS calculated but equal to the default value provided for developed countries in table B-7 of the Revised 1996 IPCC Guidelines.*
4B7 – Mules & Asses	T1	D	
4B8 – Swine	T1	D	*VS calculated but equal to the default value provided for Western Europe in table B-6 of the Revised 1996 IPCC Guidelines.*
4B9 – Poultry – Chickens	T1	D	*VS for developed countries directly taken from table B-7 of the Revised 1996 IPCC Guidelines.*
4B10 – Other – Other Poultry	T1	D	
4B10 – Other – Rabbits	T1	D	*Value taken from table 10.16 of the 2006 IPCC Guidelines.*
4B10 – Other – Cervidae Species	T1	D	*Value taken from table 10.16 of the 2006 IPCC Guidelines. It refers to deer.*

Source: Ministry of the Environment.

Abbreviations:

T1 = Tier 1 T2 = Tier 2 CS = Country Specific D = IPCC Default

Tier 2 method – cattle

For cattle, the IEF has been calculated by combining the following activity data, coefficients and parameters:

Table 6-22 – Activity data, coefficients and parameters used for IPCC Sub-category 4B1 – Cattle

AD, parameter, coefficient	Unit	Source(s)	Type of value
Livestock (# of heads)	#	SER & STATEC (updated 070214)	AD (see Table 6-5)
Live Weight	kg	SER, not published (provided 070601)	AD (see Table 6-8), invariable
Gross Energy Intake (average)	MJ/day	equation 4.11 – 2000 IPCC-GPG	calculated
Digestible Energy	%	- mature dairy & non-dairy cattle: German value - young cattle: table A-2 – 1996 Revised IPCC Guidelines	- invariable - 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 4.16 – 2000 IPCC-GPG	calculated
CH_4 Producing Potential	m^3CH_4/kg VS	table B-1 – 1996 Revised IPCC Guidelines	default for Western Europe
Manure System/AWMS	%	SER & ASTA, not published (prepared 070619)	expert judgement (see Table 6-20), invariable for PRP
CH_4 Conversion Factor	%	- table 4.10 – 2000 IPCC-GPG	default for a cool region, except for anaerobic digester (0%) for which an expert judgement has been applied

Tier 1 method – all farm animal categories except cattle

For farm animals that are not cattle, the IEF is generally the default manure management EF for a cool region in developed countries presented in Table 4-5 of the Revised 1996 IPCC Guidelines. More details are provided in Table 6-23.

Table 6-23 – Activity data, coefficients and parameters used for IPCC Sub-categories 4B3 to 4B10[70]

AD, parameter, coefficient	Unit	Source(s)	Type of value
Livestock (# of heads)	#	SER & STATEC (updated 070214)	AD (see Table 6-5)
Live Weight	kg	- 4B3 to 4B9: SER, not published (provided 070601) - 4B10 – rabbits: table 10A-9 – 2006 IPCC Guidelines (italian value) - 4B10 – cervidae species: table 10.10 – 2006 IPCC Guidelines (deer's value)	AD (see Table 6-8), invariable
Gross Energy Intake (average)	MJ/day	- 4B3 to 4B8: table A-4 – Revised 1996 IPCC Guidelines - 4B9: EC average value - 4B10 – rabbits: Italian reported value	- default for developed countries - invariable - invariable
Digestible Energy	%	- 4B3 to 4B7: table B-7 – Revised 1996 IPCC Guidelines - 4B8: table B-2 – Revised 1996 IPCC Guidelines	default for developed countries
Ash Content of the Manure	%	- 4B3 to 4B7: table B-7 – Revised 1996 IPCC Guidelines - 4B8: table B-2 – 1996 Revised IPCC Guidelines	default for developed countries
Volatile Solid Daily Excretion	kg-dm/day	- 4B3 to 4B8: equation 4.16 – 2000 IPCC-GPG - 4B9 & 4B10 – other poultry: table B-7 – Revised 1996 IPCC Guidelines	- calculated - default for developed countries
CH_4 Producing Potential	m^3CH_4/kg VS	- 4B3 to 4B7, 4B9, 4B10 – other poultry: table B-7 – Revised 1996 IPCC Guidelines - 4B8: table B-2 – Revised 1996 IPCC Guidelines	default for developed countries

70 CRF Categories 4B2 – Buffalo and 4B5 – Camels & Llamas do not exist in Luxembourg.

Manure System/AWMS	%	- 4B3 to 4B9: SER & ASTA, not published (prepared 070607) - 4B10: SER & Ministry of the Environment	expert judgement (see Table 6-19), invariable
CH_4 Conversion Factor	%	table 4.10 – 2000 IPCC-GPG	default for a cool region, except for anaerobic digester (0%) for which an expert judgement has been applied

Notes:

If an animal category is not indicated, it means that the value is NE for that particular AD, parameter or coefficient.

When default values were used for GE, DE and ASH, the VS calculated equals the default VS provided for developed countries in table B-6 (4B8) and B-7 (4B3 to 4B7) of the Revised 1996 IPCC Guidelines.

Methane IEFs for IPCC Category 4B – Manure Management

Table 6-24 presents the IEFs obtained for each farm animal category using the Tier 1 or Tier 2 methods described above.

For those animal categories for which no accurate data are available in official statistics for the years prior to 1997 (i.e. 4B4 and 4B10), it **has not been attempted** to "backcast" the methane emissions back to the base year, because:

- Not estimated (NE) emissions under- but not overestimate the base year GHG emissions;
- it would not make much sense to devote efforts for estimating the missing years since CH_4 emissions for the concerned animal categories are particularly low and almost negligible.

6.3.4. Methodological issues – nitrous oxide emissions

The IPCC Tier 1 method has been applied to all farm animal categories.

6.3.4.1. Activity data

The following activity data were used to calculate N_2O emissions per AWMS and animal category:

- livestock population extracted from national statistics: see Table 6-5 in Section 6.2.2;
- AWMS shares per animal category: see Tables 6-19 and 6-20 in Section 6.3.3.1;
- yearly nitrogen excretion (Nex_i) per head for each animal category i: see Table 6-25.

Table 6-24 – CH_4 IEFs trends for IPCC Category 4B – Manure Management: 1990-2006

Year	IEF for CH_4 (kg CH_4/head/year) – Livestock category																
	4B1 Cattle - Mature Dairy Cattle	4B1 Non-Dairy Cattle	*4B1 Cattle - Mature Non-Dairy Cattle - Females*	*4B1 Cattle - Mature Non-Dairy Cattle - Males*	*4B1 Cattle - Young Cattle - Calves*	*4B1 Cattle - Young Cattle - Growing Heifers*	4B2 Buffalo	4B3 Sheep	4B4 Goats	4B5 Camels & Llamas	4B6 Horses	4B7 Mules & Asses	4B8 Swine	4B9 Poultry - Chickens	4B10 Other - Other Poultry	4B10 Other - Rabbits	4B10 Other - Cervidae Species
1990	25.95	6.40	*7.08*	*6.88*	*4.72*	*7.56*	NO	0.19	NE	NO	1.39	IE	19.52	0.80	NE	NE	NE
1991	32.09	7.81	*8.59*	*8.35*	*5.73*	*9.18*	NO	0.19	NE	NO	1.39	IE	19.52	0.80	NE	NE	NE
1992	34.75	8.20	*8.98*	*8.74*	*6.00*	*9.60*	NO	0.19	NE	NO	1.39	IE	19.52	0.80	NE	NE	NE
1993	36.21	8.33	*9.11*	*8.86*	*6.10*	*9.74*	NO	0.19	NE	NO	1.39	IE	19.52	0.80	NE	NE	NE
1994	37.35	8.55	*9.41*	*9.15*	*6.30*	*10.06*	NO	0.19	NE	NO	1.39	IE	19.52	0.80	NE	NE	NE
1995	38.93	8.78	*9.61*	*9.34*	*6.43*	*10.27*	NO	0.19	NE	NO	1.39	IE	19.52	0.80	NE	NE	NE
1996	39.08	8.78	*9.61*	*9.34*	*6.43*	*10.27*	NO	0.19	NE	NO	1.39	IE	19.52	0.80	NE	NE	NE
1997	40.81	9.07	*9.90*	*9.63*	*6.63*	*10.59*	NO	0.19	0.12	NO	1.39	IE	19.52	0.80	0.08	0.08	0.22
1998	42.47	9.39	*10.23*	*9.95*	*6.85*	*10.94*	NO	0.19	0.12	NO	1.39	IE	19.52	0.80	0.08	0.08	0.22
1999	48.34	10.47	*11.42*	*11.10*	*7.65*	*12.21*	NO	0.19	0.12	NO	1.39	IE	19.52	0.80	0.08	0.08	0.22
2000	48.27	10.25	*11.18*	*10.87*	*7.49*	*11.95*	NO	0.19	0.12	NO	1.39	IE	19.52	0.80	0.08	0.08	0.22
2001	47.90	9.99	*10.87*	*10.57*	*7.29*	*11.63*	NO	0.19	0.12	NO	1.39	IE	19.52	0.80	0.08	0.08	0.22
2002	47.86	9.75	*10.67*	*10.37*	*7.15*	*11.41*	NO	0.19	0.12	NO	1.39	IE	19.52	0.80	0.08	0.08	0.22
2003	46.80	9.33	*10.20*	*9.92*	*6.84*	*10.91*	NO	0.19	0.12	NO	1.39	IE	19.52	0.80	0.08	0.08	0.22
2004	46.08	9.02	*9.86*	*9.59*	*6.61*	*10.55*	NO	0.19	0.12	NO	1.39	IE	19.52	0.80	0.08	0.08	0.22
2005	47.65	9.26	*10.09*	*9.81*	*6.76*	*10.79*	NO	0.19	0.12	NO	1.39	0.76	19.52	0.80	0.08	0.08	0.22
2006	49.14	9.46	*10.32*	*10.04*	*6.92*	*11.04*	NO	0.19	0.12	NO	1.39	0.76	19.52	0.80	0.08	0.08	0.22
Trend 1990-2006	*89.38%*	*47.67%*	*45.83%*	*45.83%*	*46.56%*	*46.03%*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
IEF type	*CS*	*CS*	*CS*	*CS*	*CS*	*CS*	*NO*	*D*	*D*	*NO*	*D*	*D*	*D*	*D*	*D*	*D*	*D*

Source: Ministry of the Environment.

Notes:

Accurate data on the population size for certain livestock categories (4B4 and 4B10) is only available since the 1997 census (hence the NE notation key).

Mules & asses were recorded together with horses (sub-category 4B6) up to and including 2004.

CS variable IEFs: the result of changing VS and manure systems for liquid and solid storages for dairy and young cattle and of manure systems for liquid and solid storages for mature non-dairy cattle (other constituting parameters and coefficients show constant values).

Table 6-25 – Nitrogen excretion for farm animals reported in the inventory

Livestock category	Nitrogen excretion *N/head/year*	Comments
4B1 – Cattle – Mature Dairy Cattle	85.00 93.50 102.00	*85.00 for a milk yield < 5500 kg/cow/year;* *93.50 for a milk yield comprises between 5500 & 6500 kg/cow/year;* *102.00 for a milk yield > 6500 kg/cow/year.*
4B1 – Cattle – Mature Non-Dairy Cattle – Females	68.00	
4B1 – Cattle – Mature Non-Dairy Cattle – Males	68.00	
4B1 – Cattle – Young Cattle – Calves	[28.08;29.34]	*weighted average using population size:* *Nex_i = 12.10 for calves for slaughter;* *Nex_i = 29.75 for other calves.*
4B1 – Cattle – Young Cattle – Growing Heifers	[50.11;51.16]	*weighted average using population size:* *Nex_i = 42.00 for bovine from 1 to 2 years;* *Nex_i = 68.00 for heifers.*
4B2 – Buffalo	NO	
4B3 – Sheep	17.00	
4B4 – Goats	17.00	
4B5 – Camels & Llamas	NO	
4B6 – Horses	53.70	*Belgian value.*
4B7 – Mules & Bsses	42.50	
4B8 – Swine	[9.77;11.53]	*weighted average using population size:* *Nex_i = 2.30 for pigs < 20kg;* *Nex_i = 11.05 for pigs weighing between 20 & 50 kg;* *Nex_i = 11.05 for fattening pigs > 50kg;* *Nex_i = 28.50 for breeding pigs.*
4B9 – Poultry – Chickens	0.60	*EC average value.*
4B10 – Other – Other Poultry	1.10	*Austrian value.*
4B10 – Other – Rabbits	8.10	*Table 10.19 – 2006 IPCC Guidelines value for Western Europe*
4B10 – Other – Cervidae Species	35.48	*Estimate based on 2000 IPCC-GPG order of magnitude calculations suggested pages 4.20 & 4.21. The calculation has been made using sheep as a basis.*

Source: SER, not published (provided on 1st June 2007), otherwise indicated.

Most of the Nex_i proposed by SER have been prepared in the framework of an EC Directive on nitrate and good agricultural practice [71] and/or for the OECD Agro-environmental Indicators Database. The Nex_i also apply for the cross compliance measures provided for the single farm payment scheme of the CAP.[72] Since they are not officially published in Luxembourg, Nex_i values should therefore be considered as an expert judgement.

6.3.4.2. Emission factors

Since the Tier 1 method has been applied to estimate manure management N_2O related emissions, default EFs have been used for all animal categories. These EFs are presented in Table 6-26 and are extracted from table 4.12 of the 2000 IPCC-GPG.[73]

71 Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

72 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.

73 These EFs are labelled EF_3 in this table.

Table 6-26 – Default EFs for N_2O emissions per selected AWMS

	AWMS			
	Liquid System	Solid Storage	PRP	Other: Anaerobic Digester
Defaukt EF *kg N_2O-N/kg N*	0.001	0.020	0.020	0.001

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 6-26. This multiplication provides nitrous oxide losses per AWMS in kg N_2O-N/year. To obtain N_2O emissions, the latest figure should be multiplied by the molecular weight ratio (44/28) ➔ see below and equation 4.18 of the 2000 IPCC-GPG.

For each animal category, nitrogen excretion per AWMS were calculated using the following formula:[74]

$$Nex_{ij} = Nex_i \bullet (\#\ of\ heads)_i \bullet AWMS_{ij}$$

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 6-25)

and, therefore:

$$Nex_j = \sum_i Nex_{ij}$$

with Nex_j = the total nitrogen excretion per AWMS j in kg N/year

then, N_2O emissions per AWMS are:

$$N_2O_j = [Nex_j \bullet EF_j] \bullet (44/28)$$

with Nex_j = the total nitrogen excretion per AWMS j in kg N/year

EF_j expressed in kg N_2O-N/kg N (see Table 6-26)

Nitrous oxide emissions reported under the source category manure management are the sum of the N_2O_j **with the exception of j = PRP**. Indeed, to avoid double counting, and to allow for a certain logic in the emission reporting, emissions related to PRP are accounted for under IPCC Category 4D – Agricultural Soils (see Section 6.5).

74 As for methane emission estimates, for those animal categories for which no accurate data are available in official statistics for the years prior to 1997 (i.e. 4B4 and 4B10), it has not been attempted to "backcast" the nitrogen excretion per AWMS back to the base year. Hence, the total nitrogen excretion values per AWMS does not comprise these livestock categories for the years prior to 1997.

6.3.5. Recalculations

See Tables 6-1 and 6-2 of Section 6.1.1.

6.3.6. Category specific QA / QC procedures

Consistency and completeness checks have been performed directly within the Microsoft Excel™ file that has been developed by the Ministry of the Environment to calculate 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 extensively discussed between the Ministry of the Environment and the sector experts, SER and ASTA.

6.3.7. Planned improvement

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 6-27 will be explored.

Table 6-27 – Planned improvements for IPCC Category 4B – Manure Management

GHG source & sink category	Planned improvement
4B – Manure Management - AWMS	analyzing whether it would be feasible to refine AWMS per livestock category and through the reporting years.
4B – Manure Management – Other AWMS: Anaerobic Digester	analyze if it would be possible to use formula 1 under table 4.10 of the 2000 IPCC-GPG (p. 4.36) in order to refine/produce a reliable emission estimate for manure used in anaerobic digesters.
4B – Manure Management - Nex	analyzing whether it would be feasible to refine Nex per livestock category and through the reporting years.
4B8 – Swine	national statistics allow for a breakdown of swine in various sub-categories for which more precise parameter values could be applied.
4B9 – Poultry – Chickens	national statistics allow for a breakdown of chickens in various sub-categories for which more precise parameter values could be applied.
4B10 – Other	investigate whether it would be worth, straightforward and not time/resources consuming to include the missing farm animals (ostriches, "productive animals").

6.4. *Rice Cultivation (IPCC Source Category 4C)*

This source category does not exist in Luxembourg.

6.5. *Agricultural Soils (IPCC Source Category 4D)*

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 2006, this source category was responsible for 94.1% of agricultural nitrous oxide emissions and for 50.3% of the total nitrous oxide emissions estimated for Luxembourg. It represented 47.7% of the total emissions due to agricultural activities and 2.49% of the total GHG emissions in CO_2e (excluding LULUCF).

6.5.1. Key source

With 2.49% of the total GHG emissions in CO_2e (excluding LULUCF) in 2006, nitrous oxide emissions from agricultural soils (IPCC Category 4D) is a key source. It has been a key source without interruption since 1990.

6.5.2. Source category description

The source category agricultural soils covers:

- direct soil emissions (IPCC Sub-category 4D1): nitrogen input to soils (such as application of synthetic fertilizers and manure) and nitrogen fixed by crops or crop residues;
- nitrogen excretion on PRP (IPCC Sub-category 4D2) calculated under IPCC Category 4B but to be reported in this category (see Section 6.3.4.2);
- indirect soil emissions (IPCC Sub-category 4D3) due to atmospheric deposition as well as to nitrogen from fertilizers and animals that is lost through leaching and run-off.

As Table 6-28 shows, about half of the nitrous oxide emissions from agricultural soils stems from direct soil emissions. A bit more than one third of the emissions are due to indirect soil emissions and the remaining 15% are the result of PRP manure. All these percentages remained pretty stable during the 1990-2006 period. Within each of the agricultural soil categories, the main emitting activities are nitrogen leaching and run-off (sub-category 4D32) and nitrogen input from the application of synthetic fertilizers (sub-category 4D11).

Since 1990, agricultural soil N_2O related emissions declined by some 12.5%. Actually, all agricultural soil source categories showed decreasing emissions over the period 1990-2006 but two: nitrogen fixed by N-fixing crops (sub-category 4D13) and nitrogen in crop residues returned to soils (sub-category 4D14). These positive evolutions are the result of a 57% increase in N-fixing crops between 1990 and 2006 (see Section 6.5.3.1).

As already underlined in Section 6.1.3, IPCC Category 4D – Agricultural Soils presented an irregular evolution at the end of the period running from 1990 to 2006. This is explained mainly by important changes in crops, and especially N-fixing crops, as well as in fertilizer use which, both, showed a slack in 2003 and a peak in 2004 (see Tables 6-30 and 6-31 in Section 6.5.3.1).

Table 6-28 – N_2O emission trends for IPCC Category 4D – Agricultural Soils: 1990-2006

Year	4D1 Direct Soil Emissions	*4D11 Synthetic Fertilizers*	*4D12 Animal Manure Applied to Soils*	*4D13 N-fixing Crops*	*4D14 Crop Residue*	*4D15 Cultivation Histosols*	*4D16 Other: Sewage Sludge Spreading*	4D2 PRP	4D3 Indirect Soil Emissions	*4D31 Atmospheric Deposition*	*4D32 N Leaching & Run-off*	4D Total
	N_2O emissions (Mg) Agricultural soils category											
1990	576.71	*334.05*	*114.36*	*38.82*	*82.07*	*NO*	*7.41*	188.94	456.41	*72.64*	*383.77*	1 222.06
1991	582.43	*348.07*	*113.36*	*33.34*	*80.24*	*NO*	*7.41*	190.61	466.85	*73.86*	*392.99*	1 239.89
1992	636.69	*375.58*	*108.55*	*53.01*	*92.06*	*NO*	*7.50*	181.38	478.75	*74.43*	*404.32*	1 296.82
1993	618.78	*342.63*	*108.96*	*61.80*	*97.61*	*NO*	*7.79*	181.35	454.45	*71.63*	*382.82*	1 254.58
1994	576.31	*325.29*	*107.56*	*52.29*	*83.03*	*NO*	*8.14*	180.06	439.67	*69.74*	*369.94*	1 196.04
1995	593.78	*319.17*	*114.08*	*58.60*	*93.85*	*NO*	*8.09*	190.65	446.23	*71.54*	*374.68*	1 230.65
1996	608.78	*320.69*	*115.14*	*61.58*	*104.34*	*NO*	*7.02*	193.44	448.91	*72.00*	*376.90*	1 251.12
1997	625.72	*315.74*	*113.91*	*77.97*	*110.74*	*NO*	*7.36*	188.30	441.81	*70.86*	*370.96*	1 255.84
1998	629.27	*309.38*	*112.85*	*83.55*	*116.11*	*NO*	*7.38*	186.09	434.96	*69.86*	*365.10*	1 250.32
1999	609.44	*319.05*	*112.88*	*66.23*	*103.95*	*NO*	*7.34*	185.55	442.01	*70.66*	*371.34*	1 237.00
2000	637.86	*315.01*	*110.69*	*89.15*	*116.57*	*NO*	*6.43*	182.98	434.97	*69.47*	*365.50*	1 255.80
2001	562.31	*268.71*	*110.94*	*73.53*	*103.08*	*NO*	*6.06*	183.17	400.03	*65.36*	*334.67*	1 145.52
2002	569.56	*279.94*	*107.65*	*67.78*	*107.88*	*NO*	*6.30*	176.91	402.60	*65.11*	*337.49*	1 149.07
2003	479.74	*228.14*	*107.97*	*46.25*	*92.52*	*NO*	*4.86*	176.00	362.24	*60.25*	*301.99*	1 017.99
2004	601.98	*289.13*	*108.62*	*79.62*	*120.26*	*NO*	*4.35*	173.50	407.36	*65.47*	*341.89*	1 182.84
2005	514.13	*251.57*	*109.62*	*52.30*	*95.93*	*NO*	*4.73*	173.65	380.29	*62.41*	*317.88*	1 068.07
2006	522.40	*248.10*	*107.39*	*60.79*	*100.84*	*NO*	*5.28*	171.50	374.95	*61.53*	*313.42*	1 068.85
Trend 1990-2006	*-9.42%*	*-25.73%*	*-6.10%*	*56.59%*	*22.87%*	*NA*	*-28.78%*	*-9.23%*	*-17.85%*	*-15.31%*	*-18.33%*	*-12.54%*

Source: Ministry of the Environment.

Note: 2006 data are provisional for sub-categories 4D16 (hence 4D1) as well as 4D31 and 4D32 (hence 4D3), hence 4D.

Soil categories description:

4D11 – Direct Soil Emissions – Synthetic Fertilizers: nitrogen input from application of synthetic (nitrogenous) fertilizers

4D12 – Direct Soil Emissions – Animal Manure Applied to Soils: nitrogen input from manure applied to soils

4D13 – Direct Soil Emissions – N-fixing Crops: nitrogen fixed by N-fixing crops

4D14 – Direct Soil Emissions – Crop Residue: nitrogen in crop residues returned to soils

4D15 – Direct Soil Emissions – cultivation of histosols: area of cultivated organic soils

4D16 – Direct Soil Emissions – Other – Sewage Sludge Spreading: nitrogen input from application of sewage sludge

4D2 – PRP Manure: nitrogen excretion on PRP

4D31 – Indirect Emissions – Atmospheric Deposition: volatized nitrogen from fertilizers, animal manures and other

4D32 – Indirect Emissions – Nitrogen Leaching & Run-off: nitrogen from fertilizers, animal manures and other that is lost through leaching and run-off

6.5.3. Methodological issues

Estimating nitrous oxide emissions from agricultural soils requests, according to IPCC Guidelines, the use of certain **fractions**. For most of these fractions, as shown in Table 6-29, Luxembourg did use default values presented in the Revised 1996 IPCC Guidelines.

Table 6-29 – Fractions used for estimating N_2O emissions for IPCC Category 4D – Agricultural Soils

Fraction	Description	Unit	Value	Source
$Frac_{BURN}$	Fraction of crop residue burned	kg N/kg crop-N	NO	table 4.19 – Revised 1996 IPCC Guidelines
$Frac_{FUEL}$	Fraction of livestock N excretion in excrements burned for fuel	kg N/kg N excreted	NO	table 4.19 – Revised 1996 IPCC Guidelines
$Frac_{GASF}$	Fraction of synthetic fertilizer N applied to soils that volatilizes as NH_3 and NOx	kg NH3-N+NOx-N/kg synthetic fertilizer N applied	0.100	table 4.19 – Revised 1996 IPCC Guidelines
$Frac_{GASM}$	Fraction of livestock N excretion that volatilizes as NH_3 and NOx	kg NH3-N+NOx-N/kgN excreted	0.200	table 4.19 – Revised 1996 IPCC Guidelines
$Frac_{GRAZ}$/$Frac_{PRP}$	Fraction of livestock N excreted and deposited onto soil during grazing	% of kgN/year	$Nex_{PRP}/\sum_j Nex_j$ j = AWMS	IPCC Category 4B calculations
$Frac_{LEACH}$	Fraction of N input to soils that is lost through leaching and run-off	kg N/kg fertilizer or manure-N	0.300	table 4.24 – Revised 1996 IPCC Guidelines
$Frac_{NCRBF}$	Fraction of total above-ground biomass of N-fixing crop that is N	kg N/kg dry biomass	0.030	table 4.19 – Revised 1996 IPCC Guidelines
$Frac_{NCRO}$	Fraction of residue dry biomass that is N	kg N/kg dry biomass	0.015	table 4.19 – Revised 1996 IPCC Guidelines
$Frac_{R}$	Fraction of total above-ground crop biomass that is removed from the field as a crop product	kg N/kg crop-N	0.450	table 4.19 – Revised 1996 IPCC Guidelines

Consequently, the use of default fractions – combined with default EFs – implies that Tier 1 methods (Tier 1, 1a or 1b) have been applied for estimating direct and indirect N_2O emissions from agricultural soils.

6.5.3.1. Activity data

Only a limited number of activity data has been used to provide N_2O estimates for IPCC Category 4D.

Some activity data are extracted from national statistics:

- the consumption of synthetic fertilizers: see Table 6-30;
- various crop productions: see Table 6-31.

For emissions due to sewage sludge spreading on fields, data have been estimated by both the Ministry of the Environment and the Environment Agency on the basis of annual reports and official statistics on wastewater treatment in Luxembourg.

Fertilizers use

Table 6-30 – Nitrogenous fertilizers consumption: 1990-2006

Year	Nitrogenous fertilizers consumption *t N*
1990	18896
1991	19689
1992	21245
1993	19381
1994	18400
1995	18054
1996	18140
1997	17860
1998	17500
break in time serie	
1999	18047
2000	17819
2001	15200
2002	15835
2003	12905
2004	16355
2005	14230
2006	14034
Trend 1990-2006	*-25.73%*

Sources : SER: http://www.ser.public.lu/statistik/betriebsmittel/duenger.pdf

STATEC, *Statistical Yearbook*, Table C.2112: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1225

data extracted on 17 January 2008 (subject to changes since that date)

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.

Crop production

The various crop productions are to be recorded for IPCC Category 4F – 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 6.7.2),

crop production data are described in this section on the methodology for agricultural soil emission estimates.

Crop production by categories are presented in Table 6-31. It is mainly the various aggregated categories (see under "Total") that are used to estimate some direct soil nitrous oxide emissions.

Table 6-31 – Crop production and trends: 1990-2006

Year	*Crop production (tonnes)* Crop category 4F1								4F2					4F3		
	Cereals	*Wheat*	*Barley*	*Maize*	*Oats*	*Rye*	*Rice*	*Other*	Pulses	*Dry Bean*	*Peas*	*Soybeans*	*Other*	Tubers & Roots	*Potatoes*	*Other*
1990	273 475	43 513	69 612	125 546	18 757	2 366	NO	13 681	1 410	NO	50	NO	1 360	25 500	24 870	630
1991	266 192	44 301	73 480	109 816	19 481	2 218	NO	16 896	1 678	NO	30	NO	1 648	20 009	19 499	510
1992	334 537	46 124	70 386	182 196	17 237	1 923	NO	16 671	2 214	NO	30	NO	2 184	27 236	26 866	370
1993	313 285	48 534	68 059	161 405	17 109	1 826	NO	16 352	2 202	NO	28	NO	2 174	26 079	25 654	425
1994	268 264	45 243	59 882	134 540	12 369	1 613	NO	14 617	1 866	NO	30	NO	1 836	18 304	17 859	445
1995	328 246	52 745	62 822	180 661	12 150	1 703	NO	18 165	1 410	NO	30	NO	1 380	23 292	22 857	435
1996	355 581	64 398	72 456	180 079	13 278	2 326	NO	23 044	1 949	NO	32	NO	1 917	20 744	20 244	500
1997	337 428	57 378	68 627	177 705	13 247	2 715	NO	17 756	1 561	NO	30	NO	1 531	23 230	22 820	410
1998	342 111	60 073	63 203	179 187	11 693	4 051	NO	23 904	1 451	NO	31	NO	1 420	22 853	22 313	540
1999	283 883	46 379	67 775	133 200	12 246	3 535	NO	20 748	2 337	NO	30	NO	2 307	26 174	25 704	470
2000	283 066	61 184	53 533	132 276	9 217	3 603	NO	23 253	1 270	NO	35	NO	1 235	28 403	27 858	545
2001	302 235	54 022	53 566	162 267	7 799	4 803	NO	19 778	2 312	NO	35	NO	2 277	23 210	22 770	440
2002	314 970	71 656	51 823	148 499	10 219	7 470	NO	25 303	2 359	NO	32	NO	2 327	20 600	20 105	495
2003	339 347	68 648	55 330	177 110	11 414	4 606	NO	22 239	2 166	NO	20	NO	2 146	18 564	18 329	235
2004	363 347	79 978	52 761	187 975	9 458	7 921	NO	25 254	1 749	NO	20	NO	1 729	22 644	22 244	400
2005	345 288	71 745	52 853	186 779	7 734	5 715	NO	20 462	1 501	NO	13	NO	1 488	19 731	19 329	402
2006	314 797	75 603	50 061	155 210	6 650	6 156	NO	21 117	1 198	NO	13	NO	1 185	16 779	16 449	330
Trend 1990-2006	15.11%	73.75%	-28.09%	23.63%	-64.55%	160.19%	NA	54.35%	-15.04%	NA	-74.00%	NA	-12.87%	-34.20%	-33.86%	-47.62%

Year	*Crop production (tonnes)* Crop category 4F4	4F5			Total			
	Sugar Cane	Other	*Non N-fixing crops*	*N-fixing crops*	Non N-fixing crops	N-fixing crops	Fodder crops	Non N-fixing crops excluding fodder crops
1990	NO	76 969	5 201	71 768	304 176	73 178	197 313	106 863
1991	NO	67 819	6 647	61 172	292 848	62 850	170 988	121 860
1992	NO	100 022	2 310	97 712	364 083	99 926	279 908	84 176
1993	NO	118 789	4 500	114 289	343 864	116 491	275 694	68 171
1994	NO	100 432	3 730	96 702	290 298	98 568	231 242	59 056
1995	NO	115 854	6 795	109 059	358 333	110 469	289 720	68 613
1996	NO	121 776	7 632	114 144	383 957	116 093	294 223	89 734
1997	NO	153 304	7 865	145 439	368 523	147 000	320 859	47 664
1998	NO	165 258	9 186	156 072	374 150	157 523	330 966	43 184
1999	NO	136 078	13 568	122 510	323 625	124 847	252 598	71 027
2000	NO	175 887	9 078	166 809	320 547	168 079	297 045	23 502
2001	NO	145 898	9 593	136 305	335 038	138 617	294 241	40 797
2002	NO	138 739	13 320	125 419	348 890	127 778	271 601	77 289
2003	NO	98 417	13 404	85 013	371 315	87 179	260 221	111 094
2004	NO	165 925	17 580	148 345	403 571	150 094	332 709	70 862
2005	NO	112 669	15 584	97 085	380 603	98 586	281 804	98 799
2006	NO	130 501	17 096	113 405	348 672	114 603	266 740	81 932
Trend 1990-2006	NA	69.55%	228.71%	58.02%	14.63%	56.61%	35.19%	-23.33%

Sources : SER: http://www.ser.public.lu/statistik/pflanz_produktion/mengen_marktfruchtbau.pdf and http://www.ser.public.lu/statistik/pflanz_produktion/mengen_obst_gemuesebau.pdf

STATEC, *Statistical Yearbook*, Table C.2104: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1217 and Table C.2106: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1219

data extracted on 26 February 2008 (subject to changes since that date)

Crop description:

4F1 – Wheat: winter & spring wheat (for fodder & bakeries)

4F1 – Barley: winter & spring barley (for fodder & breweries)

4F1 – Maize: fodder maize and maize seeds

4F1 – Oats: oats

4F1 – Rye: winter & summer rye (for fodder & breads)

4F1 – Rice: rice

4F1 – Other: triticale (winter & summer) and secondary & mixed cereals not indicated elsewhere (winter & spring)

4F2 – Dry Bean: dry beans

4F2 – Peas: peas (quantity sold !)

4F2 – Soybeans: soybeans

4F2 – Other: dry vegetable cropped for their grains & used as fodder (mainly peas & beans)

4F3 – Potatoes: potatoes

4F3 – Other: carrots & leeks (quantity sold !)

4F4 – Sugar Cane: sugar cane

4F5 – Other – Non N-fixing Crops: colza & seeds from/for fodder plants

4F5 – Other – N-fixing Crops: clovers (including clover-grass mixes), lucernes & beets used as forage

Total – Non N-fixing crops = 4F1 + 4F3 + 4F5(non N-fixing crops)

Total – N-fixing Crops = 4F2 + 4F5(N-fixing crops)

Total – Fodder Crops = fodder maize, fodder crops (including leguminous plants for fodder)

Total - Non N-fixing Crops excluding Fodder Crops = Total-non N-fixing crops – Total-fodder crops.

Sewage sludge spreading on fields

Under IPCC Sub-category 4D16 – 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 pilot 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.[75]

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. For the years up to 2005 included, these estimates have been prepared by the Environment Agency on 24 July 2007. For 2006, it has been estimated by the Ministry of the Environment on the basis of the average calculated for a ratio computed for the last six years (2000 to 2005) – this explains the "provisional data" note in Table 6-28 above;
- annual reports on sewage sludge that are regularly issued since 2003.[76] 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 6D – and incineration – an operation done in Germany.

Consequently, activity data used as basis for calculating sewage sludge spreading related N_2O emissions should be associated with an expert judgement. They are summarized in the Table 6-32. It is also recommended to have a look at the Microsoft Excel™ file that has been developed to calculate GHG emissions from the agriculture sector (**Agriculture_GHG Estimates.xls**).

75 See http://www.soil-concept.lu/.

76 See http://www.environnement.public.lu/dechets/statistiques_indicateurs/index.html under "*Statistiques sur les boues d'épuration*".

Table 6-32 – Sewage sludge estimates and trends: 1990-2006

Year	*Sewage sludge from WWTPs (tonnes 100% dry matter)* Estimates			
	All WWTPs	WWTPs over 2000 inhab.-eq.	*going to the agri. sector in Luxembourg*	Sewage sludge spreading on fields
	(a)	(b)	(c)	(d)
1990	9 668.23	NE	*NE*	9 668.23
1991	9 673.95	NE	*NE*	9 673.95
1992	9 785.35	NE	*NE*	9 785.35
1993	10 165.71	NE	*NE*	10 165.71
1994	10 631.70	NE	*NE*	10 631.70
1995	10 556.94	NE	*NE*	10 556.94
1996	11 461.86	NE	*NE*	9 169.49
1997	12 012.56	NE	*NE*	9 610.05
1998	12 047.69	NE	*NE*	9 638.15
1999	11 983.06	NE	*NE*	9 586.45
2000	12 093.75	NE	*NE*	8 393.40
2001	12 204.45	NE	*NE*	7 905.66
2002	12 807.74	NE	*NE*	8 228.09
2003	12 922.87	7 750.00	*3 807.58*	6 349.01
2004	13 663.32	7 503.94	*3 116.92*	5 675.35
2005	13 373.38	8 191.54	*3 780.15*	6 171.41
2006	13 390.45	8 298.83	*4 267.56*	6 885.87
Trend 1990-2006	*38.50%*	*7.08%*	*12.08%*	*-28.78%*

Sources: columns (a) to (c): Environment Agency (1990-2005) and Ministry of the Environment estimate (2006);

column (d): Environment Agency & Ministry of the Environment estimates.

Note: For column (d), the estimates have been calculated as follows:

1990 to 1995: (d) = (a);

1996 to 1999: (d) = (a) ● 0.8;

2000 to 2002: (d) = [(a) ● 0.8] – fraction of sludge diverted for composting;

2003 to 2006: (d) = [(c) / (b)] ● (a).

6.5.3.2. Emission factors

For estimating agricultural soils nitrous oxide emissions, as indicated above, Tier 1 methods have been applied. Table 6-33 specifies, for each source category, which method has been used for estimating the emissions as well as the corresponding EF type.

Table 6-33 – Method and type of EF used in the inventory

Agricultural soils sub-category	Estimation method	EF	Comments
4D11 – Direct Soil Emissions – Synthetic Fertilizers	T1a	D	*Equation 4.20 – 2000 IPCC-GPG has been used for calculating N_2O emissions. It is referenced as a T1a method.*
4D12 – Direct Soil Emissions – Animal Manure Applied to Soils	T1a	D	
4D13 – Direct Soil Emissions – N-fixing Crops	T1b	D	*Though equation 4.20 – 2000 IPCC-GPG has been used for calculating N_2O emissions, N fixed by crops has been estimated using equation 4.26 – 2000 IPCC-GPG which is referenced as a T1b method.*
4D14 – Direct Soil Emissions – Crop Residue	T1a	D	*Both equations used (4.20 & 4.28 2000 IPCC-GPG) are referenced as T1a methods.*
4D15 – Direct Soil Emissions – cultivation of histosols	NO	NO	

4D16 – Direct Soil Emissions – Other – Sewage Sludge Spreading	T1b	D	*The method followed is the one applied by Austria in its inventory. It is referenced as a T1b method.*
4D2 – PRP Manure	T1	D	*Equation 4.18 – 2000 IPCC-GPG has been used for calculating N_2O emissions (see Section 6.3.4.2). It is referenced as a T1 method.*
4D31 – Indirect Emissions – Atmospheric Deposition	T1a	D	*Equation 4.30 – 2000 IPCC-GPG has been used for calculating N_2O emissions. However, both atmospheric deposition and nitrogen leaching & run-off have been estimated using equations 4.32 and 4.36 – 2000 IPCC-GPG which are referenced as T1b methods.*
4D32 – Indirect Emissions – Nitrogen Leaching & Run-off	T1a	D	

Source: Ministry of the Environment.

Abbreviations:

T1, T1a & T1b = Tier 1 methods D = IPCC Default

IPCC Sub-category 4D11 – Direct Soil Emissions – Synthetic Fertilizers

For synthetic fertilizers – i.e. nitrogenous fertilizers – application to soils, N_2O emissions have been estimated using equations 4.20 and 4.22 – 2000 IPCC-GPG:

$$N_2O_{FERT} = N_2O\text{-}N_{FERT} \bullet (44/28)$$

with:

$$N_2O\text{-}N_{FERT} = [EF_{FERT} \bullet F_{SN}] / 10^6$$

with EF_{FERT} in kg N_2O-N/kg N extracted from table 4.17 – 2000 IPCC-GPG

F_{SN} in kg N calculated using equation 4.22 – 2000 IPCC-GPG

activity data used for calculating F_{SN} = nitrogenous fertilizers consumption (see Table 6.30)

IPCC Sub-category 4D12 – Direct Soil Emissions – Animal Manure Applied to Soils

For animal manure application to soils, N_2O emissions have been estimated using equations 4.20 and 4.23 – 2000 IPCC-GPG:

$$N_2O_{AM} = N_2O\text{-}N_{AM} \bullet (44/28)$$

with:

$$N_2O\text{-}N_{AM} = IEF_{AM} \bullet F_{AM}] / 10^6$$

with EF_{AM} in kg N_2O-N/kg N extracted from table 4.17 – 2000 IPCC-GPG

F_{AM} in kg N calculated using equation 4.23 – 2000 IPCC-GPG

activity data used for calculating F_{AM} = total nitrogen excretion ($\sum_j Nex_j$) (j = AWMS types including PRP): see Microsoft Excel™ file Agriculture_GHG Estimates.xls

IPCC Sub-category 4D13 – Direct Soil Emissions – N-fixing Crops

For determining nitrogen fixed by N-fixing crops and its related N_2O emissions, equations 4.20 and 4.26 – 2000 IPCC-GPG have been used:

$$N_2O_{BN} = N_2O\text{-}N_{BN} \bullet (44/28)$$

with:

$$N_2O\text{-}N_{BN} = [EF_{BN} \bullet F_{BN}] / 10^6$$

with EF_{BN} in kg N_2O-N/kg N extracted from table 4.17 – 2000 IPCC-GPG

F_{BN} in kg N calculated using equation 4.26 – 2000 IPCC-GPG

activity data used for calculating F_{BN} are crop productions of N-fixing crops, the residue/crop ratio and the dry matter fraction

F_{BN} has not been calculated for the N-fixing crops as a whole, but rather for each of the crops that constitute the total N-fixing crops, i.e. peas (4F2), other pulses (i.e. dry vegetable cropped for their grains & used as fodder – 4F2) and other N-fixing crops (4F5): see Table 6-31. For each of these crop categories, ratios and fractions are extracted from the following sources (see also Section 6.7.3.2):

- peas: residue/crop ratio & dry matter fraction come from table 4.16 – 2000 IPCC-GPG;
- other pulses: residue/crop ratio comes from table 4.16 – 2000 IPCC-GPG & dry matter fraction from table 11.2 of the Revised 1996 IPCC Guidelines;
- other N-fixing crops: as indicated page 4.57 of the 2000 IPCC-GPG, forage N-fixing crops will have a residue/crop ratio equals to zero. The dry matter fraction comes from table 11.2 of the Revised 1996 IPCC Guidelines.

IPCC Sub-category 4D14 – Direct Soil Emissions – Crop Residue

For N_2O emissions related to nitrogen in crop residue returned to soils, equations 4.20 and 4.28 – 2000 IPCC-GPG have been used:

$$N_2O_{CR} = N_2O\text{-}N_{CR} \bullet (44/28)$$

with:

$$N_2O\text{-}N_{CR} = [EF_{CR} \bullet F_{CR}] / 10^6$$

with EF_{CR} in kg N_2O-N/kg N extracted from table 4.17 – 2000 IPCC-GPG

F_{CR} in kg N calculated using equation 4.28 – 2000 IPCC-GPG

activity data used for calculating F_{CR} are the total crop productions excluding fodder crops

The calculation of F_{CR} has been realized using a slightly modified equation 4.28 as suggested in the 2000 IPCC-GPG on pages 4.58-4.59. More precisely, the crops included in the calculation are the N-fixing crops and the non N-fixing crops excluding fodder crops (or, in other words, the total crops excluding fodder crops). Indeed, the 2000 IPCC-GPG says that "*The Tier 1a approach (i.e. equation 4.28) can be modified in several ways to estimate more accurately the amount of crop residue nitrogen that is incorporated into soils:*

- *(…)*
- *fourth, the equation should be modified to account for additional uses of crop residues, specifically as fuel, construction material, and* ***fodder****. (…).*"

<u>IPCC Sub-category 4D15 – Direct Soil Emissions – Cultivation of Histosols</u>

This source category does not exist in Luxembourg.

<u>IPCC Sub-category 4D16 – Direct Soil Emissions – Other: Sewage Sludge Spreading</u>

For sewage sludge spreading application to soils, N_2O emissions have been estimated using equation 4.20 – 2000 IPCC-GPG:

$$N_2O_{SSlu} = N_2O\text{-}N_{SSlu} \bullet (44/28)$$

with:

$$N_2O\text{-}N_{SSlu} = [EF_{SSlu} \bullet F_{SSlu}] / 10^6$$

with EF_{SSlu} in kg N_2O-N/kg N extracted from table 4.17 – 2000 IPCC-GPG[77]

F_{SSlu} in kg N calculated using the method proposed by Austria:

$$F_{SSlu} = SSlu_{DM}AS \bullet SSlu_N$$

with $SSlu_{DM}AS$ = sewage sludge spreading on agricultural soils – dry matter (see Table 6.32, column (d))

$SSlu_N$ = N content in dry matter: default value from the Austrian inventory (3.90%)

<u>IPCC Sub-category 4D2 – PRP Manure</u>

For Nex on PRP, N_2O emissions have been estimated using equation 4.18 – 2000 IPCC-GPG. The calculation has been presented in Section 6.3.4.2. Nitrous oxide emissions reported under sub-category 4D2 are:

$$N_2O_j = [Nex_j \bullet EF_j] \bullet (44/28)$$

with Nex_j = the total nitrogen excretion per AWMS j in kg N/year

EF_j expressed in kg N_2O-N/kg N

for **j = PRP**.

[77] By hypothesis, the IEF for sewage sludge spreading equals the one used for other direct soil emissions, i.e. 1.25% (referenced as EF_1 in table 4.17 – 2000 IPCC-GPG).

IPCC Sub-category 4D31 – Atmospheric Deposition

For volatized nitrogen from fertilizers, animal manures and other, N_2O emissions have been estimated using equations 4.30 and 4.32 – 2000 IPCC-GPG:

$$N_2O_{(G\text{-}SOIL)} = N_2O\text{-}N_{(G\text{-}SOIL)} \bullet (44/28)$$

with $N_2O\text{-}N_{(G\text{-}SOIL)}$ in Gg calculated using equation 4.32 – 2000 IPCC-GPG

and $EF_{(G\text{-}SOIL)}$ in kg N_2O-N/kg N extracted from table 4.18 – 2000 IPCC-GPG

activity data & parameters used for calculating $N_2O\text{-}N_{(G\text{-}SOIL)}$ = nitrogenous fertilizers consumption (see Table 6.30), Nex (see Section 6.3.4.2) and N Input from sewage sludge applied to agricultural soils (F_{SSlu})

fractions used for calculating $N_2O\text{-}N_{(G\text{-}SOIL)}$ = $Frac_{GASF}$ & $Frac_{GASM}$ (see Table 6-29)

IPCC Sub-category 4D32– Nitrogen Leaching & Run-off

For nitrogen from fertilizers, animal manures and other that is lost through leaching and run-off, N_2O emissions have been estimated using equations 4.30 and 4.36 – 2000 IPCC-GPG:

$$N_2O_{(L\text{-}SOIL)} = N_2O\text{-}N_{(L\text{-}SOIL)} \bullet (44/28)$$

with $N_2O\text{-}N_{(L\text{-}SOIL)}$ in Gg calculated using equation 4.36 – 2000 IPCC-GPG

and $EF_{(L\text{-}SOIL)}$ in kg N_2O-N/kg N extracted from table 4.18 – 2000 IPCC-GPG

activity data & parameters used for calculating $N_2O\text{-}N_{(L\text{-}SOIL)}$ = nitrogenous fertilizers consumption (see Table 6.30), Nex (see Section 6.3.4.2) and N Input from sewage sludge applied to agricultural soils (F_{SSlu})

fraction used for calculating $N_2O\text{-}N_{(L\text{-}SOIL)}$ = $Frac_{LEACH}$ (see Table 6-29)

Nitrous oxide EFs for IPCC Category 4D – Agricultural Soils

Table 6-34 summarizes the default EFs used for estimating nitrous oxide emissions from agricultural soils.

Table 6-34 – N_2O default EFs for IPCC Category 4D – Agricultural Soils

Agricultural soils sub-category	Default EF	Value *kg N2O-N/kg N*	Source
4D11 – Direct Soil Emissions – Synthetic Fertilizers	$EF_{FERT} = EF_1$	0.0125	table 4-17 – 2000 IPCC-GPG
4D12 – Direct Soil Emissions – Animal Manure Applied to Soils	$EF_{AM} = EF_1$ for F_{AM}	0.0125	
4D13 – Direct Soil Emissions – N-fixing Crops	$EF_{BN} = EF_1$ for F_{BN}	0.0125	
4D14 – Direct Soil Emissions – Crop Residue	$EF_{CR} = EF_1$ for F_{CR}	0.0125	
4D15 – Direct Soil Emissions – cultivation of histosols	NO	NO	
4D16 – Direct Soil Emissions – Other – Sewage Sludge Spreading	$EF_{SSlu} = EF_1$	0.0125	table 4-17 – 2000 IPCC-GPG
4D2 – PRP Manure	EF_3	D	table 4-12 – 2000 IPCC-GPG
4D31 – Indirect Emissions – Atmospheric Deposition	$EF_{(G\text{-}SOIL)} = EF_4$	0.0100	table 4-18 – 2000 IPCC-GPG
4D32 – Indirect Emissions – Nitrogen Leaching & Run-off	$EF_{(L\text{-}SOIL)} = EF_5$	0.0250	

6.5.4. Recalculations

See Tables 6-1 and 6-2 of Section 6.1.1.

6.5.5. Category specific QA/QC procedures

Consistency and completeness checks have been performed directly within the Microsoft Excel™ file that has been developed by the Ministry of the Environment to calculate 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 extensively discussed between the Ministry of the Environment and the sector experts, SER and ASTA.

6.5.6. Planned improvement

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 6-35 will be explored.

Table 6-35 – Planned improvements for IPCC Category 4D – Agricultural Soils

GHG source & sink category	Planned improvement
4D – Agricultural Soils	analyze whether it would be possible to replace some default parameters, coefficients or EFs by national values.
4D13 & 4D14 – Agricultural Soils – N-fixing Crops & Crop Residue	refine the various crop categories: allocation, possible correction, etc. especially with regard to the non N-fixing & the fixing crops as well with regard to forage crops contribution to emissions.
4D16 – Agricultural Soils – Other – Sewage Sludge Spreading	analyze further the impact of sludge spreading and compost application on agriculture GHG emissions in order to refine first estimates presented in the inventory.

6.6. *Prescribed Burning of Savannas (IPCC Source Category 4E)*

This source category does not exist in Luxembourg.

6.7. *Field Burning of Agricultural Residues (IPCC Source Category 4F)*

This section describes emissions resulting from field burning of agricultural residues. However, as explained in Section 6.7.2, field burning of residues is not a common practice and, therefore, does not occur in Luxembourg.

6.7.1. Key source

Since field burning of agricultural residues is not occurring in Luxembourg, there are no key sources for IPCC Source Category 4F.

6.7.2. Source category description

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[78] forbids clearing and burning[79] of fields, meadows, grass-lands, roadsides, forests between the 1st of March and the 30th of September. According to the law, the clearing and burning of agricultural residues (such as straw) is not strictly forbidden. However, for economic reasons (residues can be used as litter, as feeding stuff for animals or can be sold), field burning is not practiced in Luxembourg and, therefore, emission estimates have been recorded as not occurring (notation key NO) in the inventory.

Though there are no emission estimates recorded, the crop production, the residue/crop ratio as well as the dry matter fraction have been reported in CRF tables 4F. Indeed, production data are used as inputs for calculating some agricultural soils sub-categories of IPCC Category 4D (see Section 6.5.3.1).

6.7.3. Methodological issues

6.7.3.1. Activity data

See Section 6.5.3.1 above.

6.7.3.2. Ratios

CRF tables on field burning of agricultural residues report two ratios for each crop category: the residue/crop ratio and the dry matter fraction of the residue. Both parameters are indicated for the sake of completeness only since they are, for most of the crops, not used.[80] The values recorded in the tables come from:

- table 4.16 of the 2000 IPCC-GPG for the residue/crop ratio;
- table 4.16 of the 2000 IPCC-GPG and, for other pulses and potatoes, table 11.2 of the 2006 IPCC Guidelines for the dry matter fraction of the residue.

6.7.4. Recalculations

Not applicable.

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78 See http://www.legilux.public.lu/leg/a/search/resultHighlight/index.php?linkId=24&SID=ae766f0dc925893886f2004b9672cc8d.

79 “essartement” in French.

80 As indicated in Section 6.5.3.2 above, these ratios have been used for estimating N_2O emissions for the sub-category 4D13 which covers only N-fixing crops.

6.7.5. Category specific QA / QC procedures

Not applicable.

6.7.6. Planned improvement

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 6-36 will be explored.

Table 6-36 – Planned improvements for IPCC Category 4F – Field Burning of Agricultural Residues

GHG source & sink category	Planned improvement
4F – Field Burning of Agricultural Residues	refine the various crop categories: allocation, possible correction, etc. especially with regard to the non N-fixing & the fixing crops as well with regard to forage crops contribution to emissions.

6.8. Other (IPCC Source Category 4G)

This source category is not used in Luxembourg's GHG inventory.

For more information on this Chapter, please contact:

Eric DE BRABANTER
Ministère de l'Environnement
18, Montée de la Pétrusse
L-2918 Luxembourg
Tel: (+352) 247-86842
Fax: (+352) 247-86835
E-mail: eric.debrabanter@mev.etat.lu

7. Land Use, Land-Use Change and Forestry (CRF sector 5)

7.1. Sector Overview

Chapter 7 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 – Land Use, Land-use Change and Forestry – i.e. LULUCF – for the period 1990 to 2006.

So far, only the carbon absorption or intake by the vegetation has been estimated in Luxembourg. This estimation is recorded under category 5G – Other in the inventory. For more details on categories where emissions are not occurring and categories that are not estimated or included elsewhere, see Table 7-2 below.

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Section 7.1 is structured as follows:

- overview of the revisions since the ICR of June 2007: submission 2007v2.1 ➔ submission 2007v3.1 ➔ submission 2008v1.2. Submission 2007v2.1 was the version reviewed by the ERT during the ICR, whereas submission 2007v3.1 was the one provided to the ERT after the ICR (see Table 1-1 in Section 1.1). This overview includes therefore information on recalculations;
- completeness analysis of the CRF Sector as reported in submission 2008v1.2. The analysis limits itself to the 6 GHG controlled by the Kyoto Protocol;
- planned improvements for this CRF Sector.

Starting with revisions and a completeness analysis is justified by the dramatic improvements the GHG inventory for Luxembourg experienced since the ICR in June 2007.

7.1.1. Overview of the revisions

Table 7-1 presents the main revisions and recalculations done after the ICR of June 2007 relevant to CRF Sector 5.

Table 7-1 – Changes in GHG inventories: submissions 2007v2.1 and 2007v3.1

GHG source & sink category	Revisions 2007v2.1 ➔ 2007v3.1	Type of revision
5G	- following ERT recommendation, deletion of N2O emissions of broadleaf & coniferous forests	- error correction

There has been no recalculation between submissions 2007v3.1 and 2008v1.2 (see also CRF tables 8).

7.1.2. 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 – LULUCF: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		Net CO_2	CH_4	N_2O
5A1	forest land remaining forest land	NE	NE	NE
5A2	land converted to forest land	NE	NE	NE
5B1	cropland remaining cropland	NE	NE	NE
5B2	land converted to cropland	NE	NE	NE
5C1	grassland remaining grassland	NE	NE	NE
5C2	land converted to grassland	NE	NE	NE
5D1	wetlands remaining wetlands	NE	NE	NE
5D2	land converted to wetlands	NE	NE	NE
5E1	settlements remaining settlements	NE	NE	NE
5E2	land converted to settlements	NE	NE	NE
5F1	other land remaining other land	NE	NE	NE
5F2	land converted to other land	NE	NE	NE
5G	other	X	NE	NE

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.

7.1.3. Planned improvements

As illustrated by Table 7-2, LULUCF related emissions are very limited for Luxembourg. So far, only one figure is recorded under the sub-category 5G – Other; a figure which is, moreover, identical for every reported year 1990 to 2006. In fact, a first estimation of carbon absorption by vegetation was done by the *Administration des Eaux et Forêts* (Water & Forestry Administration) in 1996. It indicated that, annually, 294 930 t of carbon dioxide are absorbed by the vegetation in Luxembourg.

Therefore, improvements are needed for this sector. In 2006, the *Administration des Eaux et Forêts* commissioned a study to a consortium for a comprehensive revision of activity data and the methodology for the estimation of emissions and removals of the LULUCF sector in the context of the GMES/GSE Forest Monitoring framework. Planned for 2 years, with a deadline initially settled for the fourth quarter of 2007, the study has unfortunately fallen behind schedule due to its close dependency on GMES developments.

The study covers the following tasks:

- support to National UNFCCC and Kyoto Protocol reporting on LULUCF activities:
    - national GHG reporting by providing statistics on land use and land use change, forest area and forest area change (afforestation, reforestation and deforestation) based on relevant maps derived using Earth Observation (*EO*) data and auxiliary information for the reference years 1990, 2000 and 2007;

- forest information update:
  - updating of forest information data and basic forest typologies (provision of forest type maps and forest type change maps), especially for areas where forest management information is not available (e.g. private forests) for the reference years 1990, 2000 and 2007;
- support to environmental monitoring:
  - environmental monitoring towards nature conservation policy by provision of fragmentation indexes based on relevant maps derived from EO data for the reference years 1990, 2000 & 2007;
- detecting and monitoring of Forest operations and disturbances:
  - monitoring of management operations, i.e. clear cutting, by provision of a clear cut map based on the land cover maps of 2004 & 2007.

The map class definitions are according to FAO TBRA 2000 definitions and 2003 IPCC-GPG-LULUCF definitions, respectively. The following maps and data will be generated:

- land cover / land use;
- forest area;
- forest type;
- clear cut.

The latest interim report regarding the study for a comprehensive revision of the activity data and the methodology for estimating emissions and removals of the LULUCF sector is presented in Annex IV to this NIR. It has been issued on the 5th of December 2007.

For more information on this Chapter, please contact:

Frank WOLTER
Administration des Eaux et Forêts
16, rue Eugène Ruppert
L-2453 Luxembourg
Tel: (+352) 40 22 01 216
Fax: (+352) 40 22 01 250
E-mail: frank.wolter@ef.etat.lu

8. Waste (CRF Sector 6)

8.1. Sector Overview

Chapter 8 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 6 – Waste for the period 1990 to 2006.

Emissions from this sector comprise emissions for the main four categories: solid waste disposal on land (6A), wastewater handling (6B), waste incineration (6C) and other (compost production) (6D). For more details on categories where emissions are not occurring and categories that are not estimated or included elsewhere, see Table 8-3 below.

Waste incineration 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 electric network from waste burned in the sole incinerator of the country.

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Section 8.1 is structured as follows:

- overview of the revisions since the ICR of June 2007: submission 2007v2.1 ➔ submission 2007v3.1 ➔ submission 2008v1.2. Submission 2007v2.1 was the version reviewed by the ERT during the ICR, whereas submission 2007v3.1 was the one provided to the ERT after the ICR (see Table 1-1 in Section 1.1). This overview includes therefore information on recalculations;
- completeness analysis of the CRF Sector as reported in submission 2008v1.2. The analysis limits itself to the 6 GHG controlled by the Kyoto Protocol;
- analysis of the emission trends of the CRF Sector, combining source categories and GHG.

Starting with revisions and a completeness analysis is justified by the dramatic improvements the GHG inventory for Luxembourg experienced since the ICR in June 2007.

Other required information, as suggested in Annex I of document FCCC/SBSTA/2006/9, will be presented under each source category review (methodology, AD, EFs, etc.).

8.1.1. Overview of the revisions

Table 8-1 presents the main revisions and recalculations done after the ICR of June 2007 relevant to CRF Sector 6.

Table 8-1 – Changes in GHG inventories: submissions 2007v2.1 and 2007v3.1

GHG source & sink category	Revisions 2007v2.1 ➔ 2007v3.1	Type of revision
6A1	- incorporation of the activity data of the SIDA dumping site that was closed down in January 1994	- refinement
6B	- new estimates (source category previously NE)	- new source category
6C	- inclusion of the SIDOR emission (waste incinerator with energy recovery) in 1A1a - revised CO_2 emissions for the SIDOR using IPCC method and default EF (2006 IPCC Guidelines) - calculation of CH_4 & N_2O emissions for the SIDOR using IPCC method and default EF (2006 IPCC Guidelines)	- misallocation correction - revised method - new estimates
6D	- new estimates for composting activities (source category previously NE)	- new source category

Table 8-2 presents the main revisions and recalculations between submissions 2007v3.1 and 2008v1.2 (see also CRF tables 8).

Table 8-2 – Changes in GHG inventories: submissions 2007v3.1 and 2008v1.2

GHG source & sink category	Revisions 2007v3.1 ➔ 2008v1.2	Type of revision
6B2	- 2005 data for CRF category 6B2 was 2004 data	- error correction

8.1.2. Completeness

Table 8-3 gives an overview of the IPCC categories included under CRF Sector 6 and provides information on the status of emission estimates of all subcategories.

Table 8-3 – Overview of subcategories of CRF Sector 6 – Waste: status of emission estimates for CO_2, CH_4 and N_2O

GHG source & sink category	Description	Status		
		CO_2	CH_4	N_2O
6A1	solid waste disposal on land – managed waste disposal on land	NO	X	
6A2	solid waste disposal on land – unmanaged waste disposal sites	NO	NO	
6A3	solid waste disposal on land - other	NA	NA	
6B1	wastewater handling – industrial wastewater		NE	NE
6B2	wastewater handling – domestic & commercial wastewater		X	X
6B3	wastewater handling – other		NA	NA
6C	waste incineration	IE *	IE *	IE *
6D	other – compost production	NO	NO (1990-1992) X (1993-2006)	NO (1990-1992) X (1993-2006)

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.

* = waste incineration is recorded under CRF Sub-category 1A1a since electricity is produced from incinerated municipal waste residues.

8.1.3. Emission trends

This section briefly describes the emission trends from 1990 to 2006 for each of the IPCC Categories under CRF Sector 6. For this analysis, IPCC Category 6C – Waste Incineration 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 6C report IE for this category (see Table 8-3).

As shown in Table 8-4 – and in Figures 8-1 and 8-2 that provide a quick overview on waste and wastewater handling related emission trends between 1990 and 2006 – total waste related GHG emissions have decreased by a bit more than 8% (-29.6% for methane but +125.5% for nitrous oxide). This evolution was mainly driven by the fact that for IPCC Category 6A – Solid Waste Disposal on Land, methane emissions have been divided by almost 2 between 1990 and 2006 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 recent installation of methane recovery systems at waste dumping sites.

For the two other categories, i.e. IPCC Categories 6B – Wastewater Handling and 6D – Other – Compost Production, unlike IPCC Category 6A, an increase of emissions is recorded for the years 1990 to 2006.

Wastewater treatment plant (*WWTP*) capacities expressed in population-equivalents have steadily grown since 1990 (see Section 8.3.2). This justifies, but only partly, the increasing N_2O emissions for this source category. Indeed, WWTP capacities grew by some 71% over the period 1990 to 2006[81] whereas nitrous oxide emissions, as shown in Table 6-4, increased only by a bit more than 11%. Therefore, technical changes with regard to wastewater treatment have an unquestionable role too as the evolution observed for the (very low) methane emissions (-40%) demonstrates.

With regard to compost production, this activity started on an "industrial scale" only in the early 1990s. This explains the very high, and therefore not really exploitable, percentage growths observed for both CH_4 and N_2O. Nevertheless, compost production developed so quickly during ten years (1993-2003)[82] that, with 34%, it has now become, behind SWDL (49%), the second contributor to waste treatment GHG related emissions: see Figure 8-3 depicting the shares of each IPCC Categories under CRF Sector 6 for both the years 1990 and 2006.

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[81] This increase is notably explained by the significant population growth – some 24% between 1990 and 2006 - and by the increasing number of commuters who are crossing the border every working days (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_2O emissions from WWTP.

[82] It stabilized since 2003 (see Section 8.5.2).

Table 8-4 – GHG emission trends in CO_2e for CRF Sector 6 – Waste: 1990-2006

Year	CO_2e emissions (Gg) – GHG source & sink category															
	6A - Solid Waste Disposal on Land				6B - Waste Water Handling				6D - Other - Compost Production				6 - Waste			
	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O
1990	42.67	NO	42.67	NA	6.86	NA	0.01	6.85	NO	NO	NO	NO	49.53	NA,NO	42.68	6.85
1991	37.47	NO	37.47	NA	6.97	NA	0.01	6.96	NO	NO	NO	NO	44.44	NA,NO	37.48	6.96
1992	36.80	NO	36.80	NA	7.09	NA	0.01	7.08	NO	NO	NO	NO	43.89	NA,NO	36.81	7.08
1993	39.11	NO	39.11	NA	7.20	NA	0.01	7.20	1.03	NO	0.49	0.54	47.34	NA,NO	39.60	7.74
1994	27.30	NO	27.30	NA	7.32	NA	0.01	7.32	1.19	NO	0.57	0.63	35.82	NA,NO	27.87	7.95
1995	27.51	NO	27.51	NA	7.28	NA	0.01	7.28	1.49	NO	0.71	0.78	36.28	NA,NO	28.22	8.06
1996	28.77	NO	28.77	NA	7.00	NA	0.01	7.00	1.30	NO	0.62	0.68	37.08	NA,NO	29.39	7.68
1997	29.19	NO	29.19	NA	7.13	NA	0.00	7.13	2.85	NO	1.35	1.50	39.17	NA,NO	30.55	8.62
1998	29.61	NO	29.61	NA	7.26	NA	0.00	7.26	4.72	NO	2.24	2.48	41.60	NA,NO	31.86	9.74
1999	29.61	NO	29.61	NA	7.39	NA	0.00	7.39	4.91	NO	2.33	2.58	41.91	NA,NO	31.94	9.97
2000	29.40	NO	29.40	NA	7.52	NA	0.00	7.51	9.11	NO	4.46	4.64	46.02	NA,NO	33.87	12.16
2001	25.83	NO	25.83	NA	7.67	NA	0.00	7.66	8.50	NO	4.17	4.33	42.00	NA,NO	30.01	11.99
2002	22.26	NO	22.26	NA	7.18	NA	0.00	7.18	10.32	NO	5.10	5.23	39.76	NA,NO	27.36	12.40
2003	23.52	NO	23.52	NA	7.26	NA	0.00	7.25	13.19	NO	6.47	6.72	43.97	NA,NO	29.99	13.97
2004	23.94	NO	23.94	NA	7.35	NA	0.00	7.34	12.88	NO	6.32	6.56	44.17	NA,NO	30.27	13.90
2005	23.94	NO	23.94	NA	7.46	NA	0.00	7.46	13.75	NO	6.75	7.00	45.16	NA,NO	30.70	14.46
2006	22.42	NO	22.42	NA	7.63	NA	0.00	7.63	15.44	NO	7.62	7.82	45.49	NA,NO	30.05	15.44
Trend 1990-2006	-47.46%	NA	-47.46%	NA	11.29%	NA	-39.97%	11.34%	1402.58%	NA	1463.23%	1347.80%	-8.15%	NA	-29.60%	125.45%

Source: Environment Agency.

Notes:

CH_4 emissions are converted in CO_2e by multiplying the emissions by 21, i.e. the global warming potential (*GWP*) value for methane based on the effects of GHG over a 100-year time horizon.

N_2O emissions are converted in CO_2e by multiplying the emissions by 310, i.e. the global warming potential (*GWP*) value for nitrous oxide based on the effects of GHG over a 100-year time horizon.

More details and explanations are also presented in the subsequent sections detailing each of the sector source categories.

Figure 8-1 – GHG emission trends in % for CRF Sector 6 – Waste: 1990-2006

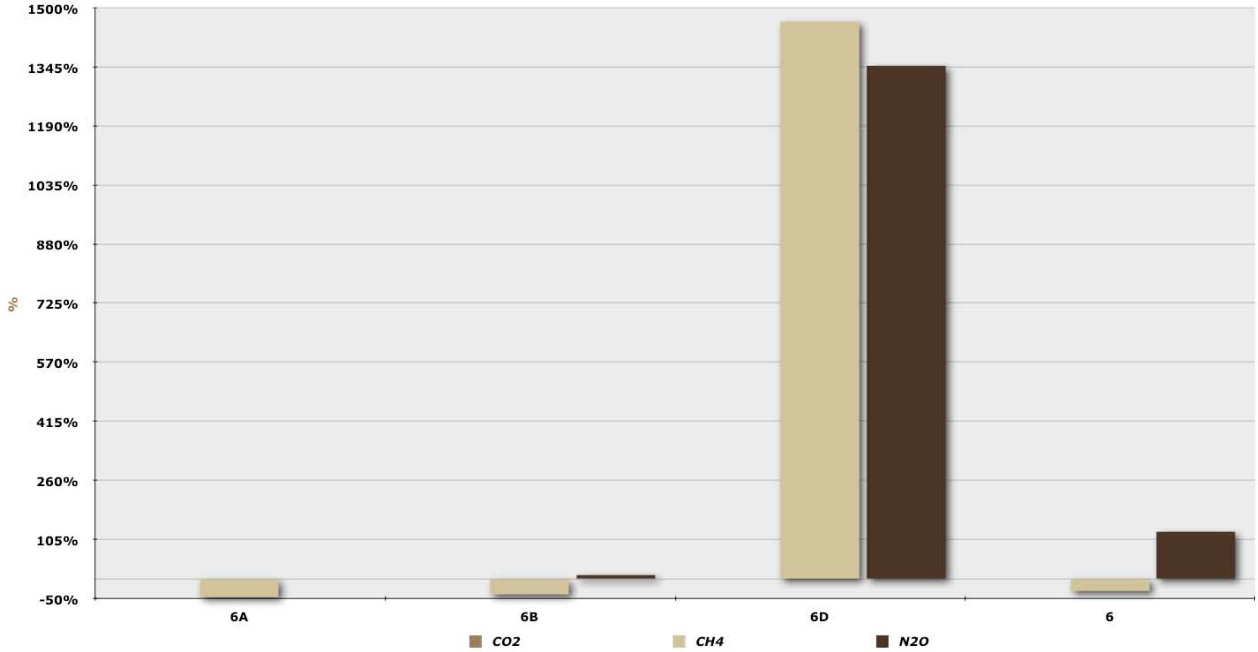


Figure 8-2 – GHG emission trends – indexes – for CRF Sector 6 – Waste: 1990-2006

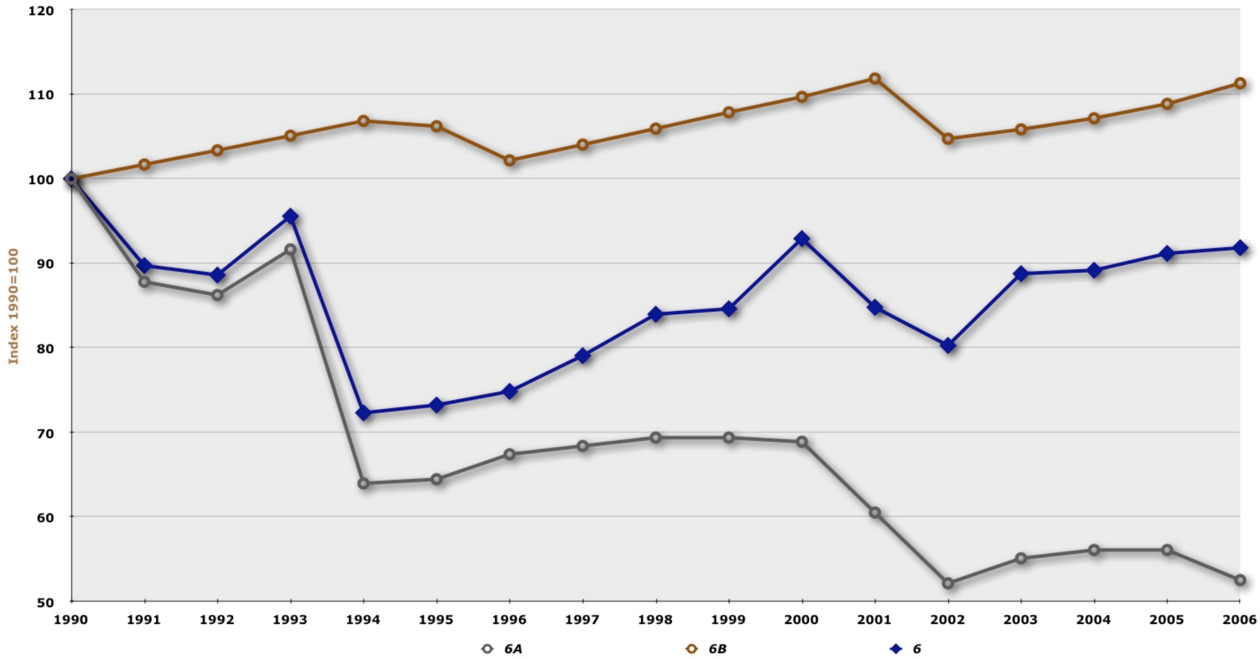
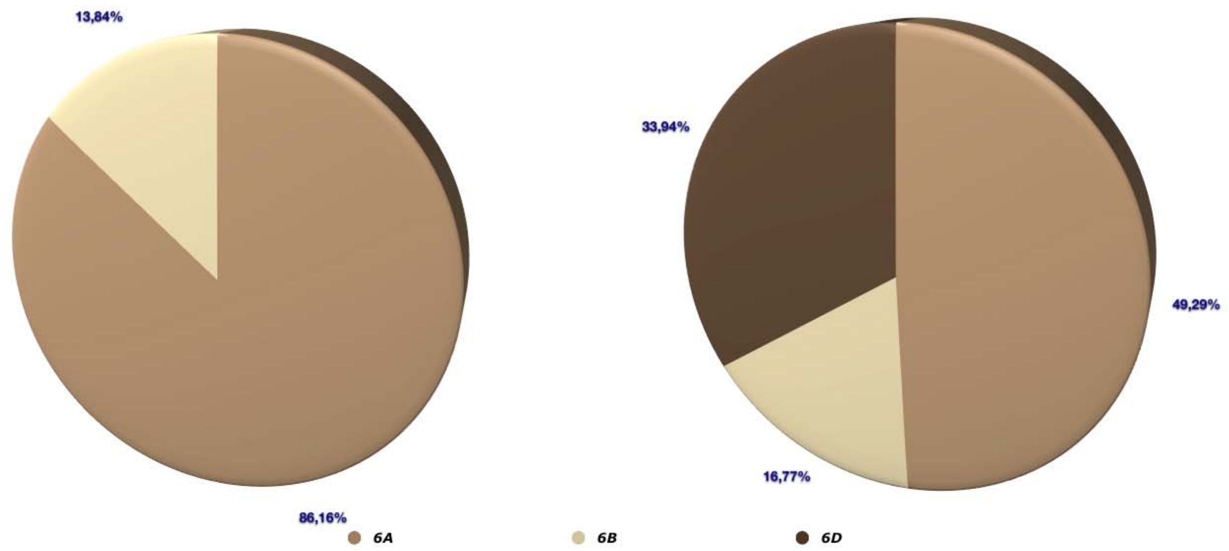


Figure 8-3 – IPCC Categories weights for CRF Sector 6 – Waste: 1990 and 2006

1990 2006



8.2. Solid Waste Disposal on Land (IPCC Source Category 6A)

This section describes the estimation of methane emissions resulting from solid waste disposal on land (*SWDL*). In 2006, this source category was responsible for 74,6% of waste treatment methane related emissions – excluding waste incineration – and for 4.8% of the total methane emissions estimated for Luxembourg. It represented 0.17% of the total GHG emissions in CO_2e (excluding LULUCF).

8.2.1. Key source

None of the source categories under SWDL is a key source.

8.2.2. Source category description

IPCC Category 6A covers waste disposal on land – or landfilled waste – whether generated by households or enterprises. For the moment, Luxembourg's GHG inventory covers only municipal waste disposal 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.[83]

[83] For details on municipal waste collection, see http://www.environnement.public.lu/dechets/statistiques_indicateurs/LUXUS_Daten/index.html (in German) and

Municipal waste is partly landfilled – i.e. the SWDL to be accounted for under IPCC Category 6A –, partly incinerated – i.e. the SWDL to be accounted for under IPCC Category 6C – and partly recycled or recovered. For the latter, door to door collections of selected refuses (paper and cardboard, packaging (plastic bottles, cans & Tetra-Pack®), garden waste, etc.), recycling centres and/or on-street specific waste containers where selected waste can be dumped exist.

In Luxembourg, the collection of municipal waste falls within the competence of municipal waste management associations. These associations are:

- SIDEC[84] = association for the management of household and similar to household waste for the municipalities of the regions Diekirch, Ettelbruck and Colmar-Berg;
- SIDOR[85] = association for the management of household and similar to household waste for the municipalities of the districts Luxembourg, Esch-sur-Alzette and Capellen;
- SIGRE[86] = association for the management of household and similar to household waste for the municipalities of the regions Grevenmacher, Remich and Echternach;
- SIDA[87] = 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 – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production.

At the site of SIGRE, a methane recovery system is operated since 2000, and since 2002 at the SIDEC site.

Table 8-5 summarizes the situation for each waste management association.

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http://www.environnement.public.lu/dechets/statistiques_indicateurs/index.html, line "*Activité des parcs à conteneurs (recycling centres)*" (in French).

84 *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.*

85 *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.*

86 *Syndicat Intercommunal pour la collecte, l'évacuation et l'élimination des ordures provenant des communes de la région de Grevenmacher, Remich et Echternach.*

87 *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.*

Table 8-5 – Municipal solid waste management in Luxembourg

Association	Waste elimination scheme	Operating years with regard to the GHG inventory
SIDEC	landfill	1990-2006
SIDOR	incineration	1990-2006
SIGRE	landfill	1990-2006
SIDA	landfill	1990-1993

Source: Environment Agency.

To summarize:

- IPCC Category 6A covers methane emissions for SNAP category 090401 – managed waste disposal on land. No CO_2 emissions deriving 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 ➔ **IPCC Category 6A = IPCC Sub-category 6A1**;
- only municipal waste from households or similar to households waste are actually accounted for in the inventory. Industrial waste disposal on land has not been yet estimated.[88]

8.2.3. Methodological issues

The Revised 1996 IPCC Guidelines outline two methods to estimate CH_4 emissions from solid waste disposal sites, the default method (Tier 1) and the First Order Decay (*FOD*) method (Tier 2).

The main difference between the two methods is that the FOD approach produces a time-dependent emission profile that better reflects the true pattern of the degradation process over time, whereas the default method is based on the assumption that all potential CH_4 is released in the year the waste is disposed of.

It is good practice to use the FOD method, if possible, because it more accurately reflects emission trends. The use of the FOD method requires current, as well as historic, data on waste quantities, composition and disposal practices for several decades. It is good practice to estimate this historical data, if unavailable, when waste disposal on land is a key source category or if there have been significant changes in waste management practices.

The IPCC Guidelines do not provide default values or methods for the estimation of some key parameters needed to use the FOD method. These data are very dependent on country-specific conditions, and currently there are not enough data available to give reliable default values or methods for them.

88 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 (Ronnebierg site).

Nevertheless, a Tier 2 method has been used for estimating SWDL related methane emissions. It relies on a detailed study on the methane generation from managed municipal waste disposal on land that has been completed in 2006 for the Environment Agency [Strauss, 2006].

8.2.3.1. Activity data

Table 8-6 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 100 000 commuters (i.e. around a quarter of the resident population) are crossing Luxembourg's borders to come to work (see Section 2.1.1.1 in Chapter 2). They, of course, generate important quantities of waste that are then divided by the resident population when estimating per capita figures.

Table 8-6 – SWDL and trends by landfill site: 1990-2006

Year	*SWDL* 6A - Solid Waste Disposal on Land				Per capita values	
	SIDEC *tonnes*	SIGRE *tonnes*	SIDA *tonnes*	Total *tonnes*	Population *#*	SWDL/capita *kg/hab.*
1990	58234	18400	11000	87634	384400	227.98
1991	39340	24600	10600	74540	389600	191.32
1992	38111	5461	10100	53672	394800	135.95
1993	39259	13712	13058	66029	400200	164.99
1994	45526	18548	NO	64074	405700	157.93
1995	47309	21361	NO	68670	411600	166.84
1996	51021	43043	NO	94064	416900	225.63
1997	42019	35004	NO	77023	422100	182.48
1998	41898	33839	NO	75737	427400	177.20
1999	40547	26570	NO	67117	433600	154.79
2000	41600	20128	NO	61728	439000	140.61
2001	43022	22096	NO	65118	444000	146.66
2002	41780	24172	NO	65952	448300	147.12
2003	41453	25874	NO	67327	455000	147.97
2004	35535	23924	NO	59459	461200	128.92
2005	40941	32247	NO	73188	469100	156.02
2006	34362	30166	NO	64528	476200	135.51
Trend 1990-2006	*-40.99%*	*63.95%*	*NA*	*-26.37%*	*23.88%*	*-40.56%*

Sources: STATEC, *Statistical Yearbook*, Table B.1100: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1058.

STATEC, *Statistical Yearbook*, Table A.3300: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1036

data extracted on 4 December 2007 (subject to changes since that date)

8.2.3.2. Emission factors

EFs for SWDL related methane emissions are actually IEFs obtained by applying the Tier 2 FOD method.

As indicated in the 2000 IPCC-GPG, "*The FOD method can be expressed equivalently by equation 5.1 and equation 5.2 below. Equation 5.1 is based on the derivative of the general FOD equation (see p 6.10, Revised 1996 IPCC Guidelines) with t replaced by t – x, representing a normalisation factor that corrects for* *the fact that the evaluation for a single year is a discrete time estimate rather than a continuous time estimate*".[89] These equations are:

$$CH_4 \text{ generated in year } t\ (Gg/yr) = \sum_x [(A \bullet k \bullet MSW_T(x) \bullet MSW_F(x) \bullet L_0(x)) \bullet e^{-k(t-x)}]$$

➔ equation 5.1 of the 2000 IPCC-GPG

which gives, when adding up the obtained results for all years (x):

$$CH_4 \text{ emitted in year } t\ (Gg/yr) = [CH_4 \text{ generated in year } t - R(t)] \bullet (1 - OX)$$

➔ equation 5.2 of the 2000 IPCC-GPG.

Table 8-7 recapitulates the various activity data, coefficients and parameters used to estimate SWDL methane emission using the Tier 2 FOD method.

Table 8-7 – Activity data, coefficients and parameters used for IPCC Category 6A – SWDL

Parameter	Description	Expressed as	Type and source of value
CH_4	methane emissions generated in year t	Gg/year	calculated by the Environment Agency (see Tables 8-11 to 8-14)
x	initial year to t	-	-
t	year of inventory	-	14
A	normalisation factor which corrects the addition	$A = \frac{(1 - e^{-k})}{k}$	0.97565
k	methane generation rate constant[90]	$k = \frac{\ln 2}{t_{1/2}}$	0.5
$MSW_T(x)$	total municipal solid waste (*MSW*) generated in year x	Gg/year	AD (see Table 8-6)
$MSW_F(x)$	fraction of MSW disposed at solid waste disposal sites (*SWDS*) in year x	fraction	calculated by the Environment Agency (see Tables 8-8 to 8-10)
$L_0(x)$	methane generation potential	$L_0(x) = MCF(x) \bullet DOC(x) \bullet DOC_F \bullet F \bullet \frac{16}{12}$ Gg CH4/Gg waste	parameter (see 2000 IPCC-GPG, p. 5.6)
MCF(x)	methane correction factor in year x	fraction	1.0 (see table 5.1 – 2000 IPCC-GPG)
DOC (x)	degradable organic carbon (*DOC*) in year x	$DOC = (0.4 \bullet A) + (0.17 \bullet B) + (0.15 \bullet C) + (0.3 \bullet D)$ fraction in Gg C/Gg waste	parameter calculated by the Environment Agency (see Tables 8-8 to 8-10 and equation 5.4 – 2000 IPCC-GPG)
DOCF	fraction of DOC dissimilated	fraction	0.5 (see 2000 IPCC-GPG, p. 5.9)
F	fraction by volume of CH_4 in landfill gas	fraction	0.5 (see 2000 IPCC-GPG, p. 5.10)
16 / 12	conversion from C to CH_4	fraction	-
R	methane recovery	m^3 gaz/h	calculated by the Environment Agency (see Tables 8-8 to 8-10)
OX	oxidation factor	fraction	0.1 (see 2000 IPCC-GPG, p. 5.10)

Tables 8-8 to 8-10 detail the values estimated for some of the parameters presented in Table 8-7: DOC, some fractions of MSW and methane recovery on SWDS for each of the 3 SWDS.

[89] 2000 IPCC-GPG, page 5.6.

[90] If no data on types of waste are available, a k value of 0.05 (a half life of about 14 years) is suggested as a default value (see 2000 IPCC-GPG, page 5.10).

Table 8-8 – Parameters: DOC, fractions and R – SIDEC: 1990-2006

Year of waste disposal	Degradable Organic Carbon (*DOC*) *%*	fraction x of MSW that is paper and textiles *A*	fraction y of MSW that is garden waste *B*	fraction w of MSW that is food waste *C*	fraction z of MSW that is wood or straw *D*	recovery (R) *m^3 gaz/h*
1990	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1991	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1992	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1993	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1994	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1995	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1996	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1997	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1998	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1999	14.61%	0.2190	0.0728	0.2912	0.0080	NO
2000	14.66%	0.2110	0.0736	0.2576	0.0368	NO
2001	14.66%	0.2110	0.0736	0.2576	0.0368	NO
2002	14.66%	0.2110	0.0736	0.2576	0.0368	85
2003	14.66%	0.2110	0.0736	0.2576	0.0368	85
2004	15.83%	0.2772	0.0333	0.2609	0.0089	85
2005	15.83%	0.2772	0.0333	0.2609	0.0089	85
2006	15.83%	0.2772	0.0333	0.2609	0.0089	85

<u>Source</u>: Environment Agency.

Table 8-9 – Parameters: DOC, fractions and R – SIGRE: 1990-2006

Year of waste disposal	Degradable Organic Carbon (*DOC*) *%*	fraction x of MSW that is paper and textiles *A*	fraction y of MSW that is garden waste *B*	fraction w of MSW that is food waste *C*	fraction z of MSW that is wood or straw *D*	recovery (R) *m^3 gaz/h*
1990	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1991	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1992	11.33%	0.2190	0.0728	0.0728	0.0080	NO
1993	11.33%	0.2190	0.0728	0.0728	0.0080	NO
1994	11.33%	0.2190	0.0728	0.0728	0.0080	NO
1995	11.33%	0.2190	0.0728	0.0728	0.0080	NO
1996	11.33%	0.2190	0.0728	0.0728	0.0080	NO
1997	11.33%	0.2190	0.0728	0.0728	0.0080	NO
1998	11.33%	0.2190	0.0728	0.0728	0.0080	NO
1999	11.33%	0.2190	0.0728	0.0728	0.0080	NO
2000	11.76%	0.2110	0.0736	0.0644	0.0368	NO
2001	11.76%	0.2110	0.0736	0.0644	0.0368	70
2002	11.76%	0.2110	0.0736	0.0644	0.0368	50
2003	11.76%	0.2110	0.0736	0.0644	0.0368	30
2004	13.53%	0.2873	0.0417	0.0669	0.0108	30
2005	13.53%	0.2873	0.0417	0.0669	0.0108	30
2006	13.53%	0.2873	0.0417	0.0669	0.0108	30

<u>Source</u>: Environment Agency.

Table 8-10 – Parameters: DOC, fractions and R – SIDA: 1990-1993

Year of waste disposal	Degradable Organic Carbon (*DOC*)	fraction x of MSW that is paper and textiles	fraction y of MSW that is garden waste	fraction w of MSW that is food waste	fraction z of MSW that is wood or straw	recovery (R)
	%	*A*	*B*	*C*	*D*	*m³ gaz/h*
1990	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1991	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1992	14.61%	0.2190	0.0728	0.2912	0.0080	NO
1993	14.61%	0.2190	0.0728	0.2912	0.0080	NO

Source: Environment Agency.

Tables 8-11 to 8-14 detail methane emissions generated in year t for each of the 3 SWDS.

Table 8-11 – CH_4 emission generated in year t: summary 1990-2006

Year	*CH_4 emissions (Gg)* 6A - Solid Waste Disposal on Land			
	SIDEC	SIGRE	SIDA	Total
1990	1 111.00	423.00	482.00	2 016.00
1991	1 095.00	419.00	464.00	1 978.00
1992	1 085.00	412.00	443.00	1 940.00
1993	1 078.00	398.00	572.00	2 048.00
1994	1 086.00	394.00	NO	1 480.00
1995	1 098.00	396.00	NO	1 494.00
1996	1 118.00	437.00	NO	1 555.00
1997	1 115.00	461.00	NO	1 576.00
1998	1 113.00	482.00	NO	1 595.00
1999	1 108.00	488.00	NO	1 596.00
2000	1 105.00	484.00	NO	1 589.00
2001	1 106.00	484.00	NO	1 590.00
2002	1 105.00	488.00	NO	1 593.00
2003	1 102.00	495.00	NO	1 597.00
2004	1 092.00	505.00	NO	1 597.00
2005	1 078.00	532.00	NO	1 610.00
2006	1 073.00	545.00	NO	1 618.00
Trend 1990-2006	*-3.42%*	*28.84%*	*NA*	*-19.74%*

Source: Environment Agency.

Table 8-12 – CH_4 emission generated in year t – SIDEC: detail 1990-2006

	Inventory year																
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1975	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26									
1976	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26								
1977	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26							
1978	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26						
1979	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26					
1980	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26				
1981	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26			
1982	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26		
1983	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26	
1984	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26
1985	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95
1986	81.09	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72
1987	85.20	81.09	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58
1988	89.53	85.20	81.09	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54

1989	94.07	89.53	85.20	81.09	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60
1990	136.95	130.34	124.04	118.05	112.35	106.92	101.75	96.84	92.16	87.71	83.47	79.44	75.60	71.95	68.48	65.17	62.02
1991		85.46	81.33	77.41	73.67	70.11	66.72	63.50	60.43	57.51	54.73	52.09	49.57	47.18	44.90	42.73	40.67
1992			89.63	85.30	81.18	77.26	73.52	69.97	66.59	63.38	60.31	57.40	54.63	51.99	49.48	47.09	44.81
1993				92.33	87.87	83.62	79.58	75.74	72.08	68.60	65.28	62.13	59.13	56.27	53.56	50.97	48.51
1994					107.07	101.89	96.97	92.29	87.83	83.59	79.55	75.71	72.05	68.57	65.26	62.10	59.10
1995						111.26	105.88	100.77	95.90	91.27	86.86	82.66	78.67	74.87	71.25	67.81	64.54
1996							119.99	114.19	108.68	103.43	98.43	93.68	89.15	84.84	80.75	76.85	73.13
1997								98.82	94.04	89.50	85.18	81.06	77.15	73.42	69.87	66.50	63.29
1998									98.53	93.77	89.24	84.93	80.83	76.93	73.21	69.67	66.31
1999										95.36	90.75	86.37	82.19	78.22	74.45	70.85	67.43
2000											98.19	93.45	88.93	84.64	80.55	76.66	72.96
2001												101.55	96.64	91.97	87.53	83.30	79.28
2002													98.62	93.85	89.32	85.00	80.90
2003														97.84	93.12	88.62	84.34
2004															90.60	86.22	82.06
2005																103.24	98.25
2006																	87.61

Source: Environment Agency.

Table 8-13 – CH_4 emission generated in year t – SIGRE: detail 1990-2006

	Inventory year																
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1975	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10									
1976	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10								
1977	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10							
1978	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10						
1979	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10					
1980	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10				
1981	24.94	1.00	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10			
1982	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10		
1983	27.54	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10	
1984	28.94	27.54	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77	13.10
1985	30.40	28.94	27.54	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47	13.77
1986	31.95	30.40	28.94	27.54	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20	14.47
1987	33.57	31.95	30.40	28.94	27.54	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97	15.20
1988	35.27	33.57	31.95	30.40	28.94	27.54	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78	15.97
1989	37.06	35.27	33.57	31.95	30.40	28.94	27.54	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64	16.78
1990	38.94	37.06	35.27	33.57	31.95	30.40	28.94	27.54	26.21	24.94	23.74	22.59	21.50	20.46	19.47	18.53	17.64
1991		57.85	55.06	52.40	49.87	47.46	45.17	42.98	40.91	38.93	37.05	35.26	33.56	31.94	30.39	28.93	27.53
1992			9.96	9.48	9.02	8.59	8.17	7.78	7.40	7.04	6.70	6.38	6.07	5.78	5.50	5.23	4.98
1993				25.01	23.81	22.66	21.56	20.52	19.53	18.59	17.69	16.83	16.02	15.25	14.51	13.81	13.14
1994					33.84	32.20	30.65	29.17	27.76	26.42	25.14	23.93	22.77	21.67	20.62	19.63	18.68
1995						38.97	37.09	35.29	33.59	31.97	30.42	28.95	27.55	26.22	24.96	23.75	22.60
1996							78.52	74.73	71.12	67.68	64.41	61.30	58.34	55.52	52.84	50.29	47.86
1997								63.86	60.77	57.84	55.04	52.38	49.85	47.44	45.15	42.97	40.90
1998									61.73	58.75	55.91	53.21	50.64	48.19	45.87	43.65	41.54
1999										48.47	46.13	43.90	41.78	39.76	37.84	36.01	34.27
2000											38.12	36.28	34.52	32.86	31.27	29.76	28.32
2001												41.84	39.82	37.90	36.07	34.33	32.67

2002													45.78	43.56	41.46	39.46	37.55
2003														49.00	46.63	44.38	42.24
2004															52.11	49.60	47.20
2005																70.24	66.85
2006																	65.71

Source: Environment Agency.

Table 8-14 – CH_4 emission generated in year t – SIDA: detail 1990-2006

	Inventory year																
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1975	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26									
1976	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26								
1977	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26							
1978	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26						
1979	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26					
1980	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26				
1981	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26			
1982	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26		
1983	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26	
1984	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95	33.26
1985	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72	34.95
1986	81.09	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58	36.72
1987	85.20	81.09	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54	38.58
1988	89.53	85.20	81.09	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60	40.54
1989	94.07	89.53	85.20	81.09	77.17	73.44	69.89	66.52	63.30	60.25	57.34	54.57	51.93	49.42	47.03	44.76	42.60
1990	25.87	24.62	23.43	22.30	21.22	20.20	19.22	18.29	17.41	16.57	15.77	15.01	14.28	13.59	12.93	12.31	11.72
1991		24.93	23.72	22.58	21.49	20.45	19.46	18.52	17.63	16.78	15.97	15.19	14.46	13.76	13.10	12.46	11.86
1992			23.75	22.61	21.51	20.47	19.49	18.54	17.65	16.80	15.98	15.21	14.48	13.78	13.11	12.48	11.88
1993				30.71	29.23	27.81	26.47	25.19	23.97	22.82	21.71	20.67	19.67	18.72	17.81	16.95	16.13
1994					NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1995						NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1996							NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1997								NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1998									NO	NO	NO	NO	NO	NO	NO	NO	NO
1999										NO	NO	NO	NO	NO	NO	NO	NO
2000											NO	NO	NO	NO	NO	NO	NO
2001												NO	NO	NO	NO	NO	NO
2002													NO	NO	NO	NO	NO
2003														NO	NO	NO	NO
2004															NO	NO	NO
2005																NO	NO
2006																	NO

Source: Environment Agency.

Methane IEFs for IPCC Category 6A – SWDL

Table 8-15 presents the IEFs obtained using the Tier 2 method described above.

Table 8-15 – CH_4 IEFs trends for IPCC Category 6A – SWDL: 1990-2006

IEF for CH_4 (kg/t MSW)	
Year	6A - SWDL
1990	23.19
1991	34.17
1992	32.65
1993	28.20
1994	20.29
1995	19.08
1996	14.57
1997	18.05
1998	18.62
1999	21.01
2000	22.68
2001	21.96
2002	21.91
2003	21.22
2004	21.66
2005	21.66
2006	21.66
Trend 1990-2006	*-6.59%*
IEF type	*D*

Source: Environment Agency.

8.2.4. Recalculations

See Tables 8-1 and 8-2 in Section 8.1.1.

8.2.5. Category specific QA / QC procedures

No category specific QA/QC procedures have been completed, only the tools embedded in CRF Reporter have been used.

8.2.6. 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 8-16 will be explored.

Table 8-16 – Planned improvements for IPCC Category 6A – SWDL

GHG source & sink category	Planned improvement
6A - SWDL	analyze whether it would be possible to include methane emission estimates for the industrial waste landfill site Ronnebierg (that is nowadays closed down).
6A – SWDL	revise the AD used for the years 1991 and 2002 to 2005: inconsistencies between data reported in CRF tables and data published by STATEC (see Table 8-6).
6A –SWDL	revise and complete additional information for CRF table 6A – sectoral background data for waste.

8.3. Wastewater Handling (IPCC Source Category 6B)

This section describes the estimation of methane and nitrous oxide emissions resulting from wastewater handling (*WWH*). In 2006, this source category was responsible for a bit less than 17% of the total GHG emissions from the waste sector – excluding waste incineration – and it represented 0.06% of the total GHG emissions in CO_2e (excluding LULUCF). For each of the two gases reported, in 2006:

- CH_4 represented 0.01% of waste treatment methane related emissions – excluding waste incineration – and 0.001% of the total methane emissions estimated for Luxembourg;
- N_2O represented 49.4% of waste treatment nitrous oxide related emissions – excluding waste incineration – and almost 1.2% of the total nitrous oxide emissions estimated for Luxembourg.

8.3.1. Key source

None of the source categories under WWH is a key source.

8.3.2. Source category description

IPCC Category 6B covers wastewater and related sludge handling whether these have been generated by households or industrial enterprises. For the moment, Luxembourg's GHG inventory covers only domestic and commercial WWH, excluding sludge.

In addition, it is assumed that domestic and commercial WWH corresponds to municipal wastewater treatment carried out in wastewater treatment plants (*WWTPs*).

Table 8-17 shows the 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 wastewater.

Table 8-17 – Municipal WWTP capacities and aerobic procedures: 1990-2006

Year	Load treated in municipal WWTP *1000 population-equivalents*	aerobic procedures %
1990	591.6	84%
1991	594.0	85%
1992	596.5	86%
1993	600.0	87%
1994	605.8	88%
1995	631.6	89%
1996	782.4	91%
1997	788.4	92%
1998	793.9	92%
1999	799.4	93%

2000	806.9	94%
2001	811.8	94%
2002	816.7	94%
2003	818.7	94%
2004	820.7	95%
2005	820.0	95%
2006	1012.0	95%
Trend 1990-2006	*71.06%*	*NA*

Sources : STATEC, *Statistical Yearbook*, Table C.2111: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1023

data extracted on 8 November 2007 (subject to changes since that date)

Finally, CO_2 emissions from municipal WWTP are not included in Luxembourg's GHG inventory for the reason that carbon emissions derive from biomass/biogenic raw materials.

To summarize:

- IPCC Category 6B covers methane and nitrous oxide emissions for SNAP category 091002 – wastewater treatment in residential and commercial sectors and, eventually, from SNAP category 091007 – latrines.[91] No CO_2 emissions deriving from non-biological or inorganic WWH residuals have been identified so far;
- IPCC Category 6B does not cover methane and nitrous oxide emissions for SNAP category 091001 –wastewater treatment in industry ➔ **IPCC Category 6B = IPCC Sub-category 6B2**;
- emissions related to the sludge residues of domestic and commercial WWH are not estimated yet. However, sewage sludge spreading has been accounted for in the agriculture sector (see Section 6.5.3 in Chapter 6) ➔ **IPCC Category 6B = IPCC Sub-category 6B2, excluding sludge**.

8.3.3. Methodological issues – methane emissions

Municipal WWTPs in Luxembourg use mainly aerobic procedures (see Table 8-17). As a result, no or negligible methane emissions are produced since such emissions only occur under anaerobic conditions. In these plants, sludge stabilisation is completed in order to prevent uncontrolled putrefaction. In facilities with a treatment capacity smaller than 30,000 population-equivalents (*p.e*), such stabilisation is usually carried out aerobically, with energy consumption, whereas for facilities with a treatment capacity larger then 30,000 p.e., the stabilisation is normally carried out anaerobicaly resulting in the emission of methane. Methane produced that way is generally used in combined heat/power generating systems or it may be flared off.

91 In the case septic tanks are considered as "latrines".

Treatment of human sewage from inhabitants not connected to sewage networks or connected to small municipal mechanical treatment facilities represents an exception. The percentage of organic loads discharged to small mechanical treatment plant or to septic tanks has been reduced since 1990.

The methodology for the septic tanks is based on the IPPC 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 2000 IPCC-GPG default value of 0.6 kg CH_4/kg BOD is used. Each habitant produce 60 g BOD/day (2000 IPCC-GPG), and a methane conversion factor (*MCF*) of 0.27 is assumed. For the MCF for septic tanks and small mechanical treatment facilities Luxembourg has used the factor calculated for Austria. Details of this Tier 1 calculation method are presented below.

<u>Calculation of the organic load</u>

BODsep (kg/year) = [inhabitants connected to septic tanks ● 60g BOD (person/day) ● 365 (days)]/1000

BODmec (kg/year) = [inhabitants connected to mechanical WWTP ● 60g BOD (person/day) ● 365 (days)]/1000

60 g BOD/person per day is the default 2000 IPCC-GPG value

<u>Calculation of methane emissions for septic tanks and mechanical treatment facilities</u>

CH_4sep (t/year) = [BODsep (kg/year) ● B0 ● MCF]/1000

CH_4mec (t/year) = [BODmec(kg/year) ● B0 ● MCF]/1000

B0 = 0.6 kg CH4/kg BOD   2000 IPCC-GPG

MCF = [0.35 ● (2/3)] + [0.1 ● (1/3)] = 0.27 (Austrian default MCF)

<u>Total methane emission from WWH</u>

CH_4tot (t/year) = CH_4sep(t/year) + CH_4mec (t/year)

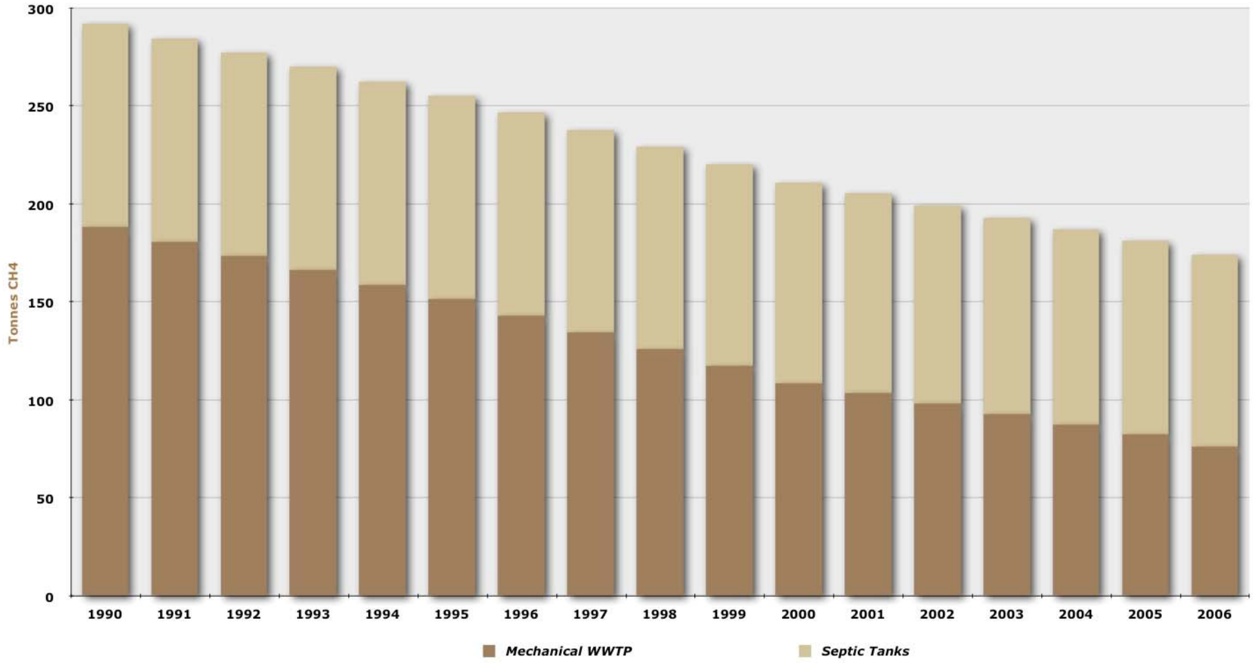
The estimated emissions obtained following the method described above are presented in Table 8-18 and Figure 8-4.

Table 8-18 – CH_4 emission trends for IPCC Sub-category 6B2 – Domestic & Commercial WWH: 1990-2006

Year	*CH_4 emissions (tonnes)* 6B2 - Domestic & Commercial WWH Mechanical	Septic Tanks	Total
1990	187.68	104.20	291.88
1991	180.38	104.20	284.58
1992	173.07	104.20	277.27
1993	165.77	104.20	269.97
1994	158.46	104.20	262.66
1995	151.16	104.20	255.36
1996	142.57	103.94	246.51
1997	133.99	103.67	237.67
1998	125.41	103.41	228.82
1999	116.83	103.15	219.97
2000	108.24	102.88	211.13
2001	102.93	102.13	205.06
2002	97.61	101.38	198.98
2003	92.29	100.62	192.91
2004	86.97	99.87	186.84
2005	82.00	99.00	181.00
2006	76.00	98.00	174.00
Trend 1990-2006	*-59.51%*	*-5.95%*	*-40.39%*

Source: Water Agency.

Figure 8-4 – CH_4 emission trends for IPCC Sub-category 6B2 – Domestic & Commercial WWH: 1990-2006



Source: Water Agency.

Methane emissions from industrial wastewater treatment

Industrial Wastewater treatment and sewage sludge treatment is carried out under aerobic conditions. As for the larger municipal WWTPs, there are no methane emissions or these are negligible.

8.3.4. Methodological issues – nitrous oxide

Pursuant to the IPCC Tier 1 method, nitrous oxide emissions from household wastewater can be evaluated in taking in 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 wastewater and for the nitrogen fraction in protein.

N_2O emissions from urban wastewater handling are calculated by distinguishing wastewater arising from population:

- not connected to a biological WWTP;
- connected to a WWTP without denitrification;
- connected to a WWTP with denitrification.

The N_2O emissions resulting from population not connected to a WWTP were calculated according to the IPCC Guidelines default approaches.

For the nitrogen calculation not only the inhabitants of the country **but also the daily commuters from neighbouring countries have been taken into account** since their number – as presented in Section 2.1.1.1 in Chapter 2 – has been steadily growing to reach, end 2006, 27% of the resident population of Luxembourg. As they are only present in the country during their working hours, only a half load of nitrogen per capita is counted for these commuters.

Figure 8-5 illustrates the population and cross-border commuters growth between 1990 and 2006. The latter is divided by 2 in the figure below (so that only a half load of nitrogen is counted for by commuting individual).

Because of Directive 91/271/EEC relating to urban wastewater treatment,[92] denitrification is a handling requirement for urban WWTPs in Luxembourg. WWTPs with an organic design capacity larger than 10,000 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.

Figure 8-6 provides an overview of the population of Luxembourg connected to WWTPs (with or without denitrification) or not.

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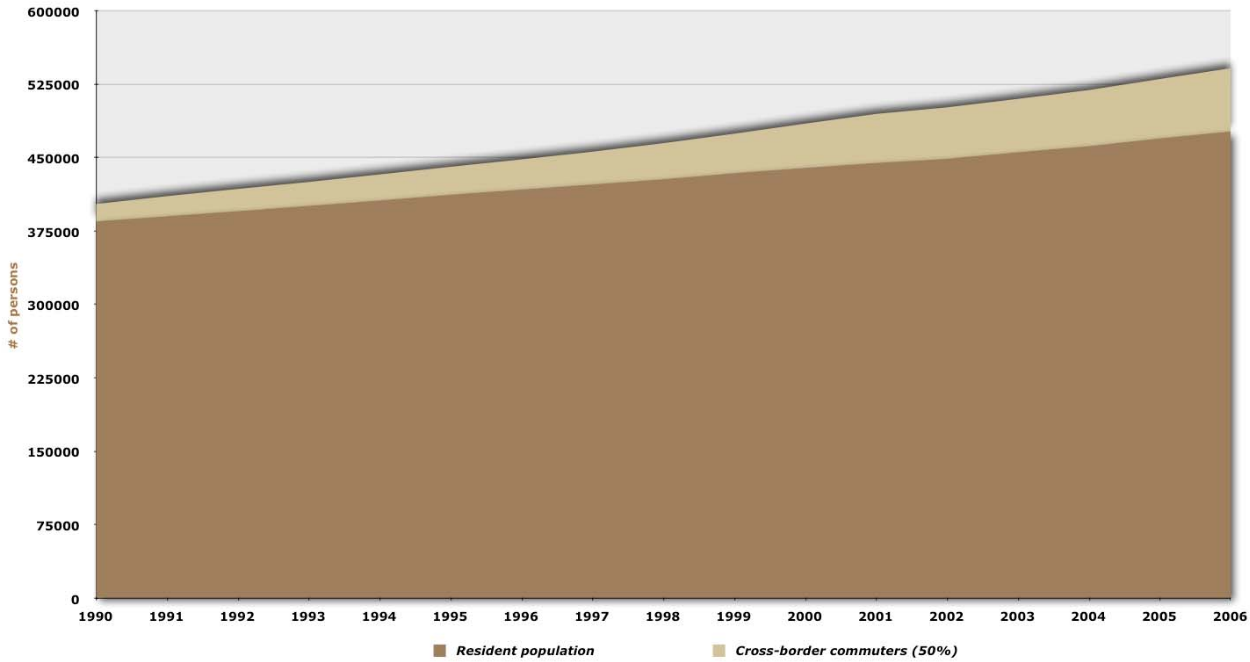
92 Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1991:135:0040:045:EN:HTML

Figure 8-5 – Resident population and cross-border commuters: 1990-2006



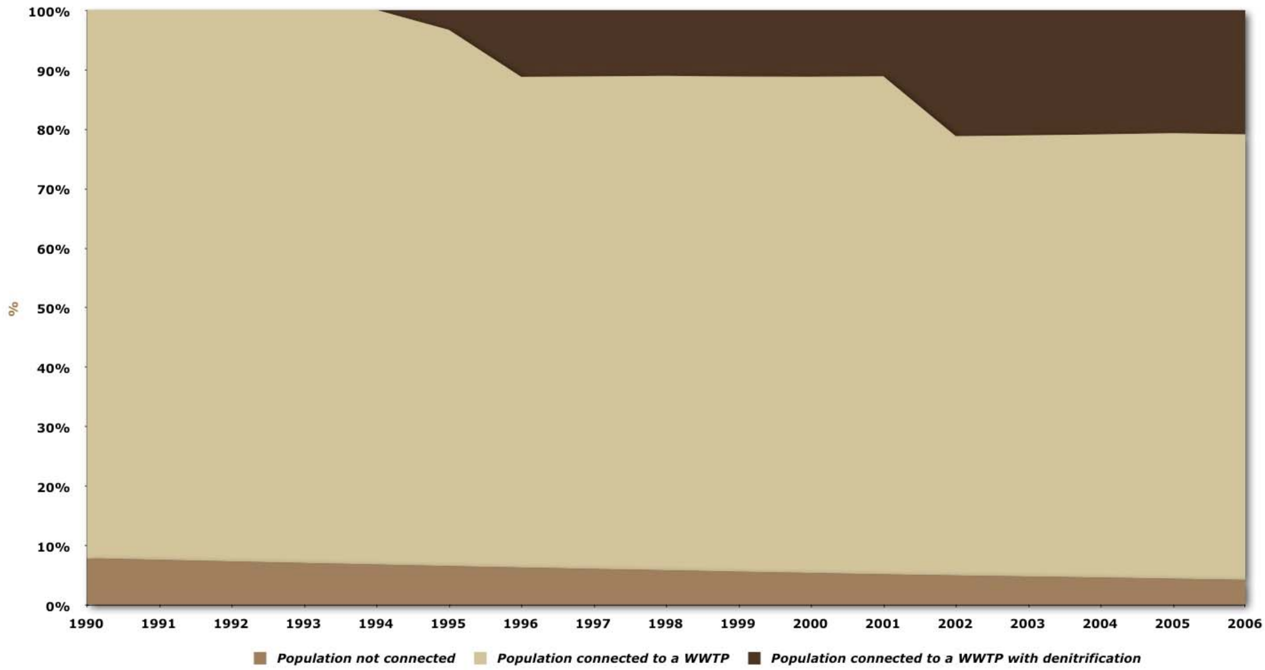
Sources: STATEC, *Statistical Yearbook*, Table B.1100: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1058

STATEC, *Statistical Yearbook*, Table B.5107: http://www.statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=1178

Note: situation on 31st December except for cross-border commuters from 2001 onwards: calculated on 30th September.

data extracted on 10 December 2007 (subject to changes since that date)

Figure 8-6 – Population connected to sewage system and biological WWTP: 1990-2006



Source: Water Agency.

Calculation of the N_2O emissions

1) determination of N_2O from wastewater not treated in a biological WWTP:

N_2Onc = [protein (kg/year) • EF]/1000 • 0.16 • 1.57

with:

protein (kg/year)	=	inhabitants (p.e.) not connected • protein intake per person	
EF	=	0.01	Revised 1996 IPCC Guidelines, table 4.23, page 4.105
			2006 IPCC Guidelines, Vol. 4, table 11.3
0.16 kg N/kg protein		Revised 1996 IPCC Guidelines, Vol. 3, page 6.28	
(44/28) = 1.57		molecular weight ratio, conversion of N_2O-N to N_2O	

2) determination of N_2O from wastewater treated in a biological WWTP without denitrification:

N_2Owwtp = [protein (kg/year)]/1000 • 0.16 • % FRAC denitri • 0.01 • 1.57

with:

protein (kg/year)	=	inhabitants (p.e.) connected • protein intake per person
0.16 kg N/kg protein		Revised 1996 IPCC Guidelines, Vol. 3, page 6.28
% FRAC denitri	=	35 % denitrification rate in % (% of wastewater which is denitrificated)
0.01		1% of the denitrificated N is emitted as N_2O (Austrian country specific factor)[93]
(44/28) = 1.57		molecular weight ratio, conversion of N_2O-N to N_2O

3) determination of N_2O from wastewater treated in a biological WWTP with denitrification:

N_2Owwtp-de = [protein (kg/year)]/1000 • 0.16 • % FRAC denitri • 0.01 • 1.57

with:

protein (kg/year)	=	inhabitants (p.e.) connected • protein intake per person
0.16 kg N/kg protein		Revised 1996 IPCC Guidelines, Vol. 3, page 6.28
% FRAC denitri	=	70 % denitrification rate in % (% of wastewater which is denitrificated)
0.01		1% of the denitrificated N is emitted as N2O (Austrian country specific factor)
(44/28) = 1.57		molecular weight ratio, conversion of N_2O-N to N_2O

4) total nitrous oxide emission from WWH:

N_2Otot = N_2Onc + N_2Owwtp + N_2Owwtp-de

93 Rudolf Orthofer, H. Martus Knoflacher & Johann Züger, *N2O-Emissioneinn Osterreich, Endbericht zum Forchungsauftrag des Bündes-ministerium für Umwelt Jugend und Familie, GZ 01 2943/2-I/7/94 von 18.Mai 1994*, Vienna, December 1994, p. 51-53.

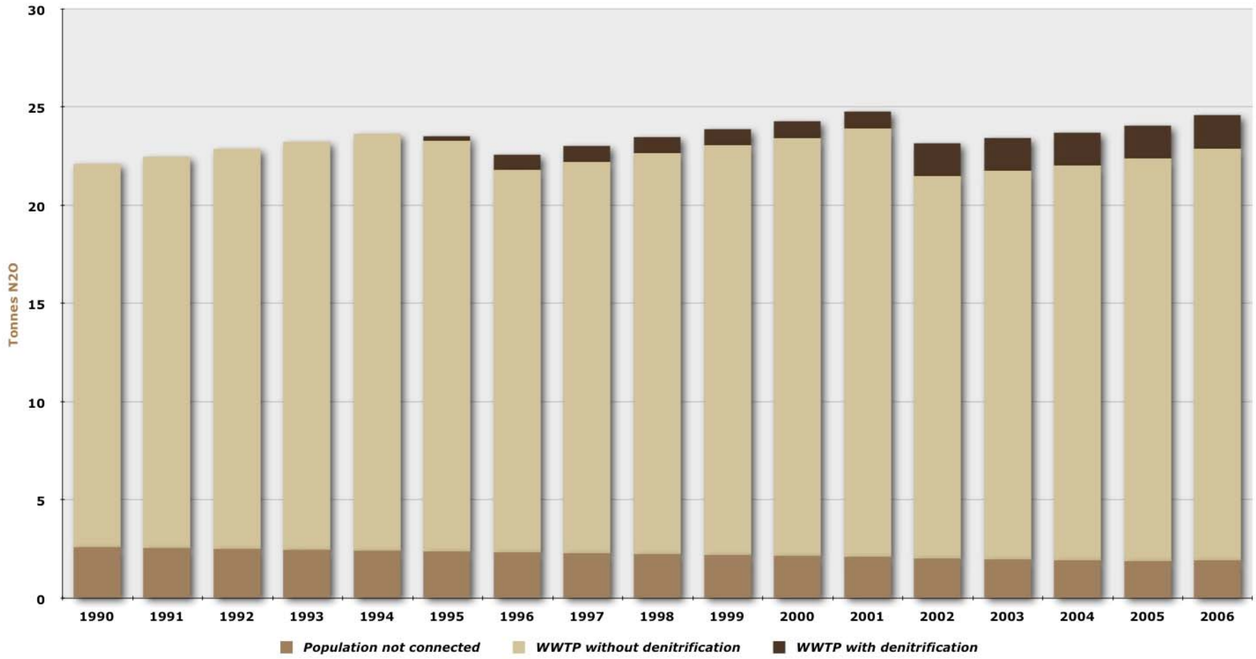
The estimated emissions obtained following the method described above are presented in Table 8-19 and Figure 8-7.

Table 8-19 – CH_4 emission trends for IPCC Sub-category 6B2 – Domestic & Commercial WWH: 1990-2006

Year	*N_2O emissions (tonnes)* 6B2 - Domestic & Commercial WWH			
	N_2Onc	N_2Owwtp	N_2Owwtp-de	Total
1990	2.55	19.55	NO	22.09
1991	2.50	19.97	NO	22.47
1992	2.46	20.38	NO	22.84
1993	2.41	20.81	NO	23.22
1994	2.36	21.25	NO	23.61
1995	2.31	20.93	0.23	23.47
1996	2.27	19.52	0.78	22.58
1997	2.23	19.97	0.79	22.99
1998	2.18	20.43	0.80	23.41
1999	2.14	20.88	0.83	23.84
2000	2.09	21.31	0.84	24.24
2001	2.05	21.82	0.85	24.72
2002	1.99	19.50	1.65	23.15
2003	1.94	19.80	1.65	23.39
2004	1.89	20.13	1.66	23.68
2005	1.84	20.55	1.67	24.06
2006	1.90	21.00	1.70	24.60
Trend 1990-2006	*-25.37%*	*7.42%*	*646.92%*	*11.34%*

Source: Water Agency.

Figure 8-7 – CH_4 emission trends for IPCC Sub-category 6B2 – Domestic & Commercial WWH: 1990-2006



Source: Water Agency.

8.3.5. Recalculations

See Tables 8-1 and 8-2 in Section 8.1.1.

8.3.6. Category specific QA/QC procedures

No category specific QA/QC procedures have been completed, only the tools embedded in CRF Reporter have been used.

8.3.7. 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 8-20 will be explored.

Table 8-20 – Planned improvements for IPCC Category 6B – WWH

GHG source & sink category	Planned improvement
6B1 – Industrial WWH	analyze whether it would be possible to include methane and nitrous oxide emission estimates for the industrial wastewater treatment.
6B2 – Domestic & Commercial WWH – CH_4	the emission estimates have to be corrected (multiplied by 1000): an error in the conversion from tonnes to Gg led to values reported in CRF tables in 1000 Gg (or millions of tonnes) instead of Gg (or thousands of tonnes).
6B2 – Domestic & Commercial WWH	analyze whether it would be possible and/or necessary to estimate emissions from sewage sludge (knowing that sewage sludge spreading is accounted for in IPCC Category 4D).

8.4. Waste Incineration (IPCC Source Category 6C)

This category is presented under IPCC Sub-category 1A1a – Fuel Combustion Activities – Energy Industries – Public Electricity and Heat Production (see Section 3.2.4 in Chapter 3) because in the sole incinerator of the country (SIDOR site), energy from waste burning is recovered and injected in the electric public network.

8.5. Other Waste – Compost Production (IPCC Source Category 6D)

This section describes the estimation of methane and nitrous oxide emissions generated by compost production. In 2006, this source category was responsible for a bit less than 34% of the total GHG emissions from the waste sector – excluding waste incineration – and it represented 0.12% of the total GHG emissions in CO_2e (excluding LULUCF). For each of the two gases reported, in 2006:

- CH_4 represented 25.4% of waste treatment methane related emissions – excluding waste incineration – and 1.64% of the total methane emissions estimated for Luxembourg;
- N_2O represented 50.6% of waste treatment nitrous oxide related emissions – excluding waste incineration – and almost 1.2% of the total nitrous oxide emissions estimated for Luxembourg.

8.5.1. Key source

Compost production is not a key source.

8.5.2. Source category description

Under IPCC Category 6D – Other, Luxembourg reports CH_4 and N_2O 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 onward. Table 8-21 shows that CH_4 and N_2O emissions generated by compost production increased a lot over time as a result of the increasing amount of waste composted.

Table 8-21 – CH_4 & N_2O emission trends for IPCC Category 6D – Other – Compost Production: 1990-2006

Year	*Emissions (Gg)* 6D – Other - Compost Production		
	CH_4	N_2O	Total in CO_2e
1990	NO	NO	NO
1991	NO	NO	NO
1992	NO	NO	NO
1993	0.023	0.002	0.853
1994	0.027	0.002	0.992
1995	0.034	0.003	1.235
1996	0.029	0.002	1.081
1997	0.064	0.005	2.364
1998	0.107	0.008	3.923
1999	0.111	0.008	4.076
2000	0.149 + *0.064*	0.011 + *0.004*	5.464 + *2.526*
2001	0.136 + *0.062*	0.010 + *0.004*	5.011 + *2.471*
2002	0.154 + *0.089*	0.012 + *0.005*	5.648 + *3.524*
2003	0.213 + *0.095*	0.016 + *0.006*	7.837 + *3.758*
2004	0.207 + *0.094*	0.016 + *0.006*	7.599 + *3.734*
2005	0.219 + *0.102*	0.016 + *0.006*	8.058 + *4.050*
2006	0.229 + *0.134*	0.017 + *0.008*	8.415 + *5.3070*

Source: Environment Agency.

Note: the added emissions (*italic*) from 2000 onwards are those of the pilot project Soil-Concept.

8.5.3. 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.

8.5.3.1. Activity data

Activity data are taken:

- from STATEC Statistical Yearbook, Table A.3312 (these data are actually 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 8-22.

Table 8-22 – Composting activities: 1993-2006

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	tonnes wet													
Total	5 805	6 746	8 398	7 354	16 083	26 685	27 729	37 169	34 088	38 424	53 310	51 692	54 817	57 242
kg/habitant			*60.2*	*49.5*	*106.8*	*100.2*	*101.6*	*133.2*	*120.8*	*134.1*	*138.2*	*133.2*	*122.3*	*125.0*
Minette-Kompost Monder-cange *(1)*	2 904	3 630	4 534	3 767	11 773	17 345	20 520	24 146	23 234	25 421	24 462	27 514	28 746	28.743
kg/habitant			*37.8*	*30.9*	*95.4*	*114.1*	*130.8*	*151.7*	*144.2*	*154.2*	*146.7*	*163.6*	*167.7*	*164.0*
SICA Mamer	2 499	2 562	3 326	3 587	4 310	3 171	3 758	4 903	4 747	4 730	4 650	4 899	5 278	5 061
kg/habitant			*170.1*	*133.5*	*158.7*	*115.6*	*135.2*	*176.0*	*170.1*	*167.5*	*164.5*	*172.2*	*181.8*	*170.4*
SIDEC Fridhaff *(3)*						6 169	3 451	8 120	5 416	5 920	6 116	6 564	6 510	6 238
SIDEC Angelsberg *(4)*									691	2 353	2 174	2 534	2 651	2 670
kg/habitant						*70.9*	*39.1*	*88.3*	*65.6*	*88.7*	*87.9*	*95.3*	*93.3*	*88.6*
Commune de Hespérange											611.4	742	786	743
kg/habitant											*50.4*	*59.2*	*59.9*	*54.9*
Ville de Luxembourg/ Reckenthal											15 297	9 439	8 083	11 108
kg/habitant											*181.5*	*113.2*	*97.5*	*122.8*
SIGRE Muertendall *(5)*													2 763	2679
kg/habitant													*51.4*	*48.5*
Pétange *(2)*	402	554	538											
tonnes dry														
Soil-Concept *(6)*								6379.8	6238.9	8898.1	9488.5	9429.8	10228.1	13401.5

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 (tonnes of 100% dry matter)

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 6D since these are "process" and not "spreading" emissions. Nevertheless, it is planned to analyze further the impact of sludge spreading and compost application on agriculture GHG emissions in order to refine these first estimates. Details on the emission calculation for Soil-Concept are given in the Microsoft Excel™ file that has been developed to calculate GHG emissions from the agriculture sector (Agriculture_GHG Estimates.xls) mentioned in Section 6.1.3.

8.5.3.2. Emission factors

EFs for compost production are actually default EFs for CH_4 and N_2O emissions from biological treatment of waste taken from the 2006 IPCC Guidelines: see Table 8-23.

Table 8-23 – Default EFs for CH_4 and N_2O emissions from biological treatment of waste

Type of biological treatment	CH_4 EF *g CH_4/kg waste treated*	N_2O EF *g N_2O/kg waste treated*	Comment
	on a wet basis		
Composting excluding Soil-Concept project	4	0.3	Assumptions on the waste treated: 25-50% DOC in dry matter, 2% N in dry matter, moisture content 60%. EF for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste.
	(0.03 - 8)	(0.06 - 0.6)	
Soil-Concept project	*on a dry basis*		
	10	0.6	
	(0.08-20)	(0.2-1.6)	

CH_4 and N_2O emissions of biological treatment are estimated using the default method given in the following equations:

$$CH_4 emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

$$N_2O\, emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3}$$

With:

CH_4 emissions	=	total CH_4 emissions in inventory year [Gg CH_4]
N_2O emissions	=	total N_2O emissions in inventory year, [Gg N_2O]
M_i	=	mass of organic waste treated by biological treatment type i [Gg]
EF_i	=	emission factor for biological treatment type i (see Table 8-23)
I	=	composting or anaerobic digestion
R	=	total amount of CH_4 recovered in inventory year [Gg CH_4][94]

8.5.4. Recalculations

See Tables 8-1 and 8-2 in Section 8.1.1.

8.5.5. Category specific QA/QC procedures

No category specific QA/QC procedures have been completed, only the tools embedded in CRF Reporter have been used.

94 So far, emission estimates for composting are not taking CH_4 recovery into account.

8.5.6. 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 8-24 will be explored.

Table 8-24 – Planned improvements for IPCC Category 6D – Other

GHG source & sink category	Planned improvement
6D – Other	analyze further composting activities of Soil-Concept where sewage sludge are used as input for producing compost that is then spread, as a fertilizer, on fields or along the roads.

8.6. Selected references

Administration de l'Environnement (AEV) - Division des Déchets (2005), *Restabfallanalyse 2004/05 im Großherzogtum Luxemburg, Band 1: Kompendium*, Luxembourg.

Administration de l'Environnement (AEV) - Division des Déchets (2002), *Restabfallanalyse 2001 im SIDOR*, Luxembourg.

Administration de l'Environnement (AEV) - Division des Déchets (2002), *Waste analysis 1992/1994*, Luxembourg.

Daniel Strauss, *Détermination des émissions atmosphériques de méthane du secteur des déchets, du secteur agricole et de la distribution de gaz naturel au Grand-Duché de Luxembourg : analyse des méthodes de calcul - calcul d'incertitudes, Rapport de Stage pour l'Administration de l'Environnement*, Luxembourg, 2006.

For more information on this Chapter, please contact:

All sectors except WWH
Serge LESS
Administration de l'Environnement
16, rue Eugène Ruppert
L-2453 Luxembourg
Tel: (+352) 40 56 56 522
Fax: (+352) 49 62 56
E-mail: serge.less@aev.etat.lu

WWH
Jean-Marie RIES
Administration de la Gestion de l'Eau - Division de la Protection des Eaux
B.P. 1212
L-1012 Luxembourg
Tel: (+352) 26 02 86 27
Fax: (+352) 26 02 86 62
E-mail: jean-marie.ries@eau.etat.lu

9. Recalculations and Improvements

This chapter quantifies the changes in emissions for all six GHG compared to the previous submission 2007v3.1. Recalculations are quantified for total GHG emissions for all years and gas specific emissions for 1990 and 2005.

Recalculations of previously submitted inventory data are performed following the 2000 IPCC-GPG, Chapter 7 "Methodological Choice and Recalculation" with the unique purpose to improve the GHG inventory.

9.1. Explanations and Justifications for Recalculations

Compiling an emission inventory includes data collecting, data transfer and data processing. Data has to be collected from different sources, for instance national statistics, plant operators, studies, personal information or other publications. The provided data must be transferred from different data formats and units into a unique electronic format to be processed further. The calculation of emissions by applying methodologies on the collected data and the final computing of time series into a predefined format (CRF) are further steps in the preparation of the final submission. Finally the submission must be delivered in due time. Even though if our future QA/QC system will give assistance so that potential error sources would be minimized, it will remain necessary to make some revisions (called recalculations) under the following circumstances:

- an emission source was not considered in the previous inventory;
- a source/data supplier has delivered new data. The causes might be that previous data were preliminary data or that methodology has been improved/modified;
- occurrence of errors in data transfer or processing: wrong data, unit-conversion, software errors, etc;
- methodological changes: a new methodology must be applied to fulfil the reporting obligations because of one of the following reasons:
  - to decrease uncertainties;
  - an emission source becomes a key source;
  - consistent input data needed for applying the methodology is no longer accessible;
  - input data for more detailed methodology is now available;
  - the methodology is no longer appropriate.

For detailed information on recalculations and their justifications see the first sub-section of the sector overview section of each Chapters 3 to 8 (tables showing revisions between submissions 2007v2.1 and 2007v3.1, respectively between submissions 2007v3.1 and 2008v1.2).

9.2. Implication for Emission Levels

The analysis is made by comparing our two last submissions, i.e. submissions 2007v3.1 and 2008v1.2. Given that, after the ICR that took place in June 2007, Luxembourg's inventory experienced dramatic improvements, it would not make much sense to compare a pre-review inventory with those produced after the ICR. Also, GHG estimates presented in submission 2007v3.1 have been accepted by the ERT and, then, by the UNFCCC Secretariat. They led to a revision of Luxembourg's base year that has been acknowledged as indicated in paragraph 116 of the Report of the review of the initial report of Luxembourg (doc. FCCC/IRR/2007/LUX of 14 December 2007).[95]

Table 9-1 presents the recalculation differences between submission 2007v3.1 and 2008v1.2 for each of the 6 GHG (a positive value indicates that submission 2008v1.2 estimate is higher).

Table 9-1 – Recalculation differences between submissions 2007v3.1 and 2008v1.2 (excl. LULUCF): 1990 and 2005

GHG	1990 (base year)	2005
	recalculation difference (%)	
CO_2	0.00%	0.01%
CH_4	0.00%	-0.01%
N_2O	4.03%	5.24%
F-gases	0.00%	0.00%
Total	0.14%	0.26%

Source: Ministry of the Environment and Environment Agency.

For CO_2, the small difference is explained by a correction in IPCC Sub-category 1A2b where fuel use has been re-allocated in the correct fuel category (from liquid to gaseous fuels) for the years 2002 to 2005. As a result, EFs for LPG have been used instead of liquid fuels related EFs (see Table 3-2 in Section 3.1.1). Of course, this re-allocation did also modify CH_4 and N_2O emissions.

For CH4, besides the re-allocation for IPCC Sub-category 1A2b, there has been a number of improvements in both IPCC Categories 4A and 4B (new activity data, re-allocation of livestock) that modified GHG emission estimates reported for the years 1997 to 2005 (see Table 6-2 in Section 6.1.1).

Finally, with regard to N_2O, on top of the previous explanations, changes were due to rather important re-allocations in IPCC Categories 4D (and 4F): crops breakdown between N-fixing and non N-fixing crops has been totally revised between the two submissions. That revision affected all years since 1990 (see Table 6-2 in Section 6.1.1).

Table 9-2 shows the recalculation effect for all years.

95 See http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/items/3765.php

Table 9-2 – Recalculation differences between submissions 2007v3.1 and 2008v1.2 for total GHG emissions (excl. LULUCF): 1990-2005

	National Total GHG Emissions excluding LULUCF		
Year	Submission 2007v3.1 *Gg CO_2e*	Submission 2008v1.2 *Gg CO_2e*	Recalculation difference *%*
1990	13167.50	13186.51	0.14%
1991	13473.34	13489.55	0.12%
1992	13330.87	13356.75	0.19%
1993	13571.23	13601.50	0.22%
1994	12739.60	12765.21	0.20%
1995	10305.92	10334.81	0.28%
1996	10398.65	10428.89	0.29%
1997	9753.66	9793.68	0.41%
1998	9011.99	9054.81	0.48%
1999	9640.18	9674.04	0.35%
2000	10139.28	10184.97	0.45%
2001	10438.75	10476.50	0.36%
2002	11277.58	11305.50	0.25%
2003	11655.15	11665.12	0.09%
2004	13348.79	13402.55	0.40%
2005	13256.59	13290.61	0.26%
Trend 1990-2006	*0.68%*	*0.79%*	*NA*

Source: Ministry of the Environment and Environment Agency.

9.3. Implications for Emissions Trend

As shown in Table 9-2, the recalculation between the two submissions 2007v3.1 and 2008v1.2 led to a slight modification in the total GHG (excluding LULUCF) emissions trend from 0.68% to 0.79%. However, the upward trend between the base year and the latest inventory year has not been modified radically by the recalculations: it is still a little positive, just a bit more for the latest inventory submission.

9.4. Planned Improvements

Since the overall goal is to produce emission inventories which are fully consistent with the UNFCCC reporting guidelines and the IPCC Guidelines, an **improvement programme** is currently being established to help meeting this goal so to avoid any adjustments under the Kyoto Protocol. The implementation of an improvement programme is driven by the results of the various review processes, as e.g. the review under the European Union Monitoring Mechanism and the review under the UNFCCC and/or under the Kyoto Protocol. These reviews showed the necessity to plan improvements sector by sector, that is why an overview of the main source specific planned improvements identified in the respective sections and sub-sections of Chapters 3 to 8 is presented below in Table 9-3. This table also lists some of the cross-cutting improvements Luxembourg commits itself to put in place.

The improvement programme will be supported by the QA/QC and QMS currently being developed. The Environment Agency acting as the "Single National Entity with overall responsibility for the GHG Inventory" will be responsible for the management of the improvement programme.

Nevertheless, due to limited resources in Luxembourg – small country, hence small administrations – prioritising resources for inventory improvement is a key point. Therefore, **those improvements for which the additional effort would be warranted by increased accuracy and/or for which key sources are considered will be prioritized**. Indeed, as indicated in the 2000 IPCC-GPG "*it would not be a good use of limited resources to spend large amounts of time exhaustively collecting data and expert judgements for a source category that has little effect on* (overall GHG total) *and uncertainty*".[96]

Table 9-3 – Main planned improvements

Issue GHG source & sink category	Planned improvement
Cross-cutting improvements	
Uncertainties	whenever a method used for the estimation of emissions/removals of a key category is not consistent with the requirements of the 2000 IPCC-GPG, the method will have to be improved in order to reduce uncertainty, which is considered in the emission inventory improvement programme.
Notation Key NE	it is planned that source or sink categories currently indicated as NE are, if possible, either estimated or allocated to NO.
Notation Key NA	it is planned to revise all the NA notation keys to confirm whether they are indeed NA or rather NE or NO.
1 – Energy 2 – Industrial Processes	a more systematic use of facilities' data is one of the major planned improvements Luxembourg has identified for its GHG inventories (see also Chapters 3 & 4). In particular, it will be inves-tigated 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.
Indirect GHG	generate better emission estimates for indirect GHG – NOx, CO, NMVOCs – and SO_2.
Source categories improvements	
1A1a - Public Electricity and Heat Production	revise activity data taking into account EU ETS reported information as well as operating permits related information.
1A1a - Public Electricity and Heat Production	investigate how reported emissions under the EU-ETS regulation could be included in the GHG inventory.
1A1a - Public Electricity and Heat Production	conversion factors: use of factors for various fuel types provided by IEA in its Energy Statistics Manual or of country/plant-specific values?
1A1a - Public Electricity and Heat Production	provide more information on estimation methods used in internal studies.
1A1a/6C - Public Electricity and Heat Production	waste incineration with energy recovery: validate the biogenic vs. non-biogenic breakdown and related emissions estimation method.
1A1a - Public Electricity and Heat Production	investigate emissions allocation between IPCC Sub-category 1A1 and 1A2: public electricity and heat production relates to energy going into the public network. What about autoproducers for their own needs or only if a fraction of the energy produced finally ends in the public network? (e.g. the power plant operated by the iron and steel industry up to 1997 or CHP directly linked to a plant)
1A2 – Manufacturing Industries and Construction	revise activity data taking into account EU ETS reported information as well as operating permits related information.
1A2 – Manufacturing Industries and Construction	investigate how reported emissions under the EU-ETS regulation could be included in the GHG inventory.
1A2 – Manufacturing Industries and Construction	conversion factors: use of factors for various fuel types provided by IEA in its Energy Statistics Manual or of country/plant-specific values?
1A2a – Iron and Steel	revise activity data used for estimating GHG emissions. Revise the CO_2 emission factor for 101A (coking coal) since it appears to be too high – the IPCC default factor is 94,6 kg/GJ (25,8 t C/TJ coal).

96 The text into bracket is an addition by Luxembourg.

1A2a – Iron and Steel	investigate whether another production unit – Primorec, a plant recycling iron from slag and collected dust (direct reduction furnace) – should be included in Sub-category 1A2a.
1A2b – Non-Ferrous Metals	revise activity data used for estimating GHG emissions.
1A2b – Non-Ferrous Metals	include other non-ferrous activities if relevant.
1A2c – Chemicals	investigate further whether this category is effectively NA or NO in Luxembourg.
1A2d – Pulp, Paper and Print	investigate further whether this category is effectively NA or NO in Luxembourg.
1A2e – Food Processing, Beverages and Tobacco	re-allocate emissions in this source category, notably using information transmitted under the EU-ETS scheme.
1A2f – Other	revise activity data used for estimating GHG emissions and re-allocate emissions in the right source categories if relevant.
1A3a – Civil Aviation	refine activity data that are based, for the moment, on an expert judgement.
1A3b – Road Transportation	investigate the possible use of COPERT IV instead of COPERT III.
1A3b – Road Transportation	it has recently been identified a source of biofuels for urban busses: the inventory should be corrected by moving related emissions from IPCC Sub-category 1A4 – where it is recorded for the moment – to 1A3b.
1A3c – Railways	refine activity data and revise EFs on the basis of possible new information from CFL.
1A3d – Navigation	revise and expand the present activity data.
1A4 – Other Sectors	revise thoroughly all the activity data.
1A4 – Other Sectors	it has recently been identified a source of biofuels for urban busses: the inventory should be corrected by moving related emissions from IPCC Sub-category 1A4 – where it is recorded for the moment – to 1A3b.
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.
1A4a – Commercial/Institutional	investigate whether it would be possible to move away from default EFs to more specific/accurate ones.
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.
1A4b – Residential	investigate whether it would be possible to move away from default EFs to more specific/accurate ones.
1A4c – Agriculture/Forestry/Fisheries	investigate whether it would be possible to move away from default EFs to more specific/accurate ones.
1A5 – Other	for the moment, emissions pertaining to this source category are supposedly recorded elsewhere: this hypothesis has to be verified and, if possible, related source category emissions should be moved to 1A5.
1B2 – Fugitive Emissions from Fuels – Oil and Natural Gas	revise thoroughly all the activity data and provide more background information by contacting oil and gas distributors in Luxembourg.
1 - Feedstocks	improve the reporting of fuels used as feedstocks.
Memo Items – International Bunkers - Aviation	re-estimate emissions taking into account LTO and plane types (CORINAIR Guidebook methodology).
Memo Items – International Bunkers - Marine	investigate whether emissions should be reported for this source category and, if yes, how to calculate them.
Memo Items – Multilateral Operations	investigate whether emissions could be identified for this source category and, if yes, how to calculate them.
Memo Items – CO_2 Emissions from Biomass	it has recently been identified a source of biofuels for urban busses: the inventory should be corrected by moving related emissions from IPCC Sub-category 1A4 – where it is recorded for the moment – to 1A3b. This will change slightly emission estimates since ad-hoc EFs will be used for the part moved to 1A3b.
2A1 – Cement Production	streamlining with the new 2006 IPCC Guidelines and the new 2007 ETS Guidelines.
2A5 – Asphalt Roofing	investigate further whether this category is effectively NA or NO in Luxembourg.
2A6 – Road Paving with Asphalt	investigate further whether this category is effectively NA or NO in Luxembourg.
2A7 – Other – Glass Production	streamlining with the new 2006 IPCC Guidelines and the new 2007 ETS Guidelines.
2C1 – Iron and Steel Production	application of the mass balance approach according to the ETS guidelines.
2C1 – Iron and Steel Production	inclusion of another production unit – Primorec – a plant recuperating iron from slag and collected dust (direct reduction furnace).
2F – Consumption of Halocarbons & SF_6	complete re-evaluation including the results of the new study.
2F – Consumption of Halocarbons & SF6	different GWPs are provided by IPCC for the different HFCs categories: should they be used instead of a generic GWP for HFCs?
3 – Solvent and Other Product Use	complete re-evaluation on the basis of the study on air emissions from solvent and other product use.
4A – Enteric Fermentation	analyze whether it would be possible to replace some default parameter values – such as GE – by national values.
4A1 – Cattle: net energy for activity	refine the calculation for this parameter taking into account the time spent by animals in stalls and on pastures.
4A3 – Sheep: live-weight	national statistics allow for a breakdown of sheep between lambs and mature animals, hence allow for calculating a more precise live-weight for this animal category since estimated weights are known for both lambs and mature animals.

4A8 – Swine	national statistics allow for a breakdown of swine in various sub-categories for which more precise parameter values could be applied.
4A9 – Poultry – Chickens	national statistics allow for a breakdown of chickens in various sub-categories for which more precise parameter values could be applied.
4A10 – Other	investigate whether it would be worth, straightforward and not time/resources consuming to include the missing farm animals (ostriches, “productive animals”).
4B – Manure Management - AWMS	analyzing whether it would be feasible to refine AWMS per livestock category and through the reporting years.
4B – Manure Management – Other AWMS: Anaerobic Digester	analyze if it would be possible to use formula 1 under table 4.10 of the 2000 IPCC-GPG (p. 4.36) in order to refine/produce a reliable emission estimate for manure used in anaerobic digesters.
4B – Manure Management - Nex	analyzing whether it would be feasible to refine Nex per livestock category and through the reporting years.
4B8 – Swine	national statistics allow for a breakdown of swine in various sub-categories for which more precise parameter values could be applied.
4B9 – Poultry – Chickens	national statistics allow for a breakdown of chickens in various sub-categories for which more precise parameter values could be applied.
4B10 – Other	investigate whether it would be worth, straightforward and not time/resources consuming to include the missing farm animals (ostriches, “productive animals”).
4D – Agricultural Soils	analyze whether it would be possible to replace some default parameters, coefficients or EFs by national values.
4D13 & 4D14 – Agricultural Soils – N-fixing Crops & Crop Residue	refine the various crop categories: allocation, possible correction, etc. especially with regard to the non N-fixing & the fixing crops as well with regard to forage crops contribution to emissions.
4D16 – Agricultural Soils – Other – Sewage Sludge Spreading	analyze further the impact of sludge spreading and compost application on agriculture GHG emissions in order to refine first estimates presented in the inventory.
4F – Field Burning of Agricultural Residues	refine the various crop categories: allocation, possible correction, etc. especially with regard to the non N-fixing & the fixing crops as well with regard to forage crops contribution to emissions.
5 – LULUCF	complete re-evaluation on the basis of the study commissioned by the *Administration des Eaux et Forêts* in the in the context of the GMES/GSE Forest Monitoring framework.
6A - SWDL	analyze whether it would be possible to include methane emission estimates for the industrial waste landfill site Ronnebierg (that is nowadays closed down).
6A – SWDL	revise the AD used for the years 1991 and 2002 to 2005: inconsistencies between data reported in CRF tables and data published by STATEC (see Table 8-6).
6A –SWDL	revise and complete additional information for CRF table 6A – sectoral background data for waste.
6B1 – Industrial WWH	analyze whether it would be possible to include methane and nitrous oxide emission estimates for the industrial wastewater treatment.
6B2 – Domestic & Commercial WWH – CH_4	the emission estimates have to be corrected (multiplied by 1000): an error in the conversion from tonnes to Gg led to values reported in CRF tables in 1000 Gg (or millions of tonnes) instead of Gg (or thousands of tonnes).
6B2 – Domestic & Commercial WWH	analyze whether it would be possible and/or necessary to estimate emissions from sewage sludge (knowing that sewage sludge spreading is accounted for in IPCC Category 4D).
6C/1A1a – Waste Incineration	waste incineration with energy recovery: validate the biogenic vs. non-biogenic breakdown and related emissions estimation method.
6D – Other	analyze further composting activities of Soil-Concept where sewage sludge are used as input for producing compost that is then spread, as a fertilizer, on fields or along the roads.

For more information on this Chapter, please contact:

Eric DE BRABANTER
Ministère de l’Environnement
18, Montée de la Pétrusse
L-2918 Luxembourg
Tel: (+352) 247-86842
Fax: (+352) 247-86835
E-mail: eric.debrabanter@mev.etat.lu

Annex I – Regulation to set-up a NIS in Luxembourg (adopted by the Government during its session of 20th of July 2007)

Text in French.

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

Nous Henri, Grand-Duc de Luxembourg, Duc de Nassau,

Vu l'article 5 de la loi modifiée du 27 novembre 1980 ayant pour objet la création d'une Administration de l'environnement ;

Vu la loi du 4 mars 1994 portant approbation de la Convention-cadre des Nations Unies sur le Changement Climatique (ci-après dénommée *CCNUCC*), faite à New York, le 9 mai 1992 ;

Vu la loi du 29 novembre 2001 portant approbation du Protocole de Kyoto à la CCNUCC, fait à Kyoto, le 11 décembre 1997 ;

Vu la Décision n° 280/2004/CE du Parlement européen et du Conseil du 11 février 2004 relative au mécanisme pour surveiller les émissions de gaz à effet de serre dans la Communauté et mettre en œuvre le Protocole de Kyoto ;

Vu la Décision de la Commission du 10 février 2005 fixant les modalités d'exécution de la décision n° 280/2004/CE du Parlement européen et du Conseil relative à un mécanisme pour surveiller les émissions de gaz à effet de serre dans la Communauté et mettre en œuvre le Protocole de Kyoto (2005/166/CE) ;

Vu les accords dits de « Marrakech », et plus particulièrement la Décision 20/CP.7 de la Conférence des Parties de la CCNUCC portant sur la définition d'un cadre directeur des systèmes nationaux permettant d'estimer les émissions anthropiques par les sources et les absorptions anthropiques par les puits des gaz à effet de serre tel que prévu par l'article 5, paragraphe 1, du Protocole de Kyoto ;

Vu la fiche financière ;

Les avis de la Chambre de commerce, de la Chambre des métiers, de la Chambre des employés privés et de la Chambre des fonctionnaires et employés publics ayant été demandés ;

Vu l'article 2(1) de la loi modifiée du 12 juillet 1996 portant réforme du Conseil d'Etat et considérant qu'il y a urgence ;

Sur le rapport de Notre Ministre de l'Environnement et après délibération du Conseil de Gouvernement ;

Arrêtons:

Art. 1er: Objet

Le présent règlement a pour objet la mise en place d'un Système d'Inventaire National (ci-après dénommé *SIN*) tel que requis par l'article 5, paragraphe 1, du Protocole de Kyoto et l'article 4, paragraphe 4, de la Décision n° 280/2004/CE du Parlement européen et du Conseil du 11 février 2004. Il détermine également les modalités de fonctionnement du SIN dans le but de produire des inventaires annuels relatifs aux émissions de gaz à effet de serre conformes aux standards de qualité, aux formats et aux délais requis.

Art. 2: Annexe

Fait partie intégrante du présent règlement :

- Annexe I : Tableau des compétences sectorielles pour l'établissement de l'inventaire et rôles dévolus.

Art. 3: Entité nationale unique

Aux fins de l'établissement des inventaires et des rapports afférents, l'Administration de l'environnement est désignée Entité nationale unique.

Celle-ci a notamment pour missions :

- la gestion globale du SIN, y compris son développement, son fonctionnement, son suivi ainsi que l'engagement de toutes les mesures requises afin d'assurer son fonctionnement continu ;
- le suivi des règles pour l'établissement des inventaires édictées par le Groupe d'experts Intergouvernemental sur l'Evolution du Climat (*GIEC*) et adoptées par les instances de la CCNUC : « lignes directrices révisées pour les inventaires nationaux de gaz à effet de serre » et « guide des bonnes pratiques et de gestion des incertitudes dans les inventaires nationaux de gaz à effet de serre » ;
- d'informer les différents experts sectoriels concernés de tout changement dans les règles édictées par le GIEC et d'évaluer, avec ces experts sectoriels, l'impact de ces changements sur les méthodes de calcul et les estimations des émissions de gaz à effet de serre ;
- l'assistance aux experts sectoriels dans leur mission et leur formation ;
- la définition d'un échéancier pour la transmission des différents éléments requis pour l'établissement de l'inventaire et des rapports afférents, ainsi que le respect de cet échéancier ;
- la mise en place d'un système cohérent de documentation et d'archivage des différentes informations en relation avec le SIN ;
- le respect des procédures de contrôle et d'assurance qualité ;
- de définir et d'approuver, ensemble avec les experts sectoriels, les méthodes appropriées pour l'acquisition des données de base, pour procéder au choix et au calcul des facteurs d'émission, pour évaluer l'incertitude liée aux estimations des émissions et pour effectuer le contrôle et l'assurance de la qualité des estimations des émissions ;
- de compiler l'ensemble des données requises pour l'inventaire et les rapports afférents à l'aide d'outils informatiques propres et/ou distribués par le Secrétariat de la CCNUCC ;
- l'analyse et la définition des sources d'émissions essentielles ;

- la transmission au Ministère de l'Environnement du rapport annuel sur l'inventaire national conforme aux lignes directrices éditées par la CCNUCC, ainsi que des tableaux associés à ce rapport dans le format requis par la CCNUCC ;
- la rédaction et la mise à jour du rapport de mise en œuvre du SIN ;
- de soulever tous les problèmes pouvant survenir au sein du SIN et qui auraient comme conséquence un retard dans la transmission des inventaires et du rapport annuel sur l'inventaire national.

Art. 4: Calculs des émissions

Les émissions proprement dites sont calculées par des experts sectoriels à désigner pour les différents secteurs de l'inventaire.

Les experts sectoriels ont notamment les missions suivantes :

- choix des méthodes appropriées pour le calcul des émissions, notamment sur base des règles édictées par le GIEC ;
- établissement des données d'activités et des facteurs d'émissions nécessaires aux calculs des émissions ;
- calcul des émissions proprement dites ;
- recalcul des émissions passées lorsque ceci s'avère nécessaire (affinements ou changements de méthodes, prise en compte de nouvelles sources d'information, corrections d'erreurs) ;
- assurance de la qualité des données et contrôle de cette qualité ;
- préparation des éléments du rapport annuel sur l'inventaire national ;
- transmission à l'Entité nationale unique des données dans les formats requis et des éléments du rapport annuel sur l'inventaire national.

Art. 5: Mise à disposition des données

Les données nécessaires pour les calculs des émissions sont fournies aux experts sectoriels par les institutions reprises à l'annexe I tout en respectant les standards de qualité, les formats et les délais établis par l'Entité nationale unique.

Il s'agit notamment de données résultant de statistiques, d'inventaires ou d'autres sources de données établies par ces instances.

Art. 6: Désignation d'agents au sein de l'Administration de l'environnement

Au sein de l'Administration de l'environnement, le directeur désigne les agents suivants :

a) un agent chargé de la gestion de l'Entité nationale unique ;

b) les experts sectoriel ;

c) un agent qui doit assurer le contrôle de la qualité des inventaires. Cet agent a notamment pour missions d'élaborer et de mettre en œuvre le plan d'assurance et de contrôle de la qualité, y compris la définition des objectifs de qualité, la coordination des procédures de contrôle et d'assurance de la qualité, la coordination des processus régissant les vérifications des examens par des experts ainsi que les mises à jour et la maintenance des documents et des systèmes d'archivage selon les normes convenues ;

d) les agents en charge de fournir aux experts sectoriels les données conformément à l'article 5 du présent règlement.

Art. 7 : Désignation d'agents au sein d'institutions autres que l'Administration de l'environnement

Pour les secteurs de l'inventaire hors du champ de compétence de l'Administration de l'environnement, des agents sont désignés au sein des institutions respectives par le Ministre de l'Environnement sur proposition du Ministre de tutelle de l'institution concernée.

Ces agents sont nommés soit experts sectoriels, soit agents chargés de fournir les données nécessaires pour les calculs des émissions.

Les institutions concernées et les missions respectives sont reprises à l'annexe I du présent Règlement.

Art. 8: Transmission des inventaires et des rapports afférents

L'Administration de l'environnement transmet l'inventaire annuel et le rapport annuel sur l'inventaire national au Ministère de l'Environnement qui, en sa qualité de Point Focal sur le Changement Climatique, les transmet au Secrétariat de la CCNUCC et à la Commission européenne.

Art. 9: Entrée en vigueur

Le présent règlement entre en vigueur le jour de sa publication au Mémorial.

Art. 10: Exécution

Notre Ministre de l'Environnement est chargé de l'exécution du présent règlement qui sera publié au Mémorial.

Annexe I

Tableau des compétences sectorielles pour l'établissement de l'inventaire et rôles dévolus

Secteurs de l'inventaire	Institutions compétentes	Rôles dévolus pour la réalisation de l'inventaire
énergie : bilans énergétiques détaillés (vecteurs, production, consommation, importations, exportations, transformation)	Ministère de l'Economie et du Commerce Extérieur, STATEC	mise à disposition de données de base
	Administration de l'Environnement	expert sectoriel
transports	Ministère de l'Economie et du Commerce Extérieur, Ministère du Transport, SNCT, Administration des Douanes et Accises	mise à disposition de données de base
	Administration de l'Environnement	expert sectoriel
procédés industriels	Administration de l'Environnement	mise à disposition de données de base, expert sectoriel
utilisation de solvants et d'autres produits	Administration de l'Environnement	mise à disposition de données de base, expert sectoriel
agriculture	Service d'Economie rurale, Administration des Services Techniques de l'Agriculture	mise à disposition de données de base, experts sectoriels
utilisation des sols, changements d'affectation des sols et forêts	Ministère de l'Environnement, Administration des Eaux & Forêts	mise à disposition de données de base, experts sectoriels
déchets, épuration des eaux	Administration de l'Environnement, Administration de la Gestion de l'Eau	mise à disposition de données de base, experts sectoriels

Annex II - Table for methodologies, data sources and emission factors used by Luxembourg for submission 2008v1.2

The table on the next page corresponds to the table presented in Annex I of Community Decision 2005/166/EC. This table is an expansion of table Summary 3 of the CRF.

ANNEX I

Table for methodologies, data sources and emission factors used by Member States for EC key sources for the purpose of Article 4(1)(b)

Table I -1: Community summary report for methods, activity data and emission factors used (Energy)

GREENHOUSE GAS SOURCE AND SINK	CO_2				CH_4				N_2O			
CATEGORIES	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
1. Energy												
A. Fuel Combustion												
1. Energy Industries												
a. Public Electricity and Heat Production		T1 T2	NS PS Q	D		T1	NS PS Q	D		T1	NS PS Q	D
b. Petroleum Refining		NA	NO	NA		NA	NO	NA		NA	NO	NA
c. Manufacture of Solid Fuels and Other Energy Industries		NA	NO	NA		NA	NO	NA		NA	NO	NA
2. Manufacturing Industries and Construction												
a. Iron and Steel		T1	PS	D		T1	PS	D		T1	PS	D
b. Non-Ferrous Metals		T1	PS	D		T1	PS	D		T1	PS	D
c. Chemicals		NA	NO	NA		NA	NO	NA		NA	NO	NA
d. Pulp, Paper and Print		NA	NO	NA		NA	NO	NA		NA	NO	NA
e. Food Processing, Beverages and Tobacco		NA	NO	NA		NA	NO	NA		NA	NO	NA
f. Other *(as specified in table 1.A(a)s2)*		T1	PS	D		T1	PS	D		T1	PS	D
3. Transport												
a. Civil Aviation		T1	PS	D		T1	PS	D		T1	PS	D
b. Road Transportation		COPERT III	NS	D		COPERT III	NS	D		COPERT III	NS	D
c. Railways		T1	PS	D		T1	PS	D		T1	PS	D
d. Navigation		T1	TÜV	D		T1	TÜV	D		T1	TÜV	D
e. Other Transportation *(as specified in table 1.A(a)s3)*		NA	NO	NA		NA	NO	NA		NA	NO	NA
4. Other Sectors												
a. Commercial/Institutional		T1	NS	D		T1	NS	D		T1	NS	D
b. Residential		T1	NS	D		T1	NS	D		T1	NS	D
c. Agriculture/Forestry/Fisheries		T1	EJ TÜV	D		T1	EJ TÜV	D		T1	EJ TÜV	D
5. Other												
a. Stationary		NA	IE	NA		NA	IE	NA		NA	IE	NA
b. Mobile		NA	IE	NA		NA	IE	NA		NA	IE	NA
B. Fugitive Emissions from Fuels												
1. Solid Fuels												
a. Coal Mining		NA	NO	NA		NA	NO	NA		NA	NO	NA
b. Solid Fuel Transformation		NA	NO	NA		NA	NO	NA		NA	NO	NA
c. Other *(as specified in table 1.B.1)*		NA	NO	NA		NA	NO	NA		NA	NO	NA
2. Oil and Natural Gas												
a. Oil		NA	NE	NA		NA	NE	NA		NA	NO	NA
b. Natural Gas		NA	IE	NA		C	NS	C				
c. Venting and Flaring		NA	NO	NA		NA	NO	NA		NA	NO	NA
d. Other *(as specified in table 1.B.2)*		NA	NO	NA		NA	NO	NA		NA	NO	NA

Table I -2: Community summary report for methods, activity data and emission factors used (industrial processes)

GREENHOUSE GAS SOURCE AND SINK	CO_2				CH_4				N_2O				HFCs				PFCs				SF_6			
CATEGORIES	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
2. Industrial Processes																								
A. Mineral Products		CS T2	PS	CS PS		NA	NO	NA		NA	NO	NA												
1. Cement Production		T2	PS	CS PS																				
2. Lime Production		NA	NO	NA																				
3. Limestone and Dolomite Use		NA	IE	NA																				
4. Soda Ash Production and Use		NA	IE	NA																				
5. Asphalt Roofing		NA	NO	NA																				
6. Road Paving with Asphalt		NA	NO	NA																				
7. Other *(as specified in table 2(I)A-G)*		CS	PS	PS		NA	NO	NA		NA	NO	NA												
B. Chemical Industry		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA
1. Ammonia Production		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA
2. Nitric Acid Production										NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA
3. Adipic Acid Production		NA	NO	NA						NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA
4. Carbide Production		NA	NO	NA		NA	NO	NA						NA	NO	NA		NA	NO	NA		NA	NO	NA
5. Other *(as specified in table 2(I)A-G)*		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA
C. Metal Production		CS T2	NS PS	CS		NA	NO	NA		NA	NO	NA						NA	NO	NA		NA	NO	NA
1. Iron and Steel Production		CS T2	NS PS	CS		NA	NO	NA										NA	NO	NA		NA	NO	NA
2. Ferroalloys Production		NA	NO	NA		NA	NO	NA										NA	NO	NA		NA	NO	NA
3. Aluminium Production		NA	NO	NA		NA	NO	NA										NA	NO	NA		NA	NO	NA
4. SF_6 Used in Aluminium and Magnesium Foundries																						NA	NO	NA
5. Other *(as specified in table 2(I)A-G)*		NA	NO	NA		NA	NO	NA		NA	NO	NA						NA	NO	NA		NA	NO	NA
D. Other Production		NA	NO	NA																				
1. Pulp and Paper																								
2. Food and Drink		NA	NO	NA																				
E. Production of Halocarbons and SF_6														NA	NO	NA		NA	NO	NA		NA	NO	NA
1. By-product Emissions														NA	NO	NA		NA	NO	NA		NA	NO	NA
2. Fugitive Emissions														NA	NO	NA		NA	NO	NA		NA	NO	NA
3. Other *(as specified in table 2(II)*														NA	NO	NA		NA	NO	NA		NA	NO	NA
F. Consumption of Halocarbons and SF_6														CS	Q	CS		NA	NO	NA		CS	Q	CS
1. Refrigeration and Air Conditioning Equipment														CS	Q	CS		NA	NO	NA		NA	NO	NA
2. Foam Blowing														CS	NS	CS		NA	NO	NA		NA	NO	NA
3. Fire Extinguishers														NA	NO	NA		NA	NO	NA		NA	NO	NA
4. Aerosols/ Metered Dose Inhalers														CS	Q	CS		NA	NO	NA		NA	NO	NA
5. Solvents														NA	NO	NA		NA	NO	NA		NA	NO	NA
6. Other applications using ODS substitutes														NA	NO	NA		NA	NO	NA		NA	NO	NA
7. Semiconductor Manufacture														NA	NO	NA		NA	NO	NA		NA	NO	NA
8. Electrical Equipment														NA	NO	NA		NA	NO	NA		CS	Q	CS
9. Other *(as specified in table 2(II)*														NA	NO	NA		NA	NO	NA		CS	Q	CS
G. Other		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA		NA	NO	NA

Table I -3: Community summary report for methods, activity data and emission factors used (solvent and other product use, agriculture)

GREENHOUSE GAS SOURCE AND SINK	CO_2				CH_4				N_2O			
CATEGORIES	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
3. Solvent and Other Product Use												
A. Paint Application		C	TÜV	C								
B. Degreasing and Dry Cleaning		C	TÜV	C						NA	NE	NE
C. Chemical Products, Manufacture and Processing												
D. Other		C	TÜV	C						CS	NS	CS
4. Agriculture												
A. Enteric Fermentation						T1 T2	NS	CS D				
1. Cattle						T2	NS	CS				
2. Buffalo						NA	NO	NA				
3. Sheep						T1	NS	D				
4. Other						T1	NS	D				
B. Manure Management						T1 T2	NS	CS D		T1	EJ	D
1. Cattle						T2	NS	CS		T1	EJ	D
2. Buffalo						NA	NO	NA		NA	NO	NA
3. Sheep						T1	NS	D		T1	EJ	D
4. Other						T1	NS	D		T1	EJ	D
8. Swine						T1	NS	D		T1	EJ	D
13. Solid Storage and Dry Lot										T1	EJ	D
C. Rice Cultivation						NA	NO	NA				
D. Agricultural Soils						NA	NO	NA		T1 T1a T1b	EJ NS	D
1. Direct Soil Emissions						NA	NA	NA		T1a T1b	EJ NS	D
2. Pasture, range and paddock manure										T1	EJ	D
3. Indirect Emissions						NA	NA	NA		T1a	EJ NS	D
4. Other *(as specified in table 4.D)*						NA	NO	NA		NA	NO	NA
E. Prescribed Burning of Savannas						NA	NO	NA		NA	NO	NA
F. Field Burning of Agricultural Residues						NA	NO	NA		NA	NO	NA
G. Other						NA	NO	NA		NA	NO	NA

Table I -4: Community summary report for methods, activity data and emission factors used (land-use change and forestry, waste, other)

GREENHOUSE GAS SOURCE AND SINK	CO_2				CH_4				N_2O			
CATEGORIES	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)	Key source (1)	Method applied (2)	Activity data (3)	Emission factor (4)
5. Land-Use, Land-Use Change and Forestry												
A. Forest Land		NA	NE	NA		NA	NE	NA		NA	NE	NA
1. Forest Land remaining Forest Lands		NA	NE	NA		NA	NE	NA		NA	NE	NA
2. Land converted to Forest Lands		NA	NE	NA		NA	NE	NA		NA	NE	NA
B. Cropland		NA	NE	NA		NA	NE	NA		NA	NE	NA
1. Cropland remaining Cropland		NA	NE	NA		NA	NE	NA		NA	NE	NA
2. Land converted to Cropland		NA	NE	NA		NA	NE	NA		NA	NE	NA
C. Grassland		NA	NE	NA		NA	NE	NA		NA	NE	NA
1. Grassland remaining Grassland		NA	NE	NA		NA	NE	NA		NA	NE	NA
2. Land converted to Grassland		NA	NE	NA		NA	NE	NA		NA	NE	NA
D. Wetlands		NA	NE	NA		NA	NE	NA		NA	NE	NA
1. Wetlands remaining Wetlands		NA	NE	NA		NA	NE	NA		NA	NE	NA
2. Land converted to Wetlands		NA	NE	NA		NA	NE	NA		NA	NE	NA
E. Settlements		NA	NE	NA		NA	NE	NA		NA	NE	NA
1. Settlements remaining Settlements		NA	NE	NA		NA	NE	NA		NA	NE	NA
2. Land converted to Settlements		NA	NE	NA		NA	NE	NA		NA	NE	NA
F. Other Land		NA	NE	NA		NA	NE	NA		NA	NE	NA
1. Other Land remaining Other Land						NA	NE	NA		NA	NE	NA
2. Land converted to Other Land		NA	NE	NA		NA	NE	NA		NA	NE	NA
G. Other (please specify)		CS	EJ	CS		NA	NE	NA		NA	NE	NA
Harvested Wood Products		NA	NE	NA		NA	NE	NA		NA	NE	NA
6. Waste												
A. Solid Waste Disposal on Land		NA	NO	NA		T2	NS	D				
1. Managed Waste Disposal on Land		NA	NO	NA		T2	NS	D				
2. Unmanaged Waste Disposal Sites		NA	NO	NA		NA	NO	NA				
3. Other *(as specified in table 6.A)*		NA	NO	NA		NA	NO	NA				
B. Wastewater Handling						T1	NS	D		T1	NS	CS D
1. Industrial Wastewater						NA	NE	NA		NA	NE	NA
2. Domestic and Commercial Wastewater						T1	NS	D		T1	NS	CS D
3. Other *(as specified in table 6.B)*						NA	NO	NA		NA	NO	NA
C. Waste Incineration		T2	NS Q	D		T1	NS Q	D		T1	NS Q	D
D. Other		NA	NO	NA		T1	NS PS	D		T1	NS PS	D
7. Other (as specified in Summary 1.A)												
Memo Items: (8)												
International Bunkers		T1	PS	D		T1	PS	D		T1	PS	D
Aviation		T1	PS	D		T1	PS	D		T1	PS	D
Marine		NA	NE	NA		NA	NE	NA		NA	NE	NA
CO_2 Emissions from Biomass		T1	EJ TÜV	D								

Legend for tables I -1 to I -4

(1) Key sources of the Community. To be completed by Commission/EEA with results from key category analysis from previous inventory submission.

(2) Use the following notation keys to specify the method applied:

D (IPCC default),	**T1a, T1b, T1c** (IPCC Tier 1a, Tier 1b and Tier 1c, respectively),	**C** (CORINAIR),	**COPERT X** (Copert Model X =
RA (Reference Approach),	**T2** (IPCC Tier 2),	**CS** (Country Specific).	
T1 (IPCC Tier 1),	**T3** (IPCC Tier 3),	**M** (Model)	

If using more than one method within one source category, enumerate the relevant methods. Explanations regarding country-specific methods or any modifications to the default IPCC methods, as well as information regarding the use of

Different methods per source category where more than one method is indicated, should be provided in the documentation box.

(3) Use the following notation keys to specify the sources of activity data used :

NS (national statistics),	**IS** (International statistics),	**AS** (associations, business organizations)
RS (regional statistics),	**PS** (Plant Specific data).	**Q** (specific questionnaires, surveys)

If keys above are not appropriate for national circumstances, use additional keys and explain those in the documentation box.

Where a mix of AD sources has been used, use different notations in one and the same cells with further explanations in the documentation box.

(4) Use the following notation keys to specify the emission factor used:

D (IPCC default),	**CS** (Country Specific),
C (CORINAIR),	**PS** (Plant Specific).

Where a mix of emission factors has been used, use different notations in one and the same cells with further explanations in the documentation box.

Documentation box:

* The full information on methodological issues, such as methods, activity data and emission factors used, can be found in the relevant sector sections of chapter 5 of the NIR. If any additional information is needed to understand the content of this table, use this documentation box to provide references to the relevant section of the NIR where further details can be found.

* Where a mix of methods/ emission factors has been used within one source category, use this documentation box to specify those methods/emission factors for the various sub-sources where they have been applied (see also footnotes 2 to 4 to this table).

1.A.1.a - CO2 - method: a T1 method is applied for liquid, solid & gaseous fuels, a T2 method for other fuels. The latter covers municipal solid waste incineration with energy recovery.

1.A.1.a - all gases - AD: for liquid fuels: PS for steel industry up to 1997 (power plant runned by the steel industry and stopped when Luxembourg's steel industry move from blast furnaces to electrical arc furnaces was completed);

for solid fuels: PS for steel industry up to 1997 (see above). 1.A.1.a - solid fuels = NO from 1998 onwards since the last blast furnaces stopped its activities in September 1997 and since Luxembourg has no thermal power plant using solid fuels;

for gaseous fuels: PS for steel industry up to 1997 (see above);

for other fuels: covers municipal solid waste incineration with energy recovery. AD are a mix of NS (waste treated every year by the incinerator) and of Q data (analysis of the incinerated waste composition for the years 1992-94, 2001 and 2004-05).

1.A.3.b - road transportation - method: for COPERT III one should read that COPERT III method has been applied on NS for the vehicle fleet in Luxembourg. Then, the amount of fuel calculated via COPERT III is deduced to the total amount of fuel sold in Luxembourg, the difference being 'fuel exports'. The latter is estimated using a T1 method with default EF since we do not have enough information on the type of transit vehicles fueling in Luxembourg.

1.A.3.d - all gases - AD: TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln.

1.A.4.c - all gases - AD: TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln as well as an expert judgement (EJ) for the years 1990 to 1995 (NO from 1996 onwards) for gaseous fuels.

2.A.1 - CO2 - EF: CS EF based on PS CaO content in clinkers provided every 5 years by the sole cement manufacturer operating in Luxembourg.

2.C.1 - CO2 - AD: NS for iron production (blast furnaces operating from 1990 to 1997) and steel production (basic oxygen furnace operating from 1990 to 1997). PS for sinter production (1990 to 1997) and steel production from electrical arc furnace (from 1993 onwards).

2.C.1 - CO2 - method: CS for every type of production and for every year, except T2 for blast furnaces and basic oxygen furnace in 1990 and T2 for electrical arc furnace (from 2004 onwards).

2.F.1 - HFCs - AD: based on a study realized end 1999 by the Environment Agency and the Centre des Ressources des Technologies pour l'Environnement (CRTE) and inter- and extrapolated using CS methods.

2.F.4 - HFCs - AD: based on a study realized end 1999 by the Environment Agency and the Centre des Ressources des Technologies pour l'Environnement (CRTE) and inter- and extrapolated using CS methods.

2.F.8 - SF6 - AD: based on a study realized end 1999 by the Environment Agency and the Centre des Ressources des Technologies pour l'Environnement (CRTE) and inter- and extrapolated using CS methods.

2.F.9 - SF6 - AD: based on a study realized end 1999 by the Environment Agency and the Centre des Ressources des Technologies pour l'Environnement (CRTE) and inter- and extrapolated using CS methods.

4.A.1 - CH4 - AD: the various AD needed to calculate CH4 emissions for cattle are coming from NS except for the Digestible Energy (DE) parameter for which we have used the German values.
4.B.1 - CH4 - AD: the various AD needed to calculate CH4 emissions for cattle are coming from NS except for the Digestible Energy (DE) parameter for which we have used the German values.
4.B.1/3/4/8/13 - N2O - AD: nitrogen excretion values per AWMS are deriving from an expert judgement (EJ).
4.D.1 - N2O - method: T1a for CRF categories 4.D.1.1/2/4 and T1b for CRF categories 4.D.1.3/6.
4.D.1 - N2O - AD: experts judgements (EJ) for nitrogen excretion values per AWMS (CRF category 4.D.1.2) and for sewage sludge production & spreading (CRF category 4.D.1.6).
4.D.2 - N2O - AD: nitrogen excretion values per AWMS are deriving from an expert judgement (EJ).
4.D.3 - N2O - AD: nitrogen excretion values per AWMS and sewage sludge production & spreading are deriving from experts judgements (EJ).
5 - LULUCF: estimated only at an aggregated level (carbon intake by temerate forests) and allocated to CRF category 5.G. AD are based on expert judgement (EJ) within the Water & Forests Administration.
6.B.2 - N2O - EF: IPCC 1996 Guidelines default values are used. However, due to the high number of commuters coming every working day in Luxembourg, the population used for estimating the N2O emissions is an adjusted population taking into account commuters (with 1 commuter = 0.5 resident). Hence the notation keys CS and D.
6.C - all gases - AD: mix of NS (waste treated every year by the incinerator) and of Q data (analysis of the incinerated waste composition for the years 1992-94, 2001 and 2004-05).
6.D - CH4 & N2O - AD: mix of NS (for all the public recycling centers) and of PS data (Soil-Concept project).
CO2 emissions from biomass - AD: TÜV Rheinland (1990): Emissionskataster für das Großherzogtum Luxemburg. Köln as well as an expert judgement (EJ) for the years 1990 to 1995 (NO from 1996 onwards) for gaseous fuels.

Annex III - Uncertainty related to Luxembourg's national GHG Inventory Report

The report presented on the next pages is the final report prepared by Austrian Research Centers GmbH – ARC, with the help of the Austrian Umweltbundesamt, describing the uncertainty assessment of Luxembourg's GHG inventory – submission 2008v1.2.

report

Uncertainty related to Luxembourg’s national Greenhouse Gas inventory

Wilfried Winiwarter,
Traute Köther

June 2008
ARC—sys-0162

systems research
AUSTRIAN RESEARCH CENTERS

Uncertainty related to Luxembourg's national Greenhouse Gas inventory

Final report to project no. 1.S2.00025.0.0

Wilfried Winiwarter[1]
Traute Köther[2]

June 2008
ARC--sys-0162

[1] ARC Bereich systems research
[2] Umweltbundesamt

systems research
AUSTRIAN RESEARCH CENTERS

Abstract

A qualitative assessment of Luxembourg's industrial and economic conditions was used as a setting against which uncertainty estimates derived from several national studies from different countries were applied. Quantitative uncertainty estimates could be derived for all input data, and both error propagation (according to a spreadsheet presented with the IPCC guidelines) and a Monte-Carlo approach were used to calculate overall uncertainty. Differences between these approaches follow the theoretical expectations. Overall uncertainty of the inventory is lower for the error propagation approach (2.86% vs. 4.04% for 2006), which is not able to fully reflect statistical dependencies between input parameters. Such dependencies occur in several instances of the data used. This also effects the uncertainty of the trend (difference between 2006 and 1990 emissions), where error propagation yields 1.77%-points compared to 2.34%-points in the Monte-Carlo approach. Due to the large importance of fossil fuel emissions in Luxembourg from transport and industry, which are in general very well supported by statistical and measurement information, and the smaller importance of agricultural activities, the uncertainties of Luxembourg's greenhouse gas inventory are fairly low. Still also in Luxembourg, like in all countries that offer detailed uncertainty analysis, the uncertainty related to the emission factor of N_2O from soils determines most strongly overall uncertainty of the emission inventory. The factors most strongly influencing the trend refer to solid fossil fuels formerly used in iron and steel industry, an activity that has been overturned fully since 1990. The structural changes in Luxembourg are well reflected in the emission changes and also in the related uncertainties.

Kurzfassung

Die industriellen und wirtschaftlichen Bedingungen Luxemburgs wurden qualitativ erfasst und als Hintergrund zur Abschätzung der Unsicherheiten der nationalen Treibhausgasinventur verwendet, wofür im wesentlichen Daten aus ähnlichen Studien anderer Länder herangezogen wurden. Quantitative Angaben konnten auf diese Weise für alle erforderlichen Eingangsdaten der Inventur aufgefunden werden. Sowohl die Methode der Fehlerfortpflanzung (unter Verwendung eines Algorithmus, der in den IPCC guidelines präsentiert wird) als auch ein Monte-Carlo Ansatz wurden verwendet, um die Gesamtunsicherheiten zu ermitteln. Die Unterschiede zwischen den Methoden entsprechen den theoretischen Erwartungen. Die Gesamtunsicherheit der Inventur ist niedriger für die Methode der Fehlerfortpflanzung (2,86% gegenüber 4,04% für das Jahr 2006), da diese Methode nicht in der Lage ist, statistische Abhängigkeiten zwischen Eingangsdaten entsprechend abzubilden. Solche Abhängigkeiten treten relativ häufig auf. Dies beeinflusst auch die Unsicherheit des Trends zwischen dem Basisjahr 1990 und dem aktuellen Jahr 2006 (1,77%- Punkte verglichen mit 2,34%-Punkten gemäß Monte-Carlo). Die im Vergleich zu anderen Ländern große Bedeutung der fossilen Brennstoffe aus Transport und Industrie, die generell recht gut statistisch und messtechnisch erfasst sind, und die geringere Bedeutung landwirtschaftlicher Tätigkeiten führen dazu, dass die Unsicherheiten der Luxemburger Inventur relativ niedrig liegen. Trotzdem ist auch in Luxemburg, wie in allen Ländern, für die Unsicherheiten detailliert erhoben wurden, der Emissionsfaktor für N_2O aus Böden bestimmend für die Gesamtunsicherheit der Inventur. Der Trend der Emissionen wird am stärksten durch die fossilen Emissionen aus Eisen- und Stahlindustrie beeinflusst, ein Sektor der seit 1990 großen Umwälzungen unterworfen war. Diese strukturellen Veränderungen werden in den Emissionen Luxemburgs und auch in deren Unsicherheiten deutlich.

Table of Contents

1 Introduction

Assessing uncertainties is one important element to assure the quality of national greenhouse gas inventories. Since assessment of uncertainties is one of the requirements for submission of national inventories to the UN Framework Convention on Climate Change (UNFCCC) also considerable background work has been performed, in order to secure the scientific basis of such assessments.

In general, one may distinguish between the mathematically more simple, but not always fully applicable "error propagation" method, for which IPCC provided simple readily usable tools (IPCC, 2000) and the more elaborate "Monte-Carlo" approach, which at the same time requires a deeper understanding of the relationships of input data used. A "Monte-Carlo" approach (see more detailed description in section 3) has first been used by Charles et al. (1998) to identify the uncertainty of the UK's national inventory. Methodological improvements and applications to Norway (Rypdal and Zhang, 1999), Austria (Winiwarter and Rypdal, 2001), Finland (Monni and Syri, 2003), the Netherlands (Ramirez-Ramirez et al., 2006) and the Flemish Region of Belgium (Boogaerts and Starckx, 2004) allow a comprehensive understanding of the issues involved for different economic structures. As Rypdal and Winiwarter (2001) and Winiwarter (2007) explain, the level of uncertainty in individual national inventories will most strongly be determined by arbitrary choice of certain uncertainty parameters, most of all the uncertainty of N_2O emissions from soils which are least understood. Some influence is also exerted by the respective pattern of emission sources in a country – the above influence will be stronger in an agriculturally dominated country, whereas in a country where energy production is dwarfing all other sectors relevant for GHG emissions this will be less important. In any case, the uncertainty reported with a national inventory will definitely not be able to indicate its quality in a cross-country comparison.

Still assessing uncertainty is of large importance for the inventory compilers themselves. It allows to define priorities in an improvement program, helps understand the robustness of the inventory and thus provides guidance to an efficient program on emission reduction.

This report describes the uncertainty assessment for the national inventory of Luxembourg, using a "Monte-Carlo" approach. This approach requires a profound knowledge on the interrelations existing between the individual input data used for the inventory. For this reason, the structural background of the emitting sectors in Luxembourg has been investigated first (section 2). This was based on a set of interviews with national experts in the different source topics, and included (wherever possible) indications on the magnitude of uncertainties. In section 3, the methodology used is outlined and described in detail, which uncertainty estimates were applied to what part of the inventory. Section 4 provides results and in section 5 an interpretation of the outcome of this study with respect to the experiences in other countries is given. All data on uncertainty, whether expressed as percentage or absolute, will refer to a coverage of 95% of the possible range (+/- 2 standard deviation), as required according to IPCC (2000).

2 Greenhouse gas emissions: the specific situation of Luxembourg

2.1 General description

Luxembourg is a country in central-western Europe, surrounded by Belgium, France and Germany. While being a major steel producer previously, the blast furnaces have been closed down and only electric arc steel production remains. The country's economy moved into the service sector. Consequently the main energy carrier is now gas, solid fuels have become sparse. Luxembourg has about 476200 inhabitants (as of December 31, 2006), living in an area of 2586 km². About half of the work force (totalling 318600 persons in 2006) consists of foreign nationals including a large number of commuters (126800 or 40% of the work force) travelling into the country on a daily basis. Significant for the country is the large amount of automotive fuel sold to be used outside the area of Luxembourg (“road fuel export”) but accounted to Luxembourg, which make up about 40% of all GHG emissions of the country (excluding LULUCF).

2.2 Description of sources

This compilation is based on a series of expert interviews. The respective experts are named within each section. While only part of the comprehensive information provided can directly be used for uncertainty assessment, this background provides a proper foundation upon individual judgements towards the respective uncertainty estimates can be justified.

2.2.1 Energy

Michel Trauffler, Simone Polfer (Ministère de l’Economie et du Commerce Extérieur)
Eric De Brabanter (Ministère de l’Environnement)

Primary energy carrier in Luxembourg is natural gas. Gas is used in the major power plant (TwinErg), in industry including electro-steel works (Arbed, now known as Arcelor-Mittal) and in domestic heating (private households as well as commerce). The ministry of economy collects consumption / import data from the only provider SOTEG. Since 2006, other providers also enter the market, but the still use the transport facilities (pipelines) of SOTEG – thus the data situation remains stable.

SOTEG sells directly to major industry, but also to 5 smaller provider companies. These individual providers deliver to small industry, commerce, private households. For the detailed split, information gets sparse. Most precise data are expected at the country level. Comparison is possible between figures reported by industry participating to the ETS, and the distributor’s figures. This is the only country-specific information on uncertainty that is available.

There is some preparatory activities for biogas cleaning to feed it into the gas network. But this is, first of all, not in place yet, and will never exceed more than a few percent of total as consumption (10 Mm^3 biogas are being planned).

The amount of gasoline and diesel fuel being sold in Luxembourg gas stations is monitored by monthly reports of the gasoline industry. 8 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. It is believed that (similar to transport fuels) fuels are rather exported than imported due to lower prices. 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 sector. 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 for CO_2 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_4 and N_2O emission factors is quite different. Factors have been taken from IPCC 2006 guidelines (default factors) or COPERT III methodology, respectively. For those factors that derive from IPCC it will be useful to look into the recommended uncertainties for these factors (with consideration of internationally reported uncertainties).

More critical is the application of COPERT default factors for N_2O emissions, especially as COPERT III derives from the situation (available N_2O measurements) as of 2000 and much more information is now available on transport N_2O emissions. This means that the COPERT factors as such would need reconsideration, especially as N_2O from transport is considered a key source. The fact that diesel fuel is more relevant in that respect than gasoline fuels (which was a key source only twice in 15 years) has to do more with the emission factors actually applied than with the real release of GHGs. Potentially the catalytic converter emissions are underestimated, or diesel emissions overestimated. Comparing COPERT III emission factors (Ntziachristos and Samaras, 2000) to alternate emission factors (see INFRAS, 2004; Winiwarter, 2005) indicates differences up to a factor 3 with COPERT III emission factors (but also within each other).

Gas sector

Simone Polfer (Ministère de l'Economie et du Commerce Extérieur)
Marco Hoffmann (Ministère de l'Economie et du Commerce Extérieur)

SOTEG – the only operator of a transboundary network – operates 4 crossing points: one to Germany, one to France and two to Belgium (Petange, Bras). Compressor stations are all situated outside Luxembourg. The quality of incoming gas is monitored hourly by gas chromatography. Losses of approx. 0.05% include the use of gas to heat depressurizing stations in wintertime. The gas network is relatively new (mostly since 1972) – thus losses are almost negligible.

Household gas meters exhibit higher uncertainties (~2%) but uncertainties need not be assessed a this stage. Gas meters are being checked annually, also because of security reasons (access to installations).

Important other contacts are the customs authority (Pierrot Reding) who may be able to split energy use by NACE sector (due to new taxation – only since ~2007) and the industry federation (general secretary Rene Winkin, at the same time general secretary of the association of oil companies) who may provide access to the respective industries which use more than a specific amount of gas. Possibly also SOTEG and the other operators can do so, but there may be an issue of data protection. These contacts may specifically provide information for an inventory improvement program, but are not expected to contribute to a quantitative uncertainty assessment.

Liquid fuels:

Simone Polfer (Ministère de l'Economie et du Commerce Extérieur)
Carlo Groff (Ministère de l'Economie et du Commerce Extérieur)

Maximum fuel prices are fixed under contract with oil companies, according to a specific formula, by the ministry of economy (SP & CG). Almost all gas stations in Luxemburg operate at this daily fixed price (after Rotterdam market prices).

Companies operating in Luxembourg are Aral / BP / BP (kerosene) / Esso / Q8 / Shell / Lukoil (Jet) / Belec (Texaco) / Total.

Imports are transported via railway / ship / trucks (only kerosene via a pipeline, for international flights only; 40 t for domestic flights concern small airplanes only, which do not use kerosene). Monthly balances are delivered to the ministry by the oil companies. These monthly balances are cross-checked annually in order to determine companies' strategic reserve obligations, and also compared to the customs authority's data. It happened once that double counting led to an error of 3-5% of the national total, which was corrected immediately with the annual cross-checks.

Measurements are taken by volume (15°C) and converted into / reported as tons. Errors have not been estimated.

Gasoline and diesel oil distributed via gas stations are thus well established. It is more difficult to differentiate heating oil, which may be used for heating, but also for railway, construction engines, agriculture (at different tax levels). E.g., even if it is on different tax levels, it may be appropriate for farmers to use heating oil (higher tax) also to operate their tractors. S-free diesel (10 ppm) is furthermore also used for heating, where normally S is limited at 1000 ppm. This makes distinguishing very difficult. The engine park (e.g. tractors) in Luxembourg is very modern.

There is a private approach estimating “road fuel export”, looking at the distribution of gas stations in Luxembourg and discounting for the border stations and those on the motorway. This approach yields an estimated third of the fuel to be attributed to tank tourism (defined as the fuel taken up by cars that specifically go to Luxembourg for the purpose of filling up), and less than another third due to transit traffic filling up on their way.

In fuel oil for heating, there is little transboundary sales. It is believed that sales would compensate (import=export). Liquefied gas is a quite small sector in Luxembourg. There are three major companies reporting to the ministry (Total / Shell / Energus). Here a summer peak due to Dutch trailers crossing the country may be discerned (monthly sales increase from 95 t to 154 t).

Solid fuels

Simone Polfer (Ministère de l’Economie et du Commerce Extérieur)
with support of Carlo Groff (Ministère de l’Economie et du Commerce Extérieur)

Solid fuels have been important in Luxembourg in the past (1990), they are no “key sources” any more. Solid fuels were applied in industry, for cement production and specifically in the iron and steel industry. Blast furnace gas was used for heat and electricity production. As blast furnace gas derives from solid fuels, in energy statistics and as a consequence also in the national CRF-tables it is registered as “solid fuel”. The use of solid fuels in public electricity and heat production thus stands for blast furnace gas as a fuel. With the closing of the old pathway of steel production (around 1997, see also section 2.2.3) in Luxembourg also the supply, and thus the use of “solid fuel” for electricity production terminated.

Coal and coke used to be imported into Luxembourg by several different importers and from a number of different countries (in 1990, coke from Germany dominated). Central statistics are held by the ministry of economy which provide the basis of the greenhouse gas inventory. Despite of good agreement of energy statistics and heat production (difference between primary energy demand and final energy demand for fossil fuel agrees reasonably well with electricity production), uncertainty of this sector has been recognized already. A 4% loss of solid fuels is generally assumed (presumably into uses not covered by statistics). As different coal qualities are on the market, and also coal is quantified on a mass basis, conversion errors and uncertainties in the respective qualities to be considered need to be recognized.

Historically, gasification of coal also provided gas to households (city of Luxembourg gas works), but this was done on a quite small scale. It is not considered important to know the exact time of termination or the magnitude of this source.

Electrodes in electric arc furnaces – the dominant use of carbon in the current pathway of steel production – are specifically not included in the national energy statistics. Information is available from trade statistics, but is not related to energy use.

Luxembourg also hosts an energy agency (Agence de l’Energie) – www.ael.lu which deals with improving energy efficiency and the use of regenerative energy in very general terms.

2.2.2 Transport

Georges Blasen (Administration de l'Environnement)

Luxembourg uses COPERT to assess emission factors of traffic CH_4 and N_2O emissions. While CO_2 is calculated from the fuel sales, extrapolation of CH_4 and N_2O assume a similar vehicle park in road fuel export as in the national situation. This is problematic as there is a very large share of fuel that is used outside of the country.

For COPERT, annual vehicle mileage is required – this is taken from inspection statistics maintained by SNCT (data derive from annual inspection – note the difficulty that the first inspection is only at the third year after purchase).

2.2.3 Processes, product use:

Pierre Dornseiffer (Administration de l'Environnement)

Within processes, two key sources are to be noted (cement production, iron and steel production). In addition, a quite limited number of industrial installations has to be considered. Product use is covered in a specific study (on F-gases) or by taking over German factors (N_2O).

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_2 emissions (according to IPCC methodology) which is a stochiometric factor. Errors could only occur at high Mg content which however is not the case.

Ca content as well as amount of production are 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.

Three Steel plants exist in Luxembourg, all of the same company (Arcelor-Mittal). In addition, a plant recuperating iron from slag and collected dust (direct reduction furnace) needs to be considered (Primorec) – currently missing from the inventory but a minor source only. 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_2 derives from electrodes. It is not clear whether this carbon is or is not included in the national energy balance (should be under “fuel as feedstock” or similar category). This does not affect uncertainty for this sector, but could have consequences on overall uncertainty calculation.

A preliminary uncertainty analysis has been performed for the iron and steel industry, using IPCC uncertainty defaults. Adding up all components presented, which may not be applicable and leads to uncertainty overestimation leads to 9% uncertainty for 1990 pathway and 5% for the current pathway. IPCC default uncertainties probably overestimate the Luxembourg situation.

Polyester production (DuPont)

This chemical plant limits its operation to polymerization. Some solvent emissions (methanol, ethanol, ethyleneglycol, THF, yielding several thousand tons CO_2 in the atmosphere subsequently for 1990, but only about 100 for 2005), which occur as a consequence to polymerization processes have not been considered as GHG’s. Even compared to total solvent emissions only this contribution is very small. Further consideration should be performed only after solvent emissions have been assessed.

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

A study assessing F-gas emissions has been completed, a new study commissioned. According to preliminary results, the new study confirms the finding of the study already completed. F-gas emissions derive primarily from refrigeration and air conditioning systems, switches, insulation windows and similar devices. All 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.

N_2O 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.

2.2.4 Agriculture

Eric De Brabanter (Ministère de l’Environnement)
Jean-Paul Hoffmann (Service d’Economie Rurale)

Assessment of CH_4 emissions from Luxembourg’s agriculture follows strictly IPCC guidelines. A previous study (from Daniel Strauss, Administration de l’Environnement) covering both agriculture and waste was not used.

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 agricultural holdings. Previously, differences less than 1% e.g. on extension of agricultural land (130000 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. In 2007, the cattle herd consisted of 40.000 milk cows, 29.000 suckler cows, 4.000 other cows, 53.000 young cattle aged less than 1 year, 44.000 young cattle and fattening cattle aged 1-2 years, 22.000 heifers and fattening cattle aged more than 2 years. The total cattle herd was 192.000 animals. Compared to pigs (84.000) and sheep (<10.000) the figures are quite large.

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 (Frank Aben – ministry of agriculture ASTA). Bovines are assumed to spend half a year (6 months) outside, and 6 months inside buildings.

In cooperation with EUROSTAT, a special survey on agricultural production methods will be made in 2010, to be published some time later.

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.

2.2.5 LULUCF

Frank Wolter (Administration de l'Environnement)
Eric De Brabanter (Ministère de l'Environnement)

Emissions from LULUCF are being assessed from an external contractor. First results are available (interim report) and will be sent to Eric De Brabanter. This report also contains information on uncertainties.

2.2.6 Waste

Serge Less (Administration de l'Environnement)

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 (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 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 SIDEC 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_2 emitted from the MWI and a potential overestimation of total DOC amounts in SIDEC.

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_4, as determined from monthly reports of the landfill operators (measured quantities) is subtracted from the estimated emissions.

Composting

7 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.

2.2.7 Wastewater

Jean-Marie Ries (Ministère de l'Intérieur et de l'Aménagement du Territoire)

The division of water protection in the interior and land management ministry 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, 5 additional > 10000, plus 19 > 2000. These plants provide analytical data of input and output N and C, thus also allowing to estimate the conversion. 90% of total wastewater from Luxembourg is covered.

All plants larger than population equivalents of > 30000 allow separate sludge digestion – CH_4 produced is being collected and used for energy production. One industrial water treatment plant (Dupont, at pop.eq. of 40000) does not have that.

IPCC default values are used for emission calculation, including default methane conversion factors (MCF).

Nitrous oxide emissions: Extrapolation towards small plants is somewhat unreliable, as assignment of villages to wastewater treatment plants is corrected only every 5 years – but this concerns less than 10% of the emissions anyway.

Sewage sludge is of high quality and fit for agricultural application, as there is no industrial waste included in municipal wastewater – at least for those 50% of total sewage sludge that are applied on fields. About 25%, which are richer in heavy metals, go into waste incineration. In any case there is good documentation both on the amounts and on the trace metal content.

3 Methods used

3.1 Selection of input data

Ideally, assessing uncertainties is being performed at a most detailed level of the inventory. However, practical considerations recommend to remain at a level of detail which encompasses some of the very source specific calculations already. The calculation sheet prepared by IPCC (2000) provides a predefined level already, and also for Monte-Carlo analysis one requirement is that all information is being combined into one calculation sheet.

In the case of Luxembourg, information is brought together specifically for each source sector, and only then copied into the CRF tables as required for submission. This is obviously a very impractical basis for uncertainty calculation. As it is not feasible to maintain a combination of those individual input tables, we mimic the approach recently taken for Austria (Winiwarter, 2008). In this Austrian approach, activities and emission factors from all source sectors are being combined in one large spreadsheet. For Luxembourg we create a similar compilation of data, which however not always bears all full details of the emission calculations. Small differences in total emissions will occur with respect of the official inventory. These differences will have virtually no effect of the resulting uncertainties. Thus we regard this approach as justified.

In order to account for the improved methodology developed as a part of the national inventory, we adapted the emission factors originally available to fit the final sector emissions of the official Luxembourg emission templates of 2008, CRF format, version 1.2. Adaptation of emission factors was performed for all key sources, and for the years 1990 and 2006 only (with linear interpolation of the factors in between, which are not used in this report). Non-key sources and –gases (e.g., N_2O emissions from fuel combustion outside the transport sector) were not adjusted. This lead to a slight underestimation of emissions considered for uncertainty assessment which will not affect our findings.

While the discrepancy in terms of results is considered negligible, a more relevant problem is recalculation. Adapting input data, either to accommodate a different inventory year, or in terms of emission adjustment, requires to also adjust the uncertainty sheets as a specific action. We suggest particular consideration of this topic in the national inventory plan.

3.2 Assessing input uncertainties

3.2.1 Method

We use information on uncertainty from a number of national assessments (Charles et al., 1998; Monni and Syri, 2003; Ramirez-Ramirez et al., 2006; Winiwarter, 2008; …) and adapt the factors presented with the information of experts on the Luxembourg situation (see section 2.2). The basic idea was to evaluate uncertainties at the same level as input data are available (section 3.1).

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.

3.2.2 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: Winiwarter, 2008)

Consequently, uncertainty estimates for activities in the energy sector were given 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, 2003, 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_2 emission factors directly derive from the carbon content, which is very well understood for gaseous and liquid fuels (0.5% uncertainty, respectively; as CO_2 emissions from transport are being calculated according to fuel sold, this factor is directly applicable also on “road fuel export”). 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, 2003, 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. (1998).

Even if a number of different emission factors on CH_4 and N_2O 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., 1998), we consider at least those four groups statistically independent, both in the case of N_2O and CH_4. In contrast to CO_2, 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. Ntziachristos (personal information, 2008) regards the uncertainty of COPERT “at least 50%” for CH_4 and N_2O. As COPERT was applied to the vehicle fleet of Luxembourg, but applied to all vehicles that buy fuel in Luxembourg, we extend this factor to 60%, and use for catalyst-created N_2O also a slightly extended range (40-250% of best estimate) compared to that suggested by Hausberger (2005) for Austria.

3.2.3 Industry and product use

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 decarbonizing 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_2 emission factor. Likewise we apply national factors also to the glass industry (2% for activity, 5% for emission factor).

Assessing emissions from solvent follows the Austrian approach (Windsperger, pers. information). Thus we also apply the Austrian uncertainty estimates (5% activity uncertainty, 10% CO_2 emission factor uncertainty). For N_2O use we consider activity (population numbers) as exact, while the emission factor is regarded at 20% uncertainty following Monni and Syri (2003). This is much higher than the 1% used but not explained by Ramirez-Ramirez et al. (2006) but in line with Boogerts and Starcks (2004) who apply 25%.

F-gas emission uncertainty (not split into activity and emission factor) has been taken over from Austria, with 54% uncertainty for HFC’s and 56% uncertainty for SF6. Again this is the order of magnitude also used by Monni and Syri (2003) but somewhat higher than the 20% suggested by Ramirez-Ramirez et al. (2006), which however are not explained.

3.2.4 Agriculture and waste

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%, just the “fallows” (which is the basis for calculating indirect soil emissions) is considered statistically dependent, but twice as high. Reason for choosing these relatively high numbers is the inadequacy of activity parameter – with respect to the emission factors’ uncertainty (see below) this contribution is negligible anyway. Animal numbers’ uncertainty is estimated between 2% (for cattle, which are extremely well covered due to their inclusion in a register) and 10% for animals distributed over many small farms (sheep, horses, chicken).

For emission factors, we follow uncertainties developed for Austria. The CH_4 emission factor for soil emissions is considered uncertain by +/-100%, the N_2O emission factor is within a factor of 10 (lognormal distribution, from 30% to 300% of the best estimate) following IPCC (2006). Enteric fermentation CH_4 emissions are uncertain by 20% for cattle, 30% for all other animals. Manure application emission factor follow a 70% uncertainty for CH_4 and a range from 50% to 200 % (lognormal distribution) for N_2O.

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_4

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.

3.3 Calculating uncertainties

3.3.1 General

Calculation of uncertainties of an inventory first of all refers to the total emissions of a country for a given year. This is generally understood as the “level” uncertainty. Due to way international agreements have been forged, it is however of specific interest to also understand the extent of uncertainty connected to the change of emissions between two years (the base year, 1990, and a given target year). This “trend” uncertainty is, due to mathematical reasons as outlined i.a. by Winiwarter and Rypdal (2001), normally considerably smaller than the “level” uncertainty.

No specific differentiation has been performed here between systematic uncertainty (i.e., uncertainty introduced by specific deviations in input data, which might be accounted for once a decision can be taken upon which out of two data sets is the correct one) and random uncertainty, the result of many unidentifiable discrepancies occurring simultaneously.

3.3.2 Tier 1 approach: Error propagation

Error propagation is a technique which allows estimating the uncertainty associated with the result of a mathematical function, based on the function’s input uncertainties. Explicit equations for error propagation can be set under a number of pre-conditions only (IPCC, 2000):

- The function consists of additive and multiplicative terms only
- Uncertainty for each input parameter is normally distributed
- Input data are not correlated
- Uncertainty does not exceed 30% of the mean

IPCC (2000) provides a template for a calculation spreadsheet containing all mathematics required for error propagation calculation (see Table 1). IPCC’s Tier 1 approach to uncertainty calculation consists of collecting input information and filling in this table. Using this table is essentially all that is needed for the Tier 1 approach. It even allows to directly assess the trend uncertainty, not only the level uncertainty.

3.3.3 Tier 2 approach: Monte-Carlo simulation

A Monte-Carlo simulation is based on a large number of repeating runs of the actual inventory calculation. For each run, input parameters are varied and (multiple) output is recorded. Variation of input is performed randomly, according to predefined boundary values and a probability density function. The set of individual output data will again follow its own probability density, and thus provide the resulting uncertainty, strictly based on the input uncertainty. In consequence, also the mean value taken from such a distribution is a random result, not necessarily fully identical to a result without considering uncertainty, or to a previous result based on exactly the same input. Differences will remain small, though, and should be considered similar to rounding errors.

As correlating inputs and outputs are stored, it is moreover possible to calculate regressions. The regression allows to obtain the sensitivity of the result towards an input parameter, thus indicating which input is responsible to the result in what extent.

Emission inventories are fairly easy to calculate and require very little computation times, such that even a few thousand repetitions will not require more than a couple of seconds to a few minutes. Commercial software packages are available that couple into standard spreadsheet programs. This facilitates an easy application on a standard PC. Within this project, we use the software "@RISK" from Palisade Co. (www.palisade.com). The standard tools of these software packages allow to define and use many different kinds of probability density functions, and the specification of full and even partial correlation between parameters. This also allows for coupling of inputs to a level of details where uncertainty is assumed to be smallest.

Input data used in the Monte-Carlo simulations are described in detail in section 3.2. The way of implementation (also in connection with statistical dependencies) is fully documented in the calculation spreadsheet. For purpose of full transparency the respective input section of this spreadsheet is also printed as an Appendix to this report.

4 Results

4.1 Detailed results using the Tier 1 (error propagation) approach

The results of the error propagation approach are strictly limited to the key sources and the potential of the IPCC spreadsheet used. Table 1 presents this resulting spreadsheet. An extension to other sources than key sources is in theory possible, but sources can only be dealt with individually. Thus their inclusion would contradict the concept expressed by IPCC (2006) to focus limited resources where they can be applied in the most useful manner. Key sources are selected understanding that a focus to other sources is not so important.

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. Thus it becomes clear that small contributions are basically negligible for the overall total listed in the bottom line of the table, and most of the influence to the total derives from the very few elevated numbers (see section 0). Nitrous oxide emissions from soil (direct and indirect) and transport, especially based on Diesel fuel, are the most pronounced contributors to the uncertainty of the 2006 inventory. Uncertainty of the trend, according to Table 1, is characterized by transport, both diesel and gasoline fuels, and only next by soil N_2O release.

Table 1: TIER 1 (Error propagation) UNCERTAINTY CALCULATION AND REPORTING according to IPCC (2000) "Table 6.1"; data from Luxembourg's submission 2008, version 1.2

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	**Gas**	**Base year emissions 1990**	**Year 2006 emissions**	**Activity data uncertainty**	**Emission factor uncertainty**	**Combined uncertainty**	**Combined uncertainty as % of total national emissions in 2006**	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in n ational emissions introduced by emission factor uncertainty**	**Uncertainty in trend in national emissions introduced by activiyt data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Input data	**Input data**	**Input data**	**Input data**							
		Gg CO_2 equivalent	**Gg CO_2 equivalent**	**%**	**%**	%	**%**	**%**	**%**	**%**	**%**	**%**
1A1a gaseous fuels	CO_2	25	1386	0.5	0.5	0.7	**0.08**	0.11	0.11	0.0540	0.0778	**0.09**
1A1a solid fuels	CO_2	1234	0	2.0	1.0	2.2	**0.00**	- 0.10	0.00	- 0.0979	-	**0.10**
1A2a gaseous fuels	CO_2	284	309	0.5	0.5	0.7	**0.02**	0.00	0.02	0.0010	0.0173	**0.02**
1A2a solid fuels	CO_2	2954	1	3.0	1.0	3.2	**0.00**	- 0.23	0.00	- 0.2339	0.0004	**0.23**
1A2f gaseous fuels	CO_2	313	762	0.5	0.5	0.7	**0.04**	0.04	0.06	0.0179	0.0428	**0.05**
1A2f liquid fuels	CO_2	442	241	2.0	0.5	2.1	**0.04**	- 0.02	0.02	- 0.0080	0.0542	**0.05**
1A2f solid fuels	CO_2	1272	296	3.0	1.0	3.2	**0.07**	- 0.08	0.02	- 0.0774	0.0996	**0.13**
1A3b diesel	CO_2	1379	5565	2.0	0.5	2.1	**0.91**	0.33	0.44	0.1661	1.2504	**1.26**
1A3b diesel	N_2O	18	141	2.0	60.0	60.0	**0.67**	0.01	0.01	0.5852	0.0316	**0.59**
1A3b gasoline	CO_2	1306	1404	2.0	0.5	2.1	**0.23**	0.01	0.11	0.0039	0.3154	**0.32**

A	B	C	D	E	F	G	H	I	J	K	L	M
1A3b gasoline	N_2O	19	127	2.0	100.0	100.0	**1.01**	0.01	0.01	0.8575	0.0285	**0.86**
1A4a gaseous	CO_2	208	301	0.5	0.5	0.7	**0.02**	0.01	0.02	0.0037	0.0169	**0.02**
1A4a liquid fuels	CO_2	351	313	2.0	0.5	2.1	**0.05**	- 0.00	0.02	- 0.0015	0.0703	**0.07**
1A4a solid fuels	CO_2	46	3	2.0	1.0	2.2	**0.00**	- 0.00	0.00	- 0.0035	0.0006	**0.00**
1A4b gaseous fuels	CO_2	208	301	0.5	0.5	0.7	**0.02**	0.01	0.02	0.0037	0.0169	**0.02**
1A4b liquid fuels	CO_2	353	316	2.0	0.5	2.1	**0.05**	- 0.00	0.03	- 0.0014	0.0711	**0.07**
1A4b solid fuels	CO_2	46	3	2.0	1.0	2.2	**0.00**	- 0.00	0.00	- 0.0035	0.0006	**0.00**
2 A 1 Cement Production	CO_2	557	431	1.5	2.0	2.5	**0.09**	- 0.01	0.03	- 0.0199	0.0727	**0.08**
2 C 1 Iron and Steel Production	CO_2	985	170	5.0	1.0	5.1	**0.07**	- 0.06	0.01	- 0.0646	0.0957	**0.12**
4 A 1 Cattle	CH_4	267	232	2.0	20.0	20.1	**0.37**	- 0.00	0.02	- 0.0555	0.0522	**0.08**
4 D 1 Direct Soil Emissions	N_2O	179	162	10.0	150.0	150.3	**1.93**	- 0.00	0.01	- 0.2017	0.1816	**0.27**
4 D 3 Indirect Emissions	N_2O	142	116	20.0	150.0	151.3	**1.40**	- 0.00	0.01	- 0.3038	0.2606	**0.40**
National Total		**12587**	**12578**				**2.86**					**1.77**

The emissions of the key source categories cover 95.5 and 94.4 % of the total GHG emissions (1990 and 2005, respectively

4.2 Detailed results using the Tier 2 (Monte-Carlo) approach

While the iterations representing the Monte-Carlo approach are being performed, all randomly selected input data are recorded, as well as all the respective results of calculations for a predefined set of output parameters. Here we selected the following outputs (all for three cases: base year 2006, reference year 1990, and their respective difference):

- Emissions of each of 22 key sources (key gas only) plus source sector LULUCF (Land Use, Land Use Change and Forestry)
- Totals of all non-key source emissions (for each of 6 gases)
- Emission totals (for each of 6 gases)
- GHG totals as reported to UNFCCC (different gases added according to their greenhouse warming potential, in CO_2-eq)
- National GHG totals including LULUCF and international bunker fuels

In the following presentation we will only refer to the GHG totals as reported to UNFCCC, as other outputs are mostly for scientific interest. Sampling the results of GHG calculations from the Monte-Carlo simulation allows first of all to derive the probability distribution of the overall inventory. Emission levels for 1990 (Figure 1) as well as for 2006 (Figure 2) show very similar results. In both cases a slightly skewed distribution occurs, indicating that the skewed input parameters used have a large influence on the result. As a consequence mean values are also not centered between the 2.5-percentile and the 97.5-percentile. Also the mean values, while representing the “best estimate” of the emission calculation, are the results of a random process and therefore do not exactly match the best estimate of the officially submitted inventory.

A clear difference between the two figures is the width of the 95%-margin. Presumably due to difficulties to recover some of the important activities that have taken place in 1990, and the economic restructuring of Luxembourg since, uncertainties in 1990 have been clearly larger than they are considered today. Compared to that, the overall increase of emissions is quite small and almost negligible.

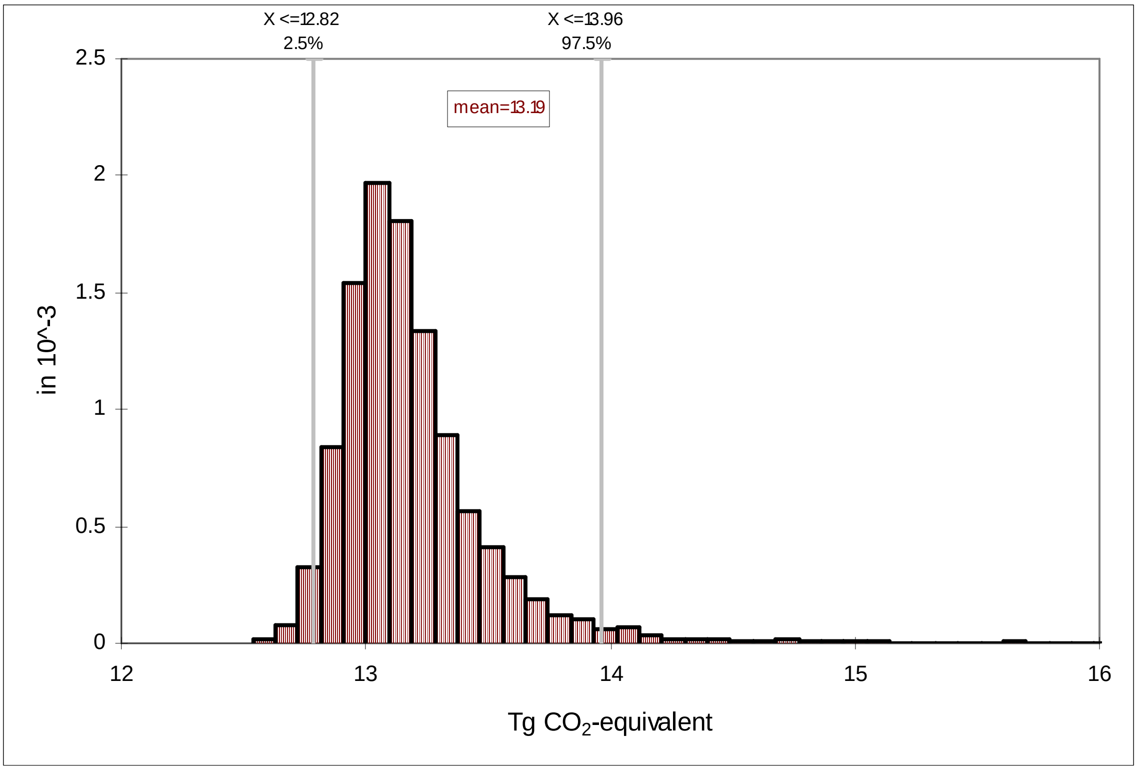


Figure 1: Probability distribution of the Luxembourg GHG inventory (without LULUCF or international bunker) for the year 1990.

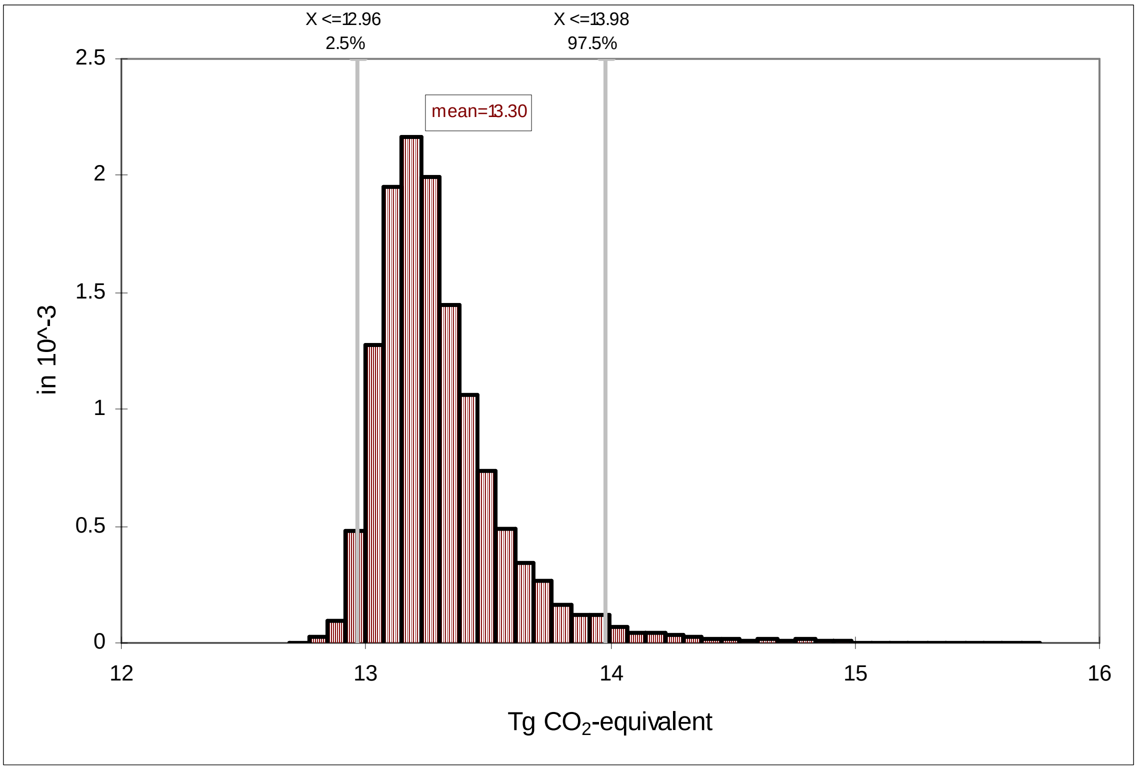


Figure 2: Probability distribution of the Luxembourg GHG inventory (without LULUCF or international bunker) for the year 2006.

The difference between the 1990 and the 2006 inventory, the inventory trend and its probability distribution, is presented in Figure 3. This figure shows a largely symmetrical distribution, indicating that the skewed effect is cancelled out. The slight increase in GHG emissions is also evident here, but from the best estimate only (not significant). The range (in terms of emission totals, CO_2-equivalent) between 2.5-percentile and 97.5-percentile is clearly smaller than a similar range of the emission levels – pointing to the well-known fact that emission trend uncertainties are systematically smaller than emission level uncertainties.

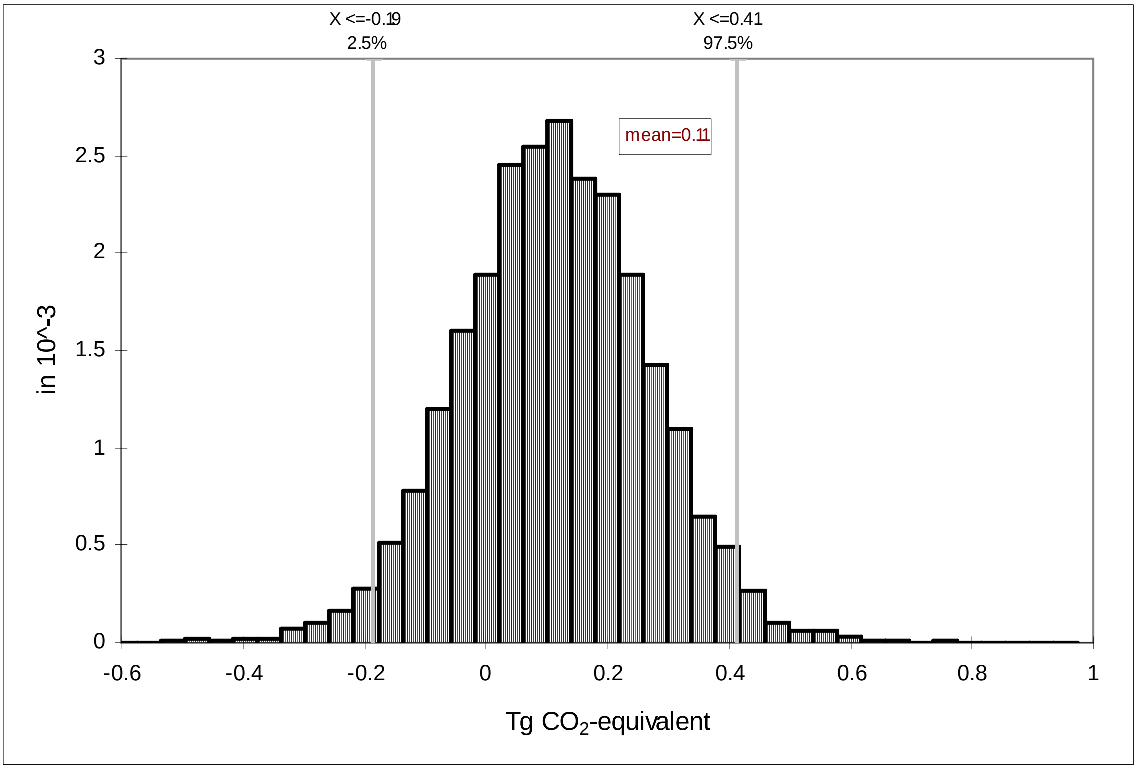


Figure 3: Probability distribution of the trend of the Luxembourg GHG inventory (without LULUCF or international bunker) between 1990 and 2006.

As the Monte-Carlo analysis allows a simultaneous recording of the input parameters and a respective output, it is possible to calculate the regressions between sets of input-output data pairs. High regression for such pairs points to a high influence of the respective input to the output parameter. This analysis of regressions has been performed for the following set of figures, where in addition input parameters were sorted according to their respective contribution. In these so-called "tornado"-diagrams, it becomes clear that very few input parameters determine most of the uncertainty of the overall inventory.

Most similar analyses of uncertainties of national GHG inventories have already shown previously that N_2O emissions from soils are poorly understood and are the highest priority for methodological improvement. This fact has been observed previously for other countries, just the level of the contribution of this single factor may somewhat differ between countries. The parameter is also responsible for the skewed distributions described above. But all other parameters shown here reflect the specific situation of Luxembourg. Figure 4 and Figure 5 also represent the changes in the economical structure between 1990 and 2006, respectively. While in 1990 solid fuels and steel production were important, affecting also the uncertainty of the inventory, the situation for 2006 changed significantly, when liquid fuels and their associated emission factors for N_2O become relevant, due to the very large share of fuel sold in Luxembourg but used elsewhere.

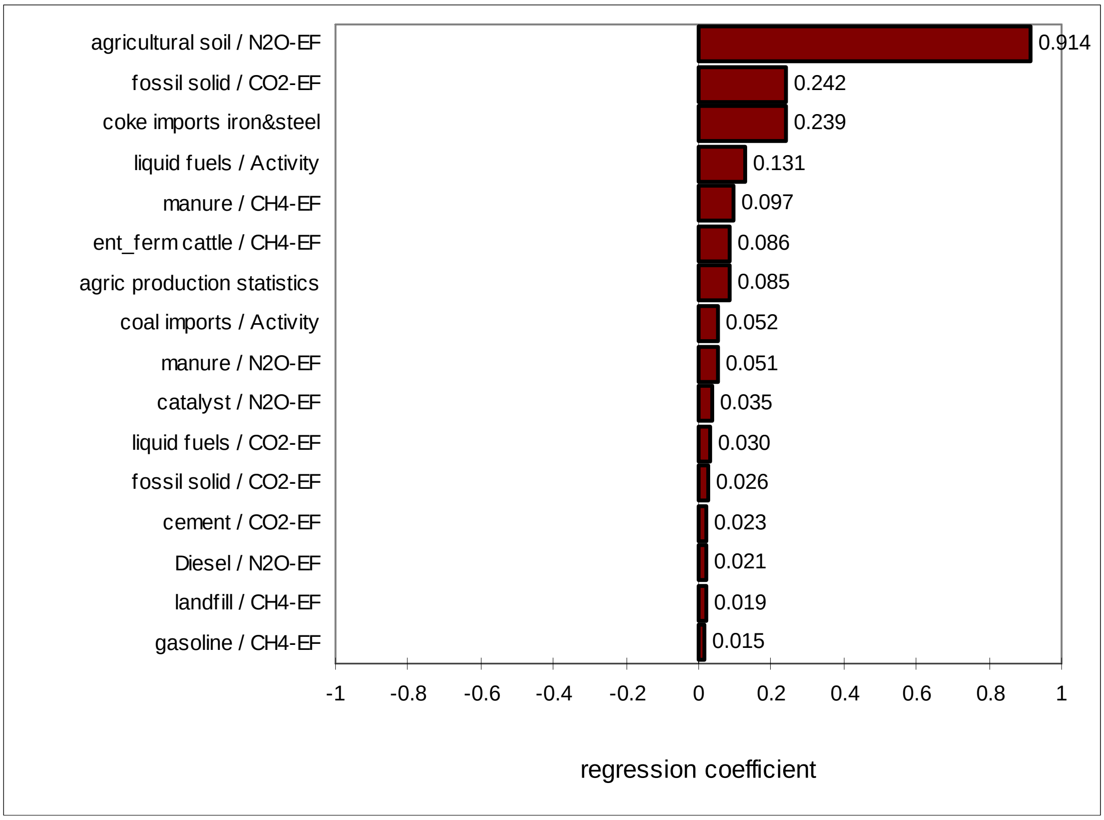


Figure 4: Sensitivity (regression) of the Luxembourg GHG inventory (1990) to the most important input parameters.

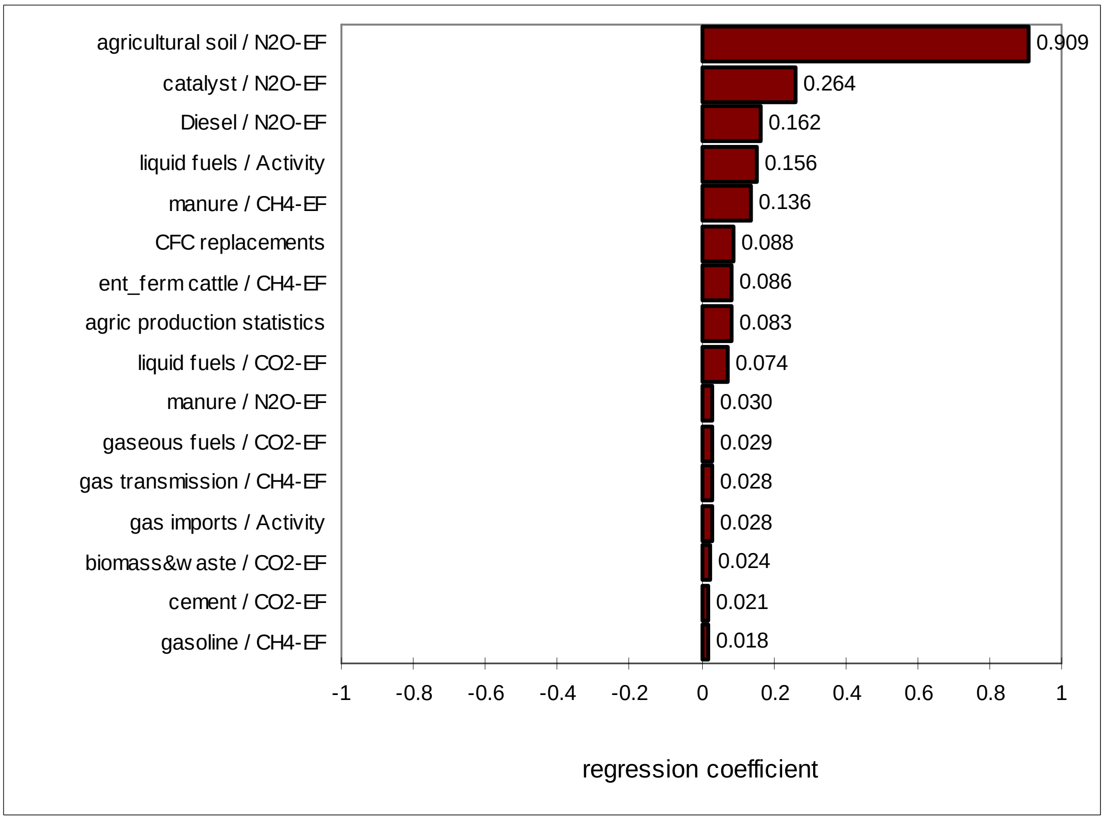


Figure 5: Sensitivity (regression) of the Luxembourg GHG inventory (2006) to the most important input parameters.

This specific Luxembourg situation also is evident in the respective contributions to trend uncertainty (Figure 6). Here regression is visible both in positive and in negative direction (negative: a higher value of a parameter leads to a lower value in the result; i.e., anything leading to higher emissions in the base year will diminish the trend). As assumed earlier, the influence of N_2O (and the associated skewed probability distribution) cancels out for the trend. Instead, it is the very specific parameters influencing emissions in just one of the two years concerned that contribute to the overall trend uncertainty: solid fuels in the case of 1990, and liquid fuels as used for transport, and associated emission factors in 2006. Uncertainty associated with gas is in general extremely small, so the fact that “gas imports” even shows up in the graph is an effect of the very high contribution to overall emissions.

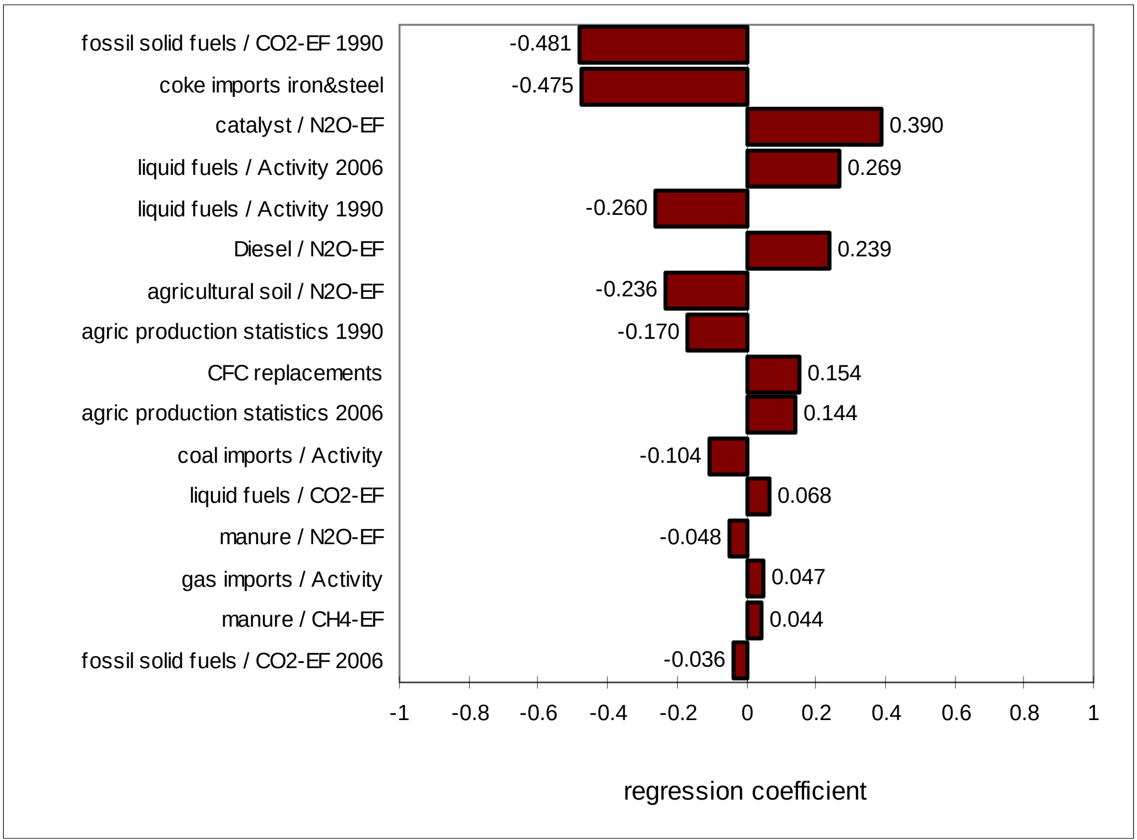


Figure 6: Sensitivity (regression) of the Luxembourg GHG inventory trend (1990 – 2006) to the most important input parameters.

For an overall assessment of all source contributions we have analyzed the key sources specifically, in a manner similar to that already presented for the Tier 1 approach. In contrast to previously, uncertainties given here (derived from the respective standard deviations of the distributions) may still contain elements of correlation between parameters. Thus it is not possible to derive the overall uncertainty from the uncertainty of the individual components presented in Table 2. Still results are sorted in a way to be comparable to Table 1 as much as possible. The respective contributions to overall uncertainty are contained in columns “G” and “K” for level uncertainty and trend uncertainty. In a very similar manner, also the total of all non-key sources (aggregated by gas) is presented for comparison in Table 3. While for methane (as well as the other gases) the contribution to overall uncertainty is the result of several sources (mostly from the manure management category), N_2O uncertainty presented here is mostly determined by emissions due to N excretion on pasture, range and paddock. The way the overall uncertainties in Table 2 are derived they include the full information available and are not limited to the key sources.

Table 2: TIER 2 (Monte Carlo) UNCERTAINTY REPORTING according IPCC (2000) "Table 6.2". Uncertainty expressed as percentiles (2.5%, 97.5%) is able to cover asymmetric distributions. Expressing percentages only (or percentage points, in the case of the trend) comes closer to the Tier 1 result, but fails to reflect the full potential of the approach. Data derive from Luxembourg's submission 2008, version 1.2

A	B	C	D	E	F	G	H	I	J	K
IPCC Source category	**Gas**	**Base year emissions 1990**	**Year 2006 emissions**	**Uncertainty in year t emis-sions as % of emissions in the category**		**Uncertainty introduced on national total in year 2006**	**% change in emissions between year t and base year**	**Range of likely % change between year t and base year**		**Uncertainty introduced into the trend in total national emissions**
		Gg CO_2 equivalent	**Gg CO_2 equivalent**	**% below (2.5 percen-tile)**	**% above (97.5 percentile)**	**%**	**%**	**Lower % (2.5 percentile)**	**Upper % (97.5 percentile)**	**%-points**
1A1a gaseous	CO_2	25	1386	0.7	0.7	**0.07**	5413.2	5344.2	5484.5	**0.07**
1A1a solid	CO_2	1234	0	---	---	**0.00**	-100.0	-107.5	-92.3	**0.40**
1A2a gaseous	CO_2	284	309	0.7	0.7	**0.02**	8.7	7.3	10.2	**0.02**
1A2a solid	CO_2	2954	1	3.0	3.2	**0.00**	-100.0	-105.3	-94.8	**0.64**
1A2f gaseous	CO_2	313	762	0.7	0.7	**0.04**	143.7	140.9	146.7	**0.04**
1A2f liquid	CO_2	442	241	1.1	1.1	**0.02**	-45.4	-49.3	-41.6	**0.07**
1A2f solid	CO_2	1272	296	2.2	2.2	**0.05**	-76.8	-81.9	-71.7	**0.27**
1A3b diesel	CO_2	1379	5565	1.1	1.1	**0.47**	303.7	294.5	313.2	**0.49**
1A3b diesel	N_2O	18	141	59.2	60.8	**0.64**	686.2	-98.5	1465.9	**0.57**
1A3b gasoline	CO_2	1306	1404	1.1	1.1	**0.12**	7.4	3.3	11.5	**0.22**
1A3b gasoline	N_2O	19	127	60.2	149.5	**1.07**	567.5	159.0	3556.4	**0.91**
1A4a gaseous	CO_2	208	301	0.7	0.7	**0.02**	44.6	42.9	46.4	**0.01**
1A4a liquid	CO_2	351	313	1.1	1.1	**0.03**	-10.8	-14.8	-6.9	**0.06**
1A4a solid	CO_2	46	3	2.2	2.2	**0.00**	-94.3	-98.3	-90.0	**0.01**

A	B	C	D	E	F	G	H	I	J	K
1A4b gaseous	CO_2	208	301	0.7	0.7	**0.02**	44.6	42.9	46.4	**0.01**
1A4b liquid	CO_2	353	316	1.1	1.1	**0.03**	-10.4	-14.3	-6.5	**0.06**
1A4b solid	CO_2	46	3	2.2	2.2	**0.00**	-94.3	-98.3	-90.0	**0.01**
2 A 1 Cement Production	CO_2	557	431	2.9	2.9	**0.09**	-22.6	-26.4	-19.0	**0.08**
2 C 1 Iron and Steel Production	CO_2	985	170	4.9	5.0	**0.07**	-82.7	-90.4	-75.1	**0.32**
4 A 1 Cattle	CH_4	267	232	19.7	19.6	**0.35**	-13.1	-20.6	-7.1	**0.08**
4 D 1 Direct Soil Emissions	N_2O	179	162	70.3	198.2	**1.80**	-9.5	-157.7	42.7	**0.31**
4 D 3 Indirect Emissions	N_2O	142	116	70.9	202.3	**1.30**	-18.1	-300.4	85.6	**0.46**
	Total	12587	12578							
		95.5%	94.4%							
National Total without LULUCF		**13187**	**13322**			**4.04**				**2.34**

Table 3: TIER 2 (Monte Carlo) UNCERTAINTY REPORTING according IPCC (2000) Table 6.2 – here for non-key sources only (aggregated by gas).

A	B	C	D	E	F	G	H	I	J	K
IPCC Source category	Gas	Base year emissions 1990	Year 2006 emissions	Uncertainty in year t emissions as % of emissions in the category		Uncertainty introduced on national total in year 2006	% change in emissions between year t and base year	Range of likely % change between year t and base year		Uncertainty introduced into the trend in total national emissions
		Gg CO_2 equivalent	Gg CO_2 equivalent	% below (2.5 percentile)	% above (97.5 percentile)	%	%	Lower % (2.5 percentile)	Upper % (97.5 percentile)	%-points
Non-Key Sources	CO_2	266	305	4.5	4.6	**0.11**	14.8	8.8	20.9	**0.07**
Non-Key Sources	CH_4	193	230	32.5	32.6	**0.57**	19.4	0.5	38.8	**0.14**
Non-Key Sources	N_2O	122	95	44.5	111.1	**0.60**	-22.2	-86.9	5.9	**0.15**
Non-Key Sources	PFC	0	0	---	---	**0.00**	---	---	---	**0.00**
Non-Key Sources	HFC	14	87	53.5	53.8	**0.36**	516.4	-209.7	1156.7	**0.37**
Non-Key Sources	SF_6	3	4	55.3	54.8	**0.02**	32.3	-136.8	234.1	**0.02**

4.3 Comparing Tier 1 and Tier 2 results

Results displayed in Table 2 underline the results already presented in Figure 1 through Figure 6. Prime contributor to the emission level uncertainty is the release of N_2O from soils. Other important parameters are transport emissions and liquid fuels (for the year 2006) in relation to N_2O as well as CO_2, and CH_4 from animal husbandry. For the trend, solid fuels need to be considered in addition, whikle soil N_2O becomes less relevant.

The results strongly match those of Table 1, even if some differences can be identified. In the Tier 2 result, N_2O from transport gets considerably more weight than CO_2 from transport, as a consequence of the simplified treatment of asymmetric distributions in Tier 1. Also, the contribution of iron and steel industry to the uncertainty is considerably higher in the Tier 2 result. This is due to inadequate coverage of the structural changes of steel production: in the error propagation approach (Tier 1) emissions and associated uncertainties are calculated as if they were statistically dependent, while Tier 2 allows treating them as independent. In consequence this leads to clearly different results, which are merely a methodological artefact

The most striking discrepancy is in the overall result. While Tier 1 approach suggests an overall level uncertainty of 2.86% and a trend uncertainty of 1.77% (all numbers as two standard deviations), in the Tier 2 approach we observe 4.04% as level uncertainty and 2.34% for the trend uncertainty. This difference can be interpreted as a result of inadequate treatment of statistical dependence in Tier 1 (see section 5 below), but also incomplete coverage of sources, as the Tier 1 approach neglects non-key sources. Especially N_2O emissions from N excretion on pasture range and paddock contribute further to overall uncertainty.

In consequence, Tier 1 provides a very good way to check and validate results of a Tier 2 analysis. There is some basic drawback, however. The fact that the more complex and demanding approach, the Monte-Carlo analysis (Tier 2) yields higher overall uncertainty results may direct efforts to the more simple error propagation approach, as this deems the results more reliable. This is, however, only an unfortunate misinterpretation which does not reflect the real situation, as will be demonstrated in section 5.

5 Discussion and conclusions

The uncertainties of the Luxembourg GHG inventory have been assessed for the years (GHG-levels) of 1990 and 2006, and for the trend between those years. The key results are shown in Table 4. Overall uncertainties are 4.65% for the year 1990, and 4.04% for the year 2006. As has been the experience from studies in a considerable number of different countries, it always has been the uncertainty related to N_2O release from soils which contribute the major share to overall uncertainty.

With respect to the specific situation in Luxembourg it is interesting to note that uncertainty associated with a previous economic situation, with steel industry a major aspect of the economy (1990), is considerably higher than today. While not as important as the (relatively constant) agricultural contribution of N_2O, uncertainty associated with solid fossil fuels may be identified as the reason for this discrepancy.

Uncertainties in the levels of one of the years important for the trend, but not for the other year, definitely also contribute to the emission trend uncertainty. In the case of Luxembourg this is the steel industry, but also consumption of liquid fuels for transport (including the associated CH_4 and N_2O emissions) which became more important recently, even if the actual point of release is outside Luxembourg's territory. Overall uncertainty is 2.34%-points (uncertainty of emission difference with respect to the base year emission), and due to the uncertainty in the base year it is clearly not possible to be decreased by further efforts in inventory compilation. While additional activities may improve knowledge on a current situation, it is almost impossible to provide a similar task for the past (see Rypdal and Winiwarter, 2001).

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

Table 4: Key results of this study on the GHG inventory uncertainty of Luxembourg (all data in Gg CO_2-equivalent)

	Random uncertainty	CO_2	CH_4	N_2O	PFC	HFC	SF_6	Total GHG emissions
1990	Mean value	12,229	459.9	479.1	0.0	14.2	2.9	13,185
	Standard deviation	114	41.5	283.4	0.0	3.8	0.8	307
	Uncertainty (2 Std. dev.)	**1.9%**	**18.0%**	**118.3%**	**---**	**54.2%**	**56.0%**	**4.65%**
2006	Mean value	12,106	462.2	640.0	0.0	87.3	3.8	13,300
	Standard deviation	47	45.1	258.9	0.0	23.8	1.1	269
	Uncertainty (2 Std. dev.)	**0.8%**	**19.5%**	**80.9%**	**---**	**54.5%**	**56.4%**	**4.04%**
trend	Difference	-123	2.2	160.9	0.0	73.1	0.9	115
	Uncertainty of trend (%-points)	**2.0**	**4.7**	**38.0**	**---**	**340.1**	**93.6**	**2.34**

In the comparison with a simpler method to assess uncertainties, this simpler error propagation method yields clearly lower results. This feature has been analyzed in more detail by Winiwarter and Muik (2008) for the case of Austria, when exactly the same phenomenon occurred. It is the result of a mathematical artefact. As error propagation can not handle skewed distributions, assumptions have to be taken to include information on lognormal distributions. These assumptions can easily twist the results, especially if (as is the case for soil N_2O, the dominant contributor to overall uncertainty) the respective source is important for uncertainty calculation. Furthermore, error propagation can not properly handle statistically correlated input parameters. As input data, especially when it comes to highly resolved information, is frequently derived in a manner that leads to statistical correlation, this is in issue to be considered. Important advantages of error propagation, leading to an overall decrease of relative errors when combining uncertain inputs, require these inputs to be independent – it will not work with correlated parameters, or the results will be wrong.

There is the possibility, also with error propagation, to find a work-around for this issue. As long as this is not settled, however, advantages to perform uncertainty assessments using a Monte-Carlo approach become evident. For this reason, in the final evaluation we disregard the numerical outcome of the error propagation approach. For qualitative information and error checks an additional independent approach is extremely helpful, moreover error propagation will be able to cover some methodological improvements in the inventory system and thus also provide a simplified guidance to the inventory system.

Compared to results of other countries (see Winiwarter and Muik, 2008, for a compilation), uncertainties of the Luxembourg inventory are unusually low. Reason for the difference is the dominance of emissions due to fossil fuel combustion (transport, industry) and the relatively smaller prevalence of agricultural sources (enteric fermentation in cattle, and most strikingly soil N_2O emissions). Energy statistics provide very reliable data on fossil fuels, and emissions of CO_2 are characterized both by carbon content and heat value of the fuels, for which reliable information is available. This is in stark contrast to agricultural sources where release processes of CH_4 and N_2O, respectively, are still only partly understood. As has been discussed previously (e.g., Winiwarter, 2007), factors determining the overall uncertainty of a national inventory are the arbitrary choice of certain important input data, and the emission structure of a country. When – as in this case – the arbitrary choice of the soil N_2O emission factor has been harmonized with comparable other countries, the overall uncertainty is most strongly determined by the overall emission structure – which is very favourable for the case of Luxembourg.

6 References

Boogaerts, B., S. Starcks, 2004.
Quantification of Uncertainties – Emissions Inventory of Greenhouse gas of the Flemish Region. Report 40003117, Det Norske Veritas, Consulting Benelux, Antwerp.

Charles, D., Jones, B.M.R., Salway, A.G., Eggleston, H.S., Milne, R., 1998.
Treatment of uncertainties for national estimates of greenhouse gas emissions. AEAT-2688-1, AEA Technology, Culham, UK.

Hausberger, S. 2005
Scenarios for the Transport Sector in Austria 1990 to 2020. Report No. FVT-68/05/ Haus Em 24/04-6790. Forschungsinstitut für Verbrennungskraftmaschinen und Thermodynamik mbH, Graz.

INFRAS, 2004.
Handbuch Emissionsfaktoren des Straßenverkehres, HBEFA Version 2.1 (CD-ROM), INFRAS AG, Bern.

IPCC, 2000.
Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change, National Greenhouse Gas Inventories Programme, Hayama.

IPCC, 2006.
2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buenida L., Miwa K., Ngara T., and Tanabe K. (eds.), IGES, Hayama.

Monni, S. and S. Syri, 2003.
Uncertainties in the Finnish 2001 Greenhouse Gas Emission Inventory. VTT RESEARCH NOTES 2209, Espoo.

Ntziachristos, L., Z. Samaras, 2000.
COPERT III – Computer programme to calculate emissions from road transport. Methodology and emission factors (Version 2.1) EEA Technical report No 49, European Environment Agency, Copenhagen

Ramirez Ramirez, A., C. de Keizer, J. P. van der Sluijs, 2006.
Monte Carlo Analysis of Uncertainties in the Netherlands Greenhouse Gas Emission Inventory for 1990 – 2004. Report NWS-E-2006-58, Copernicus Institute for Sustainable Development and Innovation, Utrecht.

Rypdal K., W. Winiwarter, 2001
Uncertainties in Greenhouse Gas Inventories – Evaluation, comparability and implications. Environmental Science and Policy 4, 107-116.

Rypdal K., L.-C. Zhang, 2000.
Uncertainties in the Norwegian Greenhouse Gas Emission Inventory. Statistics Norway, Oslo, Norway.

Winiwarter, W., 2005.
The GAINS Model for Greenhouse Gases: Nitrous Oxide (N_2O). Interim Report IR-05-055, IIASA, Laxenburg.

Winiwarter, W., 2007.
National Greenhouse Gas Inventories: Understanding Uncertainties vs. Potential for Improving Reliability. Water Air and Soil Pollution: Focus, 7, 443-450.

Winiwarter, W., 2008.
Quantifying Uncertainties of the Austrian Greenhouse Gas Inventory. ARC--sys-0154, Vienna.

Winiwarter, W., B. Muik, 2008.
Statistical Dependences in Input Data of National Greenhouse Gas Inventories: Effects on the Overall Inventory Uncertainty. Manuscript submitted to Climatic Change.

Winiwarter, W., K. Rypdal, 2001.
Assessing the Uncertainty Associated with National Greenhouse Gas Emission Inventories: A Case Study for Austria. Atmospheric Environment 35, 5425-5440.

Appendix:
Detailed uncertainty data used in emission calculation

Input parameters for Monte Carlo approach, based on CORINAIR type emission assessment (extracted from the calculation spreadsheet)

For documentation purposes only. Please refer to the @RISK manual for an explanation of the specific random variation functions (@RISK-functions)

Color Legend:

	source cells for MC analysis (random variation)
	cells that refer to source cells (fully correlated)
	other (more elaborate) attribution
	set arbitrarily to 1 (no uncertainty information)
NIR 06	uncertainty figure adopted from national information contained in the national inventory report (AT or LU)

	D	E	G	H	I	J	K	L	M	N	O	P	Q	R	S
4	SNAP	IPCC_FUEL	IPCC_Index	Activity_Type	Act_Min	Act_Max	Reference	Description	Activity 1990	Activity_Type	Act_Min	Act_Max	Reference	Description	Activity 2006
5	Combustion plants >= 50 and < 30(	liquid	1A1a liquid	normal	2			liquid fuels	=RiskNormal(1;+I5/200)	=+H5	1			liquid fuels "st	=RiskNormal(1;+O5/200)
6	Combustion plants >= 50 and < 30(	gaseous	1A1a gaseous	normal	0.5			SOTEC gas in	=RiskNormal(1;+I6/200)	=+H6	=+I6			SOTEC gas in	=RiskNormal(1;+O6/200)
7	Combustion plants >= 50 and < 30(	solid	1A1a solid						=+M$47						=+S$47
8	Combustion plants < 50 MW (boiler	liquid	1A1a liquid						=+M$5						=+S$5
9	Combustion plants < 50 MW (boiler	gaseous	1A1a gaseous						=+M$6						=+S$6
10	Combustion plants >= 50 and < 30(	liquid	1A1c liquid						=+M$5						=+S$5
11	Combustion plants >= 50 and < 30(	gaseous	1A1c gaseous						=+M$6						=+S$6
12	Combustion plants < 50 MW (boiler	solid	1A1c solid	normal	2			coal imports 1	=RiskNormal(1;+I12/200)	=+H12	=+I12			coal imports 2	=RiskNormal(1;+O12/200)
13	Combustion plants < 50 MW (boiler	solid	1A1c solid						=+M$12						=+S$12
14	Combustion plants < 50 MW (boiler	liquid	1A1c liquid						=+M$5						=+S$5
15	Combustion plants < 50 MW (boiler	liquid	1A1c liquid						=+M$5						=+S$5
16	Combustion plants < 50 MW (boiler	gaseous	1A1c gaseous						=+M$6						=+S$6
17	Combustion plants < 50 MW (boiler	solid	1A1c solid						=+M$47						=+S$47
18	Gas turbines	liquid	1A1c liquid						=+M$5						=+S$5
19	Gas turbines	gaseous	1A1c gaseous						=+M$6						=+S$6
20	Combustion plants < 50 MW (boiler	solid	1A4a solid						=+M$12						=+S$12
21	Combustion plants < 50 MW (boiler	solid	1A4a solid						=+M$12						=+S$12
22	Combustion plants < 50 MW (boiler	biomass	1A4a biomass	normal	10			biomass	=RiskNormal(1;+I22/200)	=+H22	=+I22			biomass	=RiskNormal(1;+O22/200)
23	Combustion plants < 50 MW (boiler	liquid	1A4a liquid						=+M$5						=+S$5
24	Combustion plants < 50 MW (boiler	gaseous	1A4a gaseous						=+M$6						=+S$6
25	Combustion plants < 50 MW (boiler	solid	1A4b solid						=+M$12						=+S$12
26	Combustion plants < 50 MW (boiler	solid	1A4b solid						=+M$12						=+S$12
27	Combustion plants < 50 MW (boiler	biomass	1A4b biomass						=+M$22						=+S$22
28	Combustion plants < 50 MW (boiler	liquid	1A4b liquid						=+M$5						=+S$5
29	Combustion plants < 50 MW (boiler	gaseous	1A4b gaseous						=+M$6						=+S$6
30	Combustion plants < 50 MW (boiler	solid	1A4c solid						=+M$12						=+S$12
31	Combustion plants < 50 MW (boiler	solid	1A4c solid						=+M$12						=+S$12
32	Combustion plants < 50 MW (boiler	biomass	1A4c biomass						=+M$22						=+S$22
33	Combustion plants < 50 MW (boiler	liquid	1A4c liquid						=+M$5						=+S$5
34	Combustion plants < 50 MW (boiler	gaseous	1A4c gaseous						=+M$6						=+S$6
35	Combustion plants >= 50 and < 30(	liquid	1A2f liquid						=+M$5						=+S$5
36	Combustion plants >= 50 and < 30(	gaseous	1A2f gaseous						=+M$6						=+S$6
37	Combustion plants < 50 MW (boiler	solid	1A2f solid						=+M$12						=+S$12
38	Combustion plants < 50 MW (boiler	solid	1A2f solid						=+M$12						=+S$12
39	Combustion plants < 50 MW (boiler	liquid	1A2f liquid						=+M$5						=+S$5
40	Combustion plants < 50 MW (boiler	liquid	1A2f liquid						=+M$5						=+S$5
41	Combustion plants < 50 MW (boiler	gaseous	1A2f gaseous						=+M$6						=+S$6
42	Combustion plants < 50 MW (boiler	liquid	1A2f liquid						=+M$5						=+S$5
43	Combustion plants < 50 MW (boiler	solid	1A2f solid						=+M$47						=+S$47
44	Gas turbines	liquid	1A2f liquid						=+M$5						=+S$5
45	Gas turbines	gaseous	1A2f gaseous						=+M$6						=+S$6
46	Blast furnace cowpers	gaseous	1A2a gaseous						=+M$6						=+S$6
47	Blast furnace cowpers	solid	1A2a solid	normal	3		Monni/Syri	coke imports i	=RiskNormal(1;+I47/200)	normal	=+I47			coke imports i	=RiskNormal(1;+O47/200)
48	Reheating furnaces steel and iron	gaseous	1A2a gaseous						=+M$6						=+S$6
49	Reheating furnaces steel and iron	solid	1A2a solid						=+M$47						=+S$47
50	Gray iron foundries	solid	1A2a solid						=+M$47						=+S$47
51	Secondary aluminium production	liquid	1A2b liquid						=+M$5						=+S$5
52	Cement (f)	solid	1A2f solid						=+M$12						=+S$12
53	Asphalt concrete plants	solid	1A2f solid						=+M$12						=+S$12
54	Flat glass (f)	gaseous	1A2f gaseous						=+M$6						=+S$6
55	Fine ceramic materials	gaseous	1A2f gaseous						=+M$6						=+S$6
56	Blast furnace charging		2 C 1						=+M$47						=+S$47
57	Pig iron tapping		2 C 1						=+M$47						=+S$47
58	Basic oxygen furnace steel plant		2 C 1						=+M$47						=+S$47
59	Electric furnace steel plant		2 C 1	normal	5			electrode impo	=RiskNormal(1;+I59/200)	=+H59	=+I59			=+L59	=RiskNormal(1;+O59/200)
60	Rolling mills		2 C 1						=+M$47						=+S$47
61	Sinter and pelletizing plant (except		2 C 1						=+M$47						=+S$47
62	Other		NR						1						1
63	Bread		NR						1						1
64	Wine		NR						1						1
65	Beer		NR						1						1
66	Spirits		NR						1						1
67	Roof covering with asphalt material		NR						1						1
68	Road paving with asphalt		NR						1						1
69	Cement (decarbonizing)		2 A 1	normal	1.5		LU Dornseiffe	cement	=RiskNormal(1;+I69/200)	=+H69	1.5		=+K69	=+L69	=RiskNormal(1;+O69/200)

	D	E	G	H	I	J	K	L	M	N	O	P	Q	R	S
4	SNAP	IPCC_FUEL	IPCC_Index	Activity_Type	Act_Min	Act_Max	Reference	Description	Activity 1990	Activity_Type	Act_Min	Act_Max	Reference	Description	Activity 2006
70	Glass (decarbonizing)		2 A 7	normal	2		LU Dornseiffe	glass	=RiskNormal(1;+I70/200)	=+H70	1.5		=+K70	=+L70	=RiskNormal(1;+O70/200)
71	Other handling and storage (includi		1 B 2 a	normal	2			liquid fuel han	=RiskNormal(1;+I71/200)	=+H71	=+I71			=+L71	=RiskNormal(1;+O71/200)
72	Transport and depots (except 05.0!		1 B 2 a						=+M$71						=+S$71
73	Service stations (including refuellin		1 B 2 a						=+M$71						=+S$71
74	Pipelines (q)		1 B 2 b	normal	1			gaseous fuel h	=RiskNormal(1;+I74/200)	=+H74	=+I74			=+L74	=RiskNormal(1;+O74/200)
75	Distribution networks		1 B 2 b						=+M$74						=+S$74
76	Paint application : car repairing		3	normal	5		Windsperger (	solvents	=RiskNormal(1;+I76/200)	=+H76	=+I76		=+K76	=+L76	=RiskNormal(1;+O76/200)
77	Paint application : construction and		3						=+M$76						=+S$76
78	Paint application : domestic use (e›		3						=+M$76						=+S$76
79	Paint application : coil coating		3						=+M$76						=+S$76
80	Paint application : boat building		3						=+M$76						=+S$76
81	Other industrial paint application		3						=+M$76						=+S$76
82	Other non industrial paint applicatic		3						=+M$76						=+S$76
83	Metal degreasing		3						=+M$76						=+S$76
84	Dry cleaning		3						=+M$76						=+S$76
85	Polyvinylchloride processing		3						=+M$76						=+S$76
86	Rubber processing		3						=+M$76						=+S$76
87	Paints manufacturing		3						=+M$76						=+S$76
88	Printing industry		3						=+M$76						=+S$76
89	Application of glues and adhesives		3						=+M$76						=+S$76
90	Preservation of wood		3						=+M$76						=+S$76
91	Underseal treatment and conservat		3						=+M$76						=+S$76
92	Domestic solvent use (other than p		3						=+M$76						=+S$76
93	Refrigeration and air conditioning e		NR						1						1
94	Refrigeration and air conditioning e		3						=+M$76						=+S$76
95	Foam blowing (except 060304)		3						=+M$76						=+S$76
96	Electrical equipments		3						=+M$76						=+S$76
97	Other/N2O use		3						1						1
98	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
99	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
100	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
101	Highway driving	liquid	1A3b diesel						=+M$5						=+S$5
102	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
103	Highway driving	liquid	1A3b LPG						=+M$5						=+S$5
104	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
105	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
106	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
107	Rural driving	liquid	1A3b diesel						=+M$5						=+S$5
108	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
109	Rural driving	liquid	1A3b fuel oil						=+M$5						=+S$5
110	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
111	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
112	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
113	Urban driving	liquid	1A3b diesel						=+M$5						=+S$5
114	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
115	Urban driving	liquid	1A3b fuel oil						=+M$5						=+S$5
116	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
117	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
118	Highway driving	liquid	1A3b diesel						=+M$5						=+S$5
119	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
120	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
121	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
122	Rural driving	liquid	1A3b diesel						=+M$5						=+S$5
123	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
124	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
125	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
126	Urban driving	liquid	1A3b diesel						=+M$5						=+S$5
127	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
128	Highway driving	liquid	1A3b diesel						=+M$5						=+S$5
129	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
130	Rural driving	liquid	1A3b diesel						=+M$5						=+S$5
131	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
132	Urban driving	liquid	1A3b diesel						=+M$5						=+S$5
133	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
134	Mopeds and Motorcycles < 50 cm3	liquid	1A3b gasoline						=+M$5						=+S$5

	D	E	G	H	I	J	K	L	M	N	O	P	Q	R	S
4	SNAP	IPCC_FUEL	IPCC_Index	Activity_Type	Act_Min	Act_Max	Reference	Description	Activity 1990	Activity_Type	Act_Min	Act_Max	Reference	Description	Activity 2006
135	Highway driving	liquid	1A3b gasoline						=+M$5						=+S$5
136	Rural driving	liquid	1A3b gasoline						=+M$5						=+S$5
137	Urban driving	liquid	1A3b gasoline						=+M$5						=+S$5
138	Gasoline evaporation from vehicles		NR						1						1
139	Automobile tyre and brake wear		NR						1						1
140	Automobile tyre and brake wear		NR						1						1
141	Railways	liquid	1A3c liquid						=+M$5						=+S$5
142	Inland waterways	liquid	1A3d liquid						=+M$5						=+S$5
143	International airport traffic (LTO cyc	liquid	I B av	normal	5			international b	=RiskNormal(1;+I143/200)						=RiskNormal(1;+O143/200
144	Agriculture	liquid	1A4c liquid						=+M$5						=+S$5
145	Agriculture	liquid	1A4c liquid						=+M$5						=+S$5
146	Forestry	liquid	1A4c liquid						=+M$5						=+S$5
147	Forestry	liquid	1A4c liquid						=+M$5						=+S$5
148	Household and gardening	liquid	1A4b liquid						=+M$5						=+S$5
149	Incineration of domestic or municip		1A1a other	normal	7		Charles et al.	waste incinera	=RiskNormal(1;+I149/200)	=+H149	=+I149		=+K149	=+L149	=RiskNormal(1;+O149/200
150	Managed Waste Disposal on Land		6 A	normal	12		AT NIR 06	waste deposit	=RiskNormal(1;+I150/200)	=+H150	=+I150		=+K150	=+L150	=RiskNormal(1;+O150/200
151	Waste water treatment in industry		6 B	normal	10				=RiskNormal(1;+I151/200)	=+H151	=+I151				=RiskNormal(1;+O151/200
152	Waste water treatment in residentia		6 B						=+M$151						=+S$151
153	Sludge spreading		6 D	normal	15			sludge&comp	=RiskNormal(1;+I153/200)	=+H153	=+I153			=+L153	=RiskNormal(1;+O153/200
154	Compost production		6 D						=+M$153						=+S$153
155	Arable land crops		4 D 1	normal	10			agri productio	=RiskNormal(1;+I155/200)	=+H155	=+I155			=+L155	=RiskNormal(1;+O155/200
156	Market gardening		4 D 1						=+M$155						=+S$155
157	Grassland		4 D 1						=+M$155						=+S$155
158	Fallows		4 D 3					indirect emissi	=+M$155*2-1					indirect emissi	=+S$155*2-1
159	Dairy cows		4 A 1	normal	2				=RiskNormal(1;+I159/200)	=+H159	=+I159				=RiskNormal(1;+O159/200
160	Other cattle		4 A 1						=+M$159						=+S$159
161	Ovines		4 A 3	normal	10				=RiskNormal(1;+I161/200)	=+H161	=+I161				=RiskNormal(1;+O161/200
162	Fattening pigs		4 A 8	normal	5				=RiskNormal(1;+I162/200)	=+H162	=+I162				=RiskNormal(1;+O162/200
163	Horses		4 A 6	normal	10				=RiskNormal(1;+I163/200)	=+H163	=+I163				=RiskNormal(1;+O163/200
164	Dairy cows		4 B 1						=+M$159						=+S$159
165	Other cattle		4 B 1						=+M$159						=+S$159
166	Fattening pigs		4 B 8						=+M$162						=+S$162
167	Sows		4 B 8						=+M$162						=+S$162
168	Ovines		4 B 3						=+M$161						=+S$161
169	Horses		4 B 6						=+M$163						=+S$163
170	Laying hens		4 B 9	normal	10				=RiskNormal(1;+I170/200)	=+H170	=+I170				=RiskNormal(1;+O170/200
171	Goats		4 B 4	normal	5				=RiskNormal(1;+I171/200)	=+H171	=+I171				=RiskNormal(1;+O171/200
172	Mules and asses		4 B 7	normal	10				=RiskNormal(1;+I172/200)	=+H172	=+I172				=RiskNormal(1;+O172/200
173	Grassland		NR						1						1
174	Lakes		NR						1						1
175	Rivers		NR						1						1
176	Mammals		NR						1						1
177	European oak		NR						1						1
178	Beech		NR						1						1
179	Norway spruce		NR						1						1
180	Temperate forests		LULUCF	normal	20		Weiss et al., 2	LULUCF	=RiskNormal(1;+I180/200)	=+H180	=+I180		=+K180	=+L180	=RiskNormal(1;+O180/200
181															
182															
183															
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198															
199		IPCC fuel	IPCC_Index												

	D	E	G	H	I	J	K	L	M	N	O	P	Q	R	S
4	SNAP	IPCC_FUEL	IPCC_Index	Activity_Type	Act_Min	Act_Max	Reference	Description	Activity 1990	Activity_Type	Act_Min	Act_Max	Reference	Description	Activity 2006
200		solid	1A2a solid						=+M$12						=+S$12
201		gaseous	1A2a gaseous						=+M$6						=+S$6
202		solid	1A2a solid						=+M$12						=+S$12
203		solid	1A2a solid						=+M$12						=+S$12
204		gaseous	1A2a gaseous						=+M$6						=+S$6
205		solid	1A2a solid						=+M$12						=+S$12
206		solid	1A2f solid						=+M$12						=+S$12
207		liquid	1A2f liquid						=+M$5						=+S$5
208		liquid	1A2f liquid						=+M$5						=+S$5
209		gaseous	1A2f gaseous						=+M$6						=+S$6
210		gaseous	1A2f gaseous						=+M$6						=+S$6
211		gaseous	1A2f gaseous						=+M$6						=+S$6
212		gaseous	1A1a gaseous						=+M$6						=+S$6
213															
214															
215															
216															
217				color legend:		source cells for MC analysis (random variation)									
218						cells that use source cells									
219						other (more elaborate) attribution									
220						set arbitrarily to 1 (no uncertainty information)									
221					NIR 06	uncertainty figure adopted from national information (AT or LU)									
222															
223															
224															

	D	E	G	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
4	SNAP	IPCC_FUEL	IPCC_Index	EF CO2 type	EF_min	EF_max	Reference	Description	=+"CO2-EF "&TEXT(BE3;	EF CO2 type	EF_min	EF_max	Reference	Description	CO2-EF 2006
5	Combustion plants >= 50 and < 30(	liquid	1A1a liquid						=+AE5	normal	0.5			liquid	=RiskNormal(1;+AA5/200)
6	Combustion plants >= 50 and < 30(	gaseous	1A1a gaseous						=+AE6	normal	0.5			gas	=RiskNormal(1;+AA6/200)
7	Combustion plants >= 50 and < 30(	solid	1A1a solid						=+Y12						=+AE$12
8	Combustion plants < 50 MW (boiler	liquid	1A1a liquid						=+AE8						=+AE$5
9	Combustion plants < 50 MW (boiler	gaseous	1A1a gaseous						=+AE9						=+AE$6
10	Combustion plants >= 50 and < 30(	liquid	1A1c liquid						=+AE10						=+AE$5
11	Combustion plants >= 50 and < 30(	gaseous	1A1c gaseous						=+AE11						=+AE$6
12	Combustion plants < 50 MW (boiler	solid	1A1c solid	normal	3		see Monni&Sy	fossil solid	=RiskNormal(1;+U12/200)	normal	1			fossil solid	=RiskNormal(1;+AA12/200
13	Combustion plants < 50 MW (boiler	solid	1A1c solid						=+AE13						=+AE$12
14	Combustion plants < 50 MW (boiler	liquid	1A1c liquid						=+AE14						=+AE$5
15	Combustion plants < 50 MW (boiler	liquid	1A1c liquid						=+AE15						=+AE$5
16	Combustion plants < 50 MW (boiler	gaseous	1A1c gaseous						=+AE16						=+AE$6
17	Combustion plants < 50 MW (boiler	solid	1A1c solid						=+Y12						=+AE$12
18	Gas turbines	liquid	1A1c liquid						=+AE18						=+AE$5
19	Gas turbines	gaseous	1A1c gaseous						=+AE19						=+AE$6
20	Combustion plants < 50 MW (boiler	solid	1A4a solid						=+AE20						=+AE$12
21	Combustion plants < 50 MW (boiler	solid	1A4a solid						=+AE21						=+AE$12
22	Combustion plants < 50 MW (boiler	biomass	1A4a biomass						=+AE22	normal	20		Charles et al.	biomass&was	=RiskNormal(1;+AA22/200
23	Combustion plants < 50 MW (boiler	liquid	1A4a liquid						=+AE23						=+AE$5
24	Combustion plants < 50 MW (boiler	gaseous	1A4a gaseous						=+AE24						=+AE$6
25	Combustion plants < 50 MW (boiler	solid	1A4b solid						=+AE25						=+AE$12
26	Combustion plants < 50 MW (boiler	solid	1A4b solid						=+AE26						=+AE$12
27	Combustion plants < 50 MW (boiler	biomass	1A4b biomass						=+AE27						=+AE$22
28	Combustion plants < 50 MW (boiler	liquid	1A4b liquid						=+AE28						=+AE$5
29	Combustion plants < 50 MW (boiler	gaseous	1A4b gaseous						=+AE29						=+AE$6
30	Combustion plants < 50 MW (boiler	solid	1A4c solid						=+AE30						=+AE$12
31	Combustion plants < 50 MW (boiler	solid	1A4c solid						=+AE31						=+AE$12
32	Combustion plants < 50 MW (boiler	biomass	1A4c biomass						=+AE32						=+AE$22
33	Combustion plants < 50 MW (boiler	liquid	1A4c liquid						=+AE33						=+AE$5
34	Combustion plants < 50 MW (boiler	gaseous	1A4c gaseous						=+AE34						=+AE$6
35	Combustion plants >= 50 and < 30(	liquid	1A2f liquid						=+AE35						=+AE$5
36	Combustion plants >= 50 and < 30(	gaseous	1A2f gaseous						=+AE36						=+AE$6
37	Combustion plants < 50 MW (boiler	solid	1A2f solid						=+AE37						=+AE$12
38	Combustion plants < 50 MW (boiler	solid	1A2f solid						=+AE38						=+AE$12
39	Combustion plants < 50 MW (boiler	liquid	1A2f liquid						=+AE39						=+AE$5
40	Combustion plants < 50 MW (boiler	liquid	1A2f liquid						=+AE40						=+AE$5
41	Combustion plants < 50 MW (boiler	gaseous	1A2f gaseous						=+AE41						=+AE$6
42	Combustion plants < 50 MW (boiler	liquid	1A2f liquid						=+AE42						=+AE$6
43	Combustion plants < 50 MW (boiler	solid	1A2f solid						=+Y12						=+AE$12
44	Gas turbines	liquid	1A2f liquid						=+AE44						=+AE$5
45	Gas turbines	gaseous	1A2f gaseous						=+AE45						=+AE$6
46	Blast furnace cowpers	gaseous	1A2a gaseous						=+AE46						=+AE$6
47	Blast furnace cowpers	solid	1A2a solid						=+Y12						=+AE$12
48	Reheating furnaces steel and iron	gaseous	1A2a gaseous						=+AE48						=+AE$6
49	Reheating furnaces steel and iron	solid	1A2a solid						=+Y12						=+AE$12
50	Gray iron foundries	solid	1A2a solid						=+Y12						=+AE$12
51	Secondary aluminium production	liquid	1A2b liquid						=+AE51						=+AE$6
52	Cement (f)	solid	1A2f solid						=+AE52						=+AE$12
53	Asphalt concrete plants	solid	1A2f solid						=+AE53						=+AE$12
54	Flat glass (f)	gaseous	1A2f gaseous						=+AE54						=+AE$6
55	Fine ceramic materials	gaseous	1A2f gaseous						=+AE55						=+AE$6
56	Blast furnace charging		2 C 1						=+Y12						=+AE$12
57	Pig iron tapping		2 C 1						=+Y12						=+AE$12
58	Basic oxygen furnace steel plant		2 C 1						=+Y12						=+AE$12
59	Electric furnace steel plant		2 C 1						=+AE59						=+AE$12
60	Rolling mills		2 C 1						=+Y12						=+AE$12
61	Sinter and pelletizing plant (except		2 C 1						=+Y12						=+AE$12
62	Other		NR						=+AE62						=+AE$6
63	Bread		NR						=+AE63						=+AE$6
64	Wine		NR						=+AE64						=+AE$6
65	Beer		NR						=+AE65						=+AE$6
66	Spirits		NR						=+AE66						=+AE$6
67	Roof covering with asphalt material		NR						=+AE67						=+AE$6
68	Road paving with asphalt		NR						=+AE68						=+AE$6
69	Cement (decarbonizing)		2 A 1						=+AE69	normal	2.5		LU Dornseiffe	cement	=RiskNormal(1;+AA69/200

	D	E	G	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
4	SNAP	IPCC_FUEL	IPCC_Index	EF CO2 type	EF min	EF max	Reference	Description	=+"CO2-EF "&TEXT(BE3;	EF CO2 type	EF min	EF max	Reference	Description	CO2-EF 2006
70	Glass (decarbonizing)		2 A 7						=+AE70	normal	5		LU Dornseiffe	glass	=RiskNormal(1;+AA70/200
71	Other handling and storage (includi		1 B 2 a						=+AE71						=+AE$5
72	Transport and depots (except 05.0!		1 B 2 a						=+AE72						=+AE$5
73	Service stations (including refuellin		1 B 2 a						=+AE73						=+AE$5
74	Pipelines (q)		1 B 2 b						=+AE74						=+AE$6
75	Distribution networks		1 B 2 b						=+AE75						=+AE$6
76	Paint application : car repairing		3						=+AE76	normal	10		Windsperger (	solvents	=RiskNormal(1;+AA76/200
77	Paint application : construction and		3						=+AE77						=+AE$76
78	Paint application : domestic use (e›		3						=+AE78						=+AE$76
79	Paint application : coil coating		3						=+AE79						=+AE$76
80	Paint application : boat building		3						=+AE80						=+AE$76
81	Other industrial paint application		3						=+AE81						=+AE$76
82	Other non industrial paint applicatic		3						=+AE82						=+AE$76
83	Metal degreasing		3						=+AE83						=+AE$76
84	Dry cleaning		3						=+AE84						=+AE$76
85	Polyvinylchloride processing		3						=+AE85						=+AE$76
86	Rubber processing		3						=+AE86						=+AE$76
87	Paints manufacturing		3						=+AE87						=+AE$76
88	Printing industry		3						=+AE88						=+AE$76
89	Application of glues and adhesives		3						=+AE89						=+AE$76
90	Preservation of wood		3						=+AE90						=+AE$76
91	Underseal treatment and conservat		3						=+AE91						=+AE$76
92	Domestic solvent use (other than p		3						=+AE92						=+AE$76
93	Refrigeration and air conditioning e		NR						=+AE93						=+AE$76
94	Refrigeration and air conditioning e		3						=+AE94						=+AE$76
95	Foam blowing (except 060304)		3						=+AE95						=+AE$76
96	Electrical equipments		3						=+AE96						=+AE$76
97	Other/N2O use		3						=+AE97						1
98	Highway driving	liquid	1A3b gasoline						=+AE98						=+AE$5
99	Highway driving	liquid	1A3b gasoline						=+AE99						=+AE$5
100	Highway driving	liquid	1A3b gasoline						=+AE100						=+AE$5
101	Highway driving	liquid	1A3b diesel						=+AE101						=+AE$5
102	Highway driving	liquid	1A3b gasoline						=+AE102						=+AE$5
103	Highway driving	liquid	1A3b LPG						=+AE103	normal	2			gas-LPG	=RiskNormal(1;+AA103/20
104	Rural driving	liquid	1A3b gasoline						=+AE104						=+AE$5
105	Rural driving	liquid	1A3b gasoline						=+AE105						=+AE$5
106	Rural driving	liquid	1A3b gasoline						=+AE106						=+AE$5
107	Rural driving	liquid	1A3b diesel						=+AE107						=+AE$5
108	Rural driving	liquid	1A3b gasoline						=+AE108						=+AE$5
109	Rural driving	liquid	1A3b fuel oil						=+AE109						=+AE$6
110	Urban driving	liquid	1A3b gasoline						=+AE110						=+AE$5
111	Urban driving	liquid	1A3b gasoline						=+AE111						=+AE$5
112	Urban driving	liquid	1A3b gasoline						=+AE112						=+AE$5
113	Urban driving	liquid	1A3b diesel						=+AE113						=+AE$5
114	Urban driving	liquid	1A3b gasoline						=+AE114						=+AE$5
115	Urban driving	liquid	1A3b fuel oil						=+AE115						=+AE$6
116	Highway driving	liquid	1A3b gasoline						=+AE116						=+AE$5
117	Highway driving	liquid	1A3b gasoline						=+AE117						=+AE$5
118	Highway driving	liquid	1A3b diesel						=+AE118						=+AE$5
119	Highway driving	liquid	1A3b gasoline						=+AE119						=+AE$5
120	Rural driving	liquid	1A3b gasoline						=+AE120						=+AE$5
121	Rural driving	liquid	1A3b gasoline						=+AE121						=+AE$5
122	Rural driving	liquid	1A3b diesel						=+AE122						=+AE$5
123	Rural driving	liquid	1A3b gasoline						=+AE123						=+AE$5
124	Urban driving	liquid	1A3b gasoline						=+AE124						=+AE$5
125	Urban driving	liquid	1A3b gasoline						=+AE125						=+AE$5
126	Urban driving	liquid	1A3b diesel						=+AE126						=+AE$5
127	Urban driving	liquid	1A3b gasoline						=+AE127						=+AE$5
128	Highway driving	liquid	1A3b diesel						=+AE128						=+AE$5
129	Highway driving	liquid	1A3b gasoline						=+AE129						=+AE$5
130	Rural driving	liquid	1A3b diesel						=+AE130						=+AE$5
131	Rural driving	liquid	1A3b gasoline						=+AE131						=+AE$5
132	Urban driving	liquid	1A3b diesel						=+AE132						=+AE$5
133	Urban driving	liquid	1A3b gasoline						=+AE133						=+AE$5
134	Mopeds and Motorcycles < 50 cm3	liquid	1A3b gasoline						=+AE134						=+AE$5

	D	E	G	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
4	SNAP	IPCC_FUEL	IPCC_Index	EF CO2_type	EF_min	EF_max	Reference	Description	=+"CO2-EF "&TEXT(BE3;	EF CO2_type	EF_min	EF_max	Reference	Description	CO2-EF 2006
135	Highway driving	liquid	1A3b gasoline						=+AE135						=+AE$5
136	Rural driving	liquid	1A3b gasoline						=+AE136						=+AE$5
137	Urban driving	liquid	1A3b gasoline						=+AE137						=+AE$5
138	Gasoline evaporation from vehicles		NR						=+AE138						1
139	Automobile tyre and brake wear		NR						=+AE139						1
140	Automobile tyre and brake wear		NR						=+AE140						1
141	Railways	liquid	1A3c liquid						=+AE141						=+AE$5
142	Inland waterways	liquid	1A3d liquid						=+AE142						=+AE$5
143	International airport traffic (LTO cyc	liquid	I B av						=+AE143						=+AE$5
144	Agriculture	liquid	1A4c liquid						=+AE144						=+AE$5
145	Agriculture	liquid	1A4c liquid						=+AE145						=+AE$5
146	Forestry	liquid	1A4c liquid						=+AE146						=+AE$5
147	Forestry	liquid	1A4c liquid						=+AE147						=+AE$5
148	Household and gardening	liquid	1A4b liquid						=+AE148						=+AE$5
149	Incineration of domestic or municip		1A1a other						=+AE149	normal	20		Charles et al.	biomass&was	=RiskNormal(1;+AA149/20
150	Managed Waste Disposal on Land		6 A						=+AE150						=+(AQ150-1)/3+1
151	Waste water treatment in industry		6 B						=+AE151						1
152	Waste water treatment in residentia		6 B						=+AE152						1
153	Sludge spreading		6 D						=+AE153						1
154	Compost production		6 D						=+AE154						1
155	Arable land crops		4 D 1						=+AE155						1
156	Market gardening		4 D 1						=+AE156						1
157	Grassland		4 D 1						=+AE157						1
158	Fallows		4 D 3						=+AE158						1
159	Dairy cows		4 A 1						=+AE159						1
160	Other cattle		4 A 1						=+AE160						1
161	Ovines		4 A 3						=+AE161						1
162	Fattening pigs		4 A 8						=+AE162						1
163	Horses		4 A 6						=+AE163						1
164	Dairy cows		4 B 1						=+AE164						1
165	Other cattle		4 B 1						=+AE165						1
166	Fattening pigs		4 B 8						=+AE166						1
167	Sows		4 B 8						=+AE167						1
168	Ovines		4 B 3						=+AE168						1
169	Horses		4 B 6						=+AE169						1
170	Laying hens		4 B 9						=+AE170						1
171	Goats		4 B 4						=+AE171						1
172	Mules and asses		4 B 7						=+AE172						1
173	Grassland		NR						=+AE173						1
174	Lakes		NR						=+AE174						1
175	Rivers		NR						=+AE175						1
176	Mammals		NR						=+AE176						1
177	European oak		NR						=+AE177						1
178	Beech		NR						=+AE178						1
179	Norway spruce		NR						=+AE179						1
180	Temperate forests		LULUCF						=+AE180	normal	10		adapted from	LULUCF	=RiskNormal(1;+AA180/20
181															
182															
183															
184															
185															
186															
187															
188															
189															
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195															
196															
197															
198															
199		IPCC fuel	IPCC_Index												

	D	E	G	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
4	SNAP	IPCC_FUEL	IPCC_Index	EF CO2 type	EF min	EF max	Reference	Description	=+"CO2-EF "&TEXT(BE3;	EF CO2 type	EF min	EF max	Reference	Description	CO2-EF 2006
200		solid	1A2a solid						=+AE200						=+AE$12
201		gaseous	1A2a gaseous						=+AE201						=+AE$6
202		solid	1A2a solid						=+AE202						=+AE$12
203		solid	1A2a solid						=+AE203						=+AE$12
204		gaseous	1A2a gaseous						=+AE204						=+AE$6
205		solid	1A2a solid						=+AE205						=+AE$12
206		solid	1A2f solid						=+AE206						=+AE$12
207		liquid	1A2f liquid						=+AE207						=+AE$5
208		liquid	1A2f liquid						=+AE208						=+AE$5
209		gaseous	1A2f gaseous						=+AE209						=+AE$6
210		gaseous	1A2f gaseous						=+AE210						=+AE$6
211		gaseous	1A2f gaseous						=+AE211						=+AE$6
212		gaseous	1A1a gaseous						=+AE212						=+AE$6
213															
214															
215															
216															
217															
218															
219															
220															
221															
222															
223															
224															

	D	E	G	AL	AM	AN	AO	AP	AQ	AX	AY	AZ	BA	BB	BC
4	SNAP	IPCC_FUEL	IPCC_Index	EF CH4 type	EF_min	EF_max	Reference	Description	CH4-EF 2006	EF N2O type	EF_min	EF_max	Reference	Description	N2O-EF 2006
5	Combustion plants >= 50 and < 30(	liquid	1A1a liquid	normal	50			liquid	=RiskNormal(1;+AM5/200)	normal	50		Monni&Syri	liquid	=RiskNormal(1;+AY5/200)
6	Combustion plants >= 50 and < 30(	gaseous	1A1a gaseous	normal	50			gas	=RiskNormal(1;+AM6/200)	normal	50		Monni&Syri	gas	=RiskNormal(1;+AY6/200)
7	Combustion plants >= 50 and < 30(	solid	1A1a solid						=+AQ$6						=+BC$6
8	Combustion plants < 50 MW (boile	liquid	1A1a liquid						=+AQ$5						=+BC$5
9	Combustion plants < 50 MW (boile	gaseous	1A1a gaseous						=+AQ$6						=+BC$6
10	Combustion plants >= 50 and < 30(	liquid	1A1c liquid						=+AQ$5						=+BC$5
11	Combustion plants >= 50 and < 30(	gaseous	1A1c gaseous						=+AQ$6						=+BC$6
12	Combustion plants < 50 MW (boile	solid	1A1c solid	normal	50			fossil solid	=RiskNormal(1;+AM12/20	normal	50		Monni&Syri	fossil solid	=RiskNormal(1;+AY12/200
13	Combustion plants < 50 MW (boile	solid	1A1c solid						=+AQ$12						=+BC$12
14	Combustion plants < 50 MW (boile	liquid	1A1c liquid						=+AQ$5						=+BC$5
15	Combustion plants < 50 MW (boile	liquid	1A1c liquid						=+AQ$5						=+BC$5
16	Combustion plants < 50 MW (boile	gaseous	1A1c gaseous						=+AQ$6						=+BC$6
17	Combustion plants < 50 MW (boile	solid	1A1c solid						=+AQ$6						=+BC$6
18	Gas turbines	liquid	1A1c liquid						=+AQ$5						=+BC$5
19	Gas turbines	gaseous	1A1c gaseous						=+AQ$6						=+BC$6
20	Combustion plants < 50 MW (boile	solid	1A4a solid						=+AQ$12						=+BC$12
21	Combustion plants < 50 MW (boile	solid	1A4a solid						=+AQ$12						=+BC$12
22	Combustion plants < 50 MW (boile	biomass	1A4a biomass	normal	50			biomass&was	=RiskNormal(1;+AM22/20	normal	50		Monni&Syri	biomass&was	=RiskNormal(1;+AY22/200
23	Combustion plants < 50 MW (boile	liquid	1A4a liquid						=+AQ$5						=+BC$5
24	Combustion plants < 50 MW (boile	gaseous	1A4a gaseous						=+AQ$6						=+BC$6
25	Combustion plants < 50 MW (boile	solid	1A4b solid						=+AQ$12						=+BC$12
26	Combustion plants < 50 MW (boile	solid	1A4b solid						=+AQ$12						=+BC$12
27	Combustion plants < 50 MW (boile	biomass	1A4b biomass						=+AQ$22						=+BC$22
28	Combustion plants < 50 MW (boile	liquid	1A4b liquid						=+AQ$5						=+BC$5
29	Combustion plants < 50 MW (boile	gaseous	1A4b gaseous						=+AQ$6						=+BC$6
30	Combustion plants < 50 MW (boile	solid	1A4c solid						=+AQ$12						=+BC$12
31	Combustion plants < 50 MW (boile	solid	1A4c solid						=+AQ$12						=+BC$12
32	Combustion plants < 50 MW (boile	biomass	1A4c biomass						=+AQ$22						=+BC$22
33	Combustion plants < 50 MW (boile	liquid	1A4c liquid						=+AQ$5						=+BC$5
34	Combustion plants < 50 MW (boile	gaseous	1A4c gaseous						=+AQ$6						=+BC$6
35	Combustion plants >= 50 and < 30(	liquid	1A2f liquid						=+AQ$5						=+BC$5
36	Combustion plants >= 50 and < 30(	gaseous	1A2f gaseous						=+AQ$6						=+BC$6
37	Combustion plants < 50 MW (boile	solid	1A2f solid						=+AQ$12						=+BC$12
38	Combustion plants < 50 MW (boile	solid	1A2f solid						=+AQ$12						=+BC$12
39	Combustion plants < 50 MW (boile	liquid	1A2f liquid						=+AQ$5						=+BC$5
40	Combustion plants < 50 MW (boile	liquid	1A2f liquid						=+AQ$5						=+BC$5
41	Combustion plants < 50 MW (boile	gaseous	1A2f gaseous						=+AQ$6						=+BC$6
42	Combustion plants < 50 MW (boile	liquid	1A2f liquid						=+AQ$6						=+BC$6
43	Combustion plants < 50 MW (boile	solid	1A2f solid						=+AQ$6						=+BC$6
44	Gas turbines	liquid	1A2f liquid						=+AQ$5						=+BC$5
45	Gas turbines	gaseous	1A2f gaseous						=+AQ$6						=+BC$6
46	Blast furnace cowpers	gaseous	1A2a gaseous						=+AQ$6						=+BC$6
47	Blast furnace cowpers	solid	1A2a solid						=+AQ$6						=+BC$6
48	Reheating furnaces steel and iron	gaseous	1A2a gaseous						=+AQ$6						=+BC$6
49	Reheating furnaces steel and iron	solid	1A2a solid						=+AQ$6						=+BC$6
50	Gray iron foundries	solid	1A2a solid						=+AQ$12						=+BC$12
51	Secondary aluminium production	liquid	1A2b liquid						=+AQ$6						=+BC$6
52	Cement (f)	solid	1A2f solid						=+AQ$12						=+BC$12
53	Asphalt concrete plants	solid	1A2f solid						=+AQ$12						=+BC$12
54	Flat glass (f)	gaseous	1A2f gaseous						=+AQ$6						=+BC$6
55	Fine ceramic materials	gaseous	1A2f gaseous						=+AQ$6						=+BC$6
56	Blast furnace charging		2 C 1						=+AQ$6						=+BC$6
57	Pig iron tapping		2 C 1						=+AQ$6						=+BC$6
58	Basic oxygen furnace steel plant		2 C 1						=+AQ$6						=+BC$6
59	Electric furnace steel plant		2 C 1						=+AQ$6						=+BC$6
60	Rolling mills		2 C 1						=+AQ$6						=+BC$6
61	Sinter and pelletizing plant (except		2 C 1						=+AQ$6						=+BC$6
62	Other		NR						1						1
63	Bread		NR						1						1
64	Wine		NR						1						1
65	Beer		NR						1						1
66	Spirits		NR						1						1
67	Roof covering with asphalt material		NR						1						1
68	Road paving with asphalt		NR						1						1
69	Cement (decarbonizing)		2 A 1						1						1

	D	E	G	AL	AM	AN	AO	AP	AQ	AX	AY	AZ	BA	BB	BC
4	SNAP	IPCC_FUEL	IPCC_Index	EF CH4 type	EF min	EF max	Reference	Description	CH4-EF 2006	EF N2O type	EF min	EF max	Reference	Description	N2O-EF 2006
70	Glass (decarbonizing)		2 A 7						1						1
71	Other handling and storage (includi		1 B 2 a						1						1
72	Transport and depots (except 05.0!		1 B 2 a						1						1
73	Service stations (including refuellin		1 B 2 a						1						1
74	Pipelines (q)		1 B 2 b	normal	40		AT NIR 06	gas transmiss	=RiskNormal(1;+AM74/20						1
75	Distribution networks		1 B 2 b	normal	15		AT NIR 06	distribution	=RiskNormal(1;+AM75/20						1
76	Paint application : car repairing		3						1						1
77	Paint application : construction and		3						1						1
78	Paint application : domestic use (e›		3						1						1
79	Paint application : coil coating		3						1						1
80	Paint application : boat building		3						1						1
81	Other industrial paint application		3						1						1
82	Other non industrial paint applicatic		3						1						1
83	Metal degreasing		3						1						1
84	Dry cleaning		3						1						1
85	Polyvinylchloride processing		3						1						1
86	Rubber processing		3						1						1
87	Paints manufacturing		3						1						1
88	Printing industry		3						1						1
89	Application of glues and adhesives		3						1						1
90	Preservation of wood		3						1						1
91	Underseal treatment and conservat		3						1						1
92	Domestic solvent use (other than p		3						1						1
93	Refrigeration and air conditioning e		NR						1						1
94	Refrigeration and air conditioning e		3						1						1
95	Foam blowing (except 060304)		3						1						1
96	Electrical equipments		3						1						1
97	Other/N2O use		3						1	normal	20		Monni&Syri		=RiskNormal(1;+AY97/200
98	Highway driving	liquid	1A3b gasoline	normal	60		Ntziachristos:		=RiskNormal(1;+AM98/20	lognorm	40	250	Hausberger 0!	catalyst	=+RiskLognormAlt("mu"; 0
99	Highway driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
100	Highway driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
101	Highway driving	liquid	1A3b diesel	normal	60		Ntziachristos:		=RiskNormal(1;+AM101/2	normal	60		Hausberger 0!	Diesel	=RiskNormal(1;+AY101/20
102	Highway driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
103	Highway driving	liquid	1A3b LPG	normal	60		Ntziachristos:		=RiskNormal(1;+AM103/2	normal	60		assumed like I	LPG	=RiskNormal(1;+AY103/20
104	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
105	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
106	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
107	Rural driving	liquid	1A3b diesel						=+AQ$101						=+BC$101
108	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
109	Rural driving	liquid	1A3b fuel oil						=+AQ$6						=+BC$6
110	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
111	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
112	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
113	Urban driving	liquid	1A3b diesel						=+AQ$101						=+BC$101
114	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
115	Urban driving	liquid	1A3b fuel oil						=+AQ$6						=+BC$6
116	Highway driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
117	Highway driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
118	Highway driving	liquid	1A3b diesel						=+AQ$101						=+BC$101
119	Highway driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
120	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
121	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
122	Rural driving	liquid	1A3b diesel						=+AQ$101						=+BC$101
123	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
124	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
125	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
126	Urban driving	liquid	1A3b diesel						=+AQ$101						=+BC$101
127	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
128	Highway driving	liquid	1A3b diesel						=+AQ$101						=+BC$101
129	Highway driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
130	Rural driving	liquid	1A3b diesel						=+AQ$101						=+BC$101
131	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
132	Urban driving	liquid	1A3b diesel						=+AQ$101						=+BC$101
133	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
134	Mopeds and Motorcycles < 50 cm3	liquid	1A3b gasoline						=+AQ$98						=+BC$98

	D	E	G	AL	AM	AN	AO	AP	AQ	AX	AY	AZ	BA	BB	BC
4	SNAP	IPCC FUEL	IPCC Index	EF CH4 type	EF min	EF max	Reference	Description	CH4-EF 2006	EF N2O type	EF min	EF max	Reference	Description	N2O-EF 2006
135	Highway driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
136	Rural driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
137	Urban driving	liquid	1A3b gasoline						=+AQ$98						=+BC$98
138	Gasoline evaporation from vehicles		NR						1						1
139	Automobile tyre and brake wear		NR						1						1
140	Automobile tyre and brake wear		NR						1						1
141	Railways	liquid	1A3c liquid						=+AQ$5						=+BC$101
142	Inland waterways	liquid	1A3d liquid						=+AQ$5						=+BC$101
143	International airport traffic (LTO cyc	liquid	I B av						=+AQ$5						=+BC$101
144	Agriculture	liquid	1A4c liquid						=+AQ$5						=+BC$101
145	Agriculture	liquid	1A4c liquid						=+AQ$5						=+BC$101
146	Forestry	liquid	1A4c liquid						=+AQ$5						=+BC$101
147	Forestry	liquid	1A4c liquid						=+AQ$5						=+BC$101
148	Household and gardening	liquid	1A4b liquid						=+AQ$5						=+BC$101
149	Incineration of domestic or municip		1A1a other						=+AQ$22						=+BC$22
150	Managed Waste Disposal on Land		6 A	normal	25		AT NIR 06	landfill	=RiskNormal(1;+AM150/2						1
151	Waste water treatment in industry		6 B	normal	50		Charles	waste water	=RiskNormal(1;+AM151/2	normal	50		IPCC 2006		=RiskNormal(1;+AY151/20
152	Waste water treatment in residentia		6 B						=+AQ$151						=+BC$151
153	Sludge spreading		6 D						=+AQ$151						=+BC$151
154	Compost production		6 D						=+AQ$150						1
155	Arable land crops		4 D 1	normal	100		Winiwarter an	soil	=RiskNormal(1;+AM155/2	lognorm	30	300	IPCC 2006	agric soil	=+RiskLognormAlt("mu"; 0
156	Market gardening		4 D 1						=+$AQ$155						=+$BC$155
157	Grassland		4 D 1						=+$AQ$155						=+$BC$155
158	Fallows		4 D 3						=+$AQ$155						=+$BC$155
159	Dairy cows		4 A 1	normal	20		Amon	ent_ferm cattl	=RiskNormal(1;+AM159/2						1
160	Other cattle		4 A 1						=+AQ$159						1
161	Ovines		4 A 3	normal	30		Amon	ent_ferm othe	=RiskNormal(1;+AM161/2						1
162	Fattening pigs		4 A 8						=+AQ$161						1
163	Horses		4 A 6						=+AQ$161						1
164	Dairy cows		4 B 1	normal	70		Amon	manure	=RiskNormal(1;+AM164/2	lognorm	50	200	IPCC	manure	=+RiskLognormAlt("mu"; 0
165	Other cattle		4 B 1						=+AQ$164						=+BC$164
166	Fattening pigs		4 B 8						=+AQ$164						=+BC$164
167	Sows		4 B 8						=+AQ$164						=+BC$164
168	Ovines		4 B 3						=+AQ$164						=+BC$164
169	Horses		4 B 6						=+AQ$164						=+BC$164
170	Laying hens		4 B 9						=+AQ$164						=+BC$164
171	Goats		4 B 4						=+AQ$164						=+BC$164
172	Mules and asses		4 B 7						=+AQ$164						=+BC$164
173	Grassland		NR						1						1
174	Lakes		NR						1						1
175	Rivers		NR						1						1
176	Mammals		NR						1						1
177	European oak		NR						1						1
178	Beech		NR						1						1
179	Norway spruce		NR						1						1
180	Temperate forests		LULUCF						1						1
181															
182															
183															
184															
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195															
196															
197															
198															
199		IPCC fuel	IPCC_Index												

	D	E	G	AL	AM	AN	AO	AP	AQ	AX	AY	AZ	BA	BB	BC
4	SNAP	IPCC_FUEL	IPCC_Index	EF CH4 type	EF min	EF max	Reference	Description	CH4-EF 2006	EF N2O type	EF min	EF max	Reference	Description	N2O-EF 2006
200		solid	1A2a solid						=+AQ$12						=+BC$12
201		gaseous	1A2a gaseous						=+AQ$6						=+BC$6
202		solid	1A2a solid						=+AQ$12						=+BC$12
203		solid	1A2a solid						=+AQ$12						=+BC$12
204		gaseous	1A2a gaseous						=+AQ$6						=+BC$6
205		solid	1A2a solid						=+AQ$12						=+BC$12
206		solid	1A2f solid						=+AQ$12						=+BC$12
207		liquid	1A2f liquid						=+AQ$5						=+BC$5
208		liquid	1A2f liquid						=+AQ$5						=+BC$5
209		gaseous	1A2f gaseous						=+AQ$6						=+BC$6
210		gaseous	1A2f gaseous						=+AQ$6						=+BC$6
211		gaseous	1A2f gaseous						=+AQ$6						=+BC$6
212		gaseous	1A1a gaseous						=+AQ$6						=+BC$6
213															
214															
215															
216															
217															
218															
219															
220															
221															
222															
223															
224															

	A	AB	AD	AE	AF	AG	AH	AI
2			F-gas uncertainty evaluation					
3	**GHG**		Base year					1990
4	**2 F 1 Refrigeration and Air Conditioning E**	IPCC sector	Emission_Type	emission_Min	emission_Max	Reference	Description	Emissions 1990
5	HFC-23	2 F 1/2/3/4/5	normal	54		AT NIR 06	ODS_substitu	=RiskNormal(1;+AE5/200)
19	**2 F 8 Electrical Equipment**							
20	SF6	2 F 8	normal	56		AT NIR 06	SF6_use	=RiskNormal(1;+AE20/200)

	A	AB	AK	AL	AM	AN	AO	AP
2			F-gas uncertainty evaluation					
3	**GHG**		Target year					2006
4	**2 F 1 Refrigeration and Air Conditioning E**	IPCC sector	Emission_Type	emission_Min	emission_Max	Reference	Description	Emissions 2006
5	HFC-23	2 F 1/2/3/4/5	normal	=+AE5		AT NIR 06	CFC_replacer	=RiskNormal(1;+AL5/200)
19	**2 F 8 Electrical Equipment**							
20	SF6	2 F 8	normal	=+AE20		AT NIR 06	SF6_use	=RiskNormal(1;+AL20/200)

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Editor, Publisher, Editoral Department,
Manufacturer:
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1220 Vienna, Donau-City-Straße 1

Division systems research
T: +43(0)50550-4500, F: +43(0)50550-4599
sys@arcs.ac.at, www.systemsresearch.ac.at

Annex IV - Forest Monitoring Inputs for National GHG Reporting Service to the Administration des Eaux et Forêts of Luxembourg

This interim report of 5 December 2007 presents the development of the GMES/GSE Forest Monitoring project prepared by LuxSpace sàrl (Luxembourg) under the aegis of GAF AG (Germany) and the ESA.

Scaling-up Consolidated GMES Services
Service Element Forest Monitoring

Stage 2 of the Earthwatch GMES Service Element

S6 Service Operations Report

Forest Monitoring Inputs for National Greenhouse Gas Reporting Service to AEF Luxembourg (Administration des Eaux et Forêts)

ESRIN/Contract No.: 17063/03/I-LG
Doc. No.: GSE-FM-LUX-S6-Ph1
Issue/Rev.: 3.0
Date: 5 December 2007

Consortium Partners

Prime Contractor	- GAF AG, Germany
Expert Consultants	- International Institute of Applied Systems Analysis (IIASA), Austria - University of Marne-la Vallèe (UMLV), France - Research Institute for Development (IRD), France - Centre for Agricultural and Environmental Engeneering Research (Cemagref), France - Informus GmbH, Germany - Quali Systems Ltd., Greece - Italian Academy of Forest Sciences (AISF), Italy - University of Molise (UNIMOL), Italy - University of Tuscia (UNITUS), Italy - Space Research Centre Poland (SRC), Poland - Ministry of Education and Science (INIA), Spain
Strategy Group	- European Environmental Agency (EEA) - Joint Research Centre (JRC) - Joanneum Research (JR)
System Partner	- German Aerospace Center (DLR), Germany - Informus GmbH, Germany
Research Partners	- Johanneum Research (JR), Austria - European Forest Institute (EFI), Finland - Sustainable Forest Management Consultants GmbH (SFM), Germany - Friedrich-Schiller-University Jena (Uni Jena), Germany
Service Providers	- Joanneum Research (JR), Austria - PRINS Engineering, Denmark - Technical Research Centre of Finland (VTT) - French National Forest Inventory (IFN), France - German Aerospace Center (DLR), Germany - Albert-Ludwigs University Freiburg (FELIS), Germany - GAF AG, Germany - Sustainable Forest Management Consultants GmbH (SFM), Germany - Remote Sensing Solutions GmbH (RSS), Germany - Friedrich-Schiller University of Jena (Uni-Jena), Germany - GEOAPIKONISIS Ltd., Greece - Intecs S.r.l., Italy - Planetek Italia S.r.l., Italy - Telespazio S.p.A., Italy - LuxSpace S.à.r.l.., Luxembourg - Netherlands Geomatics & Earth Observation B.V. (NEO), Netherlands - Geosystems Polska Ltd. (GEOSYS), Poland - GMV S.A., Spain - Metria Milijöanalys (METRIA), Sweden
End-User s	- Austria: Federal Environment Agency (UBA-A) - Denmark: Forest & Landscape Denmark (FLD) - Europe: European Environmental Agency (EEA) - France: Centre Interprofessionel Technique d`Etudes de la Pollution Atmosphèrique (CITEPA) - France: Association Forêt Cellulose (AFOCEL) - France: Coopèrative Agricole et Forestière Sud Atlantique (CAFSA) - France: Coopèrative Forestière Bourgogne Limousin (CFBL) - Germany: German Environmental Agency (UBA-G) - Germany: Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) - Germany: Thuringian State Institute for Forest, Game and Fishery (TLWJF) - Germany: Global-Woods AG - Germany: State Agency for Nature and Environment Schleswig-Holstein (LANU) - Germany: Regional authorities for forest and large nature protected areas of Mecklenburg- Vorpommern (LFG) - Greece: National Observatory of Athens (NOA) - Italy: Ministry for the Environment and Territory (MATT) - Indonesia: MASLI - Latvia: State Forest Service (SFS) - Luxembourg : Ministère de l'Environnement, Administration des Eaux et Forêts (AEF) - Netherlands: Ministry of Agriculture, Nature, and Food Quality (LNV) - Poland: Ministry of Environment (ME-Po) - Russia: Forest Service of Irkutsk General Survey of Natural Resources (FS-I) - South Africa: Council for Scientific and Industrial Research, Institute for Environmental Technologies (CSIR) - Spain: Ministry of Environment (MMA) - Spain: Ministry of Environment, State Biodiversity Office (SBO-ME) - Sweden: The National Board of Forestry (NBF) - Switzerland: Swiss Agency for the Environment, Forests and Landscape (SAEFL)

Summary

The first issue of this document reported on the production of the georeferenced satellite image mosaic (to LUREF) from SPOT1 imagery recorded in 1989 over Luxembourg, delivered 30 July 2007. The second issue of the document was complemented by descriptions of the services and the products that were successfully delivered to the Luxembourg user of GSE-FM, the Luxembourg Environment Ministry and its Forestry Administration (AEF: Administration des Eaux et Forêts) on 19. October 2007, i.e. maps on land use, forest area and forest types according to LULUCF nomenclature, based on the OBS89 and the SPOT1 imagery recorded in 1989.

This third issue of the document is complemented by description of the services and products delivered to the users, AEF and Ministry of Environment of Luxembourg on 5 December 2007.

A general description of the service is given referring to the specifications that were formulated in the Service Level Agreement between the user (AEF) and the service provider (LuxSpace S.à.r.l.). Additionally methods are outlined that were used for data processing, i.e. developed processing chain for update of the OBS99 map focused on the forest classes and the results are presented, consisting of testing the developed method. In addition to that, landscape indicators have been calculated in accordance with the SLA for further analysis by the users.

In total the following products have been delivered to the users in phase 1 of the project:

- SPOT1 image mosaic covering the entire territory of Luxembourg from 1989
- a land use / cover map for 1989 based on the OBS89 in accordance to the LULUCF definitions,
- a forest area map in accordance to the LULUCF definitions based on the above and the SPOT1 imagery of 1989,
- a forest type map in accordance to the LULUCF definitions based on the above and the SPOT1 imagery of 1989,
- a processing chain for updating the forest classes of the OBS99 land cover map
- a test of the developed processing chain using an IKONOS image from 2004 covering a test site in northern Luxembourg
- Landscape indicators for 1989 at the level of Eco-Regions (-section) of Luxembourg defined by AEF

This includes accuracy assessment and verification results. The detailed quality control reports will be delivered after reception of the templates from the prime contractor.

	Affiliation/Function	**Name**	**Date**
Prepared	Luxspace S.à.r.l.	Willibald Croi Christian Kehl	5 December, 2007
Reviewed			
Approved			
Authorized	GAF AG / Prime Project Manager	Thomas Häusler	
Accepted	ESA/ Project Manager	Frank-Martin Seifert	

Signatures

	Name	**Date**	**Signature**
Signature of authorisation and overall approval	Thomas Häusler		
Signature of acceptance by ESA	Frank-Martin Seifert		

The document is accepted under the assumption that all verification activities were carried out correctly and any discrepancies are documented properly in compliance matrices or else.

Distribution

Affiliation	Name	Address	Copies
ESRIN	Frank-Martin Seifert	Via G. Galilei, Frascati (Rome), Italy	electronic copy
	Consortium Members	See list on webpage www.gmes-forest.info	electronic copy

Document Status Sheet

Issue	Date	Details
1.0	30 July 2007	First Document Issue
2.0	19 October 2007	Second Document Issue
3.0	5 December 2007	Third Document Issue

Document Change Record

#	Date	Request	Location	Details
1	19 October 2007	Luxspace	Betzdorf (Luxembourg)	Adding operation reporting regarding the thematic processing, i.e. generation of maps on Land Use, Forest Area and Forest Type 1989 acc. to LULUCF nomenclature.
2	5 December 2007	LuxSpace	Betzdorf (Luxembourg)	Adding operation reporting regarding the processing chain and test of updating the OBS99 land cover map based on very high resolution satellite Earth Observation images from the IKONOS satellite sensor, and the calculation of landscape indicators

Executive Summary

This document reports on the data acquisition, pre-processing and thematic activities in the framework of the service delivery and product generation for the "GSE-Forest Monitoring extension for Luxembourg". The required services/products are described in the SLA, agreed with the user, the Luxembourg Forestry Administration (AEF) and the Environment Ministry.

Activities carried out:

1. Data acquisition:
    - Suitable Earth Observation satellite imagery (5 SPOT1 scenes covering the whole territory of Luxembourg) for the reference year 1989 was selected and acquired through ESA from SPOT Image.
    - A test scene of the very high resolution satellite Earth Observation satellite IKONOS recorded in 2004 covering a test site in northern Luxembourg
    - The additional data necessary for the generation of the selected products, i.e. Land use map, Forest Area map, Forest Type Map in accordance to the LULUCF GPG, have been received from the user:
        i. OBS89
        ii. OBS99
        iii. DTM
        iv. BD-L-TC
        v. IFN (National Forest Inventory 1998-2000)
        vi. Ecoregions and –section as defined by AEF
2. Data input
    - Data integration into Image Processing System and GIS
3. Data preprocessing:
    - DTM creation from contour lines file
    - Georeferencing using GCP/ICPs and DTM
    - Mosaicking of SPOT1 1989 data
    - Atmospheric correction and topographic normalisation supported by DTM elevation information of SPOT1 1989 data
    - Pre-processing of the IKONOS test scene (ortho-rectification, carried out by our partner GIM)
4. Thematic processing:
    - Generation of land use map LULUCF 1989 based on the OBS89 map
    - Generation of the Forest Area map 1989 based on the SPOT1 satellite imagery and the OBS89 map
    - Generation of the Forest Type map 1989 based on the OBS89 map
    - Development of the processing chain for updating the OBS99 based on IKONOS data
    - Test of the method for updating OBS99
    - Calculation of landscape indicators for further analysis by the users

The products have been delivered in time, i.e. made available to the user in electronic format (via ftp server and on CD-ROM) on 5 December 2007.

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List of Abbreviations

AEF	Administration des Eaux et Forêts
AFOCEL	Association Forêt Cellulose
AIL	Action Item List
AISF	Italian Academy of Forest Sciences
BMVEL	Federal Ministry of Consumer Protection, Food and Agriculture
CAFSA	Coopèrative Agricole et Forestière Sud Atlantique
CDM	Clean Development Mechanism, International Treaty related to the Kyoto Protocol
CEMAGREF	Centre for Agricultural and Environmental Engineering Research
CFBL	Coopèrative Forestière Bourgogne Limousin
CITEPA	Centre Interprofessionel Technique d`Etudes de la Pollution Atmosphèrique
CSIR	CSIR-Environmentek, Division of Water, Environment and Forest Technology
DLR	German Aerospace Centre – Deutsches Zentrum für Luft- und Raumfahrt
EEA	European Environmental Agency
EFI	European Forest Institute
FAO	Food and Agriculture Organisation
FELIS	Department of Remote Sensing and Landscape Information Systems, University Freiburg, Germany
FLD	Forest & Landscape Denmark
FS-I	Forest Service of Irkutsk General Survey of Natural Resources
GAF	Consultant and main contractor
GEOAP	Geoapikonisis Ltd.
GEOSYS	Geosystems Polska Ltd.
Global-Woods	Global-Woods AG
GMES	Global Monitoring for Environment and Security
GMV	GMV - GMV S.A.
GSE	GMES Service Element
IFN	French National Forest Inventory
IIASA	International Institute of Applied Systems Analysis
INFORMUS	Informus GmbH
INIA	Instituto nacional de Investigacióny Tecnologia Agraria y Alimentaria
INTECS	Intecs S.r.l.
IRD	Research Institute for Development
JR	Joanneum Research
JRC	Joint Research Centre
KP	Kyoto Protocol
LANU	State Agency for Nature and Environment Schleswig-Holstein
LFG	Regional authorities for forest and large nature protected areas of Mecklenburg-Vorpommern
LNV	Ministry of Agriculture, Nature, and Food Quality
MASLI	Indonesian Society for Natural Resources and Environment Accounting
MATT	Ministry for the Environment and Territory
ME-Po	Ministry of Environment
METRIA	Metria Milijöanalys
MMA	Ministry of Environment
NBF	The National Board of Forestry
NEO	Netherlands Geomatics & Earth Observation B.V.
NOA	National Observatory of Athens
PLANETEK	Planetek Italia S.r.l.
PM	Progress Meeting
PNDD	Plan National pour un Developpement Durable
PRINS	PRINS Engineering
QUALISYS	Quali Systems Ltd.
RSS	Remote Sensing Solutions GmbH

SAEFL	Swiss Agency for the Environment, Forests and Landscape
SBO-ME	Ministry of Environment, State Biodiversity Office
SFM	Sustainable Forest Management Consultants GmbH
SFS	State Forest Service
SoW	Statement of Work
SRC	Space Research Centre Poland
TBFRA2000	Temperate and Boreal Forest Resources Assessment for the year 2000
TELESPAZIO	Telespazio S.p.A.
TLWJF	Thuringian State Institute for Forest, Game and Fishery
TOC	Table of Contents
UBA-A	Federal Environment Agency Austria
UBA-G	Federal Environmental Agency Germany
UMLV	Université de Marne la Valleé, Institute Francilien des Géosciences
UNI JENA	Friedrich-Schiller-University Jena
UNIMOL	University of Molise
UNITUS	University of Tuscia
VTT	Technical Research Centre of Finland
WP	Work Package

1 Introduction

1.1 GSE Extensions for Luxembourg, an integrated approach

Given the small surface area of Luxembourg and the related limited number of GSE users, the Luxembourg stakeholders from research and industry concerned with Earth Observation applications joined their forces – supported by the Luxembourg Research Ministry - to propose the implementation of GSE Extensions for Luxembourg following an integrated approach.

Integrated approach means on the one hand that a number of tasks, which are common to all services proposed, will be implemented under an additional work package to benefit from synergies such as streamlining the activities and avoiding duplications of efforts. The following tasks are considered as common:
EO Data procurement
- Pre-processing of common EO imagery (IKONOS imagery: test scenes 2004; new acquisition in 2007)
- Common GI database (GSE-LUX-DB)
- Creation and maintenance of a common GSE – Luxembourg website for promotion purposes and product distribution
- Overall GSE Luxembourg coordination (performed by LuxSpace), being implemented in the framework of the GSE-FM-LUX as a separate WP.

On the other hand, the partnership proposed an integration of the production across three GSE services. Concretely, the OBS (Occupation Biophysique du Sol) land cover map of 2007 being produced in the framework of GSE Land extension for Luxembourg will be used as basis for product generation in the framework of GSE Risk-EOS (for Assets mapping 2007) and for GSE Forest Monitoring (Forest type mapping 2007). By this approach, duplication of work can be avoided what also leads to consistent data sets across different GSEs for the benefit of the user group.
Figure 1-1 presents the partnership and the organisation of the GSE-Extensions for Luxembourg.

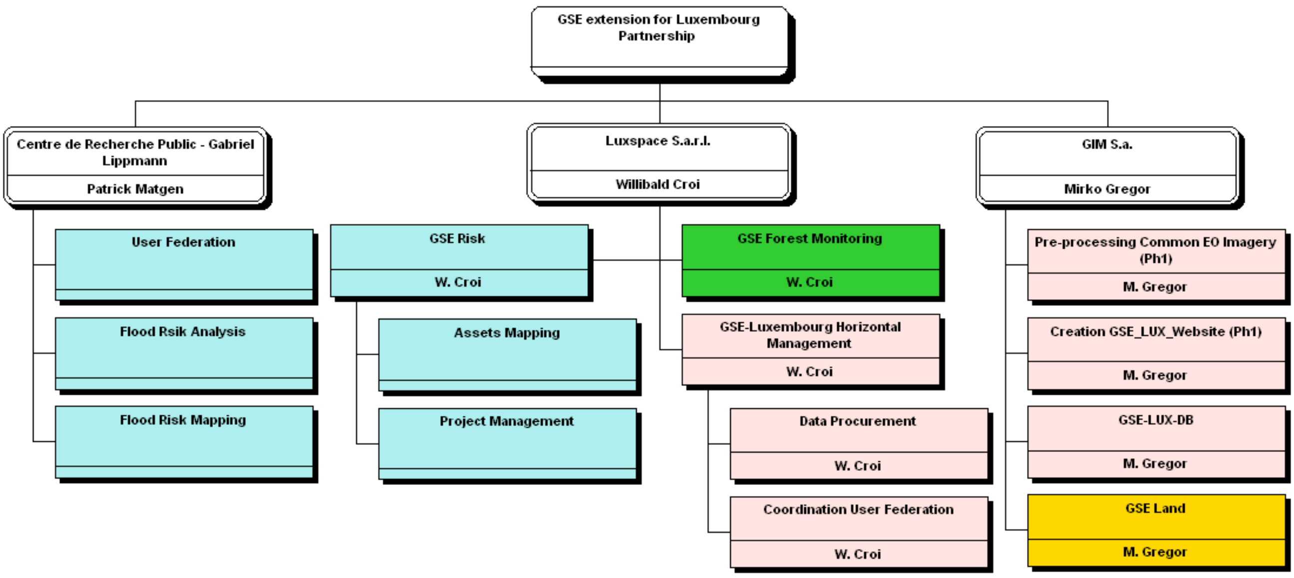


Figure 1-1: Partnership for GSE-Luxembourg Extension (horizontal tasks in pink)

1.2 User description: The Environment Ministry and the Forestry Administration

The principle users of the GSE Forest Monitoring services in Luxembourg are the Environment Ministry (Ministère de l'Environnement) and the Forestry Administration (l'Administration des Eaux et Forêts) under the ministry's authority.

The major missions1 of the Luxembourg Environment Ministry are

- to implement the environmental programme defined by the government,
- to coordinate the activities regarding the implementation of the National Plan for Sustainable Development (Plan National pour un Developpement Durable - PNDD) and
- to take adequate measures for Protecting the Natural and Human Environment.

The ministry defines and implements various prospective activities, information and sensitisation campaigns, specific state-aid and subsidies, legal acts etc.

It is assisted by two administrations under its authority:

- the Environment Agency (l'Administration de l'Environnement), and
- the Forestry Administration (l'Administration des Eaux et Forêts).

The **Forestry Administration** is the main user in the framework of the GSE extension for Luxembourg regarding Forest Monitoring while the ministry itself is interested in the support to environmental monitoring of the GSE-FM with regards to nature conservation.

Out of the total territory of Luxembourg, that is 2586 Km2, about 886 Km2 are forested according to the FAO TBFRA2000 definition2. The Forestry Administration3 is responsible for management of 44.8 % of the Luxembourg forests (app. 40.000 ha), namely the communal forests (32.8%), the forests belonging to the State (10.7%) and to the publicly-owned establishments (1.3%). Management and annual planning, based on the principles of a sustainable forest management as stated in the resolution H1 of Helsinki[4], are carried out by the external services (6 regional departments, 61 divisions). Decennial planning and the other missions are under the responsibility of the central services (Directorate, Department of the forestry planning and forestry economics). The private forests account for 55.2% of the Luxembourg forests. The Association of Private Forest Owners (Groupement des Sylviculteurs a.s.b.l.), a non-profit-making association, is representing the interests of the private forest owners in Luxembourg. The Grouping will be addressed as potential user in the framework of Task 2 User Federation.

[1] Source: Internet site http://www.environnement.public.lu/functions/apropos_du_site/mev/index.html,

[2] Source: Administration des Eaux et Forèts, Service de l'Aménagement des Bois et de l'Economie Forestière, d'après l'inventaire de la forêt privée et les inventaires d'aménagement en forêt publique.

[3]Source: http://www.environnement.public.lu/forets/index.html

[4] namely *"the management and the use of the forests and the timbered grounds, in a manner and with an intensity such as they maintain their biological diversity, their productivity, their capacity of regeneration, their vitality and their capacity to satisfy, currently and for the future, the relevant ecological, economic and social functions, on the local, national and international level"*.

2 Service Description

In the following section a brief outline is given for the service as it was realised in the phase 1 of the GSE Extension for Luxembourg (May – December 2007) and as it was delivered to the user by 5 December 2007.

2.1 Service case

The service: Forest Monitoring inputs for National Greenhouse Gas Reporting

Service Type: GSE-FM-NAT-KYOTO

Service case description

The service was agreed between the service provider LuxSpace S.à.r.l. (in collaboration with the partnership created for the GSE Extensions for Luxembourg, i.e. Geographic Information Management (GIM) S.A. and Centre de Recherche Public Gabriel Lippmann - CRP-GL) in cooperation with the user, the Luxembourg Forestry Administration under the authority of the Luxembourg Environment Ministry.

The agreed SLA covers in phase 1 of the project (phase 2 of stage 2 of the GSE-FM service element) the provision of maps and related statistical information of 1989 for Forests, Land Use and Land Use Changes for the service area that is the entire territory of the Grand Duchy of Luxembourg based on the OBS1989 and SPOT1 satellite imagery (multispectral, 20m resolution).

In addition to that, the service includes the development of a processing chain for updating forest categories according to the Luxembourg OBS99 nomenclature (Occupation Biophysique du Sol) that is a very detailed land cover map, using very high resolution satellite imagery (IKONOS satellite, 1m / 4m resolution). The developed method was applied to a test area covering about 100 km^2 of northern Luxembourg. The IKONOS data used for the test has been recorded in 2004.

In phase 2 (GSE-FM stage 2 phase 3 = final year) similar information is planned to be provided for the year 2007 using very high resolution Earth Observation images of the IKONOS satellite acquired in 2007 pl Then, change detection will be carried out from 1989 to 2007 and change maps and statistics produced.

2.2 Service Actors

All the actors can be described according their roles and responsibilities in the service production chain. This is briefly described in the following section.

Service Providers

Official Name: LuxSpace S.à.r.l.
Acronym: LuxSpace

Description

LuxSpace acts as the service provider responsible for all aspects of map production in the service chain. All steps including data handling, pre processing, thematic processing and service dissemination were taken over by LuxSpace for the SPOT1 satellite data treatment. The IKONOS satellite image pre-processing (geometric correction) over the test site in northern Luxembourg was carried out by our sub-contractor GIM sa.

With respect to optimised data procurement especially ancillary data acquisition was carried out in coordination with the user, AEF.

User

Official Name: Administration des Eaux et Forêts
Acronym: AEF

Description:
The user AEF receives the service products such as maps and statistical products as well as training and information sessions.
On the other hand AEF provides reference (digital Orthophotos, DTM, digital topographic data) and ancillary data required for service production (as specified in the Source Data List). AEF will participate in the evaluation and validation process of delivered products. This includes user requirement assessment before the formulation or updating of the SLA and the utility assessment following delivery of the final products.

2.3 Policy Driver

Policy Driver Name:
The UN Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol

Policy Driver Code: GSE-FM-GLOBAL-KP

Description:
The service is anchored as a contribution to the reporting obligations for the first commitment period (2008 to 2012) under the United Nations Framework Convention on Climate Change (UN-FCCC) and Article 3.3 of the Kyoto Protocol
The service provides the land use and the forest area maps for the reference years 1989 (this phase) and 2007 (in next phase).

2.4 Service Area

Area Name: Luxembourg
Area Code: LU
Continent: Europe
Latitude: 49° 45' N
Longitude: 6° 10'

Description:
The complete coverage of the service performed over all phases will cover the entire country area of Luxembourg (2586 km^2).
In phase 1, a complete coverage was produced with SPOT1 imagery (XS multispectral, 20m) recorded in 1989.
In addition to that, a test scene from the IKONOS satellite (taken in 2004) was used to test the developed production chain for forest mapping covering a test area in the north of the country.

In phase 2, the entire country will be processed using IKONOS imagery that was acquired in July/August 2007 (panchromatic 1m, multispectral 4m) for land use, forest areas and forest types mapping.

Figure 2-1: Luxembourg and northern test site (© 2000 Microsoft Corp. © NavTech)

2.5 Service Temporal Range

Period Begin: 1.1.1989
Period End: 31.12.2007
Description:
The service extensions for Luxembourg joined the GSE FM Stage 2 / Phase 2 starting at project Progress Meeting 6 (June 2007). The sub-contract from the prime contractor GAF AG has been received by Luxspace 30 August 2007. The extensions phase 1 will last until November 2007 (6 months). Phase 2 of the extension project will start – after approval of ESA – in December 2007 and last 12 months, until November 2008.
According to the Service Delivery Schedule for Phase 1 all components regarding products and documentation were delivered by the end of project month 6, tentative date: 5 December 2007.
The delivered products are valid for a specific range, i.e. the reference years 1989 (and 2007 in next phase). The test scene of IKONOS was recorded in 2004.
Training as an additional feature to the service and especially the application of the delivered products is planned during two half day presentation meetings in October and December 2007.

2.6 Product List

In accordance with the Service Level Agreement (SLA), the following results and products are presented in this report. The product types refer to the document S5, Service Portfolio Specification. According to this listing the following product types were delivered for this service.

2.6.1 Image Products

Product : **Ortho images and mosaic 1989**
Product Code: GSE-FM-OIM-1989
Description: Ortho-rectified SPOT1 satellite images, multispectral mode (20m resolution) and mosaicked covering the entire Luxembourg territory in a seam less manner

Product : **Ortho image IKONOS 2004**
Product Code: GSE-FM-OI-IKONOS2004
Description: Ortho-rectified IKONOS Test scene recorded in 2004, pan-sharpened-multispectral mode (1m resolution, multispectral original image 4m) covering a test area in the northern part of Luxembourg

2.6.2 Map Products

Product : **Land Use Map 1989 for Luxembourg**
Product Code: GSE-FM-LFM-LULC
Description:
A Land Use Map for the reference year 1989, suitable for Kyoto reporting was produced based on the OBS89 map. Herein the classes Forest Land, Cropland, Grassland, Settlements, Wetland, Water and Other Land (according to the nomenclature defined in the LULUCF Good Practice Guidance) were mapped. To respect the definitions agreed in the SLA, the base data (OBS89) has been thematically generalised (only land use attribute data changed, not geometry of original polygons) to present a Minimum Mapping Unit of 0.5ha, the geometric and thematic accuracy of the original OBS89 map was not changed.

Product: **Forest Area Map 1989 for Luxembourg**
Product Code: GSE-FM-LFM-FTM
Description:

A Forest Area Map for the reference year 1989 was produced based on the OBS89 map and EO data (SPOT1 satellite imagery) in the time frame 01/01/1989 – 31/12/1989. Herein the classes Forest, Reforestation, Clear Cut and Other land (according to the nomenclature defined in the LULUCF Good Practice Guidance) were mapped. The *Clear Cut* areas were mapped using the SPOT1 imagery. The product is specified by a geometric accuracy of < 10 m RMS and a thematic accuracy of 70 - 90% for all sub-classes.

Product: **Forest Type Map 1989 for Luxembourg**
Product Code: GSE-FM-LFM-FTM
Description:
A Forest Type Map for the reference year 1989 was produced based on the OBS89 map. Herein the classes Forest (Coniferous, Deciduous, Mixed subclasses) and Other land (according to the nomenclature defined in the LULUCF Good Practice Guidance) were mapped. The product is specified by the Minimum Mapping Unit, the geometric accuracy and the thematic accuracy of the original OBS89 map.

Product: **Forest Type Map 2004 for test area in northern Luxembourg**
Product Code: GSE-FM-LFM-FTM
Description:
A Forest Type Map for the reference year 2004 was produced based on EO IKONOS test data in the time frame 01/01/2004 – 31/12/2004 and the OBS99 map.
Herein the classes *Other Land* and the *Forest classes* (according to the nomenclature defined in the Luxembourg OBS99 map) were mapped (see Table 3-9: Nomenclature of forest classes in the OBS99, page 29):
The product is specified by a Minimum Mapping Unit of 0.15 ha, a geometric accuracy of < 2 m RMS and a thematic accuracy of 90% +/- 5% for all sub-classes.

Product: **Forest Fragmentation and Structural Diversity indicators**
Product Code: GSE-FM-FEI
Description:
Fragmentation indices will be used by the Forestry Administration and the Environment Ministry to support reporting under the environment monitoring schemes of the European Commission (Forest Focus, Conservation of natural habitats and of wild fauna and flora), the National Plan for Sustainable Development, the Ministerial Conference on the Protection of Forests in Europe (MCPFE) and the National Forestry Plan, i.e. monitoring of sustainable forest management.
Indicator products were calculated for 1989 for Luxembourg at the level of Eco-Regions and –Section as defined by the AEF.

Table 2-1: Fragmentation and Structural Diversity Indicators

Index	Description
Area metrics	The index “Area Percentage of Landscape” (APL) expresses the area proportion of one class type in % of a specific landscape.
Patch metrics	The Patch Density (PD) index describes the total number of patches or their relative proportions in a given area (e.g. 100ha).
Edge metric	The Edge Density (ED) index describes the amount of edges occurring between patches or classes per given area (e.g. 100ha).
Shape metrics	The Landscape Shape Index (LSI) is a measure for the complexity of forest shapes.
Core area metrics	Core area metrics compute statistics about the inner central parts of patches in relation to the total patches and provide information about the quality of habitats for certain species. The Total Core Area Index (TCAI) is computed as percentage of the total core area in relation to the total area.
Nearest Neighbour metrics	Nearest neighbour indices quantify landscape configuration. The Mean nearest Neighbour Distance (MNN) index averages all minimum distances of all patches to their nearest patch partner.
Diversity metrics	The Shannon Diversity Index (SHDI) measures the extent to which one or a few class types dominate the landscape index.

2.6.3 Other service features

Service Delivery Model:
The service delivery model is one of service out-sourcing – where an external service provider will provide the GSE FM service to AEF.

Terms of Access:
Web Portal, on request products are delivered on several media such as CD-ROM, DVD

Training:
Presentations of the results in combination with training are performed.
The first meeting concerned with the product delivery has been arranged as a ½ day event held at AEF, Luxembourg on the 19 October 2007. A second meeting will be arranged together with the users of the AEF and the Environment Ministry before the end of December 2007.
The material for presentation will focus on service results, applications and use of the delivered maps. The training package provided for GSE FM training exercises provides the framework of the GSE Forest Monitoring services.

3 Service Operation

3.1 Data Order Handling and Acquisition

As already described in chapter 1.1, data procurement is being done centrally by LuxSpace S.à.r.l. for all GSE Extensions for Luxembourg.

The required satellite scenes of SPOT1 satellite from 1989 were selected through a search using the ESA EOLI SA client software, the ESA Earth Observation, Multi-mission, Catalogue and Ordering Service. Ordering has been done using the GSE-FM account at ESA res. SPOT Image.
The service provider took benefit of the ESA category 1 pricing for archived SPOT imagery.
The IKONOS test scene covering partly the north part of the country has been made available by European Space Imaging under a demo-license agreement at no cost.
Regarding the acquisition of the very high resolution imagery from the IKONOS satellite, the agreement made by the GSE-FM prime contractor GAF AG and European Space Imaging (data provider for IKONOS) enabled the ordering of the required scenes for the 2007 coverage on the entire area of Luxembourg for a reduced price (-20%), i.e. about 40 KEuro. Under commercial conditions, the price for IKONOS data (valid in October 2007) as used in this project is 23 US$ per km^2 (ortho-kit, bundle panchromatic 1m and multispectral 4m resolution), with a minimum order of $100km^2$ (for archived data, the price is 18 US$ per km^2, minimum order $49km^2$).

3.2 Source Data

According to the data procurement plan various data types were acquired.

3.2.1 High Resolution Optical Satellite Data

SPOT 1 images recorded in 1989

The SPOT 1 satellite was started in 1986 with a spatial resolution of 20m in the single bands and a spectral resolution of four bands, two in the visible, one in the near infrared. The merged panchromatic band has a spatial resolution of 10m. The catalogue search on EOLI SA resulted in the selected imagery (see Table 4-1: SPOT1 images acquired and used for product generation, page 40).

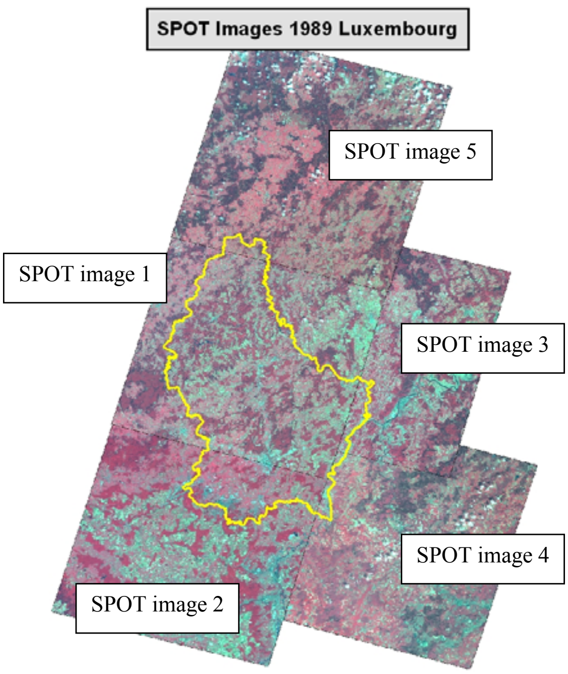


Figure 3-1: SPOT images 1989 covering entire Luxembourg

IKONOS images 2004 : Test site in northern Luxembourg

Considering the requirement of the Luxembourg users for a very detailed land cover / use map in terms of thematic content (OBS99 nomenclature with about 77 classes in two levels of detail) and geometry (MMU 0.15ha, to be used at 1:15.000 scale), very high resolution imagery of the American satellite IKONOS have been selected for application of the OBS updating.

The ESA Technical Officers responsible for GSE Land and GSE Forest Monitoring required performing a test to develop the processing chain using this very high resolution data.

Table 3-1 IKONOS 2 sensor characteristics

Swath width (km)	11 by 11	
Field of view (FOV)	0.93	
Stereo imaging	In & Cross track	
Sensor position	GPS	
Sensor attitude	3 Star trackers	
Pointing in track Cross track	45	
Resolution at Nadir	Panchromatic	Multispectral
Resolutions	1 m	4m
Spectral band widths	0.45-0.9 µm	0.445-0.516 Blue (1) 0.506-0.595 Green (2) 0.632-0.698 Red (3) 0.757-0.853 Near Infrared (4)
Cloud and haze	Cloud free and free of strong haze	

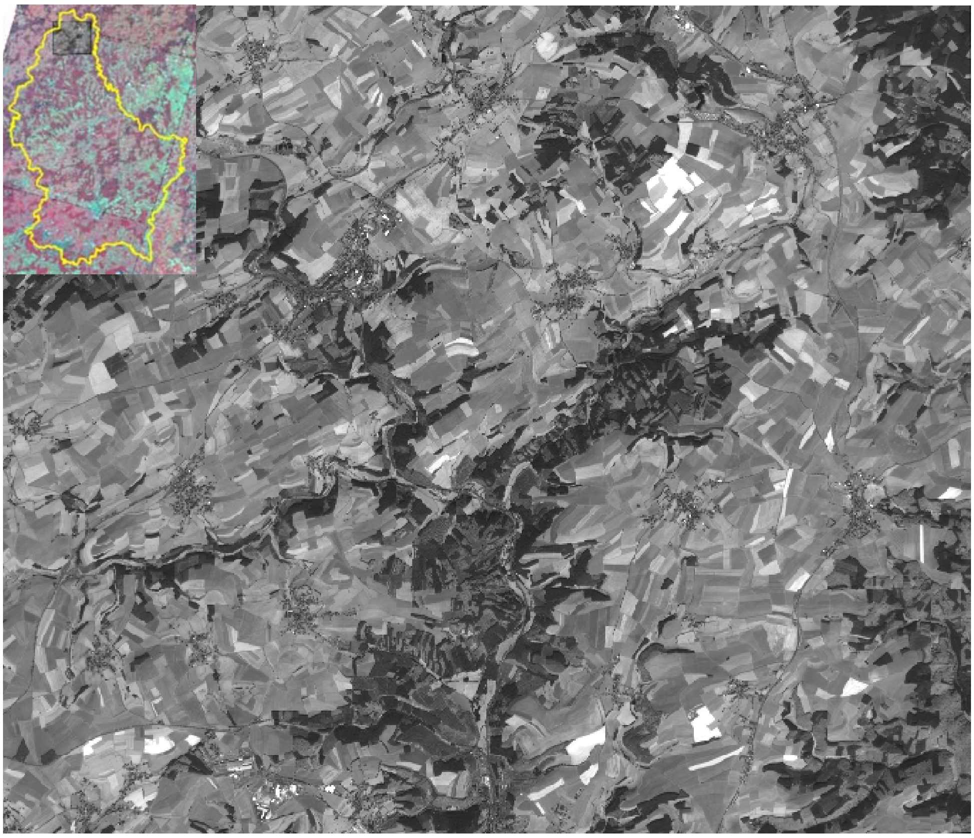


Figure 3-2: IKONOS panchromatic band over the test area (north of Luxembourg)

3.2.2 In Situ data: Inventaire Forestier National au Grand-duché de Luxembourg (IFN) – National Forest Inventory

Data from the IFN has been made available to the project by the AEF (Forestry Administration).
The National Forest Inventory was carried out for the first time in the period from May 1998 to December 2000. The method, based on the Forest Inventory methodology applied in the Walloon region of Belgium, has been adapted by the University of Gembloux in collaboration with the Forestry Administration in Luxembourg.
The characteristics of the Luxembourg National Forest Inventory[5)] are listed in the Table 3-2.

Table 3-2: Characteristics of the "Inventaire Forestier National au Grand-Duché de Luxembourg IFL"

Characteristics of the inventory	Description
Stocktaking procedure	National forest inventory with permanent sample areas
Coverage	Country-wide inventory
Objective	Forest areas in accordance with TBFRA 20006 - definition, both public and private forests. „Not "- forest surfaces are only identified and described briefly.
Sampling design	One-stage systematic random sampling using a W-E oriented grid with cell size of 1000mx500m over the whole territory, resulting in about 5200 sample points/areas, each point of sample is thus representative for a patch of 50 hectares.
Sample area	On the basis of the individual knots of the grid network, three concentric circles with radii of 4,5m, 9m and 18m are drawn. Within each circle, different variables are observed.
Sampling proportion	The observed area (=total surveyed sample area) amounts to 0.2% of to the total forest area. This number is calculated by the total number of the forest sample points, estimated on altogether 1.720, multiplied by the sample area of 10 acre (largest circular area).
Duration of the field survey and repetition interval	Ground survey duration 2 years, planned interval between two surveys = 5 - 10 years
Interpretation of aerial photos	Panchromatic aerial photographs (1:20.000 scale, recorded in 1994 by IGN France for the Cadastre and Topography Administration of Luxembourg (l'Administration du Cadastre et de la Topographie à Luxembourg - ACT) were photo-interpreted to identify non-forest and forest sample points as well as for the preparation of the field work.

The collected data includes information on various topics such as measurements on sample trees, forest structure information, and economical, ecological and administrative data.
The statistical data enables estimation of forest area, area per forest types, age structure of forests, stem volume, biomass etc. The data was made available by the Forestry Administration.
The data is used for forest area and type classification of satellite imagery respectively for accuracy assessment purposes.

3.2.3 Other data

All other data used by the project has been made available by - or through - the Forestry Administration (AEF).

3.2.3.1 Digital Elevation Model

Digital Elevation data covering exactly the entire territory of Luxembourg with a vertical resolution of 10m has been made available to the project by the Forestry Administration in form of a CAD file with

[5] (source: http://www.environnement.public.lu/forets/dossiers/ifn/index.html).
[6] Temperate and Boreal Forest Resources Assessment 2000 (UN-ECE - FAO)

contour lines. The DTM is derived from the BD-L-TC topographic database at scale 1:5000 (source: Administration du Cadastre et de la Topographie à Luxembourg).
The data was used for the purpose of geometric correction and topographic normalisation during atmospheric correction step as well as supporting the mapping.

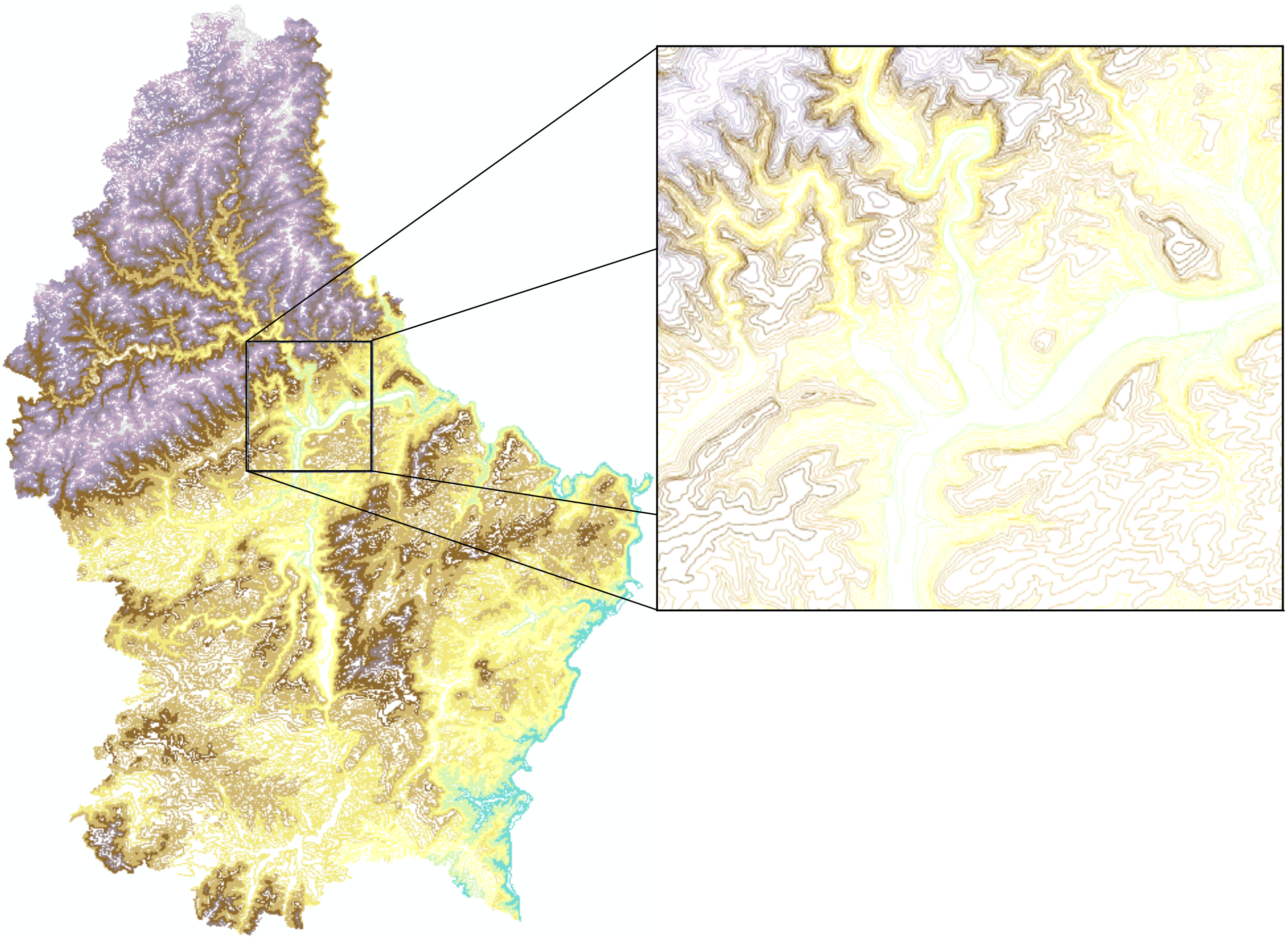


Figure 3-4: DEM of Luxembourg and subset

3.2.3.2 Aerial Orthophotographs 2004

Aerial orthophotographs are regularly recorded on a three yearly basis over the whole country by the ACT for updating topographic information. The images are made available to ministries free of charge. Aerial orthophotos from 2004 were made available, the photos planned to be available by the end 2007 will also be made available by the user in phase 2 of the project. The images will be used as additional data for verification / validation purposes and for thematic processing.

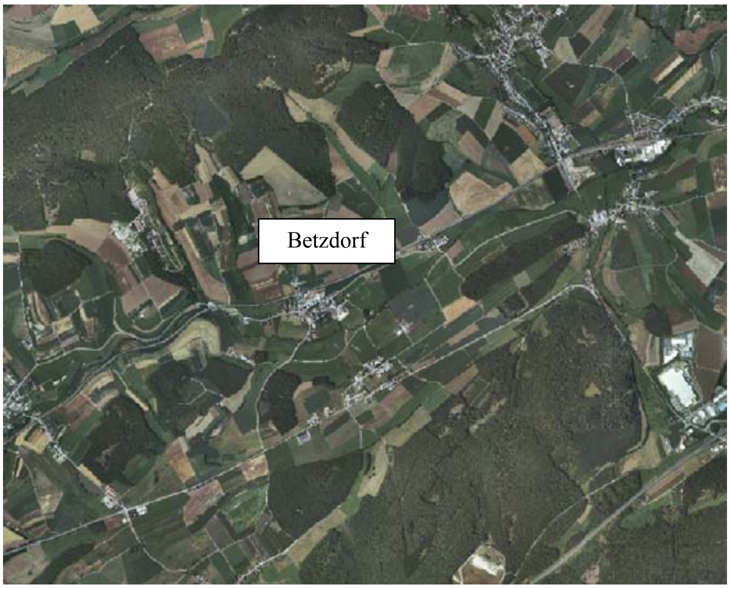


Figure 3-3: Subset of BD-L-TC

3.2.3.3 Topographic database 1:5.000 (BD-L-TC) of the Cadastre and Topography Administration of Luxembourg

The Topographic/Cartographic database of Luxembourg (BD-L-TC - “Base de Données Topo/Cartographique du Luxembourg”) is created and maintained by the Cadastre and Topography Administration of Luxembourg (l'Administration du Cadastre et de la Topographie à Luxembourg – ACT). The BD-L-TC contains vector data on topography at a scale of 1:5000 based on aerial photography covering the whole national territory of Luxembourg[7].

It includes data on:

- Roads
- Buildings and other infrastructures
- Administrative boundaries
- Railways,
- Vegetation
- Geodesic infrastructures
- Energy transport
- Orography
- Taxonomy
- Hydrograph
- Altimetry

The data was used for geometric correction and mapping purposes.

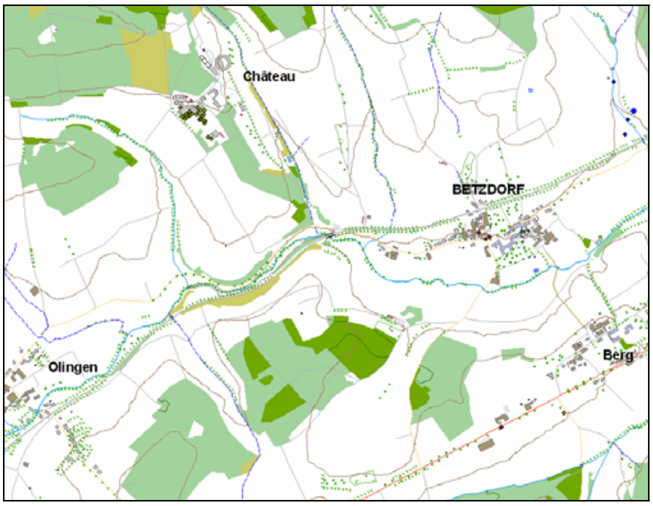


Figure 3-5: Subset of BD-L-TC

3.2.3.4 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 orthophotographs showing delineated areas, experts from the “Oeko Fonds“ and the association “Hellef fir`d Natur” mapped / classified the areas during field work according to a 6-level nomenclature with 5 main classes[8]:

The map data was used for land use, forest area and type classification of satellite imagery of 1989. The detailed nomenclature is attached in Annex. There is no further detailed description or information on accuracy of the OBS89 available.

Table 3-3: OBS89 Nomenclature at Level 1 and number of classes in level 2-6

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Artificial areas	4	11	22	27	
Agricultural areas	3	4	9	10	3
Forest and semi-natural areas	3	9	27	37	
Wetlands	1	1	5	6	
Water surfaces	1	5	7	12	
Landscape elements	2	6	11		
Number of classes:	14	36	81	92	3

The OBS data has been provided by AEF as a shapefile.

[7] Source: Website ACT Luxembourg http://www.act.etat.lu/bdltc1.html

[8] Source: Ministere de lènvironnement (1994): Cartographie de lòccupation biophysique du sol 1988 - Legende.- Luxembourg

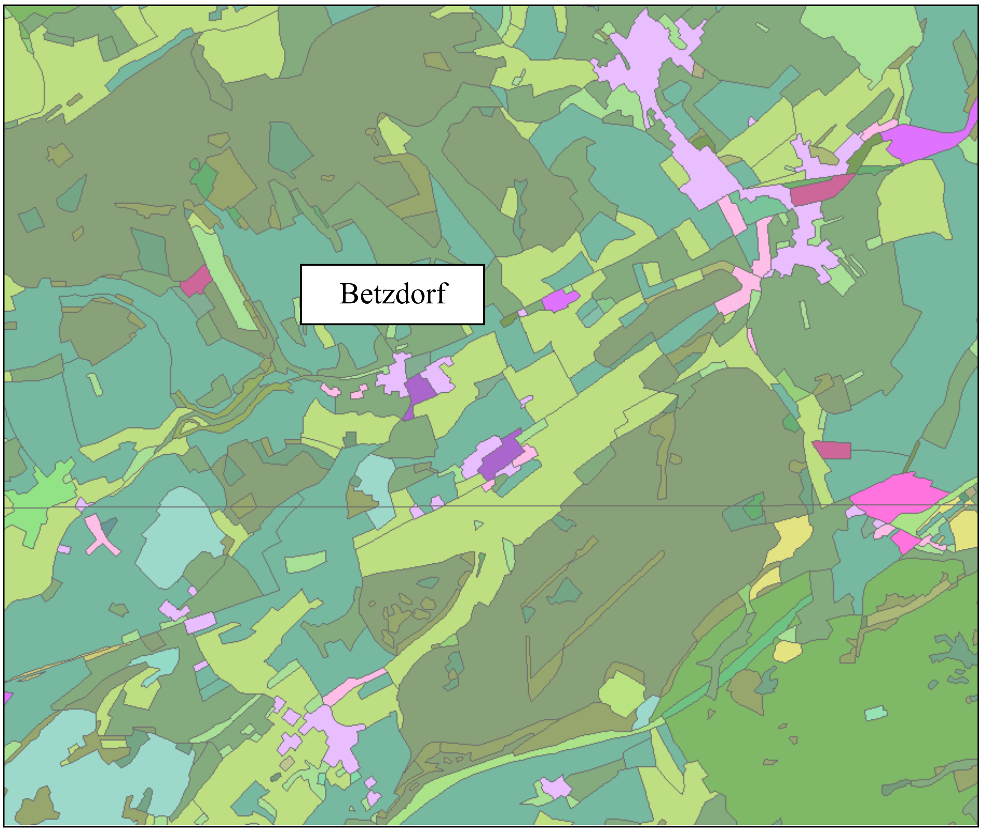


Figure 3-6: Subset of the OBS89 with its 158 classes

The OBS89 map has been used as base information for the generation for the mapping of land use, forest areas and forest types in this project.

3.2.3.5 Biophysical Land Cover Map 1999 – "Occupation Biophysique du Sol" OBS99[9]

The Environment Ministry carried out in 1999 an updating 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 88 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 2.500 m^2 (0.25ha) but adapted for important but small areas, i.e. wetlands and little lakes/ponds to 1500 m^2 (0.15ha). 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:

- Built-up and artificial areas (32 classes)
- Forests and semi-natural areas (26 classes)
- Water areas (18 classes)
- Agricultural areas (8 classes)
- Wetlands (3 classes)

Concerning the nomenclature, the document describing the content of the OBS99 classes and showing examples of aerial photos has been made available by AEF.
The data has been used for forest type mapping of the test site using the IKONOS satellite image.

[9] Hansa Luftbild AG (1999): Occupation Biophysique du Sol Grand Duche de Luxembourg – Interpretationsschlüssel zur Color-Infrarotbefliegung 1999.- Münster

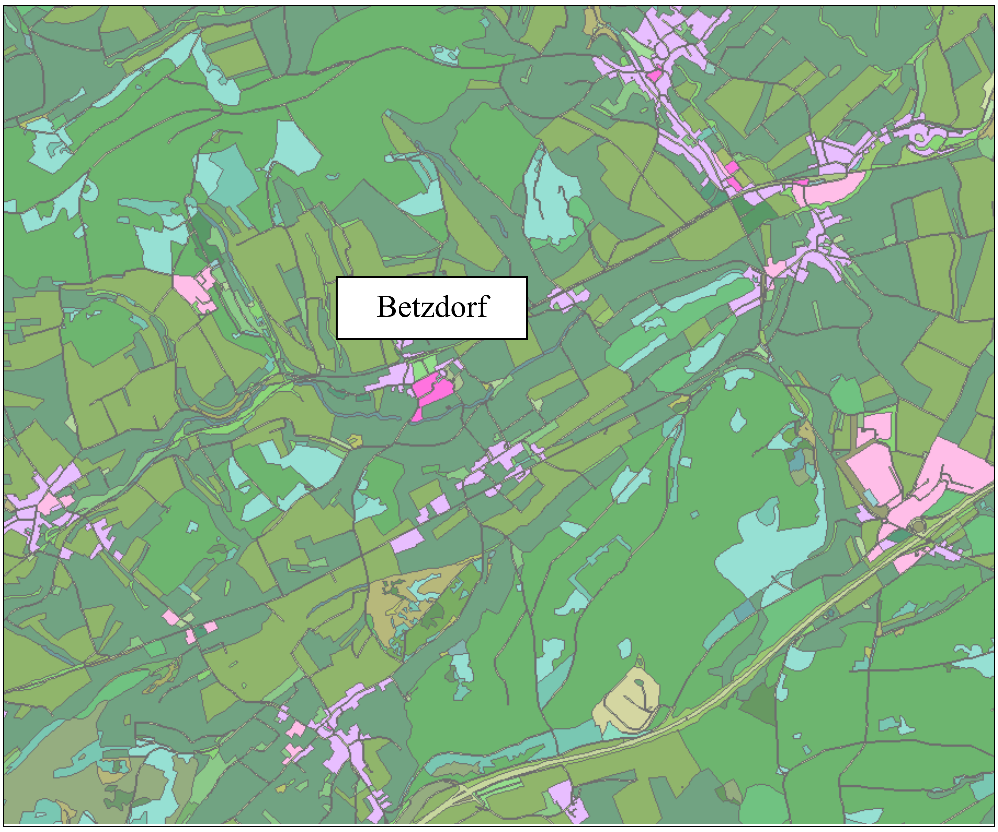


Figure 3-7: Subset of the OBS99 with its 76 classes

3.2.3.6 Ecological regions and sections of Luxembourg

Geographic data on the borders of the ecological regions and sections for Luxembourg have been provided by the AEF.

Table 3-4: Ecological regions and sections in Luxembourg

Region	Section
Oesling	Noerdliches Hochoesling
	Suedliches Hochoesling
	Obersauer-, Wiltz-, Clierf- und Bleestal
	Ourtal
Gutland	Oesling-Vorland
	Attert-Gutland
	Stegener Gutland
	Alzette-,Attert- und Mittelsauertal
	Untersauertal
	Eisch-Mamer-Gutland
	Schoffielser und Mullerthaler Gutland
	Suedliches Gutland
	Rebierger Gutland
	Pafebierger und Oetringer Gutland
	Mosel-Vorland und Syretal
Moseltal	Moseltal
Minette	Minette-Vorland
	Minette
	Minette
	Minette
	Minette

The country has been divided into bio-geo-climatological sections according to an ecological classification based on climate, geology and soil. The ecological sections are considered to be regions with similar conditions for the growth and development of forest trees and other plants. The sections are published by the "Administration des Eaux et Forêts du Grand-Duché de Luxembourg, Service de l'Aménagement des Bois et de l'Economie Forestière » (ref : AEF (2003) : Delimitation des territoires écologiques pour la gestion forestière, avec carte des domaines et secteurs écologiques.- Luxembourg) These regions serve as areas for the calculation of landscape indicators.

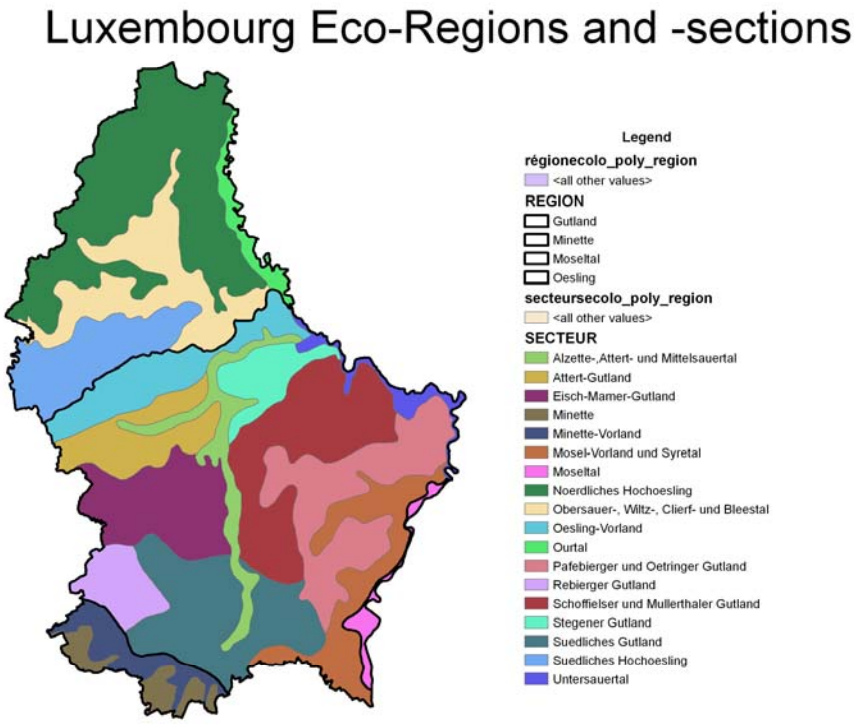


Figure 3-8: Ecoregions and –sections as defined by the Forestry Administration

3.3 Data processing

In the following section the main techniques and standards used for service operation are summarised. The document S5, Service Portfolio Specification and its upgraded version covers the complete set of methods and algorithms for data analysis, processing and modelling as well as verification using references and cartographic standard procedures. Since that specification document provides the framework for the whole GSE FM service network, the actually used methods are listed in the following sections according to the processing chain. The top-level processing is presented in Figure 3-9.

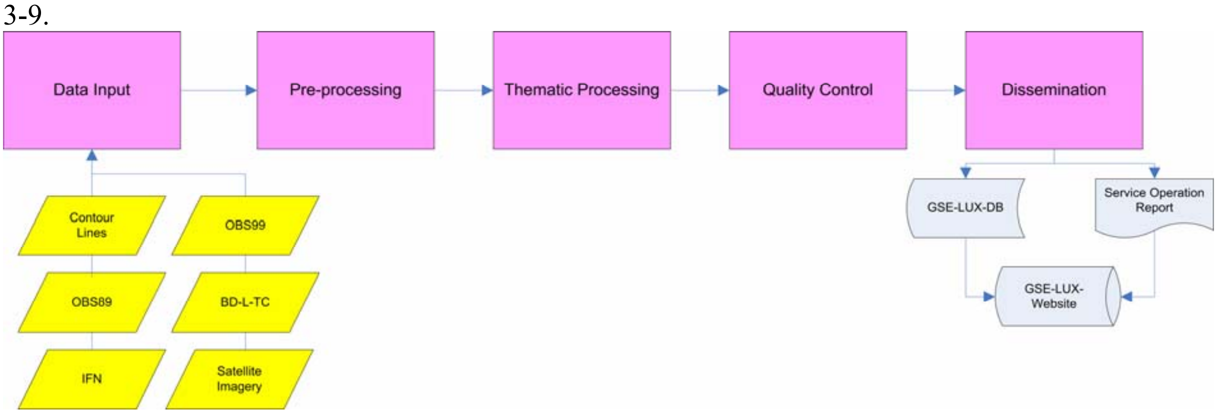


Figure 3-9: Level 1 Processing chain GSE-FM-LUX

Figure 3-10 presents the processing chain for GSE-LUX-FM LULUCF89 mapping in Phase 1.

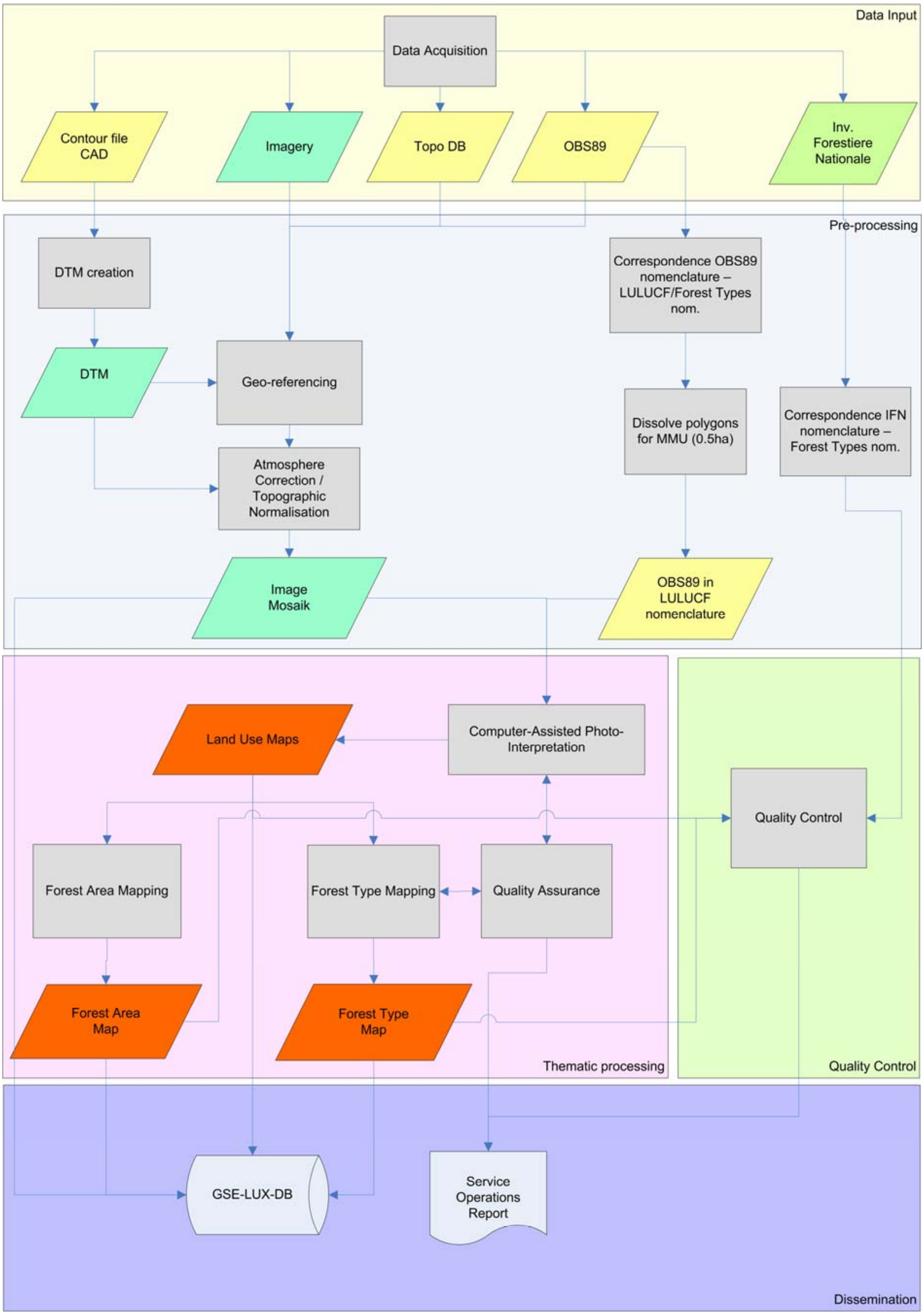


Figure 3-10: Processing Chain GSE-FM-LULUCF89 mapping in Phase 1

3.3.1 Data Input

Data were imported using standard tools and techniques coming with the software for the specific sensor involved. Imported Earth Observation data were checked for radiometric problems (salt and pepper, band striping, band shifting, histogram...) and spatial consistency coverage of the area of interest.

3.3.2 Pre-processing

3.3.2.1 SPOT1 imagery

First the imagery has been geo-rectified minimizing the distortion of the pixels due to different recording angles with the help of the Digital Terrain Model provided by the user. The DTM has been resampled to the Pixel size of the SPOT1 imagery (20m). The LUREF (Luxembourg Reference Frame) was defined using the parameters acquired from the web site of the Luxembourg Administration for Cadastre and Topography (ACT, http://www.act.etat.lu/datum.html).
The reference ellipsoid is HAYFORD International 1924:

- Semi-great axe a: 6378388 (m)
- Semi-small axe b: 6356911.946 (m)
- Oblateness: 1/f : 1/297
- Excentricity e2 : 0.006768170197

Projection specifications:
Type of Projection : Transverse Mercator
Projection Parameters:

- Longitude du méridien central: 6° 10'
- Facteur d'échelle au méridien central: 1
- Longitude de l'origine: 6° 10'
- Latitude de l'origine : 49° 50'
- False easting: Y = 80 000 m
- False northing : X = 100 000 m

Ground Control Points (in total 216 distributed over the 5 scenes) were selected in both, the SPOT1 imagery and the OBS89– referenced to LUREF coordinates. The points were controlled based on the BD Topo database. Table 3-5 provides georeferencing characteristics of the imagery, including RMS errors.

Table 3-5: Georeferencing characteristics of used SPOT1 images

Imagename	Nr. of GCP's	RMSE [m]	polynomial order used for transformation
SPOT image 1	62	8.8597	second
SPOT image 2	45	8.0077	second
SPOT image 3	48	5.9265	second
SPOT image 4	43	6.3175	second
SPOT image 5	18	8.7826	first
	216		

In a second step, the atmospheric conditions are estimated to reduce the influence of different contents of aerosols on the reflection. During the atmospheric correction, a topographical normalization is calculated with the aid of the Digital Terrain Model to eliminate higher reflectance values due to direct sun illumination or lower reflectance due to shadows.
Finally, the atmospherically corrected SPOT images were merged (mosaicked) into one image covering the entire area of interest, i.e. Luxembourg country wide.

Minor problems occurred due to the incompleteness of the DTM in 2 border regions in the SW of the country. There, the image mosaic could not be completed. During thematric processing, these "gaps" had been complemented by a visual comparison between the raw satellite images – that is not cut at the borderline - and the missing areas in the processed satellite image, i.e. the land use map and further derivates are not affected.

3.3.2.2 IKONOS test scene

As described above, the pre-processing of the IKONOS test scene has been performed by our partner GIM in the framework of "GSE-LUX common tasks". The scene has been ortho-rectified to fit the OBS99 geometry, i.e. to LUREF projection using DEM and Ground Control Points.

3.3.3 Thematic Processing

3.3.3.1 Creation of the land use map 1989 (GSE-FM-LFM-LULC)

For the creation of the land use map, it has to be to be considered, that the spectral resolution of the SPOT1 satellite imagery is not sufficient for classifying the land use/cover classes to the detailed level of the OBS89 nomenclature.
With regards to the LULUCF nomenclature, the spectral resolution is in general sufficient.
Most classes can be easily classified; especially forests (see Figure 3-13). Difficulties arise – as already mentioned in the SLA (see Table 3-6: LULUCF Nomenclature) for the correct image interpretation with regards to the classes "*Cropland*" and "*Grassland*". The "*Wetland*" class is also difficult to be classified, depending on the degree of wetness at the time of image recording.

In consultation and agreement with the user, who would like to keep as much as possible the basis of the work on existing information (the OBS89) it has been decided for this service, i.e. the land use mapping for the reference year 1989 in accordance to the LULUCF nomenclature, to create the land use map based on the OBS89, i.e. to convert the OBS89 classes into the required 6 classes and to aggregate the polygons to the required Minimum Mapping Unit (0.5 ha).

The contribution based on the exploitation of Earth Observation data is the identification of clear cut areas within the Forests, which were not identified as such in the OBS89 map. Such clear cut areas might be assigned to Reforestation or Deforestation areas after change detection with the information generated in phase 2 of the project, based on IKONOS imagery recorded in 2007.

3.3.3.1.1 Conversion of OBS89 Classes to LULUCF nomenclature

The very detailed OBS nomenclature from 1989 (Occupation Biophysique du Sol) and its class descriptions was analysed to enable correspondence and aggregation to the required LULUCF nomenclature (see Table 3-6).

Table 3-6: LULUCF Nomenclature

Land Use class	Definition
Forest Land	All forest and wooded land according to the FAO TBRA2000 definition: • tree crown cover >= 10 % • tree height >= 5 m.
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
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). The Grassland definition could partially overlap with Cropland, due to the grassland in Agricultural fields. Grassland in agricultural field would have the same spectral behaviour than the Grassland. In this case a Knowledge based approach might be used in order to disambiguate, because a mere classification approach would not be sufficient.
Settlements	All developed land, including transportation and any size of human settlement unless already included under other categories.(IPCC GPG definition)
Wetland	Land that is covered or saturated by water for all or part of the year (e.g. peat land) and that does not fall into other categories. 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.

The majority of the OBS89 classes could be easily linked to the corresponding LULUCF class. Some correspondences seems to be strange at first sight, e.g. *Vineyards* have to be aggregated to *Grassland* due to the cropland definition that excludes all permanent agriculture products, whereas *Ameliorated Mesophillic Grassland* need to be put into the *Cropland* class because *Cropland* includes artificial meadows.
With regards to clear cut areas, there are 2 distinct classes in the OB89 nomenclature:

32414 vegetation des coupes forestiere and *32415 recrus divers.*

These were converted to *Grassland* in accordance with the LULUCF *Grassland* definition. The detailed correspondence table OBS89 classes to LULUCF classes is attached in Annex (see Table 6-1 Table of correspondence OBS89 – LULUCF).
After aggregation of the class assignments, the next step in this process is to dissolve the polygons to the LULUCF class, i.e. all neighbouring polygons belonging to the same LULUFC class were aggregated to one simple polygon. By this operation the amount of polygons was reduced from a total amount of 47029 polygons in the OBS89 to 17348 polygons in the LULUCF89.
Figure 3-11 shows the OBS89 map converted to the LULUCF nomenclature in accordance to Table 6-1 in annex.

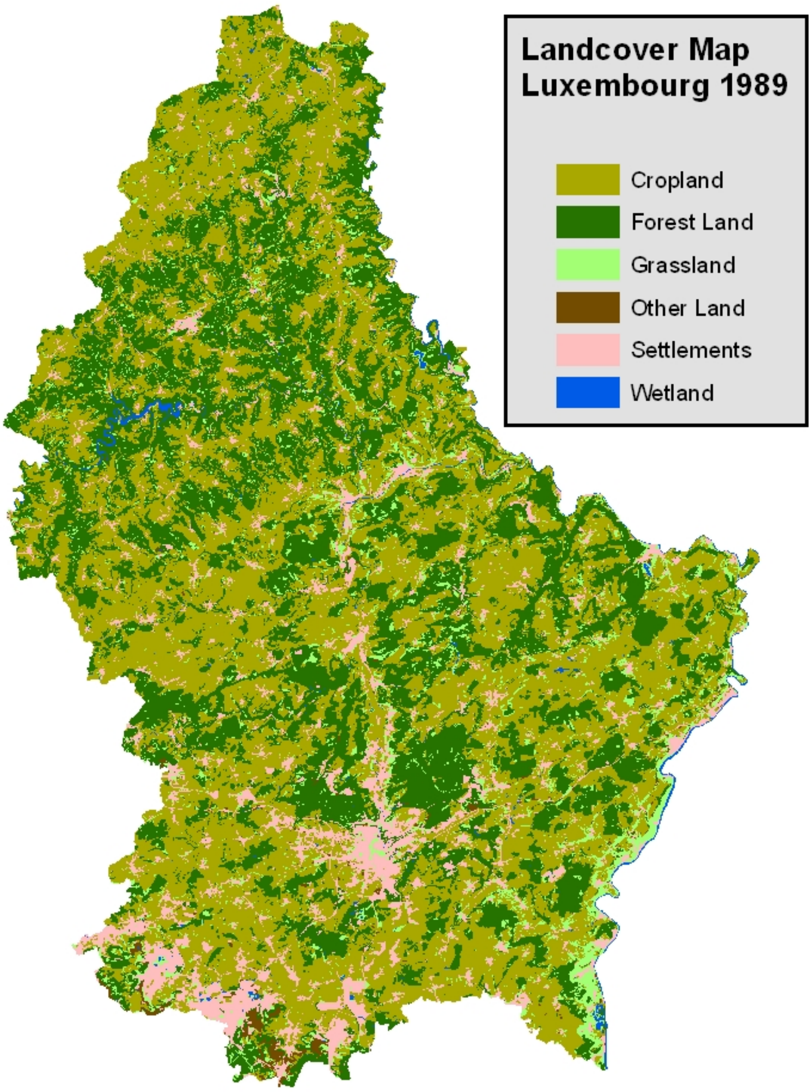


Figure 3-11: OBS 1989 with LULUCF Classes

3.3.3.1.2 Aggregate polygons in accordance to the required Minimum Mapping Unit

The Minimum Mapping Unit (MMU) as defined in the SLA is 0.5ha. As the OBS89 has been prepared at scale 1:15.000, there are of course polygons smaller than the MMU for the satellite data derived map.
After assigning the LULUCF classes to all OBS89 polygons according to the conversion table, these polygons were spatially aggregated following the decision tree for the assignment of polygons < 0.5ha way (Figure 3-12).

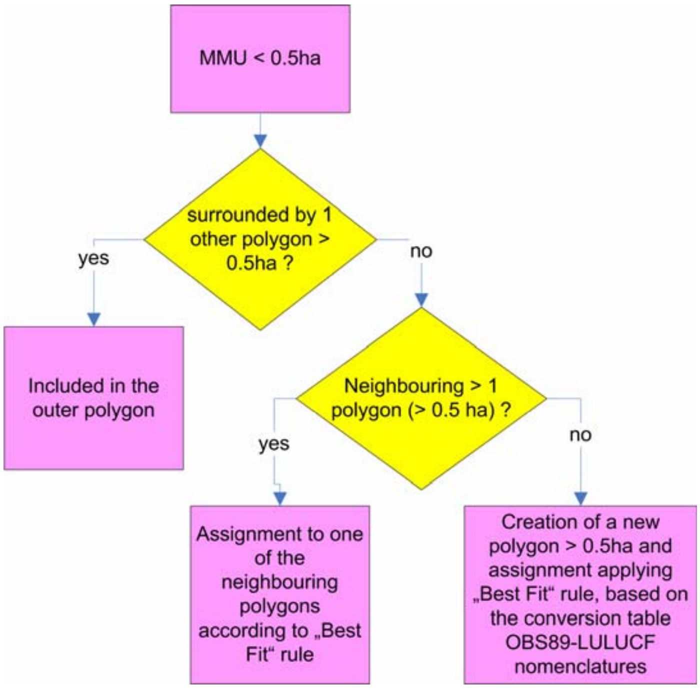


Figure 3-12: Decision tree for aggregation of OBS89 polygons < 0.5ha (MMU)

At the end of this operation, there were 11931 polygons remaining in the LULUCF89 map (see Figure 4-3).

3.3.3.1.3 Identification of Clear Cut areas based on Earth Observation data

Clear cut areas within the forest land, that are covered by bare land or pioneer vegetation (grass, bushes, small trees), can be detected using the SPOT images. This is of utmost interest to reach the objective of the project, i.e. to support the AEF in the reporting to the Kyoto protocol.
A number of areas classified as "Forest" within the Land Use 89 map could clearly be identified as not covered by trees using the SPOT imagery. Figure 3-13 presents an area covered by forest and mainly grassland. The left part shows the area in the SPOT image from 1989 while the right part of the figure shows an aerial photo recorded in 2004. The outlines (in yellow) are the borders of the original OBS89 polygons. The forest areas can clearly be detected. As can be seen here, the OBS89 "coniferous forest" polygon includes the whole area but the satellite image shows clearly different spectral signatures within the polygon. The blue coloured area can be interpreted as clear cut area in 1989, especially with the aerial photo showing low tree or bush cover in 2004 at the same area.

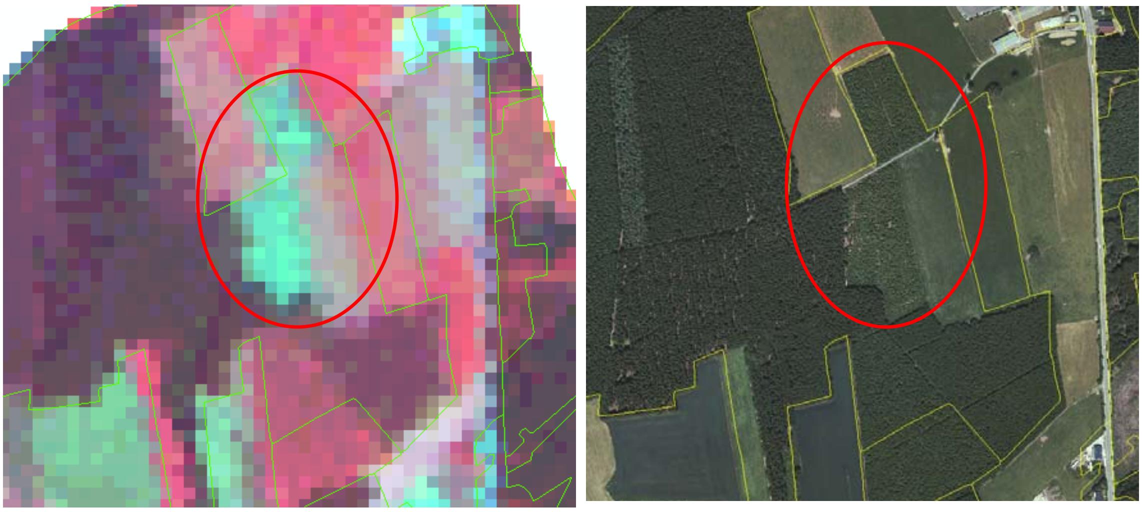


Figure 3-13: Forest and Grassland are shown on the SPOT1 image 1989 (left) and in an aerial photograph from 2004 and the outlines of OBS89 polygons (yellow)

The classification of clear cut areas was based on their reflectance signature using a supervised classification process (non-parametric parallelepiped decision rule) to detect clear cut areas within the OBS89 forest area. All other areas remained unclassified. Areas smaller than the MMU (0.5ha) were excluded. Care was taken not to assign “clear cut area” to former polygons <0.5h, e.g. cropland, which had been assigned to forest area during the dissolve of small polygons in the pre-processing (see 0).
Following this automatic step, the areas detected as clear cuts were checked using the SPOT1 image and the aerial photos from 2004 and assigned to class “new clear cut”. All together, 269 new clear cut areas have been classified.

3.3.3.2 Creation of the forest area map 1989 (GSE-FM-LFM-FA)

The Forest Area 89 map was created based on the Land use map 89, i.e. assignment of *Forest land* areas according to the Forest Area classes described in Table 3-7.

Table 3-7: Forest Area types definitions (LULUCF nomenclature)

Forest classes	Subclasses definition
Forest	All forest and wooded land according to the FAO TBRA2000 definition: • tree crown cover >= 10 % • tree height >= 5 m.
Afforestation	“The direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.”*
Deforestation	The direct human-induced conversion of forested land to non-forested land.*
Reforestation	Direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989.* * In the context of the Kyoto Protocol, as stipulated by the Marrakesh Accords, cf. paragraph 1 of the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry) contained in document FCCC/CP/2001/13/Add.1, p58:
Other land	This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other categories. It allows the total of identified land areas to match the national area, where data are available.

In general, *Forest land* is assigned to *Forest*.

It is not be possible to classify *Afforestation* because of a lack of forest area information during the last fifty years.
Deforestation can only be identified after change detection when the 2007 mapping is available (to be done in phase 2).
Reforestation areas have been taken from the OBS1989 class *32414 vegetation des coupes forestiere* and *32415 recrus divers* that consist of areas with vegetation after a clear cut.
The newly identified clear cut areas (see above) can be assigned to *Reforestation* area only after the change detection with the 2007 mapping because it is just known that these areas were cut down in 1989, but the further development is unknown, i.e. they might also be *Deforestation* areas. They have been assigned a dedicated class labelled *" clear cut*".

Figure 3-14 presents an example of a deforestation area comparing the SPOT 1989 image and the aerial photograph taken in 2004. The SPOT image – overlaid with the OBS89 polygon outline (in yellow) and a forest mask - shows errors in the original OS89 forest section. In comparison with the aerial photograph from 2004 (right), the bright blue area on the SPOT image set as new clear cut was already "no forest area" in 1989, the sandy area below the settlement in the aerial photo did not exist 1989; both will belong to *Deforestation* class in all likelihood when creating the forest area map in comparison between OBS1989 and OBS2007.

Figure 3-14: Example of a deforestation area

The final Forest Area Map presents the following classes:
- forest land,
- reforestation,
- clear cut
- no forest land.
- The final Forest Area map is presented in Figure 4-4.

3.3.3.3 Creation of the forest type map 1989 (GSE-FM-LFM-FTM)

In consultation with the user, it has been decided to create the forest type use map 1989 based on the OBS89 to enable the reporting for the reference year 1989, i.e. to aggregate the OBS89 classes into the required 3 classes as defined in Table 3-8 while polygons were not dissolved and the original size has been kept.

Table 3-8: Forest Types according to SLA specifications

Forest subclasses	Subclasses definition
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.
Decidious:	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 (conifer and deciduous):	with > 10 % crown cover and less than 75 % crown cover of one class.

The OBS89 classes were aggregated to the three forest type classes using the following class aggregations:

- All classes belonging to the higher level class 311 (forêts de feuillus) including the classes 32421 and 32422 (willow trees on moist soils) were aggregated to *deciduous forest*
- All classes belonging to the higher level class 312 (forêts de conifères) were set to *coniferous forest* and
- All classes belonging to the higher level class 313 (forêts mélangés) were set to *mixed forest*

The newly identified clear cut areas were assigned to class No forest land because they are not covered by forest. The final Forest Type map is presented in Figure 4-5.

3.3.3.4 Development of a processing chain for updating the OBS99 using Very High Resolution satellite imagery of the IKONOS sensor

The development and testing of a processing chain for the updating of the OBS99 data using Very High Resolution (VHR) Earth Observation satellite imagery of the IKONOS sensor is required before the roll-out of the project to cover the entire Luxembourg territory in phase 2 of the project.
The procedure has been developed in close collaboration with our partner GIM, which is responsible in GSE-LUX-Land information services for the updating of the OBS99 with IKONOS data.
Figure 3-15 presents the different processing steps required for updating the OBS99 map of Luxembourg.

The **preprocessing** (georectification, atmospheric correction using standard tool provided by image processing software *Erdas Imagine*, mosaicking) is performed by our partner under the integrated approach, i.e. the "Common tasks for GSE-Luxembourg".
A forest mask of the OBS99 within the test site has been generated, containing all polygons assigned to forest classes coded 3.1.xx in the OBS99 nomenclature.
The outer boundaries of the forest polygons, i.e. the lines of forest polygons with neighbouring non-forest classes, are updated based on the IKONOS imagery before delivery of the forest mask to LuxSpace, this to facilitate the later integration of the updated forest polygons without problems after the change detection.

There are two options for the **thematic processing**, i.e. the updating of the OBS99 map:

1. **semi-automatic classification** of IKONOS data based on spectral signatures and textural features without taking into account the existing OBS99 information
2. **computer assisted photo-interpretation (CAP) of IKONOS image based on the OBS99 polygons** and their classification to detect changes in thematic (e.g. deforested polygons) and in geometry (e.g. deforested areas within forest polygons)

The first option will certainly lead to varying geometry, i.e. the borders of (raster) polygons might not exactly correspond to those in the OBS99 vector layer what would create artifical "changes". Far more important is the fact that the spectral differences of tree species as recorded by the IKONOS sensor do not vary enough so that the OBS99 classification cannot be achieved using IKONOS data without the additional information of the OBS99 (see 3.3.3.4.1).
Therefore, the **second option is chosen**. It is the most cost efficient option regarding the needed efforts for setting up an automatic expert classification system including object recognition and existing knowledge from the OBS99 in relation to the area to be dealt with.

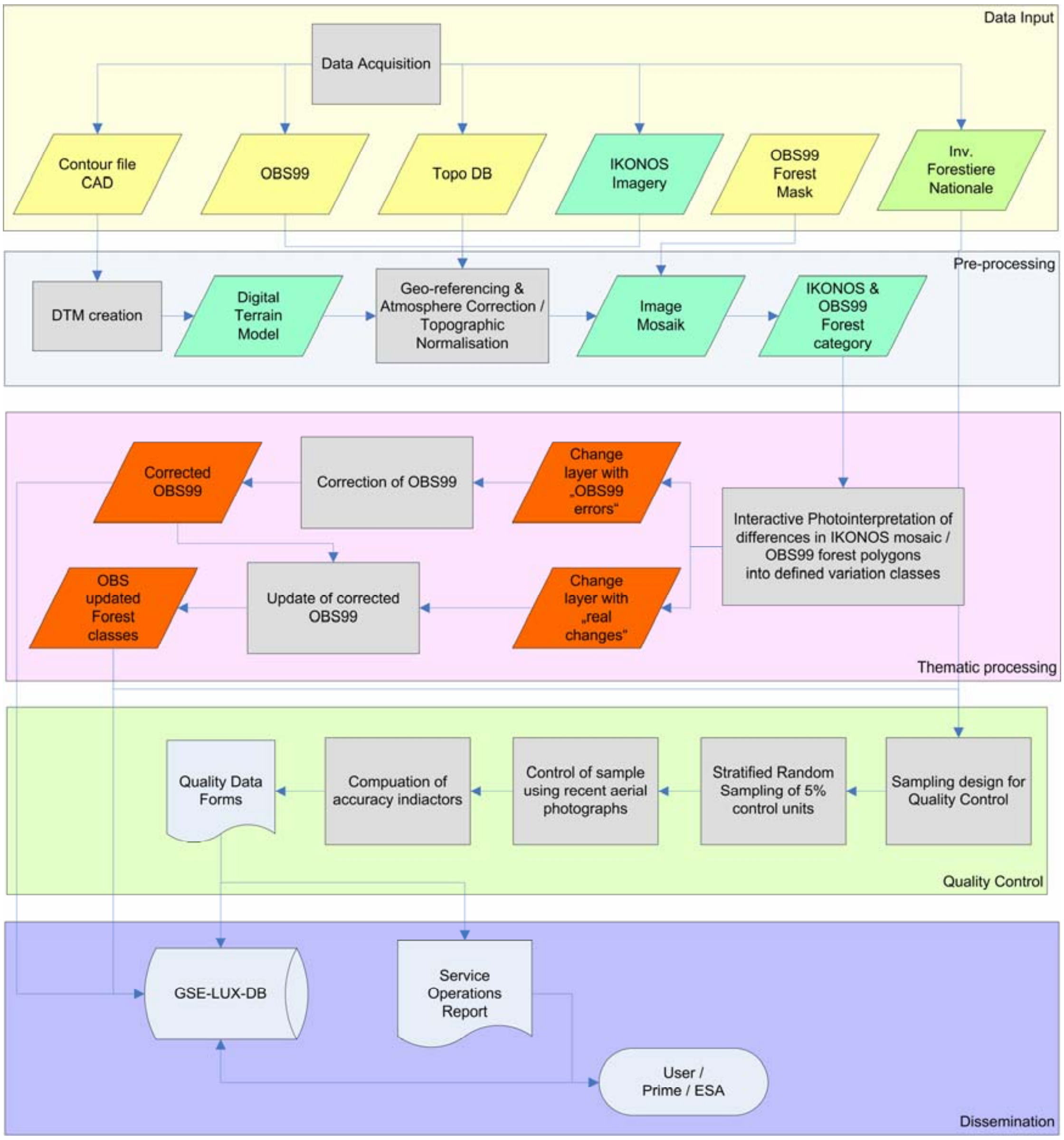


Figure 3-15: Processing chain for updating forest classes of the OBS99 using IKONOS imagery

3.3.3.4.1 Differentiation potential for forest classes by CAPI of IKONOS imagery

In principle, photo-interpretation aims at detection of (geometric and thematic) changes in the forest classification, based on the expertise and experience of the human interpreter. However the interpretation can only be as good as the information content of the IKONOS imagery.

Before starting the interpretation, the potential of these images for distinguishing forest classes and / or tree species need to be analysed.

The IKONOS sensor provides for very good differentiation between the main forest types, i.e. deciduous and coniferous forest species. While the coniferous forest is displayed in a dark colour (low spectral reflectance), the deciduous trees “appear much brighter” i.e. have a higher spectral reflectance in the near infra-red.

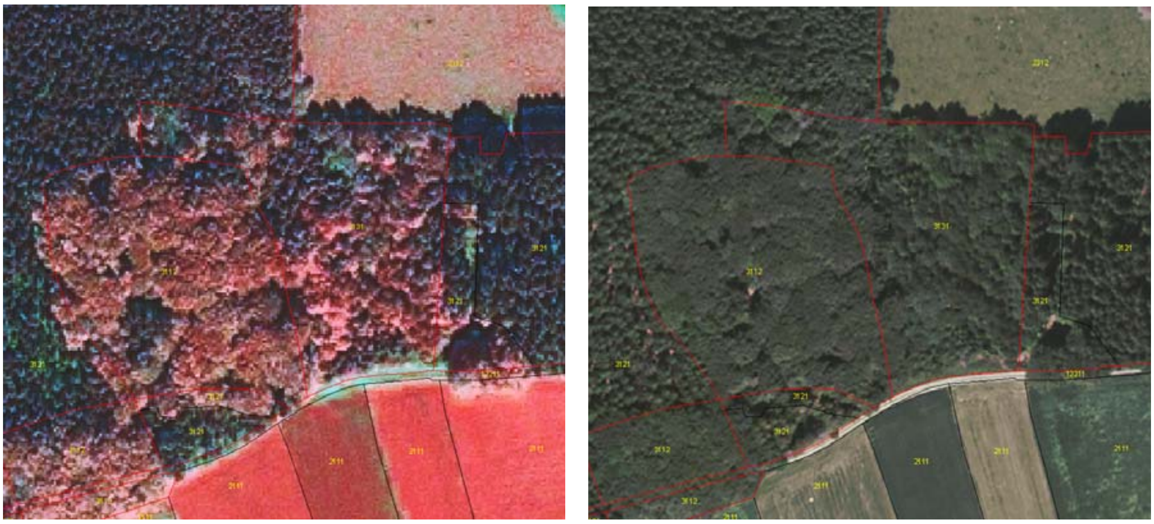


Figure 3-16: Clear differences between deciduous and coniferous forest in Ikonos imagery (left) and the aerial photograph (right)

The IKONOS imagery allows detecting differences within both broad classes but it is not possible to identify the tree species from the satellite sensor information from scratch. This means on the one hand, that the OBS99 information, i.e. the classification of the polygons into the detailed forest types or tree species, is absolutely necessary as a reference for the continuation (updating) of the OBS map.

It is assumed that changes in the classification of a polygon, for example from "oak forest" to "beech forest" do not occur in the timeframe of a few years meaning that the observed information of the OBS99 will prevail. True changes in forest land cover will mainly consist in loss of forests (cut areas) or reforestation (human induced – plantations or natural re-growth).

On the other hand, the potential of differentiation using the spectral signals received from the satellite sensor within a single polygon of the OBS allows improving the OBS99 classification. For example, knowing that a polygon should consist of an oak wood according to the OBS99 (as the polygon in the centre and the central south in Figure 3-17) some impurities can be detected based on the different spectral reflectance. Comparing the more "red coloured" region in the south west of the oak wood polygon with the beech wood polygon in the north-east of the image sub-set, the interpretation of the satellite image may lead to change the polygon class to "Oak-Beech forest" or to a separation of the polygon into 2 polygons, one remaining "oak" and the other assigned to the "beech forest" class.

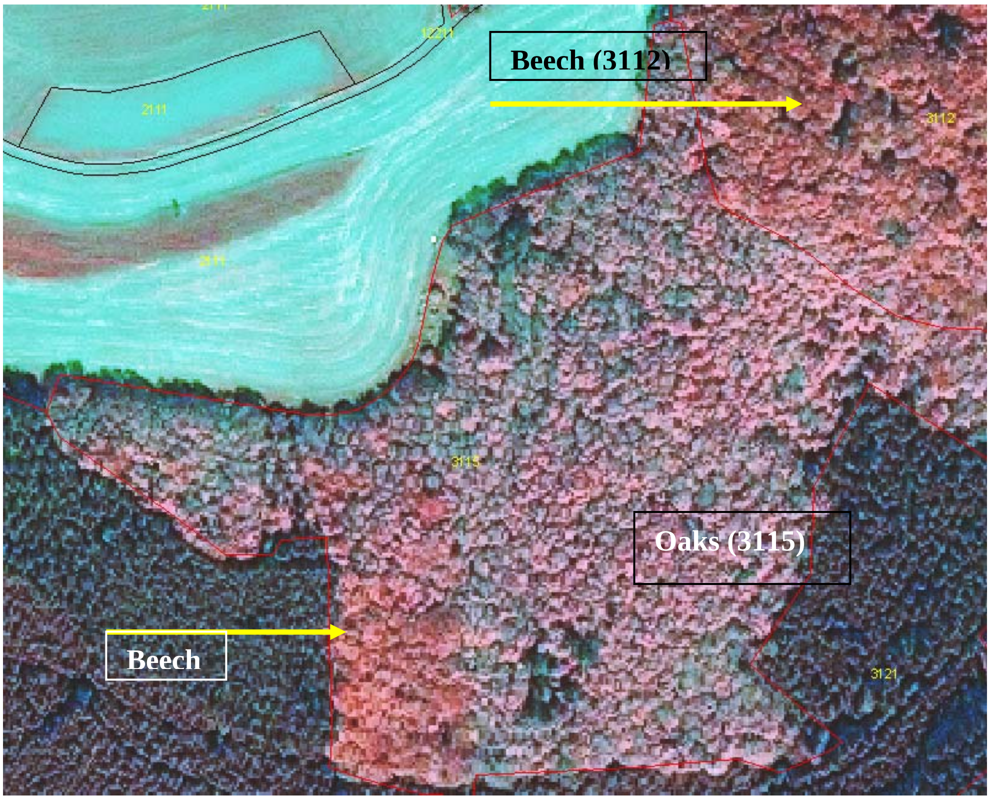


Figure 3-17: Distinguishing Oak coppice (class 3115) and beech trees (class 3112) within an OBS99 pure oak coppice polygon based on the spectral signature in the IKONOS satellite image

In other cases, there are OBS polygons classified into different classes having almost the same spectral signature in the satellite image (see Figure 3-18). The "oak forest" polygon (left) displays about the same signature / structure ("green") as the "other deciduous trees" polygon (right). Again, the OBS99 information is necessary for the updating, assuming that the field surveys done to establish the OBS99 classification are correct.

Figure 3-18: Similar appearance of "other deciduous trees" (right polygon; 3113) and "oak trees" (left polygon; 3111)

Such uncertainties occur in both broad classes but specifically in coniferous forest, where differentiation is only based on OBS99 information.

Regarding the classification of reforested areas (with young stands) the age information of the trees is needed for a correct classification. Crown radius or the plantation structure as seen in the satellite image are only very rough indicators for the age of a forest. Figure 3-19 presents an example of the of reforested coniferous forest area showing trees following linear plantation structure. In older stands, this structure disappears due to selected felling. In deciduous forests, size of crown radius offers differentiation potential between young and old trees.

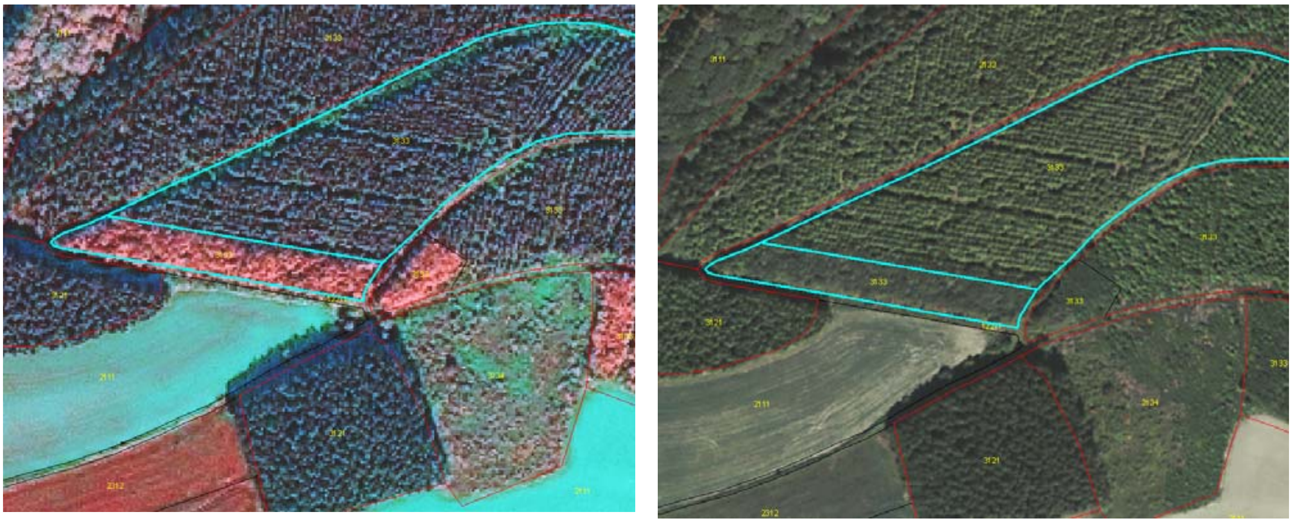


Figure 3-19: good differences between coniferous and deciduous forest but no real age information above all in coniferous forest (in deciduous forest because of crown structure

Classification errors in the OBS99

In other cases it is evident that there is a content error in the OBS99 as shown in Figure 3-20, where there is a deciduous forest region classified as coniferous forest. Due to the very similar spectral signatures in the IKONOS sensor bands, it is not possible to specify the tree species. These areas were interpreted being "beech-oak forests" (class 3114) when there are some trees showing the typical beech tree or oak tree reflectance, or to "other deciduous forests"(class 3113).

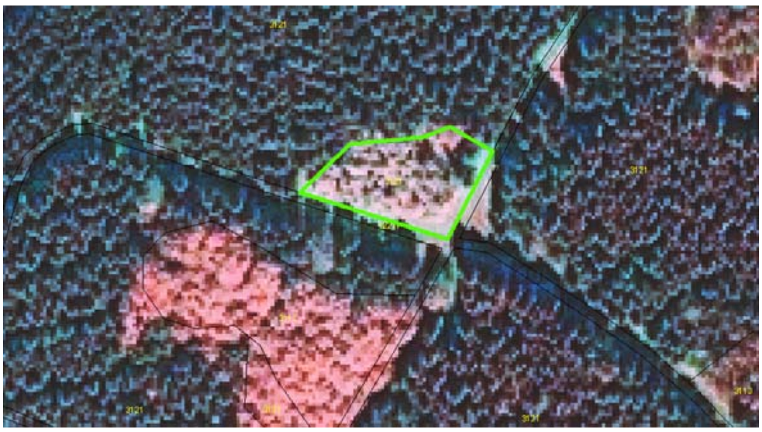


Figure 3-20: Deciduous forest classified as coniferous forest in the OBS99

Geometrical errors in the OBS99

During the test, geometrical errors in the OBS99 could be detected. Figure 3-21 presents an example of such geometrical errors in the OBS99 forest areas: the OBS99 outlines (in red) do not match the borders of homogeneous land cover areas as they can be detected in the satellite image, i.e. in the Western and the central part of the area, while in the Eastern part the borders coincide (so it seems not to be a problem of georectification of the satellite image). The labels (in yellow) are the original OBS99 class codes for every corrected polygon, 12211 being roads, 2312 being meadows, 3111 and

3112 being deciduous forest, 3121 being coniferous forest, 3133 being reforestation area and 3134 being other forest area after clear cuts. The black lines represent the corrected outlines. Figure 3-22 shows the same area with the aerial images as background confirming the errors in the OBS99.

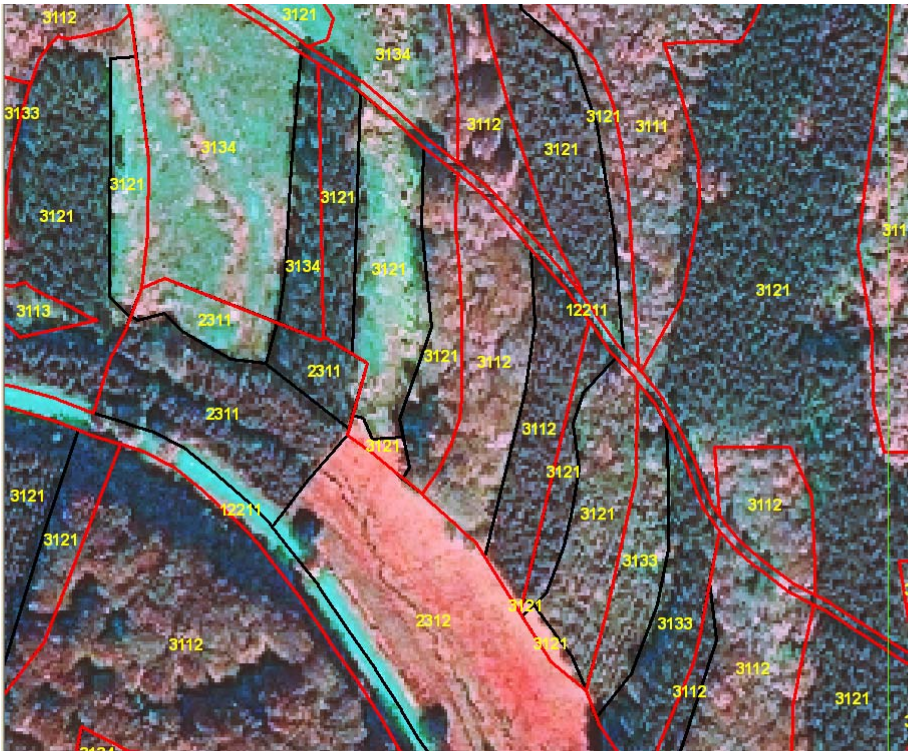


Figure 3-21: evidence of errors in the OBS borders as seen by the IKONOS sensor

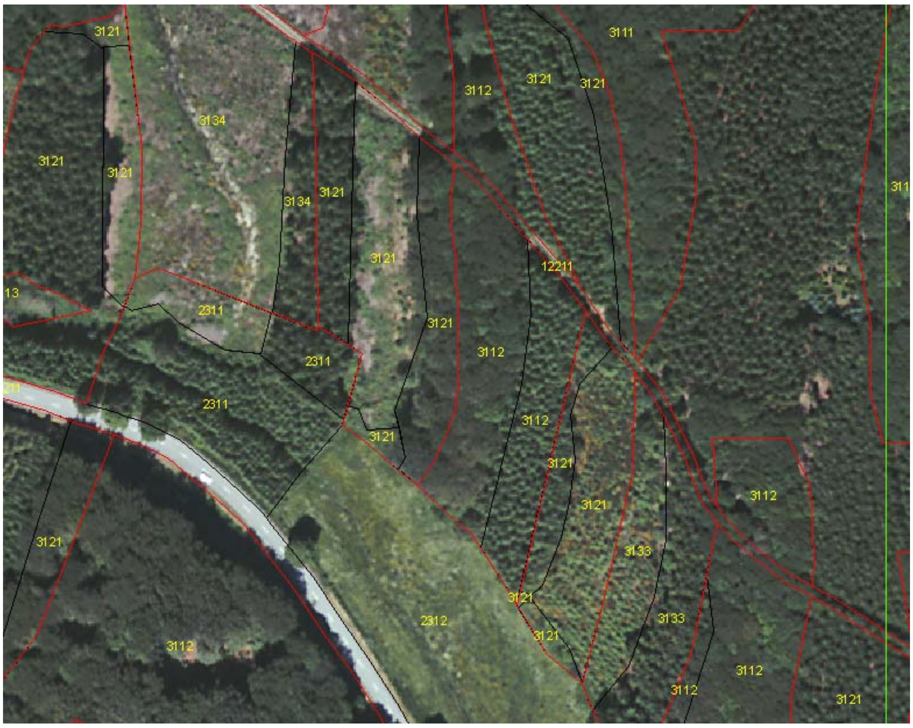


Figure 3-22: Evidence of errors in the OBS borders as seen by the aerial photograph

In any case, care is to be taken due to shadows that often have a similar signal as the forest signal as shown in Figure 3-23. This might lead especially in coniferous forest polygons to an overestimation of the forest area.

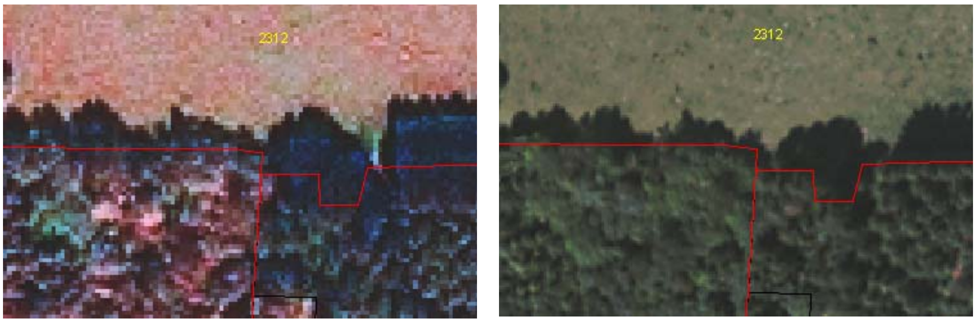


Figure 3-23: Left: Ikonos False-color Image; Right: true color aerial orthophoto; Shadows signatures are similar to forest signals in Ikonos imagery

Resuming this analysis, the IKONOS imagery used for the test provides a good possibility to detect changes in the OBS99. Taking into account the available information from OBS99, distinction of different forest classes is continued.

3.3.3.4.2 Forest classes

The concerned – thematic - **forest classes** for updating the OBS99 are defined in Table 3-9

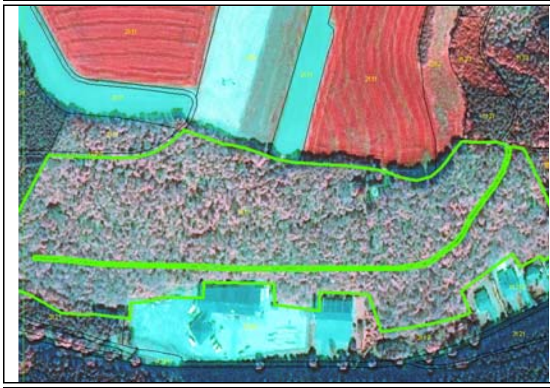
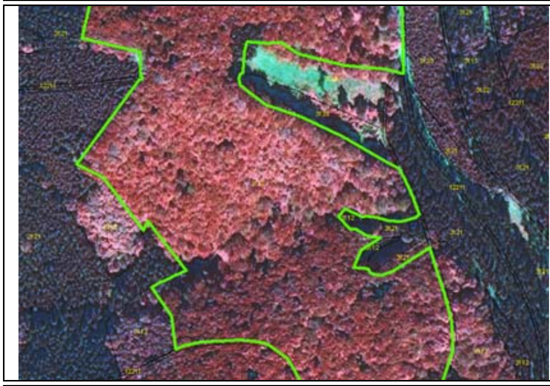
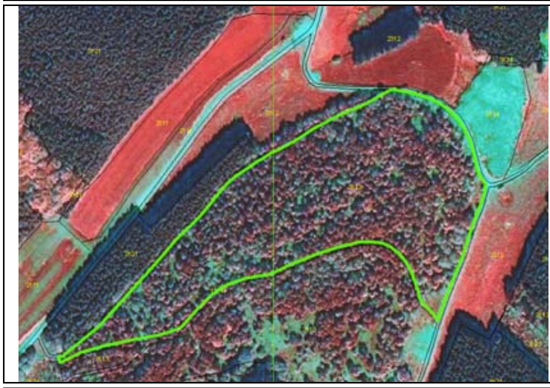
Table 3-9: Nomenclature of forest classes in the OBS99[10]

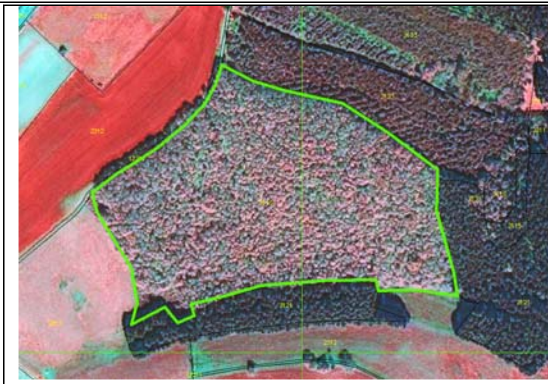
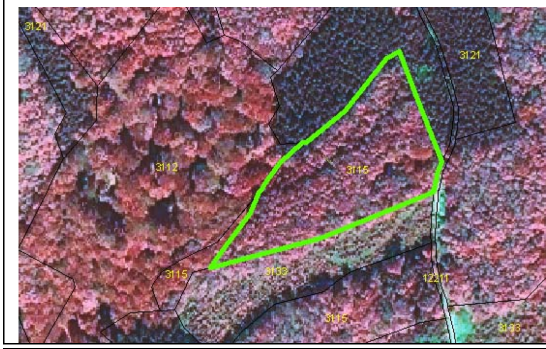
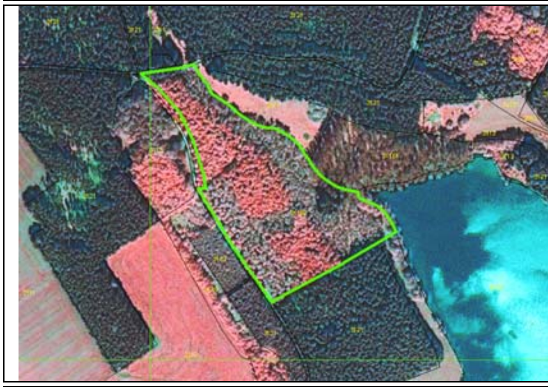
Code OBS99	Legend (EN)	Abbrev. (DE)	Legend (DE)
3.1.1.1	Deciduous Forest, Oak	WLE	Laubwald, Eiche
3.1.1.2	Deciduous Forest, Beech	WLB	Laubwald, Buche
3.1.1.3	Deciduous Forest, Mixed	WLS	Laubwald, sonstige Laubbaumarten
3.1.1.4	Deciduous Forest, Mixed Oak and Beech	WLM	Laubwald, gemischt, Eiche, Buche
3.1.1.5	Oak coppice	WLN	Eichen-Niederwald
3.1.1.6.1	Monoculture - Poplars	WLP	Laubwald, Pappel-Monokulturen
3.1.1.6.2	Monoculture - other deciduous	WLO	Laubwald, forstliche Monokulturen
3.1.2.1	Coniferous, Spruce/Douglas Fir/Fir	WNF	Nadelwald, Fichte/Douglasie/Tanne
3.1.2.2	Coniferous Pine/Larch	WNK	Nadelwald, Kiefer/LΣrche
3.1.2.3	Coniferous mixed	WNM	Nadelwald, gemischt
3.1.3.1	Mixed forest (deciduous/coniferous), mixed stands	WMT	Mischwald (Laub/Nadel), truppweise Mischung
3.1.3.2	Mixed forest (deciduous/coniferous), continuously mixed	WMF	Mischwald (Laub/Nadel), fliessende Mischung
3.1.3.3	Affforestation, species not recognisable	WAU	Aufforstungen, Dickungen (Baumart nicht erkennbar)
3.1.3.4	other forest land, (clear cut areas, Windfall)	WSF	Sonstige ForstflΣchen (Schlagflur, Windbruch)

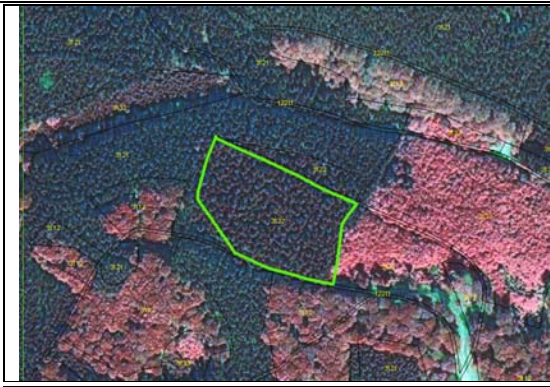
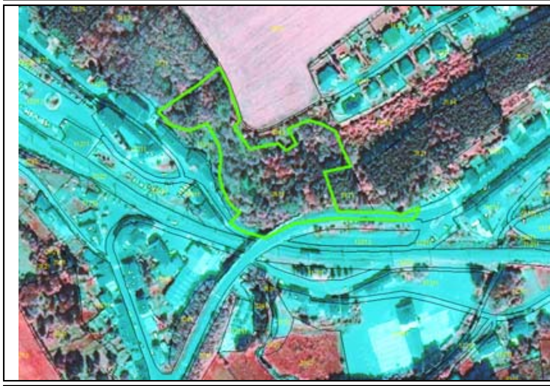
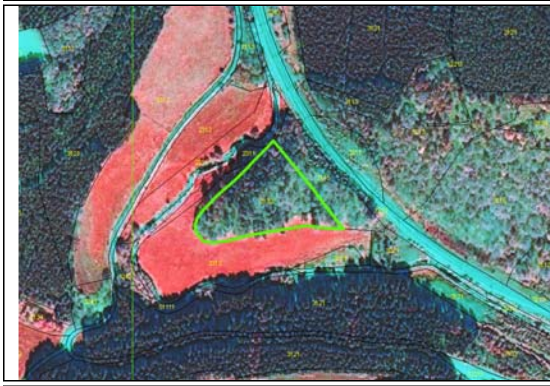
The "interpretation key" developed for the OBS99 mapping includes more or less detailed class descriptions and example photographs (aerial and in-situ) to help the photo-interpreter in the task.
Table 3-10 presents image sub-sets as examples taken from the IKONOS image (in pseudo-color for best distinction, i.e. Red [Near-Infrared], Green [Red] and Blue [Green]) for the defined forest classes (but the class "coniferous mixed" that is not represented in the test area).

[10] source: Hansa Luftbild (1999): Occupation Biophysique du Sol – Grand Duché de Luxembourg – Interpretationsschlüssel

Table 3-10: IKONOS image examples for forest classes in the OBS99

Code	Legend (EN)	
3.1.1.1	Deciduous Forest, Oak	
3.1.1.2	Deciduous Forest, Beech	
3.1.1.3	Deciduous Forest, Mixed	
3.1.1.4	Deciduous Forest, Mixed Oak and Beech	

3.1.1.5	Oak coppice (2 examples to illustrate differences in spectral signatures)	 
3.1.1.6.1	Monoculture - Poplars	
3.1.1.6.2	Monoculture - other deciduous	
3.1.2.1	Coniferous, Spruce/Douglas Fir/Fir	

3.1.2.2	Coniferous Pine/Larch	
3.1.2.3	Coniferous mixed	Not available in test area
3.1.3.1	Mixed forest (deciduous/coniferous), mixed stands	
3.1.3.2	Mixed forest (deciduous/coniferous), continuously mixed	
3.1.3.3	Affforestation, species not recognisable	

3.1.3.4	other forest land, (clear cut areas, Windfall)	

This table will be completed in the next project phase.
It is proposed to complete the photo-interpretation key developed in the framework of the OBS99 mapping project with additional IKONOS image examples.

3.3.3.4.3 Classification of detected changes

As described above, a number of changes have been detected during the test. In fact not all these changes are "real" land cover changes but errors in the OBS99 – both geometrically and thematically. Therefore it is proposed to develop in the next phase a **classification of detected changes.** Such a classification might look like Table 3-11.

Table 3-11: Examples for change categories

ID	Change type
1	Real changes
2	Classification error in the OBS99 layer
3	Geometrical errors in the OBS99 layer
4	…
5	… (other specific errors that might appear outside the forest mask
…	…

In the delivered data file, there are fields containing information on the type of change (geometric change, content change).

3.3.3.5 Creation of the forest type map – update of the OBS99 forest classification using Very High Resolution satellite imagery of the IKONOS sensor (GSE-FM-SUB-FI2004Test)

The forest information of the OBS99 has been updated by application of the developed processing chain as described in chapter 3.3.3.4 above.
The final Forest Type map is presented in (page 52).

3.3.3.6 Landscape indicators

The following indicator products were calculated based on the 1989 LULUCF data for the Ecological Sections as delivered by the AEF.
Analysis of the indicators require deep knowledge and understanding of the regions concerned. Such analysis will have to be performed by the users and is not subject of this project.

Table 3-12: Fragmentation and Structural Diversity Indicators

Index	Description
Area metrics	The index "Area Percentage of Landscape" (APL) expresses the area proportion of one class type in % of a specific landscape.
Patch metrics	The Patch Density (PD) index describes the total number of patches or their relative proportions in a given area (e.g. 100ha).
Edge metric	The Edge Density (ED) index describes the amount of edges occurring between patches or classes per given area (e.g. 100ha).
Shape metrics	The Landscape Shape Index (LSI) is a measure for the complexity of forest shapes.
Core area metrics	Core area metrics compute statistics about the inner central parts of patches in relation to the total patches and provide information about the quality of habitats for certain species. The Total Core Area Index (TCAI) is computed as percentage of the total core area in relation to the total area.
Nearest Neighbour metrics	Nearest neighbour indices quantify landscape configuration. The Mean Nearest Neighbour Distance (MNN) index averages all minimum distances of all patches to their nearest patch partner.
Diversity metrics	The Shannon Diversity Index (SHDI) measures the extent to which one or a few class types dominate the landscape index.

The processing chain for the calculation of the indicators is presented in Figure 3-24.

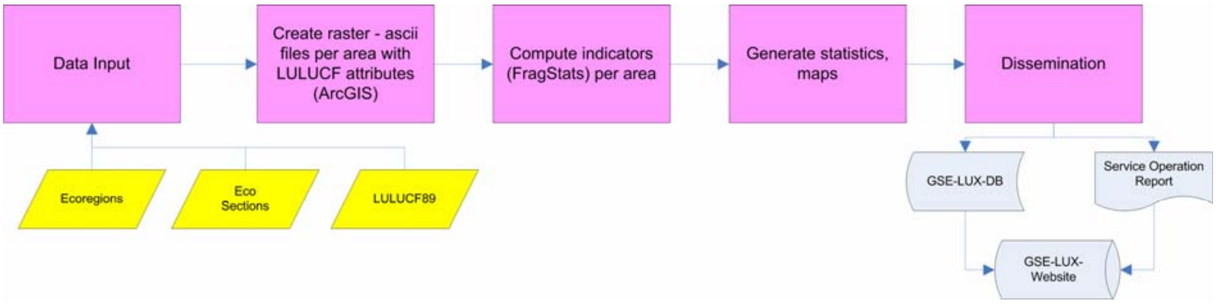


Figure 3-24: Processing chain for fragmentation indicators

First, the geographic data (borders) of the eco-regions and eco-sections are to be joined with the LULUCF89 data to know the assignment of each polygon to its eco-region/section. For the calculation of the indicators the *Fragstats* software[11] is used. Input format for Fragstats is ASCII, so the geographic data is to be transformed into raster format and then to ASCII format. After some trials 50m has been found to be the most suitable cell size for the raster with regards to interpretation of the results of the small structured landscape in Luxembourg.
The following indicators were computed:

[11] see http://www.umass.edu/landeco/pubs/pubs.html#fragstats; McGarigal, K., and B. J. Marks (1995): FRAGSTATS: spatial pattern analysis program for quantifying landscape structure.- USDA Forestry Service, General Technical Report PNW-351

Table 3-13: Fragmentation indicators based on the LULUCF89 data at level of Ecoregions and Ecosections for Luxembourg as defined by AEF

<table>
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- Total area CA/TA: For the calculation of the APL (AREA PERCENTAGE (OF LANDSCAPE), Total Area CA/TA is chosen (not percentage of Landscape, PLAND) because Fragstats takes into account the background for this specific calculation of PLAND. APL is then calucaled using spreadsheet software.
- Patch Density PD
- Landscape Shape Index LSI
- Edge Density

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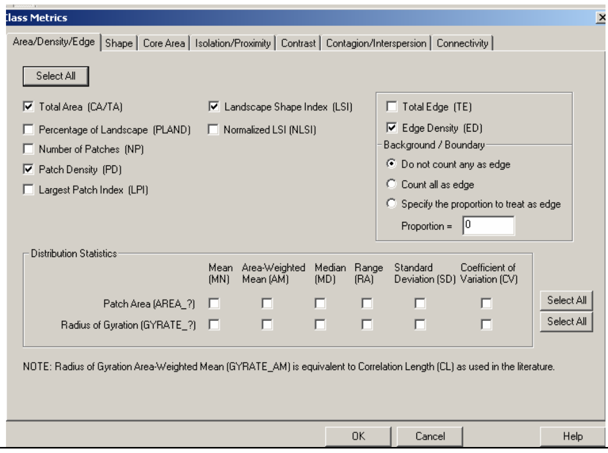

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- Core Area index – Weighted Mean CAI_AM (under Core Area tab). This is the same as Total Core Area Index (TCAI). As fixed Edge Depth the 50 m resolution (raster cell size) is introduced.

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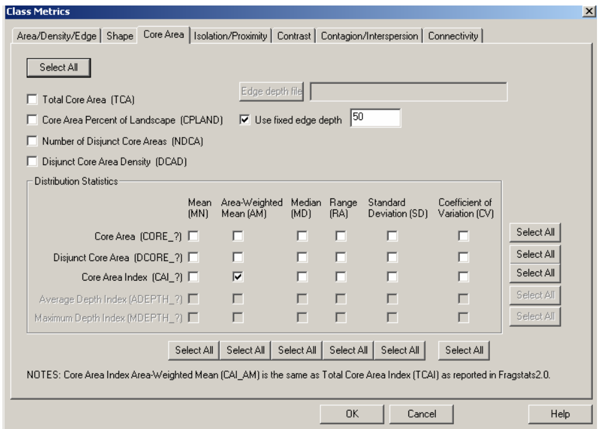

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- Euclidean Nearest Neighbour – Mean ENN_MN (under Isolation/proximity tab): It corresponds to the Mean Nearest Neighbour Distance.

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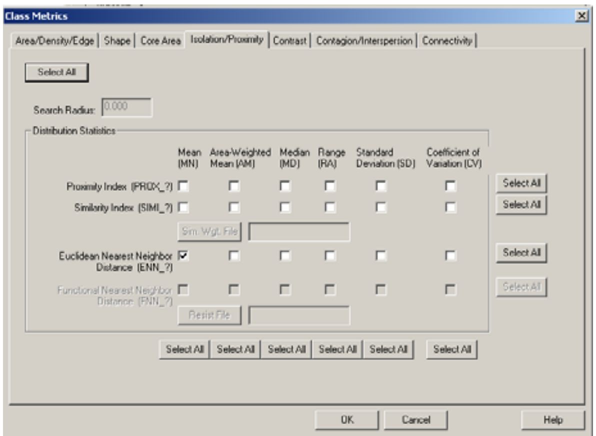

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- Shannon´s Diversity Index SHDI (in the Land metrics menu, under Diversity tab)

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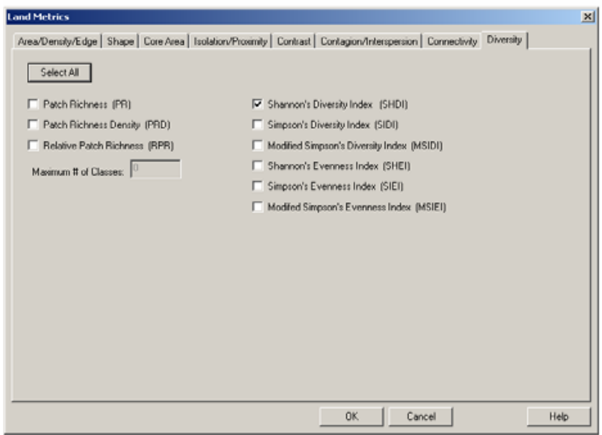

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</table>

The resulting statistics are put into tables in a spreadsheet to produce the tables Table 4-12, Table 4-13 and Table 4-14 on page 54 ff.

3.4 Data Dissemination

Date products as well as all the related documentation will be made available on a restricted area of the project's web portal (creation in progress).
This portal generally represents an implementation of the metadata standard that will be used for all data exchange and cataloguing of GSE FM services. It is accessible to the user and to all partners of the GSE FM consortium.
The deliverables were made available on 5 December 2007 to the user via FTP download and on media at the second user meeting.

3.5 Quality Control - Approach in GSE-FM-LUX phase 1

The quality control system records and documents the production process and provides the verification results of the products. This assessment is done – as far as possible - on the base of quantitative measures that are compared to the requirements specified in the SLA.
The overall concept of quality control for the GSE FM services is presented in the document M2, Project Quality Plan. Furthermore it serves as one basic information source for the independent validation process.

3.5.1 Quality Control - Approach in GSE-FM-LUX phase 1 on 1989 products

As stated above, most of the work carried out in this phase has been based on the use of the OBS89, i.e. conversion of the nomenclature to the LULUCF definitions with regards to land use, forest area and forest type classes.
The work based on the SPOT1 imagery from 1989 concerned the identification of clear cut areas, which were not identified as such in the OBS89 map, i.e. areas that were not classified as classes *32414 "vegetation des coupes forestiere"* and *32415 "recrus divers"*. This means in fact, that the quality of the OBS89 was increased by adding clear cut areas that were not identified during the OBS89 data collection.

That is why the focus of the quality control has been put on the accuracy assessment of the correct identification of the clear cut areas detected in the SPOT1 mosaic.

Besides the OBS89, there is no other reference data that was collected in that year (or close by in time) available to control the classification of *new clear cut* areas.
To get somehow an indication of the quality, the only possibility to derive a quantitative statement on the accuracy of the interpretation is to re-interpret the image by another person, which in fact compares the experience and regional knowledge of both photo-interpreters, but does not deliver an objective comparison with the reality at that time.

Control with photo-interpretation by another interpreter

A random sample of 25% of the new clear cut areas have been controlled by a different interpreter, meaning that the 69 newly identified clear cut areas have been checked on–screen by the project manager.

The result is as follows:

Table 3-14: Result of control of clear cut areas assignment by different interpreter

Original OBS89 class	new clear cut	%
3121 Coniferous forest – Spruce	4	5.80%
3131 Mixed forest	1	1.45%
31121 Beech with orchids	2	2.90%
31153 plantations of deciduous species	3	4.35%
new clear cut	59	85.51%
Total	69	100.00%

The control showed that **85% of the controlled sample has been correctly classified**.

This approach just controls the correct assignment of "New Clear Cut" areas, but does not control the completeness of these assignments, i.e. it does not answer the question: *Were all new clear cut areas identified ?*

Therefore in addition to the above, another approach has been applied:
- Creation of a regular grid (cell size 1*1 Km2) covering the entire territory of Luxembourg
- Intersect with the forest layer of the OBS89 map (about 2581 cells)
- Random selection of 5% of these cells (129 cells)
- Interactive control of the sample on-screen by the project manager: identification of "New Clear Cut" areas in case these are not mapped by the interpreter

The result of this control is that in 9 of 129 cells, a clear cut area has been found that was not identified before, i.e. about 7% of omission errors or **93% accuracy**.

3.5.2 Quality Control - Approach in GSE-FM-LUX phase 1 on 2004 product (test scene)

3.5.2.1 Quality Control using the IFN2000 data

One option to assess the quality of the classification is to compare it with the available information from the IFN (National Forest Inventory). This point data has been collected in the field during a period from 1998-2000. The approach is simply to compare the classification of the forest stand in the IFN with the polygon classification, in which the IFN is located.
First, the corresponding classes of both classification systems need to be identified in a conversion table, focussed on the forest classes of the OBS99. There is no 1:1 relationship between the OBS99 and the IFN classes, as shown in Table 3-15, i.e. for the quality control, the classification has been assessed "correct" if one of the IFN classes coincide with the classification done in the test.

Table 3-15: Nomenclature of forest classes in the OBS99[12]

OBS99 Code	Legend (EN)	IFN class label	IFN Label 2
31110	Deciduous Forest, Oak	Deciduous Oak forest	
31120	Deciduous Forest, Beech	Deciduous Beech forest	
31130	Deciduous Forest, Mixed	Deciduous Mixed forest	
31140	Deciduous Forest, Mixed Oak and Beech	Deciduous Mixed forest	
31150	Oak coppice	Deciduous Oak forest	
31161	Monoculture - Poplars	Deciduous Poplar forest	

[12] source: Hansa Luftbild (1999): Occupation Biophysique du Sol – Grand Duché de Luxembourg – Interpretationsschlüssel

31162	Monoculture - other deciduous	Deciduous, other species	
31210	Coniferous, Spruce/Douglas Fir/Fir	Coniferous Douglas Fir forest	Coniferous Spruce forest
31220	Coniferous Pine/Larch	Coniferous Pine Forest	Coniferous Larch forest
31230	Coniferous mixed	Coniferous mixed forest	Coniferous, other species
31310	Mixed forest (deciduous/coniferous), mixed stands	Mixed forest, dominated by Coniferous trees	Mixed forest, dominated by deciduous trees
31320	Mixed forest (deciduous/coniferous), continuously mixed	Mixed forest, dominated by Coniferous trees	Mixed forest, dominated by deciduous trees
31330	Affforestation, species not recognisable	Other wooded land (fallow land, clearing, bushy area)	
31340	other forest land, (clear cut areas, Windfall)	Clear Cut area	

The following table provides the results of this comparison.

Count of QC	IFN_Label								
OBS99 Label	Clear cut area	Coniferous Douglas fir forest	Coniferous Spruce forest	Deciduous Beech forest	Deciduous Oak forest	Deciduous valuable forests	Mixed forest, dominated by Coniferous trees	Mixed forest, dominated by Deciduous trees	Grand Total
Coniferous Pine/Larch		1							1
Coniferous, Spruce/Douglas Fir/Fir			26		1				27
Deciduous Forest, Beech				7		1			8
Deciduous Forest, Mixed					1				1
Deciduous Forest, Oak					3			1	4
Mixed forest (deciduous/coniferous), mixed stands				2				1	3
Oak coppice					1			1	2
other forest land, (clear cut areas, Windfall)			1						1
Prairie mesophile	1								1
Afforestation, species not recognisable			7		2		1	2	12
Grand Total	1	1	34	9	8	1	1	5	60

The analysis shows first of all, that 60 IFN points fall into the forested area within the test site. Having a close look to the comparison, it can be concluded that 22 classifications do not coincide, i.e. 36.6 % misclassification. Here it is assumed that in the IFN survey, "Afforestation" or "windfall" or "clear cut areas" have been classified to the forest types they belong to, so the confusion between "Afforestation, species not recognisable" and several classes of the IFN forest type classification might be explained by that. Some 12 "errors" can then be deducted resulting in 10 cases of confusion between IFN and OBS99, about 16.7% or 83,3% accuracy. It is to be noted, that in fact 4 IFN points fall into polygons that were updated during the test based on the IKONOS image (out of which three are differently classified). This means concretely, that in fact the comparison performed is done between the OBS99 and the IFN2000 data.

3.5.2.2 Quality control based on a random sample of control points

A second approach to assess the thematic accuracy is to control a sample of control points, randomly distributed over the test area. The QC is focussed on the forest categories, so control points outside the forest mask are not subject of this Quality Control (these were controlled by our colleagues doing the OBS99 update for the other land cover classes. The control points have been created using a specific GIS tool allowing random point sampling over the area of interest. In total 500 control points were selected randomly, of which 121 fall into the forest mask.

The sampled control points are visually interpreted by another interpreter using true-colour aerial photographs recorded in 2004. The result of the quality control is presented in Table 3-16.

Table 3-16: Confusion matrix – result of quality control OBS99 update (IKONOS2004) on test site vs aerial photographs of 2004

Count of CHANGE	OBS_Poly										
OBS_2007	31110	31120	31130	31140	31150	31210	31310	31330	31340	32430	Grand Total
31110	2										2
31120		12									12
31130			1								1
31140				2							2
31150					8						8
31210						63		1		1	65
31310							2				2
31330								25	1		26
31340									3		3
Grand Total	2	12	1	2	8	63	2	26	4	1	121

As can be seen, the control by another photo-interpreter (project manager) resulted in the detection of 3 errors out of 121 controlled points. Accordingly the total accuracy of the test result is assessed to be of 97,5%.

4 Results

This section covers the presentation of the final products and its verification and accuracy assessment results. Explanatory information will be given for each of the products in terms of overview images, visualisation or a brief description.

4.1 Image Products

Product : **Ortho images and mosaics 1989**
Product Code: GSE-FM-OIM-1989
Description: Ortho-rectified SPOT1 satellite images, multispectral mode (20m resolution) and mosaicked covering the entire Luxembourg territory in a seamless coverage
File:
Tiff file: GSE-LUX-FM_1989_SPOT1_Mosaic
Erdas img file format: GSE-LUX-FM_1989_SPOT1_Mosaic.img
Opening the tiff file with a standard image processing program (e.g. Microsoft Imaging) does not correctly apply a histogram stretch, so the image looks too dark. It is recommended to open it using ArcGIS or Erdas Imagine results in a correct look.

Main data source:

• SPOT1 (ms) scenes recorded in 1989:

Table 4-1: SPOT1 images acquired and used for product generation

Scene N°	Description (source: SPOT image Metadata)	Date
1	1 046-249 89-07-19 10:52:24 1 X Level 1B SAT 0	19/07/1989
2	1 048-250 89-05-07 10:55:55 2 X Level 1B SAT 0	07/05/1989
3	1 047-249 89-05-23 10:47:51 2 X Level 1B SAT 0	23/05/1989
4	1 046-250 89-07-19 10:52:32 1 X Level 1B SAT 0	19/07/1989
5	1 046-248 89-07-19 10:52:15 1 X Level 1A SAT 0	19/07/1989

Auxiliary data sources used in production process:

• OBS89
• DEM Digital Elevation Model

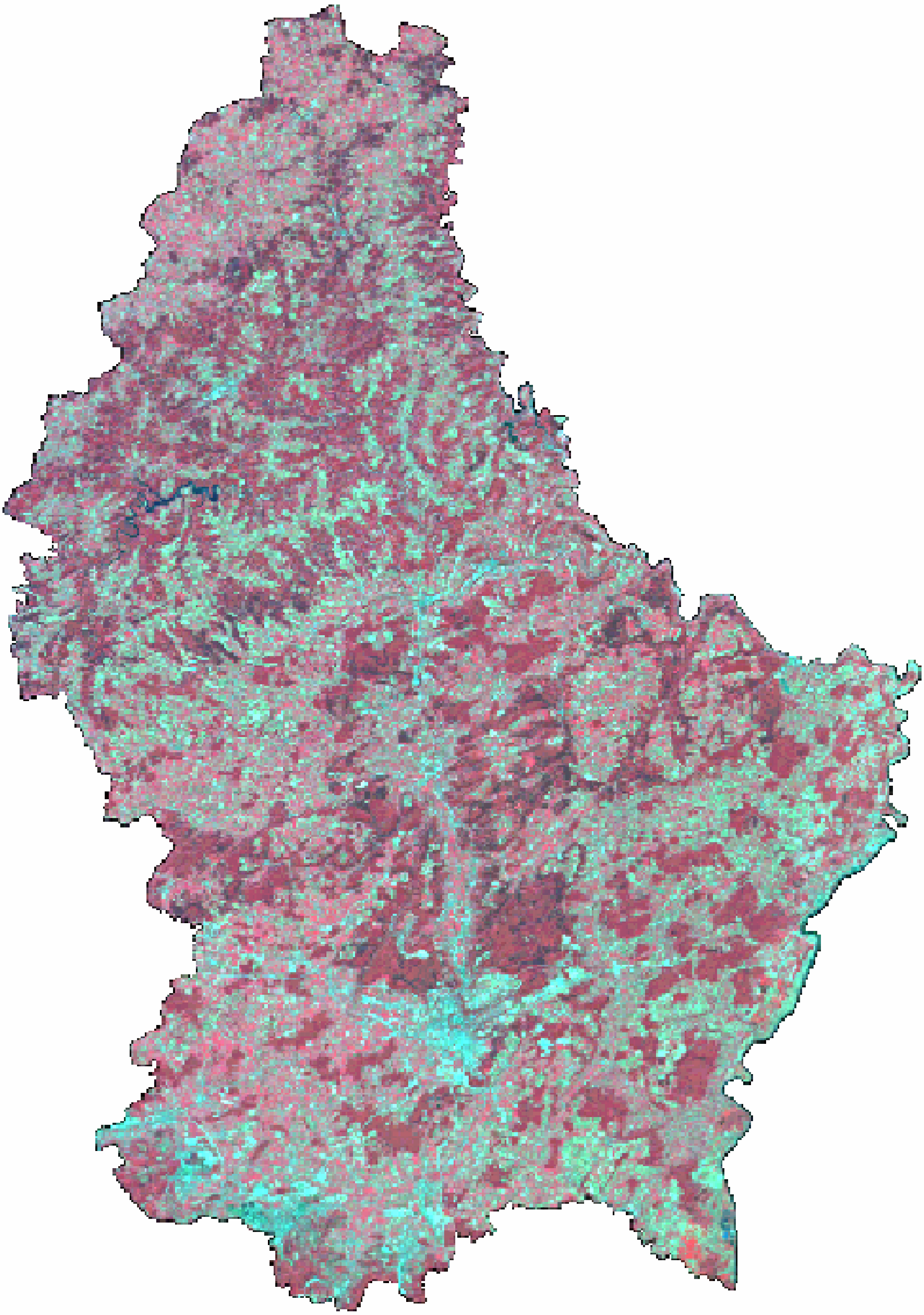

Figure 4-1: Mosaic image (GSE-LUX-FM_1989_SPOT1_Mosaic)

Verification Results:

The Accuracy assessment procedures used for verification of this product are described in the document S5, Service Portfolio Specification. During the production process these results are recorded, as shown in Figure 3-10: Processing Chain GSE-FM-LULUCF89 mapping in Phase 1 (see page 16).

Table 4-2: Georeferencing characteristics of used SPOT1 images

Imagename	Nr. of GCP's	RMSE [m]	polynomial order used for transformation
SPOT image 1	62	8.8597	second
SPOT image 2	45	8.0077	second
SPOT image 3	48	5.9265	second
SPOT image 4	43	6.3175	second
SPOT image 5	18	8.7826	first

A Comparison of achieved and predefined values is presented in the following table.

Table 4-3: Product specifications – Ortho images and mosaic 1989

Criteria	Specification in Service Level Agreement	Accepta-bility threshold in Service Level Agreement (if exists)	Realized property	Compliant	Comment
Product:	**Ortho images and mosaics 1989**				
Product number:	**GSE-FM-OIM-1989**				
Geometric accuracy	RMS error < 0.5 * spatial resolution	RMSE < 10 m (0.5 pixel SPOT XS)	Total RMS: < 10 m (0.5 pixel SPOT XS)	y	RMS between 6-9m
Image channels	Original channels & Resolution merged multi-spectral channels	NA	Original channels & radiometric corrected mosaic image	y	No high resolution panchromatic image available
Reference system	Luxembourg Reference Frame (LUREF)	Geographic coordinates, Spheroid WGS 84, Datum WGS 84, LUREF	Luxembourg Reference Frame (LUREF)	y	For overlay over OBS89
Image quality	Cloud and haze free.	+/- 10-20% clouds	Cloud free and free of strong haze.	y	-
Image acquisition	During the vegetation season May-September, Due to vegetation phenology and to minimised shadow effects caused by sun incidence angle	May - September	July 1989	y	-

Product : Ortho image 2004 covering northern test site
Product Code: GSE-FM-IKONOS_2004
Description: Ortho-rectified IKONOS Test scene, pan-sharpened-multispectral mode (1m resolution, multispectral original image 4m) covering a test area in the northern part of Luxembourg
Ervice Provider: **GIM sa**
Main data source:

- IKONOS (ms) scene recorded 19 May 2004:

Table 4-4: IKONOS image acquired and used for product generation

Reference system	Luxembourg Reference System (LUREF)
Îmage channels	Pan sharpened image 1x1 m resolution 4 bands
Image Qualitay	Cloud free and free of strong haze
Source Image ID:	2004051910550520000011328983
Scan Azimuth:	0.06 degrees
Nominal Collection Azimuth:	3.5104 degrees
Nominal Collection Elevation:	67.03165 degrees
Sun Angle Azimuth:	162.5055 degrees
Sun Angle Elevation:	59.09803 degrees
Acquisition Date/Time:	2004-05-19 10:55 GMT
Percent Cloud Cover:	0 percent
Pixel Size X:	1 m
Pixel Size Y:	1 m

Auxiliary data sources used in production process:

- Aerial Images 2004
- DEM Digital Elevation Model

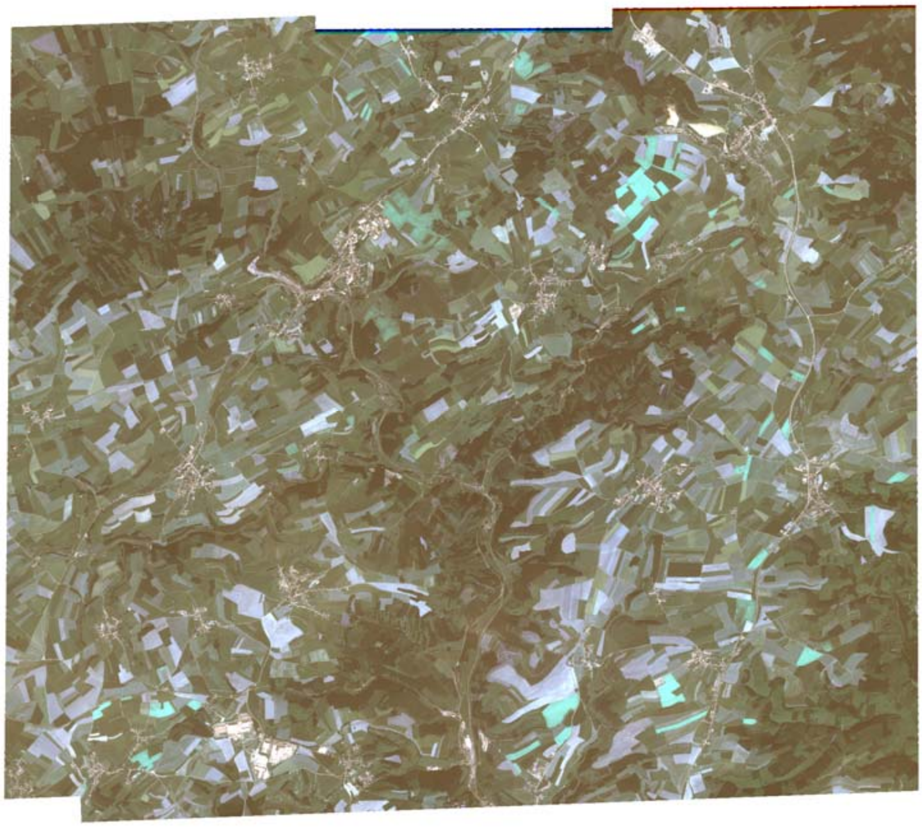

Figure 4-2: IKONOS scene (pansharpened)

Verification Results:

The Accuracy assessment procedures used for verification of this product are described in the document S5, Service Portfolio Specification.

Table 4-5: Georeferencing characteristics of used IKONOS scene

Imagename	Nr. of GCP's	RMSE [m]	polynomial order used for transformation
IKONOS 2004	55	X (0,81) Y(1,95) -> TOTAL RMS: 0,8	second polynomial

A Comparison of achieved and predefined values is presented in the following table.

Table 4-6: Product specifications – Ortho image IKONOS 2004 test site (north Luxembourg)

Criteria	Specification in Service Level Agreement	Acceptability threshold in Service Level Agreement (if exists)	Realized property	Compliant	Comment
Product:	**Ortho image IKONOS 2004**				
Product number:	**GSE-FM-OI-2004**				
Geometric accuracy	RMS error < 0.5 * spatial resolution	RMSE < 0.5 m (0.5 multispectral pixel IKONOS)	Total RMS: < 0.5 m (0.5 multispectral pixel IKONOS)	y	Total RMS: 0,8: X (0,81) Y(1,95) Pansharpened multispectral IKONOS image with 4m Pixel size resampled to 1m
Image channels	Original channels & Resolution merged multi-spectral channels	Pansharpened merged multi-spectral channels	Original channels & radiometric corrected image	y	
Reference system	Luxembourg Reference Frame (LUREF)	Geographic coordinates, Spheroid WGS 84, Datum WGS 84, LUREF	Luxembourg Reference Frame (LUREF)	y	For overlay over OBS89
Image quality	Cloud and haze free.	+/- 10-20% clouds	Cloud free and free of strong haze.	y	-
Image acquisition	During the vegetation season May-September, Due to vegetation phenology and to minimised shadow effects caused by sun incidence angle	May - September	19.05.2004	y	-

4.2 Map Products

Product : **Land Use Map 1989 for Luxembourg**
Product Code: GSE-FM-LFM-LULC
Description:
A Land Use Map for the reference year 1989, suitable for Kyoto reporting was produced based on the OBS89 data. Herein the classes Forest Land, Cropland, Grassland, Settlements, Wetland, Water and Other Land (according to the nomenclature defined in the LULUCF Good Practice Guidance) were mapped. The product is specified by a Minimum Mapping Unit of 0.5ha, the geometric and thematic accuracy is that of the OBS89 that is itself the reference data.

Table 4-7: Product specifications – Land Use Map 1989 for Luxembourg

Criteria	Specification in Service Level Agreement	Acceptability threshold in Service Level Agreement (if exists)	Realized property	Compliant	Comment
Product: **Land Use Map 1989 for Luxembourg** **Product Nr:** **GSE-FM-LFM-LULC**					
Geometric accuracy	RMS error < 0.5 * spatial resolution	RMSE < 10 m (0.5 pixel SPOT1)	OBS geometry	y	Generated using the OBS89, no change in geometry but change in MMU (0.5ha)
Reference system	Luxembourg Reference Frame (LUREF)	Geographic coordinates, Spheroid WGS 84, Datum WGS 84, LUREF	Luxembourg Reference Frame (LUREF)	y	
Minimum Mapping Unit	0.5 ha		0.5ha	y	
Class definitions	According to LULUCF land use / land cover nomenclature		According to LULUCF land use / land cover nomenclature	y	
Thematic Accuracy	User accuracy between > 70% and >90% for all classes		Thematic accuracy = OBS89 accuracy	y	Generated using the OBS89, no change in accuracy but generalisation effect due to the dissolve of polygons applying the 0.5ha MMU

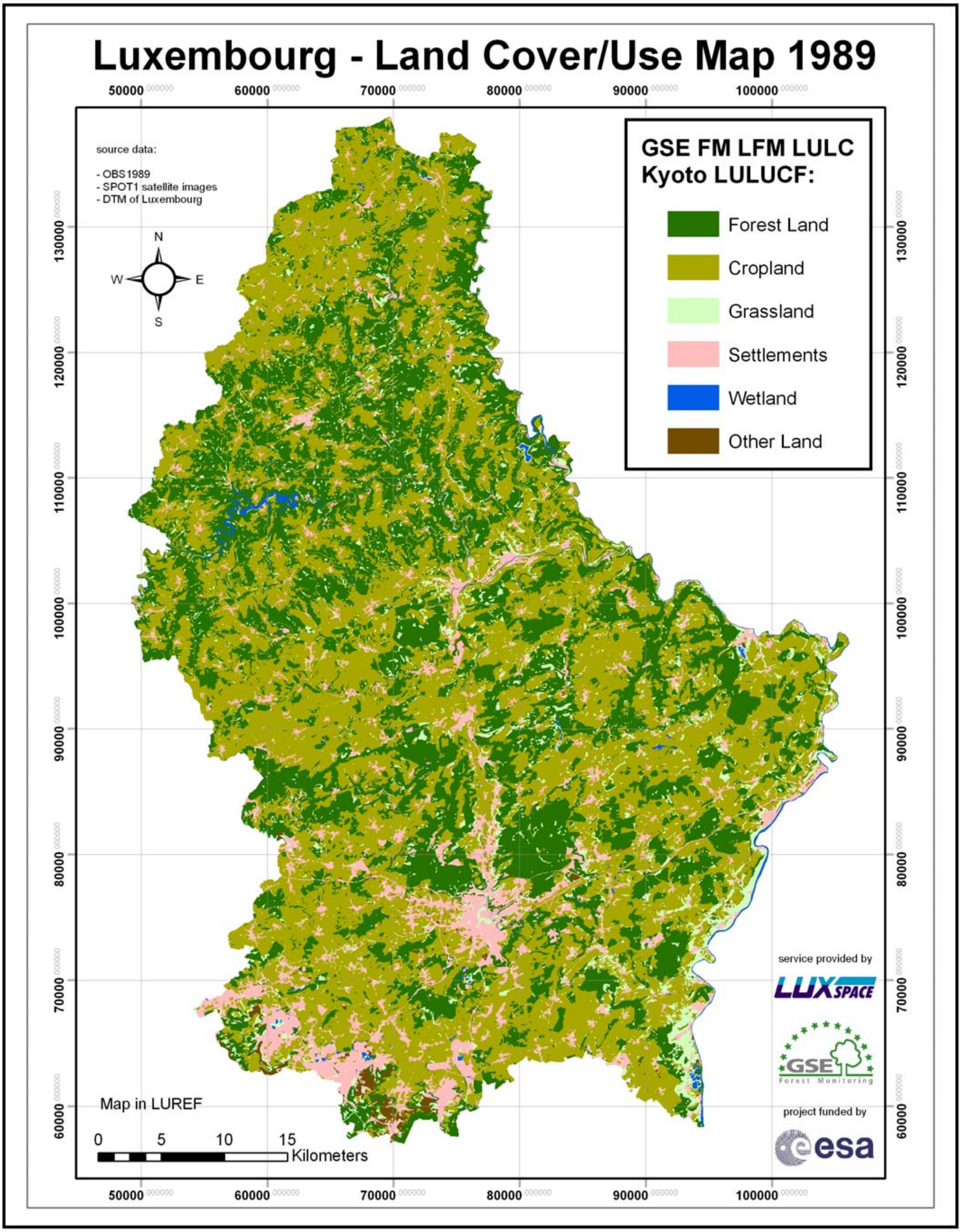

Figure 4-3: Land Cover / Use Map 1989 based on OBS89

Product: **Forest Area Map 1989 for Luxembourg**
Product Code: GSE-FM-LFM-FA
Description:
A Forest Area Map for the reference year 1989 was produced based on the OBS89 data and SPOT1 imagery in the time frame 01/01/1989 – 31/12/1989.
Herein the classes ***Forest, Reforestation***, ***Clear Cut*** and ***No Forest land*** (according to the nomenclature defined in the LULUCF Good Practice Guidance) were mapped.
The product is specified by the Minimum Mapping Unit of the original OBS89 and 0.5 ha for the new class ***Clear cuts***, a geometric accuracy of < 10 m and the thematic accuracy of the original OBS89 map and 90% +/- 5% for the new *Clear cut* areas. All new 269 new Clear cut areas were double checked. The thematic accuracy assessment was focussed on the *clear cut* areas that were detected using the SPOT1 mosaic of 1989.

Table 4-8: Product specifications – Forest Area Map 1989 for Luxembourg

Criteria	Specification in Service Level Agreement	Acceptability threshold in Service Level Agreement (if exists)	Realized property	Compliant	Comment
Product:	**Forest Area Map 1989 for Luxembourg**				
Product Nr:	**GSE-FM-LFM-FA**				
Geometric accuracy	RMS error < 0.5 * spatial resolution	RMSE < 10 m (0.5 pixel SPOT1)	< 10 m (0.5 pixel SPOT XS	y	OBS89, no change in geometry; SPOT mosaic: Total RMS: between 6-9m:
Reference system	Luxembourg Reference Frame (LUREF)	Geographic coordinates, Spheroid WGS 84, Datum WGS 84, LUREF	Luxembourg Reference Frame (LUREF)	y	
Minimum Mapping Unit	0.5 ha	0.5ha	OBS89 MMU (original scale 1:15.000),	y	
Class definitions	According to LULUCF land use / land cover nomenclature		According to LULUCF land use / land cover nomenclature PLUS: New Clear cut areas	y	Newly identified Clear cut areas by photo-interpretation of SPOT1 imagery
Thematic Accuracy	User accuracy between > 70% and >90% for all classes		Thematic accuracy = OBS89 accuracy, Clear cut areas: 85%-93%	y	85 % correctly classified “new detected clear cut areas” (control of 69 (25%) of in total 273 new Clear cut areas), 93 % detection accuracy through control of 5% (129 cells) sample of 1 km2 cells containing forest over the entire territory)

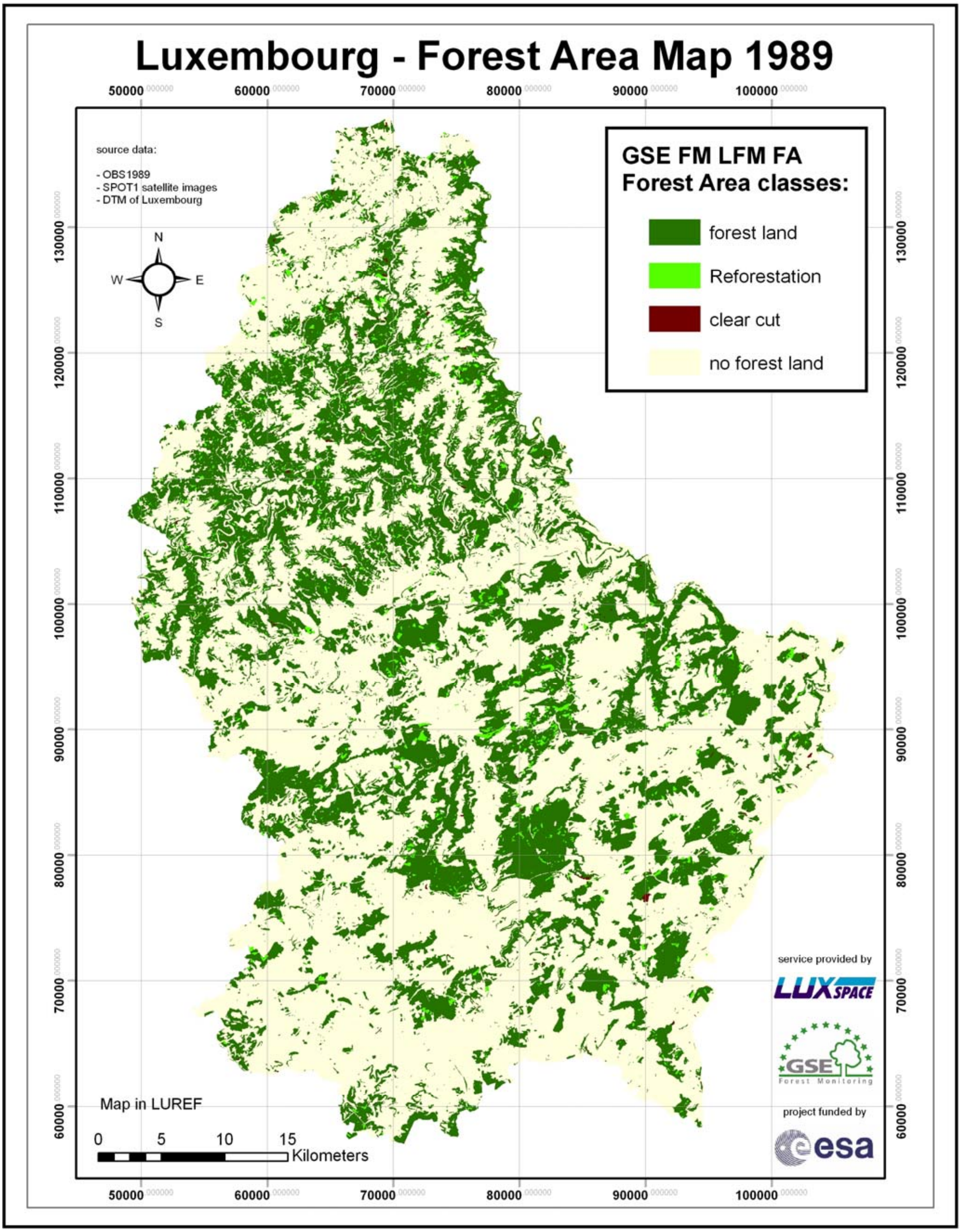

Figure 4-4: Forest Area Map 1989 based on SPOT 1 satellite imagery and the OBS89

Product: **Forest Type Map 1989 for Luxembourg**
Product Code: GSE-FM-LFM-FTM
Description:
A Forest Type Map for the reference year 1989 was produced based on the OBS89 map. Herein the classes Forest (Coniferous, Deciduous, Mixed subclasses) and Other land (according to the nomenclature defined in the LULUCF Good Practice Guidance) were mapped by aggregation of OBS89 more detailed classes to the three forest type classes using the following class aggregations:

- All classes belonging to the upper class 311 (forêts de feuillus) including the classes 32421 and 32422 (willow trees on moist soils) were aggregated to deciduous forest
- All classes belonging to the upper class 312 (forêts de conifères) were set to coniferous forest and
- All classes belonging to the upper class 313 (forêts mélangés) were set to mixed forest

Newly identified Clear Cut areas were assigned to No-Forest land. The product is specified by the Minimum Mapping Unit, the geometric and thematic accuracy of the original OBS89 map.

Table 4-9: Product specifications – Forest Type Map 1989 for Luxembourg

Criteria	Specification in Service Level Agreement	Acceptability threshold in Service Level Agreement (if exists)	Realized property	Compliant	Comment
Product: **Forest Type Map 1989 for Luxembourg** **Product Nr:** **GSE-FM-LFM-FTM89**					
Geometric accuracy	RMS error < 0.5 * spatial resolution	RMSE < 10 m (0.5 pixel SPOT1)	OBS geometry	y	Generated using the OBS89, no change in geometry
Reference system	Luxembourg Reference Frame (LUREF)	Geographic coordinates, Spheroid WGS 84, Datum WGS 84, LUREF	Luxembourg Reference Frame (LUREF)	y	
Minimum Mapping Unit	0.5 ha		OBS geometry	y	
Class definitions	According to LULUCF land use / land cover nomenclature: Coniferous forest, deciduous forest, mixed forest, Other land		According to LULUCF land use / land cover nomenclature	y	Generated by aggregation of OBS89 forest classes
Thematic Accuracy	User accuracy between > 70% and >90% for all classes		Thematic accuracy = OBS89 accuracy	y	Generated using the OBS89, no change in accuracy

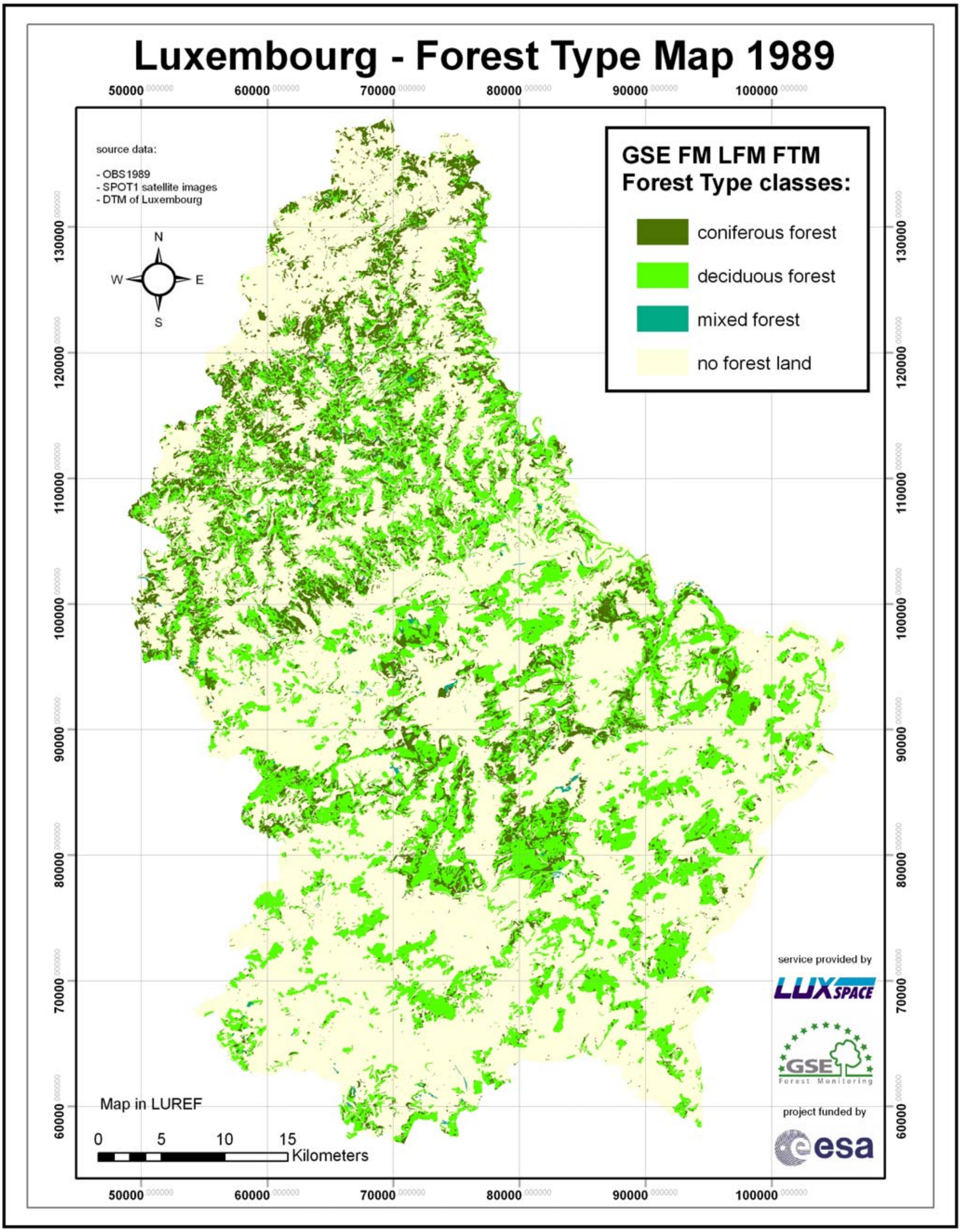

Figure 4-5: Forest Type 1989 based on the OBS89

Product: **Forest Type Map 2004 for test area in northern Luxembourg**
Product Code: GSE-FM-LFM-FTM04
Description:
A Forest Type Map for the year 2004 covering the test site in northern Luxembourg was produced based on the OBS99 map and the IKONOS test scene.
Herein the Forest classes - as defined in the OBS99 - and No Forest Land were mapped
- This Forest mask is being integrated into the updated OBS99 for the northern test site to complete the OBS2004 map.
-

Table 4-10: Product specifications – Forest Type Map 2004 Test site in Northern Luxembourg

Criteria	Specification in Service Level Agreement	Acceptability threshold in Service Level Agreement (if exists)	Realized property	Compliant	Comment
Product: **Forest Type Map Test N-Luxembourg** **Product Nr:** **GSE-FM-SIB-FI2004Test**					
Geometric accuracy	RMS error < 0.5 * spatial resolution	RMSE < 0.5 m (0.5 multispectral pixel IKONOS)	Total RMS: < 0.5 m (0.5 multispectral pixel IKONOS)	y	Total RMS: 0,8: X (0,81) Y(1,95) Pansharpened multispectral IKONOS image with 4m Pixel size resampled to 1m
Reference system	Luxembourg Reference Frame (LUREF)	Geographic coordinates, Spheroid WGS 84, Datum WGS 84, LUREF	Luxembourg Reference Frame (LUREF)	y	
Minimum Mapping Unit	0.15 ha		0.15ha	y	
Class definitions	According to OBS99 nomenclature		According to OBS99 nomenclature	y	Generated by photointer-pretation of IKONOS image in combination with OBS99
Thematic Accuracy	User accuracy between > 70% and >90% for all classes		Thematic accuracy = 97.5% total accuracy	y	Random sample of 121 control points checked with aerial photos of 2004; 3 errors detected

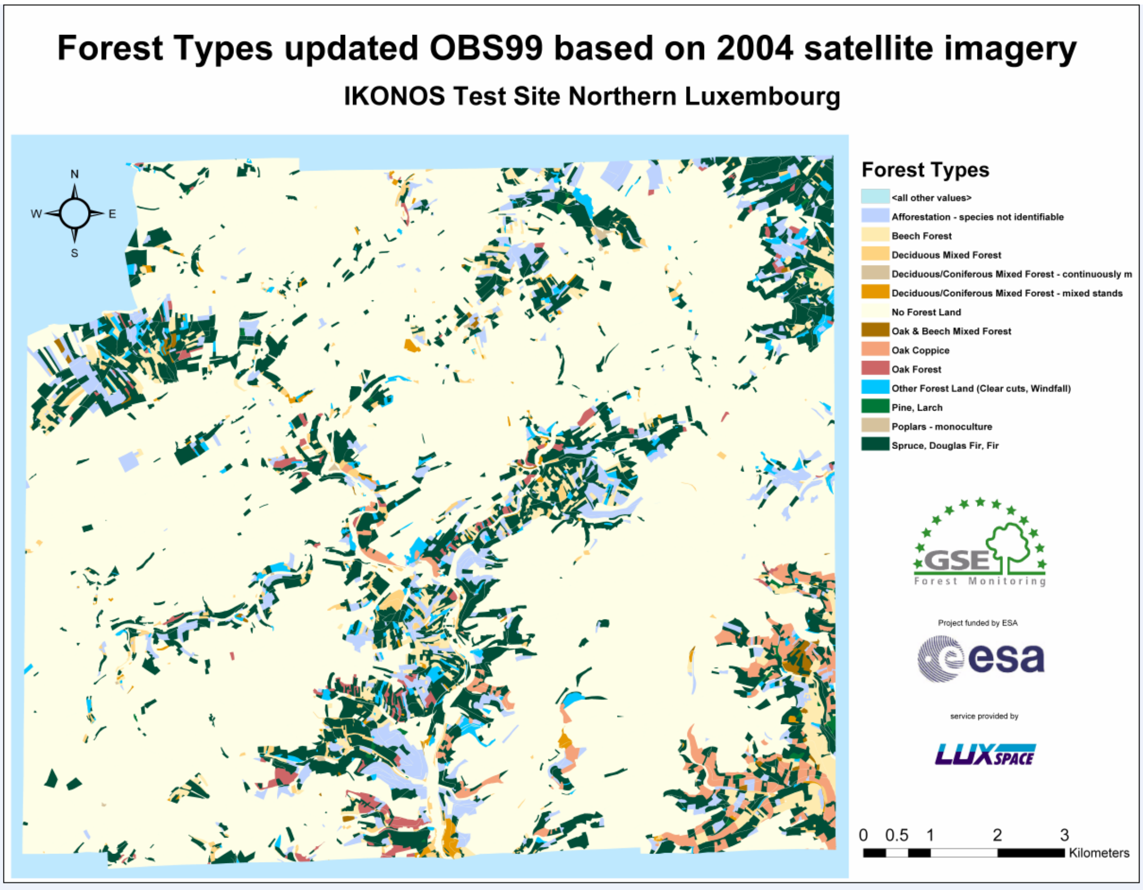

Figure 4-6: Updated OBS99 Forest Types using 2004 IKONOS data in test site Northern Luxembourg

There are about 1000 polygons with about 203 ha total area (146 ha within the 14 occurring Forest classes) that were subject to changes in classification.

Product: Forest Fragmentation and Structural Diversity indicators
Product Code: GSE-FM-FEI
Description:
Landscape indices will be used by the Forestry Administration and the Environment Ministry to support reporting under the environment monitoring schemes of the European Commission (Forest Focus, Conservation of natural habitats and of wild fauna and flora), the National Plan for Sustainable Development, the Ministerial Conference on the Protection of Forests in Europe (MCPFE) and the National Forestry Plan, i.e. monitoring of sustainable forest management.
Analysis of the indicators for each eco regions or sections requires very deep knowledge and understanding of the local conditions and will be performed by the users. .
The following indicator products were delivered based on the LULUCF89 map per Eco Region and – section and the entire Luxembourg territory (text from *Fragstats User Guide*).

Table 4-11: Fragmentation and Structural Diversity Indicators

Index	Description
Area metrics	The index "Area Percentage of Landscape" (APL) expresses the area proportion of one class type in % of a specific landscape. *It is a measure of landscape composition important in many ecological applications.*
Patch metrics	The Patch Density (PD) index describes the total number of patches or their relative proportions in a given area (e.g. 100ha). *PD is ultimately constrained by the grain size of the raster image (resolution), because the maximum PD is attained when every cell is a separate patch. Therefore, ultimately cell size will determine the maximum number of patches per unit area. However, the maximum density of patches of a single class is attained when every other cell is of that focal class (i.e., in a checker board manner; because adjacent cells of the same class would be in the same patch).* *Patch density is a limited, but fundamental, aspect of landscape pattern. Patch density has the same basic utility as number of patches as an index, except that it expresses number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size. Of course, if total landscape area is held constant, then patch density and number of patches convey the same information. Like number of patches, patch density often has limited interpretive value by itself because it conveys no information about the sizes and spatial distribution of patches. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.*
Edge metric	The Edge Density (ED) index describes the amount of edges occurring between patches or classes per given area (here: per ha). *ED = 0 when there is no class edge in the landscape; that is, when the entire landscape and landscape border, if present, consists of the corresponding patch type and the user specifies that none of the landscape boundary and background edge be treated as edge.*
Shape metrics	The Landscape Shape Index (LSI) is a measure for the complexity of landscape shapes. *LSI = 1 when the landscape consists of a single square or maximally compact (i.e., almost square) patch of the corresponding type; LSI increases without limit as the patch type becomes more disaggregated (i.e., the length of edge within the landscape of the corresponding patch type increases).* *Landscape shape index provides a simple measure of class aggregation or clumpiness.*
Core area metrics	Core area metrics compute statistics about the inner central parts of patches in relation to the total patches and provide information about the quality of habitats for certain species. The Total Core Area Index (TCAI) is computed as percentage of the total core area in relation to the total area.
Nearest Neighbour metrics	Nearest neighbour indices quantify landscape configuration. The Euclidian Nearest Neighbour distance (ENN) index averages all minimum distances of all patches to their nearest patch partner (meters). *ENN approaches 0 as the distance to the nearest neighbor decreases. The minium*

	ENN is constrained by the cell size, and is equal to twice the cell size when the 8-neighbor patch rule is used or the distance between diagonal neighbors when the 4-neighbor rule is used. The upper limit is constrained by the extent of the landscape. *Euclidean nearest-neighbor distance is perhaps the simplest measure of patch context and has been used extensively to quantify patch isolation. Here, nearest neighbor distance is defined using simple Euclidean geometry as the shortest straight-line distance between the focal patch and its nearest neighbor of the same class.*
Diversity metrics	The Shannon Diversity Index (SHDI) measures the extent to which one or a few class types dominate the landscape index. *Shannon's diversity index (SHDI) is based on information theory (Shannon and Weaver 1949). The value of this index represents the amount of "information" per individual (or patch, in this case). Information is a somewhat abstract mathematical concept that is not attempted to define here. The absolute magnitude of Shannon's diversity index is not particularly meaningful; therefore, it is used as a relative index for comparing different landscapes or the same landscape at different times.* *SHDI = 0 when the landscape contains only 1 patch (i.e., no diversity). SHDI increases as the number of different patch types (i.e., patch richness, PR) increases and/or the proportional distribution of area among patch types becomes more equitable.*

The landscape indicator statistics are provided for the entire territory of Luxembourg, the 4 Eco – Regions results of the (Gutland, Minette, Moseltal, Oeling) and the 21 Eco-Sections.

Table 4-12: Landscape Indicators for entire Luxembourg territory

	Area Percentage of Landscape	**Area of Landscape (ha)**	**Patch Density (per 100ha)**	**Edge Density (m/ha)**	**Landscape Shape Index**	**Total Core Area Index (%)**	**Mean Nearest Neighbour Distance (m)**
Luxembourg Country							
Cropland	51.80%	134238	0.3871	25.7458	83.2231	70.821	137.1942
Settlements	7.95%	20615	0.4455	8.4777	69.8852	45.0473	232.1693
Forest Land	33.09%	85768.25	0.5111	20.2245	81.8942	65.1421	162.7785
Grassland	5.99%	15515.25	1.2829	10.832	102.6353	21.3226	209.1861
Wetland	0.51%	1325.25	0.2177	1.0277	35.2329	20.2415	350.1741
Other Land	0.66%	1705.75	0.1071	0.9415	27.012	34.457	621.3483
TOTAL AREA	100.00%	259168					

Table 4-13: Landscape Indicators for Ecoregions of Luxembourg

Eco Regions in Luxembourg	Area Percentage of Landscape	Area of Landscape (ha)	Patch Density (per 100ha)	Edge Density (m/ha)	Landscape Shape Index	Total Core Area Index (%)	Mean Nearest Neighbour Distance (m)	Shannon Diversity Index
Gutland								
Cropland	54.69%	87827	0.248	25.7509	60.4148	73.1409	143.0712	
Forest Land	30.16%	48433	0.5161	17.4781	54.8468	69.1271	173.9091	
Grassland	6.22%	9985	1.3271	11.6462	80.79	21.7337	209.5223	
Settlements	8.27%	13274	0.4872	9.5732	57.3948	43.5567	231.7705	
Wetland	0.28%	457	0.1685	0.7646	25.4535	8.4885	481.3572	
Other Land	0.39%	620	0.1216	0.8637	23.73	13.4274	685.5606	
TOTAL AREA	100.00%	160594						1.1085
Minette								
Grassland	8.11%	961	0.8597	8.8556	24.1452	20.4321	184.6618	
Forest Land	19.80%	2346	0.3965	10.0164	18.567	53.0001	192.5201	
Cropland	30.72%	3640	0.4177	13.328	19.3471	59.0138	172.2958	
Settlements	32.56%	3858	0.2543	11.4452	16.1165	66.617	211.0113	
Other Land	8.13%	963	0.1998	4.5632	12.576	51.0517	383.2109	
Wetland	0.68%	81	0.0878	0.7144	6.5833	24.5342	758.5424	
TOTAL AREA	100.00%	11848						1.4902
Moseltal								
Settlements	22.04%	599	0.1347	2.5575	11.2245	48.5595	193.9373	
Wetland	4.53%	123	0.303	1.0031	11.0889	18.9024	191.0678	
Forest Land	6.83%	186	0.0982	0.8838	6.2545	49.1914	375.0558	
Cropland	28.48%	774	0.1712	3.1187	11.0536	54.1195	213.1414	
Grassland	36.37%	988	0.2245	4.2789	15.5079	44.2308	127.6784	
Other Land	1.75%	48	0.0786	0.5233	7.1786	6.8421	499.7796	
TOTAL AREA	100.00%	2717						1.4531
Oesling								
Cropland	50.03%	42033	0.6101	27.4725	55.3386	66.6754	129.9101	
Settlements	3.40%	2859	0.4255	5.3912	41.1262	21.8296	239.7918	
Forest Land	41.43%	34807	0.5252	26.7193	59.0388	60.2443	146.8521	
Grassland	4.26%	3582	1.2845	8.8627	60.2417	10.4837	215.3161	
Wetland	0.81%	678	0.2589	1.3313	21.6667	28.2344	274.8847	
Other Land	0.07%	61	0.0384	0.2053	10.375	0.8264	971.0302	
TOTAL AREA	100.00%	84019						1.0052

Table 4-14: Landscape Indicators for Ecosections of Luxembourg

EcoSectionsinLuxembourg	Area Percentage of Landscape	Area of Landscape (ha)	Patch Density (per 100ha)	Edge Density (m/ha)	Landscape Shape Index	Total Core Area Index (%)	Mean Nearest Neighbour Distance (m)	Shannon Diversity Index
Noerdhochoesling_Results								
Cropland	59.62	26112	0.3538	20.2493	36.3091	71.3998	133.8879	
Settlements	3.41	1494	0.3113	4.2077	30.2968	19.9163	233.2345	
ForestLand	32.96	14435	0.6027	17.7647	43.3451	56.3076	154.5291	
Grassland	3.75	1643	0.8489	5.738	39.8528	11.1534	226.2793	
Wetland	0.21	91	0.0344	0.2462	7.2051	25.2747	894.3159	
OtherLand	0.04	20	0.0217	0.1063	6.6111	0	1635.8947	
TOTALAREA	100.00	43794						0.9288
Ourtal								
ForestLand	61.16	2387	0.0859	8.9102	13.5663	63.0917	144.7163	
Grassland	7.02	274	0.5891	3.7392	14.8507	17.2445	214.8679	
Cropland	26.31	1027	0.5032	7.0529	15.8915	42.0886	151.7873	
Wetland	1.48	58	0.2455	0.6464	7.3226	24.6753	341.8245	
Settlements	3.94	154	0.1514	1.8307	9.78	19.187	250.9176	
OtherLand	0.08	3	0.0205	0.0716	2.375	0	1799.6525	
TOTALAREA	100.00	3903						1.0342
Obersauer-Wiltz-Clierf-undBleestal								
Cropland	32.47	6807		14.1123	37.2417	47.8753	143.0271	
ForestLand	55.99	11736	0.2251	16.0931	32.5806	61.4575	125.3037	
Grassland	5.50	1154	0.8957	5.7665	35.4338	8.6476	196.0327	
Wetland	2.43	510	0.3617	2.0171	18.1758	28.4593	166.8079	
OtherLand	0.10	21	0.0246	0.1193	5.2632	0	1458.6778	
Settlements	3.51	735	0.2079	2.5166	19.2385	25.9612	376.9093	
TOTALAREA	100.00	20961						1.0642
Oesling-Vorland								
ForestLand	28.70	3882	0.3906	8.1106	21.904	58.3076	156.9569	
Cropland	60.76	8220	0.1349	11.2073	21.5592	68.749	119.8773	
Grassland	5.67	767	0.5051	4.1251	24.3514	16.0365	241.5807	
Settlements	4.61	624	0.1788	2.5273	16.95	27.3055	282.006	
OtherLand	0.17	24	0.0188	0.1318	4.4	8.5106	2278.8503	
Wetland	0.09	12	0.022	0.0902	4.2857	6.25	593.7602	
TOTALAREA	100.00	13528						0.9828
SuedlichesHochoesling								
Cropland	52.37	8045	0.585	23.1086	24.7187	66.2347	132.3369	
ForestLand	40.80	6267	0.419	21.5509	26.4196	58.1219	136.7266	
Grassland	3.41	524	0.9931	6.1805	25.2391	6.3901	242.9814	
Settlements	3.18	489	0.3211	4.0786	17.1798	20.3173	242.2107	
OtherLand	0.11	17	0.0381	0.2326	5.0588	0	590.6792	
Wetland	0.14	21	0.1088	0.2218	6.6842	1.1765	290.6699	
TOTALAREA	100.00	15362						0.9459
Untersauertal								
Cropland	46.17	1726	0.1465	4.6172	15.976	54.3242	176.1865	
ForestLand	24.51	916	0.1274	2.7896	13.8279	45.8788	222.9467	
Wetland	1.87	70	0.172	0.5405	9.9118	17.8571	272.3968	
OtherLand	0.53	20	0.0297	0.1572	4.8333	12.6582	1743.7952	
Grassland	16.01	598	0.3058	3.5213	19.102	21.2286	163.4232	
Settlements	10.92	408	0.1678	1.7203	11.9012	37.3775	189.7732	
TOTALAREA	100.00	3738						1.3387
Attert-Alzette-Mittelsauer								
Cropland	52.49	4982	0.1399	5.6102	21.9011	59.9267	137.6738	
ForestLand	14.67	1393	0.1815	2.6954	19.3867	40.9874	204.9853	
Settlements	24.21	2298	0.1442	3.7782	20.1146	49.0262	163.57	
Grassland	6.96	660	0.3385	2.343	22.8252	16.7739	198.1572	
Wetland	1.27	121	0.1997	0.8244	17.5682	0	153.9405	
OtherLand	0.40	38	0.0267	0.1575	6.08	12.4183	897.2867	
TOTALAREA	100.00	9491						1.2264
StegenerGutland								
Cropland	52.99	3841	0.1828	16.6863	14.5565	68.9579	153.516	
ForestLand	38.01	2755	0.3909	12.4932	13.1048	68.8776	163.087	
Grassland	6.16	447	1.0508	8.2213	19.6118	14.4376	192.4231	
Settlements	2.74	199	0.33	3.0459	10.8596	22.5441	369.2448	
OtherLand	0.09	7	0.0406	0.1853	3.3636	0	2211.1214	
TOTALAREA	100.00	7248						0.981
SchoffielserundMullerthalerGutland								
ForestLand	47.00	12300	0.2628	15.5163	22.8581	73.1896	148.328	
Cropland	40.37	10565	0.3154	16.9716	26.0243	67.5122	161.4201	
Settlements	6.09	1593	0.4353	6.1103	24.1687	34.8297	241.258	
OtherLand	0.34	88	0.0476	0.3959	6.3947	32.1023	1403.6684	
Grassland	6.15	1609	1.0627	8.7071	33.6894	17.2596	205.8242	
Wetland	0.05	14	0.0197	0.0953	3.9333	9.0909	2979.2347	
TOTALAREA	100.00	26169						1.086
Attert-Gutland								
ForestLand	22.25	2652	0.5383	10.5316	15.835	63.075	186.0701	
Grassland	2.70	321	0.672	4.1602	17.2778	12.7626	303.1571	
Cropland	70.75	8433	0.1055	14.9328	13.4402	80.1132	169.5091	
Settlements	3.95	471	0.3202	4.0353	13.931	29.4368	258.8619	
Wetland	0.22	26	0.1759	0.526	7.2857	1.9048	483.4609	
OtherLand	0.14	17	0.0281	0.2111	3.5294	14.7059	536.2509	
TOTALAREA	100.00	11920						0.827

Eco Sections in Luxembourg	Area Percentage of Landscape	Area of Landscape (ha)	Patch Density (per 100ha)	Edge Density (m/ha)	Landscape Shape Index	Total Core Area Index (%)	Mean Nearest Neighbour Distance (m)	Shannon Diversity Index
Pafebierger und Oetringer Gutland								
Cropland	59.49%	14123	0.1063	13.796	22.9643	74.326	152.354	
Grassland	7.36%	1748	0.8697	7.6607	33.9643	20.7696	197.611	
Forest Land	28.46%	6757	0.2871	8.667	20.693	68.4797	195.9603	
Settlements	4.23%	1005	0.2443	3.4669	20.622	29.8185	322.1393	
Other Land	0.12%	29	0.0331	0.1836	6.4091	3.4188	1554.4203	
Wetland	0.33%	78	0.0442	0.3582	7.3056	16.4516	1113.9199	
TOTAL AREA	100.00%	23740						1.0195
Eisch-Mamer-Gutland								
Forest Land	47.46%	8414	0.4376	23.5614	19.03	73.4817	156.1987	
Cropland	40.99%	7267	0.5052	25.3422	22.1056	66.8994	158.8633	
Other Land	0.50%	88	0.1601	1.1083	8.3158	14.4476	519.4894	
Settlements	6.99%	1240	0.5266	9.6993	19.9504	35.8669	235.8226	
Grassland	3.92%	695	1.3022	8.9521	24.2453	15.0719	252.5495	
Wetland	0.15%	26	0.1245	0.4981	6.7619	2.9126	617.2605	
TOTAL AREA	100.00%	17730						1.0682
Mosel-Vorland und Syretal								
Grassland	13.35%	2032	0.537	5.9968	27.0994	37.2462	191.3381	
Cropland	57.41%	8736	0.1316	8.6454	20.1711	72.207	144.469	
Forest Land	21.68%	3300	0.2	4.3155	15.6217	67.2096	236.3316	
Settlements	6.46%	984	0.2066	2.9559	19.0952	32.6048	276.1125	
Other Land	0.87%	133	0.1066	0.7449	12.2979	6.9549	489.1532	
Wetland	0.22%	33	0.0263	0.1402	5.6957	3.0534	1287.5142	
TOTAL AREA	100.00%	15217						1.1506
Moseltal								
Settlements	22.04%	599	0.1347	2.5575	11.2245	48.5595	193.9373	
Wetland	4.53%	123	0.303	1.0031	11.0889	18.9024	191.0678	
Forest Land	6.83%	186	0.0982	0.8838	6.2545	49.1914	375.0558	
Cropland	28.48%	774	0.1712	3.1187	11.0536	54.1195	213.1414	
Grassland	36.37%	988	0.2245	4.2789	15.5079	44.2308	127.6784	
Other Land	1.75%	48	0.0786	0.5233	7.1786	6.8421	499.7796	
TOTAL AREA	100.00%	2717						1.4531
Suedliches Gutland								
Cropland	59.44%	14474	0.201	19.9532	22.5788	75.0479	162.5978	
Forest Land	20.01%	4873	0.4179	10.992	20.6786	63.9563	224.155	
Settlements	16.05%	3908	0.4478	11.3214	23.8048	54.389	207.3812	
Grassland	3.52%	856	0.7861	6.1642	26.7458	14.2815	289.9922	
Other Land	0.67%	164	0.1811	1.203	11.7308	14.3731	610.8635	
Wetland	0.32%	77	0.0816	0.5632	7.8889	14.6104	779.1569	
TOTAL AREA	100.00%	24351						1.0943
Rebierger Gutland								
Cropland	72.86%	5446	0.1435	22.9776	11.9797	77.893	144.845	
Settlements	7.18%	537	0.4018	9.2448	14.1828	30.6008	238.3482	
Forest Land	15.95%	1193	0.7175	11.4834	12.1655	59.7275	193.5176	
Grassland	3.64%	272	1.1839	7.8386	17.1061	12.0294	231.9935	
Other Land	0.28%	21	0.1076	0.6565	5.1579	5.9524	832.7792	
Wetland	0.08%	6	0.0359	0.1901	2.8	8	2586.1089	
TOTAL AREA	100.00%	7475						0.8557
Minette\minvorland								
Grassland	5.08%	348	0.4866	3.5554	16.4133	14.8201	227.6727	
Forest Land	6.45%	441	0.2772	2.65	11.7176	39.2635	239.7815	
Cropland	37.58%	2573	0.2802	8.1116	14.9803	62.2741	202.1974	
Settlements	47.89%	3279	0.1663	8.164	13.2478	69.4982	171.7388	
Other Land	1.94%	133	0.1078	0.9731	7.9362	23.1203	667.8011	
Wetland	1.07%	73	0.077	0.6313	5.9429	25.3425	457.4722	
TOTAL AREA	100.00%	6846						1.1734
Minette (19)								
Cropland	31.84%	612	0.3682	15.0969	8.7778	54.7424	207.3453	
Forest Land	32.44%	623	0.6977	17.5097	9.82	51.565	157.8332	
Other Land	11.95%	230	0.3488	7.3934	7.2787	42.9194	293.4587	
Grassland	15.89%	305	1.2209	15.9109	12.4143	22.6044	166.3312	
Settlements	7.69%	148	0.6395	6.0271	8.2857	25.2115	266.8951	
Wetland	0.20%	4	0.0775	0.3876	2.5	0	1215.1532	
TOTAL AREA	100.00%	1921						1.4852
Minette (20)								
Settlements	14.01%	259	0.7385	15.6497	7.8308	42.029	238.961	
Cropland	11.87%	219	0.9847	16.5993	9.0167	29.6465	183.449	
Forest Land	41.32%	763	0.9144	35.7306	10.0631	54.5872	127.2349	
Other Land	22.45%	415	0.5275	18.4807	6.7683	58.2027	333.6087	
Grassland	10.32%	191	1.6881	20.2743	10.625	21.5223	206.54	
Wetland	0.03%	1	0.0352	0.1055	1	0	N/A	
TOTAL AREA	100.00%	1847						1.4655
Minette (21)								
Cropland	15.34%	134	1.2121	13.7626	6.5957	35.0746	211.2701	
Settlements	12.71%	111	0.6566	9.3939	5.3256	37.8378	261.291	
Forest Land	40.90%	357	0.4545	17.7273	5.5921	61.3716	134.3851	
Grassland	9.42%	82	0.8586	11.3384	6.2432	26.1398	223.1375	
Other Land	21.35%	187	0.3535	12.6263	5.0727	52.0107	115.0468	
Wetland	0.29%	3	0.0505	0.3535	1	20	N/A	
TOTAL AREA	100.00%	874						1.4843
Minette (22)								
Settlements	18.33%	67	1.5764	18.8177	3.9091	40.4494	231.3509	
Forest Land	41.80%	152	1.5764	27.8818	3.86	58.6207	185.9644	
Cropland	28.35%	103	1.5764	33.1034	4.3171	44.7942	101.4754	
Other Land	0.75%	3	0.3941	2.1675	1.7143	0	2596.151	
Grassland	10.78%	39	2.9557	23.6453	4.9615	15.9236	122.7074	
TOTAL AREA	100.00%	364						1.3099

One example of mapping landscape indicators is provided in Figure 4-7, the Shannon Diversity Index is shown for the 21 Eco-sections in Luxembourg as defined by the “Administration des Eaux et Forets”.

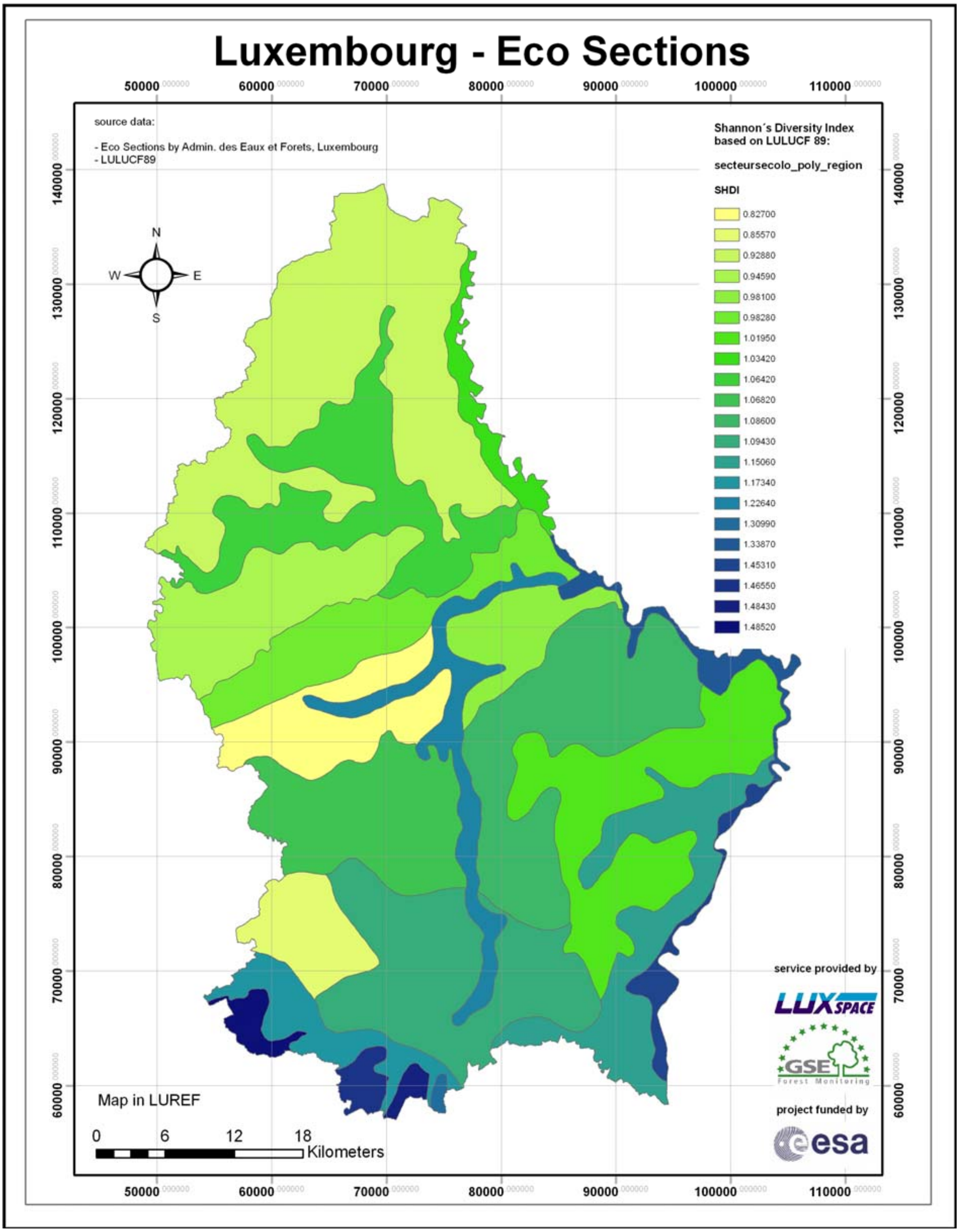

Figure 4-7: Luxembourg – Shannon´s Diversity Index per Eco Section based on LULUCF89

As can be seen the *Minette* and the *Moseltal* Eco-sections show the most diversity, i.e. occurrence of dispersed patches of different land use classes.
Further analysis will be performed by the users.

5 References

ATCOR (2006): ATCOR Basics in 10 minutes. Geosystems, Germering, Germany (http://www.geosystems.de/atcor/downloads/index.html)

ERDAS (2005): ERDAS Field Guide. ERDAS LLC, Norcross, Georgia, USA.

RICHTER, R. (2006): ATCOR-2/3 User Guide, Version 6.2, Wessling, Germany

6 ANNEX:

Table 6-1 Table of correspondence OBS89 – LULUCF

LULUFC nomenclature		OBS Nomenclature			
	Code	Acronym	Code	Original in French	translated into German
Forest Land	1		31	forets	Wald
Forest Land	1		311	forets de feuillus	Laubwald
Forest Land	1	P	312	forets de coniferes	Nadelwald
Forest Land	1	P	313	forets melangees	Mischwald
Forest Land	1	F/Q	3111	forets acidophiles	Saure Wälder
Forest Land	1	F/Q	3112	forets neutroclines a mull	Wälder auf neutralen Bodenverhältnissen
Forest Land	1	F/Q	3113	forets basiclines	Wälder auf basischen Bodenverhältnissen
Forest Land	1	R	3114	forets ruderales	Schuttwälder
Forest Land	1	P	3115	plantation de feuillus	Laubwald Anpflanzung
Forest Land	1	E	3116	forets de ravins	Schluchtwälder
Forest Land	1	V	3117	forets alluviales sur sols mineraux	Auewald auf mineralischem Boden
Forest Land	1	V	3118	forets marecageuses a sedimentation organique	Moorbruchwälder
Forest Land	1	Pe	3121	epiceas, sapins	Fichte, Tannen
Forest Land	1	Pm	3122	pins, mezeles	Pinien, ?
Forest Land	1	Pr	3123	autres resineux	Other Land Nadelbaeume
Forest Land	1	Pl	3131	par pied ou par bouquet	truppenweise Mischung (uebernommen aus 1999)
Forest Land	1	Pp	3132	par parcelle	Mischung in Parzellen
Forest Land	1	Qb	31111	chenaie acidophile tres pauvre	artenarmer saurer Eichenwald
Forest Land	1	Fs	31112	hetraie et chenaie-hetraie acidophile	saurer Buchen und Eichen-Buchenwald
Forest Land	1	Qs	31113	chenaie acidophile	saurer Eichenwald
Forest Land	1	Fl	31114	hetraie a luzule blanche	Buchen mit weissen Luzernen
Forest Land	1	Ql	31115	chenaie a luzule blanche	Eichenwald mit Luzernen
Forest Land	1	Ff	31116	hetraie a grande fetuque	Buchenwald mit hohen Graesern
Forest Land	1	Qx	31117	chenaie a charmes xerophile sur schistes et gres	besondere trockenheitsliebende Eichenart auf Schiefer und Sandstein
Forest Land	1	Fm	31121	hetraie a melique et asperule	Buchenwald mit irgendeinem bestimmten Unterwuchs
Forest Land	1	Qa	31122	chenaie a charmes humide	besondere Eichenart auf feuchten Standorten
Forest Land	1	Qm	31123	chenaie-charmaie a melique et asperule	besondere Eichenart mit irgendeinem Unterwuchs
Forest Land	1	Fk	31131	hetraie calcicole	Buchenwald auf kalkhaltigem Substrat
Forest Land	1	Qk	31132	chenaie a charmes xerophile	trockenheitsliebende besondere Eichenart
Forest Land	1	Ru	31141	ormaie ruderale	Ulmenwald in Aufschuettungen
Forest Land	1	Ps	31151	peupleraie en site sec	Pappelwald in trockenen Gebieten
Forest Land	1	Ph	31152	peupleraie en site humide	Pappelwald in feuchten Gebieten
Forest Land	1	Pf	31153	plantation d'autres essences feuillus	Anpflanzungen Other Landr Laubbaeume
Forest Land	1	Ek	31161	foret de ravin sur substrat calcaire	Schluchtwald auf kalkhaltigem Substrat
Forest Land	1	Es	31162	foret de ravin sur substrat siliceux	Schluchtwald auf silikatischem Substrat
Forest Land	1	Va	31171	ormaie-frenaie alluviale	Ulmen-Eschenwald in Flusssedimenten
Forest Land	1	Vb	31172	aulnaie-frenaie alluviale mesotrophe	Erlen-Eschenwaelder in Flusssedimenten
Forest Land	1	Vn	31173	aulnaie alluviale nitrophile	Erlenwaelder in nitrtreichen Flusssedimenten
Forest Land	1	Vc	31174	aulnaie-frenaie des sources et ruisseaux	Erlen-Eschenwaelder in Quellgebieten und an Rinnsalen
Forest Land	1	Vm	31181	aulnaie mesotrophe a laiches	Erlenwaelder mit Seggen
Forest Land	1	Vx	31182	boulaie marcageuse	sumpfiger Birkenwald
Forest Land	1	So	32421	saulaie humide sur sol tourbeux ou acide	Weidenbaeume auf einem feuchten, torfigen oder sauren Boden
Forest Land	1	Sf	32422	saulnaie humide mesotrophe ou eutrophe	Weidenbaeume auf einem feuchten, mittelmaessig oder gut mit Naehrstoffen versorgten Boden
Cropland	2	B	21	terres arables	Ackerland
Cropland	2		211	terres arables hors perimetre d'irrigation	Ackerland, nicht bewässert
Cropland	2	Ba	2111	culture annuelle	jaehrliche Kulturen
Cropland	2		2312	prairies mesophiles ameliorees	mesophile Weidewiese
Cropland	2	Hu	23121	prairie mesophile de fauche	mesophile Mahdwiese
Cropland	2	Hua	23122	prairie mesophile de fauche atypique	untypische mesophile Mahdwiese
Cropland	2	Hp	23123	pature a ray grass et trefle blanc	Futterpflanzen in breiten Streifen und Klee
Cropland	2	Hx	23124	prairie a flore tres pauvre	Wiesen mit geringer Biodiversitaet
Cropland	2	Hr	23125	prairie mesophile abandonnee a flore ruderale	aufgegebene mesophile Wiese mit Ruderalvegetation
Grassland	3	N	14	espcaes verts artificialises, non agricoles	Grünflachen, nicht landwirtschaftlich genutzt
Grassland	3	B	22	cultures permanentes	Dauerkulturen
Grassland	3	H	23	prairies	Wiesen
Grassland	3		32	milieux a vegetation arbustive et/ou herbacee	Gehölze und Buschwerk
Grassland	3		141	espaces verts urbains	städtische Grünflächen
Grassland	3	Bv	221	vignobles	Weinberge
Grassland	3	Be	222	verges et petits fruits	Streuobst und kleine/niedrigwachsende Fruechte
Grassland	3		231	prairies permanentes	Dauerwiesen
Grassland	3	H	321	pelouses et paturages naturels	Naturnahe Weideflächen
Grassland	3	C	322	landes et broussailes	Heide und Buschwerk
Grassland	3		323	vegetations sclerophylles	Holzartiges Gebüsch
Grassland	3	S	324	forets et vegetation arbustive en mutation	Wald und Gehölz im übergang
Grassland	3	Nv	1412	zone vertes, parcs	Gruenanlagen, Parks
Grassland	3	Nr	1422	zone recreative	Erholungsgebiet
Grassland	3	Bp	2112	pepiniere	Baumschule
Grassland	3	Bvn	2211	vignobles en pentes	Weinberge in Steillagen
Grassland	3	Bvt	2212	vignobels en terrasses	Weinberge in Terrassen
Grassland	3	Bve	2213	vignobles en plaine	Weinberge in ebenen Gebieten
Grassland	3	Beh	2221	verges, hautes tiges	Streuobst mit hohen Staemmen
Grassland	3	Beb	2222	verges, basses tiges	Streuobst mit niedrigen Staemmen
Grassland	3		2311	prairies semi-naturelles, humides et non-amendees	Halbnatürliche Wiesen
Grassland	3	Ha	3211	pelouses silicicole a agrostis	Silikatrasen mit irgendeiner Viehfutterpflanze
Grassland	3	Hn	3212	pelouse silicicole a nard	Silikatraseen mit irgendeiner aromatischen Krautpflanze
Grassland	3	Hk	3213	pelouse calcaire	Kalkrasen
Grassland	3	Hg	3214	pelouse pionniere des carrieres	Pionierrasen in Steinbruechen
Grassland	3	Hz	3215	pelouse sur sol intoxique	Rasen auf giftigem (vielleicht schwermetallbelasteten) Gelaende
Grassland	3	Cg	3221	lande seche a callune	trockene Heide mit irgendeinem speziellen Heidekrautgewaechs
Grassland	3	Cj	3222	lande a callune genevrier	Heidekrautgewaechse mit Strauch mit widerstaendigen, stacheligen Blaettern, der Beeren ausbildet
Grassland	3	Cd	3223	lande a callune degradee	degradierte Heide mit speziellem Heidekrautgewaechs
Grassland	3	Cv	3224	lande seche a myrtille	trockene Heide mit Heidelbeere
Grassland	3	Ct	3225	lande tourbeuse a myrtille	Torfheide mit Heidelbeere
Grassland	3	Cs	3226	lande a genets	Heide mit einem robusten Strauch mit gelben Blaettern
Grassland	3		3241	fourres en sites secs	Wälder auf trockenen Standorten
Grassland	3		3242	fourres en sites humides	Wälder auf feuchten Standorten
Grassland	3	Hc	23111	prairie humide peu ou non fertilisee	Feuchtwiese kaum oder nicht geduengt
Grassland	3	Hj	23112	prairie humide peu ou non fertilisee a joncs	Feuchtwiese kaum oder nicht geduengt mit einem wasserliebenden Kraut mit langem Stengel
Grassland	3	Hf	23113	prairie humide a reine des pres	Feuchtwiese mit einem krautigen Rosaceaengewaechs
Grassland	3	Hm	23114	prairie humide non fertilisee a molinie	ungeduengte Feuchtwiese mit bestimmtem Suessgrasgewaechs
Grassland	3	Hkm	32131	sur marne	auf Mergel
Grassland	3	Hkx	32132	sur sol pierreux	auf steinreichem Boden
Grassland	3	Hks	32133	sur sol sableux	auf sandreichem Boden
Grassland	3	Cdm	32231	a dominance de molinie	mit Dominanz irgendeines Suessgrasgewaechses
Grassland	3	Cdc	32232	a dominance de canche flexueuse	mit Dominanz einer flexible biegsamen Futterpflanze
Grassland	3	Cdf	32233	a dominance de fougere aigle	mit Dominanz eines bestimmten Farns
Grassland	3	Sp	32411	fourre d'epineux	dorniges Dickicht
Grassland	3	Sk	32412	fourre calcaire	Dickicht auf kalkhaltigem Untergrund
Grassland	3	Sx	32413	fourre de buis	Buchsbaumdickicht
Grassland	3	Se	32414	vegetation des coupes forestiere	Vegetation der Waldrodungsflaechen
Grassland	3	Sz	32415	recrus divers	verscheidene Pionierpflanzen nach Rodung
Grassland	3	Hmo	231141	type oligotrophe	wenig Naehrstoffe
Grassland	3	Hmm	231142	type mesotrophe	mittelmaessig Naehrstoffe
Grassland	3	Hme	231143	type eutrophe	viel Naehrstoffe

LULUFC nomenclature		OBS Nomenclature			
	Code	Acronym	Code	Original in French	translated into German
Settlements	4	U	11	zones urbanisees	Städtisches Gebiet
Settlements	4	I/T	12	zones industrielles, commerciales et reseaux de communication	Industrie- und Handelsflächen sowie Transportgelände
Settlements	4	K	13	mines, decharges et chantiers	Minen, Schutthalden und Baustellen
Settlements	4		111	tissu urbain continu	Zusammenhängendes Stadtgebiet
Settlements	4		112	tissu urbain discontinu	Unzusammenhängendes Stadtgebiet
Settlements	4		121	zones industrielles, commerciales et socio-culturelles	Flächen genutzt von Industrie, Handel und Kultur
Settlements	4		122	reseau routier, ferroviaire et espaces associes	Schienewegenetz und zugehörige Flächen
Settlements	4	Ip	123	zones portuaires	Hafengebiete
Settlements	4	Ia	124	aeroports	Flughafen
Settlements	4		131	extraction de materiaux (en activite)	Abbauflächen
Settlements	4		133	chantiers	Baustellen
Settlements	4		142	equipements sportifs et de loisir	Sport- und Freizeitanlagen
Settlements	4	Uh	1111	zone urbaine dense	dicht besiedeltes Gebiet
Settlements	4	Uf	1121	zone semi-urbaine	semiurbaner Raum
Settlements	4	Ul	1122	extention de l'habitat le long des routes	Siedlungen entlang von Strassen
Settlements	4	Ue	1123	espace urbain ouvert sans verdure importante	unbebauter staedtischer Raum ohne bedeutende Vegetation
Settlements	4	Ur	1124	zone d'habitat rural	laendlicher Siedlungsraum
Settlements	4		1211	industrie et commerce	Industrie- und Handelsflächen
Settlements	4		1212	installations socio-culturelles	Flächen für Freizeit- und Kulturnutzung
Settlements	4		1213	installations specialisees	Sonderflächen
Settlements	4		1221	routes	Strassennetz
Settlements	4		1222	chemins de fer	schienewegenetz
Settlements	4	Ipi	1231	installation portuaire industrielle	Industriehafen
Settlements	4	Ipp	1232	zone portuaire de plaisance	Yachthaften
Settlements	4	Iah	1241	terminal, hangar	Terminals, Hangar
Settlements	4	Iaa	1242	piste et taxiways	Landebahnen
Settlements	4	Ks	1311	carriere (sable, pierres …)	Steinbruch
Settlements	4	Kg	1312	graviere	Kiesgrube
Settlements	4	Km	1313	mines a ciel ouvert (minerais)	Tagebau
Settlements	4	Ko	1321	depotoir	Muelldeponie
Settlements	4	Ki	1322	crassier et friche industrielle	Halde und industrielle Brache
Settlements	4	Kc	1331	chantier en cours	aktuelle Baustellen
Settlements	4	Nc	1411	cimetiere	Friedhof
Settlements	4	Nb	1413	route bordee d'espace vert important	Strasse mit bedeutenden Gruenstreifen
Settlements	4	Np	1414	parking avec verdure important	Parkplatz mit bedeutender Vegetation
Settlements	4	Nj	1421	plaine de sport et/ou de jeux	Sport- oder Spielplatz
Settlements	4	Ns	1423	amenagement particulier	besondere Einrichtung
Settlements	4	Ng	1424	cite jardiniere	Kleingartenanlagen
Settlements	4	Uhh	11111	batiments hauts	mit hohen Gebaeuden
Settlements	4	Uhb	11112	batiments bas	mit niedrigen Gebaeuden
Settlements	4	Ufv	11211	avec vegetation importante	mit bedeutenden Vegetationsanteilen
Settlements	4	Ufs	11212	sans vegetation importante	ohne bedeutende Vegetationsanteile
Settlements	4	Uea	11231	places	Plaetze
Settlements	4	Uep	11232	parkings	Parkplaetze
Settlements	4	Uef	11233	friche urbaine	Siedlungsbrache
Settlements	4	Il	12111	industrie lourde	Schwerindustrie
Settlements	4	Iz	12112	zoning industriel (+ domaine militaire)	Industriegebiet (+ militaerische Nutzung)
Settlements	4	Im	12113	zone d'activites multiples	Zone zahlreicher Nutzungen
Settlements	4	Is	12114	infrastructure agricole, horticole	Gartenbau- und Landwirtschaftsinfrastruktur
Settlements	4	Iu	12121	campus universitaire/ecole	Universitaetscampus und Schulhof
Settlements	4	If	12122	expositions et foires	Ausstellungen und Messen
Settlements	4	Ih	12123	hopitaux	Krankenhaeuser
Settlements	4	Ic	12124	centre culturel et/ou sportif	Zentrum fuer Kultur und Sport
Settlements	4	It	12131	distribution haute tension	Stromversorgung
Settlements	4	Ik	12132	installation d'assainissement des eaux usees	Klaeranlage
Settlements	4	Ir	12133	stockage d'hydrocarbures ou gaz	Gas- oder Kohlenwasserstofftanks
Settlements	4	Ta	12211	autoroutes	Autobahnen
Settlements	4	Tn	12212	route nationale	Bundesstrasse
Settlements	4	Tr	12213	chemin repris	Weg zur Entnahme (von Holz …) ?
Settlements	4	Tc	12214	route communale	Landstrasse
Settlements	4	Te	12215	chemin d'exploitation	Betriebsstrassen ?
Settlements	4	Ts	12216	aires et surfaces carrossables	befahrbare Oberflaechen und Plaetze
Settlements	4	Tg	12221	gare importante	wichtiger Bahnhof
Settlements	4	Tt	12222	tirage	Zug
Settlements	4	Tv	12223	voies ferrees	Schienennetz
Wetland	5	M	41	zones humides interieures	Feuchtflächen im Binnenland
Wetland	5	A	51	eaux continentales	Wasserflächen im Binnenland
Wetland	5		411	marais interieurs	Sumpfgebiete
Wetland	5		511	cours et voies d'eaux	Wasserläufe und -strassen
Wetland	5		512	plans d'eau	Wasserflächen (Seen, Teiche etc.)
Wetland	5	Mr	4111	roseliere	Schilf
Wetland	5	Mc	4112	magnocaricaie	Feuchtgebietsvegetation
Wetland	5	Ms	4113	bas-marais acide	saures Niedermoor
Wetland	5	Ma	4114	bas-marais alcalin	basisches Niedermoor
Wetland	5	Mb	4115	bas-marais alcalin ruderalise	basisches Niedermoor (ruderal)
Wetland	5	An	5111	cours d'eau natuels	natuerliche Wasserlaeufe
Wetland	5	Ac	5112	voies d'eau artificielles	kuenstliche Wasserlaeufe
Wetland	5	Al	5121	plan d'eau naturel	natuerliche Wasserflaeche
Wetland	5	Aa	5122	plan d'eau artificiel	kuenstliche Wasserflaeche
Wetland	5	Ab	5123	bras mort	Altarm
Wetland	5	?	5124	petit plan d'eau, mardelle	Teich
Wetland	5	Ar	5125	bassin, reservoir, etc. …	Becken, Reservoir
Wetland	5	Mrp	41111	a baldingere	mit Rohrglanzgras (aehnlich Schilfrohr)
Wetland	5	Mrg	41112	a glycerie	wasserliebendes Suessgras mit langen Blaettern
Wetland	5	Mrs	41113	a jonc des chaisiers	wasserliebendes Kraut mit langem Stengel
Wetland	5	Mrt	41114	a massette	mit schmalblaettrigem Rohrkolben
Wetland	5	Mrm	41115	melangee	gemischt
Wetland	5	Mrr	41116	a roseaux	Schilf
Wetland	5	Alh	51211	plus ou mojns sale	mehr oder weniger salzhaltig
Wetland	5	Alo	51212	oligotrophe	wenig Naehrstoffe
Wetland	5	Alm	51213	mesotrophe	mittelmaessig Naehrstoffe
Wetland	5	Ale	51214	eutrophe	viel Naehrstoffe
Wetland	5	Aah	51221	plus ou mojns sale	mehr oder weniger salzhaltig
Wetland	5	Aao	51222	oligotrophe	wenig Naehrstoffe
Wetland	5	Aam	51223	mesotrophe	mittelmaessig Naehrstoffe
Wetland	5	Aae	51224	eutrophe	viel Naehrstoffe
Wetland	5	Aro	51251	oligotrophe	wenig Naehrstoffe
Wetland	5	Arm	51252	mesotrophe	mittelmaessig Naehrstoffe
Wetland	5	Are	51253	eutrophe	viel Naehrstoffe
Wetland	5	Arz	51254	sans valeur biologique	ohne biologischen Wert
Other Land	6		33	espaces ouverts sans ou avec peu de vegetation	Offene Flächen mit wenig oder keiner Vegetation
Other Land	6		132	decharges et friches	Brachflächen
Other Land	6		332	roches nues	Offener Fels
Other Land	6	Ky	1323	friche hors zone urbaine et industrielle	Brachen ausserhalb besiedelter und industrieller Gebiete
Other Land	6	Ku	1332	surface ruderale ou remblais	Aufschuettungen
Other Land	6	G	3321	carriere abondonnee	aufgegebener Steinbruch

Table 6-2 Nomenclature of OBS99

german acronyms	french acronyms	Code	german legend OBS99	french legend OBS99	LULUFC nomenclature	Forest Type
BSC	UAD	1.1.1	Settlements, verdichtet, City	Tissu urbain dense	Settlements	
BSM	UAA	1.1.2.1.1	Settlements mit bedeutender Vegetation	Zone semi-urbaine avec vegetation importante	Settlements	
BSO	UAS	1.1.2.1.2	Settlements ohne bedeutende Vegetation	Zone semi-urbaine sans vegetation importante	Settlements	
BSB	UAL	1.1.2.2	Settlementssbaender entlang von Strassen	Urbanisation longiligne, Bandes urbanisees le long des routes	Settlements	
BSP	UAP	1.1.2.3.1	Oeffentliche Plaetze	Place	Settlements	
BSR	UAF	1.1.2.3.2	Settlementssbrachen ohne/geringe Vegetation	Friche urbaine, Espace urbain ouvert sans verdure importante	Settlements	
BSE	UAH	1.1.2.4	Einzelhaeuser, Hoefe etc. ausserhalb Bebauung	Habitat dissemine en zone rurale, hameau	Settlements	
BSF	UAI	1.1.2.4	Bebauung < 2500m2 im Aussenbereich	Constructions isolees en zone rurale < 2500m2	Settlements	
BII	UIL	1.2.1.1.1	Industrie	Industrie lourde	Settlements	
BIG	UIA	1.2.1.1.2	Gewerbe, Militaer, Dienstleistung	Zone d'activites economiques, terrain militaire	Settlements	
BIO	UPS	1.2.1.2	Oeffentliche Bebauung	BI˜timents et installations α destination socio-culturelle	Settlements	
BIS	UPE	1.2.1.3.1	Sondergebiete, Stromversorgung	Installations de distribution electrique	Settlements	
BIW	UPU	1.2.1.3.2	Sondergebiete, Wasserversorgung	Installation de traitement des eaux usees	Settlements	
BIA	UPH	1.2.1.3.3	Sondergebiete, Gasversorgung	Installations de stockage d'hydrocarbures et de gaz	Settlements	
BIL	UAC	1.2.1.4	gewerbliche Landwirtschaft (Stallanlagen, Gewaechshaeuser)	Constructions agricoles et horticoles, etables, serres	Settlements	
BVS	UTR	1.2.2.1.1	bedeutende Strassen (>20m)	Routes importantes (>20m), voies rapides	Settlements	
BVW	UTR	1.2.2.1.1	Strassen <20m Breite	Route < 20m de largeur	Settlements	
BVWB	UTS	1.2.2.1.2	Parkplatz	Zones de stationnement	Settlements	
BVB	UTF	1.2.2.2	Bahnanlage	Infrastructure ferroviaire, gare	Settlements	
BVE	UTF	1.2.2.2	Eisenbahn <20m Breite	Voies ferrees < 20m de largeur	Settlements	
BVH	UTP	1.2.3	Hafengebiete	Zone portuaire	Settlements	
BVT	UTA	1.2.4.1	Flughafen, Gebaeude, Terminal	Aeroport; terminal, hangar	Settlements	
BVL	UTT	1.2.4.2	Flughafen, Landebahn	Aeroport; piste et taxiways	Settlements	
BAF	UEM	1.3.1	Abbauflaeche, Tagebau	Zone d'extraction de materiaux	Settlements	
BAA	UER	1.3.2.1	Aufschuettung, Deponie	Remblais et decharges	Settlements	
BAH	UEC	1.3.2.2	Halden	Crassier	Settlements	
BAB	UEF	1.3.2.3	Brachen industrieller Gebiete	Friche industrielle	Settlements	
BAU	UEH	1.3.2.4	Baustellen	Chantier	Settlements	
BGF	UVC	1.4.1.1	Friedhoefe	Cimetiere	Settlements	
BGG	UVV	1.4.1.2	Gruenanlagen, Parks	Zones de verdure, parcs	Grassland	
BGS	UVS	1.4.2.1	Sport-, Spiel-, Camping-, Golfplaetze	Terrain de sport, espace recreatif, camping, golf etc.	Settlements	
BGK	UVJ	1.4.2.2	Kleingartenanlagen	Cite jardiniere	Settlements	
LAA	RAA	2.1.1.1	Acker	Terres agricoles, cultures annuelles	Cropland	
LBG	RAH	2.1.1.2	Baumschule, Gartenbau	Pepinieres, horticulture, arbres de Noõl	Grassland	
LWT	RVT	2.2.1.1	Weinbau, Terrasse	Vignoble en terrasse	Grassland	
LWS	RVA	2.2.1.2	Weinbau, sonstige	Autres vignoble	Grassland	
LSH	RHT	2.2.2.1	Streuobst, Hochstamm	Verger α hautes tiges	Grassland	
LSN	RBT	2.2.2.2	Obst, Niederstamm	Verger α basses tiges	Grassland	
LFG	RPR	2.3.1.1	Feuchtgruenland	Prairie humide	Grassland	
LMG	RPM	2.3.1.2	Mesophiles Gruenland	Prairie mesophile	Cropland	
WLE	FFC	3.1.1.1	Laubwald, Eiche	Futaie feuillue α dominance de chene	Forest Land	Deciduous Forest, Oak
WLB	FFH	3.1.1.2	Laubwald, Buche	Futaie feuillue α dominance de hetre	Forest Land	Deciduous Forest, Beech
WLS	FFD	3.1.1.3	Laubwald, sonstige Laubbaumarten	Futaie de feuillus divers	Forest Land	Deciduous Forest, Mixed
WLM	FFM	3.1.1.4	Laubwald, gemischt, Eiche, Buche	Futaie feuillue melangee de chenes et de hetres	Forest Land	Deciduous Forest, Mixed Oak and Beech
WLN	FTC	3.1.1.5	Eichen-Niederwald	Taillis de chene	Forest Land	Oak coppice
WLP	FFP	3.1.1.6.1	Laubwald, Pappel-Monokulturen	Peupleraie et autres monocultures feuillues	Forest Land	Poplars - monoculture
WLO	FFP	3.1.1.6.2	Laubwald, Forest Landliche Monokulturen	Peupleraie et autres monocultures feuillues	Forest Land	Poplars - monoculture
WNF	FRE	3.1.2.1	Nadelwald, Fichte/Douglasie/Tanne	Foret resineuse (epiceas, douglas, sapins)	Forest Land	Coniferous, Spruce/Douglas Fir/Fir
WNK	FRP	3.1.2.2	Nadelwald, Kiefer/Laerche	Foret resineuse (pins, melezes et autres resineux)	Forest Land	Coniferous Pine/Larch
WNM	FRM	3.1.2.3	Nadelwald, gemischt	Foret resineuse melangee	Forest Land	Coniferous mixed
WMT	FMP	3.1.3.1	Mischwald (Laub/Nadel), truppweise Mischung	Foret melangee (feuillus/resineux) par pied, par bouquet	Forest Land	Mixed forest (deciduous/coniferous), mixed stands
WMF	FMM	3.1.3.2	Mischwald (Laub/Nadel), fliessende Mischung	Foret melangee (feuillus/resineux), melange intime	Forest Land	Mixed forest (deciduous/coniferous), continuously mixed
WAU	FCD	3.1.3.3	AufForest Landungen, Dickungen (Baumart nicht erkennbar)	Culture forestiere d'essences non definies	Forest Land	Affforestation, species not recognisable
WSF	FSD	3.1.3.4	Sonstige Forest Landflaechen (Schlagflur, Windbruch)	Autres surfaces forestieres (coupes rases, chablis)	Forest Land	other forest land, (clear cut areas, Windfall)
KSI	PSI	3.2.1.1	Silicattrockenrasen	Pelouse silicicole	Grassland	
KKA	PCA	3.2.1.2	Kalkmagerrasen	Pelouse calcaire	Grassland	
KFE	PSR	3.2.1.3	Fels- und Schotterrasen, Pionierfluren	Pelouses pionnieres (sur substrat rocheux ou graveleux)	Grassland	
KHE	PLR	3.2.2	Heiden, Rohbodenstandorte	Landes, sols nus	Grassland	
KRM	PFR	3.2.3.1	Ruderalstandorte, Staudenfluren mittlerer bis trock	Surfaces ruderalisees et friches sur sols secs α frais	Grassland	
KRF	PFH	3.2.3.2	Ruderalstandorte, Staudenfluren feuchter Standorte	Surfaces ruderalisees et friches sur sols humides	Grassland	
SBT	BPS	3.2.4.1	Buschwerk, Vorwaelder trockener Standorte	Buissons, prebois sur sols secs	Grassland	
SBM	BPF	3.2.4.2	Buschwerk, Vorwaelder mittlerer Standorte	Buissons, prebois sur sols frais	Grassland	
SBF	BPH	3.2.4.3	Buschwerk, Vorwaelder feuchter Standorte	Buissons, prebois sur sols humides	Grassland	
SBG	BPE	3.2.4.4	Blockschutt- und Geroellwaelder	Forets, prebois sur eboulis	Grassland	
SBP	BPA	3.2.4.5	Gehoelzplanzungen	Plantations cubustives	Grassland	
OFF	RNU	3.3.2	Offene Felsflaechen	Roche nue	Other Land	
OFK	RNU	3.3.2	Offene Felsflaechen < 1500m2	Roche nue < 1500m2	Other Land	
OBS	REN	3.3.2.1	Offene Blockschutt- und Schotterflaechen	Eboulis et graviers non colonises	Other Land	
FRL	ROS	4.1.1.1	Roehrichte < 1500 m2	Roseliere < 1500m2	Wetland	
FRO	ROS	4.1.1.1	Roehrichte	Roseliere	Wetland	
FGG	MAG	4.1.1.2	Seggenrieder < 1500 m2	Magnocariтaie < 1500m2	Wetland	
FGS	MAG	4.1.1.2	Grossseggenrieder	Magnocariтaie	Wetland	
FKN	MBA	4.1.1.3	Uebergangsmoore < 1500m2	Bas marais < 1500m2	Wetland	
FKS	MBA	4.1.1.3	Kleinseggenrieder	Bas marais	Wetland	
GFA	ENP	5.1.1.1.1	Fliessgewaesser < 20m Breite, naturnah	Cours d'eau naturel < 20m de largeur	Wetland	
GFN	ECN	5.1.1.1.1	Fliessgewaesser natuerlicher Entstehung, naturnah	Cours d'eau naturel	Wetland	
GFB	EAP	5.1.1.1.2	Fliessgewaesser < 20m Breite, naturfern	Cours d'eau artificialise < 20m de largeur	Wetland	
GFF	ECA	5.1.1.1.2	Fliessgewaesser natuerlicher Entstehung, naturfern	Cours d'eau artificialise	Wetland	
GFC	EEP	5.1.1.2	Kanal, Fliessgewaesser (anthropogen) < 20m Breite	Voies d'eau artificielles < 20m de largeur	Wetland	
GFK	EEA	5.1.1.2	Fliessgewaesser kuenstlicher Entstehung	Cours d'eau artificiels	Wetland	
GFV	EAS	5.1.1.3	Fliessgewaesser < 20m Breite, naturfern, verrohrt	Cours d'eau artificialise < 20m de largeur sous sol	Wetland	
GFW	EES	5.1.1.4	Kanal, Fliessgewaesser (anthropogen) < 20m Breite, ve	Voies d'eau artificielles < 20m de largeur sous sol	Wetland	
GSA	EPP	5.1.2.1	Stillgewaesser < 1500m2, anthropogen, naturnah	Plans d'eau anthropogene proche de l'etat naturel < 1500m2	Wetland	
GSN	EPN	5.1.2.1	Stillgewaesser natuerlicher Entstehung	Plans d'eau anthropogene proche de l'etat naturel	Wetland	
GSB	EPH	5.1.2.2	Stillgewaesser < 1500m2, anthropogen, naturfern	Plans d'eau anthropogene artificiels < 1500 m2	Wetland	
GSK	EPA	5.1.2.2	Stillgewaesser kuenstlicher Entstehung	Plan d'eau artificiel	Wetland	
GAA	EBM	5.1.2.3	Altarme, Altwasser	Bras mort	Wetland	
GAM	EBP	5.1.2.3	Altarme, < 1500m2	Bras mort < 1500m2	Wetland	
GMD	EMA	5.1.2.4	"Mardelle"	Mardelle	Wetland	
GMM	EMP	5.1.2.4	"Mardelle" < 1500 m2	Mardelle < 1500m2	Wetland	
GBB	BRE	5.1.2.5.1	Becken, Reservoir von biol. Interesse	Bassin, reservoir ayant un interet ecologique	Wetland	
GBC	BRP	5.1.2.5.1	Becken, Reservoir < 1500m2, von biol. Interesse	Bassin, reservoir ayant un interet biologique < 1500 m2	Wetland	
GBD	BRS	5.1.2.5.2	Becken, Reservoir < 1500m2, ohne biol. Wert	Bassin, reservoir sans valeur biologique < 1500 m2	Wetland	
GBO	BRS	5.1.2.5.2	Becken, Reservoir ohne biol. Wert	Bassin, reservoir α ciel ouvert sans interet ecologique	Wetland	
LEB	ASO	6.2.1.1	markante Einzelbaeume	Arbre solitaire		
LBA	AGB	6.2.1.2	Baumgruppen	Groupe d'arbres, bosquets		
LBR	ARA	6.2.1.3	Baumreihen	Rangee d'arbres		
LHE	AHA	6.2.1.4	Hecken	Haie		