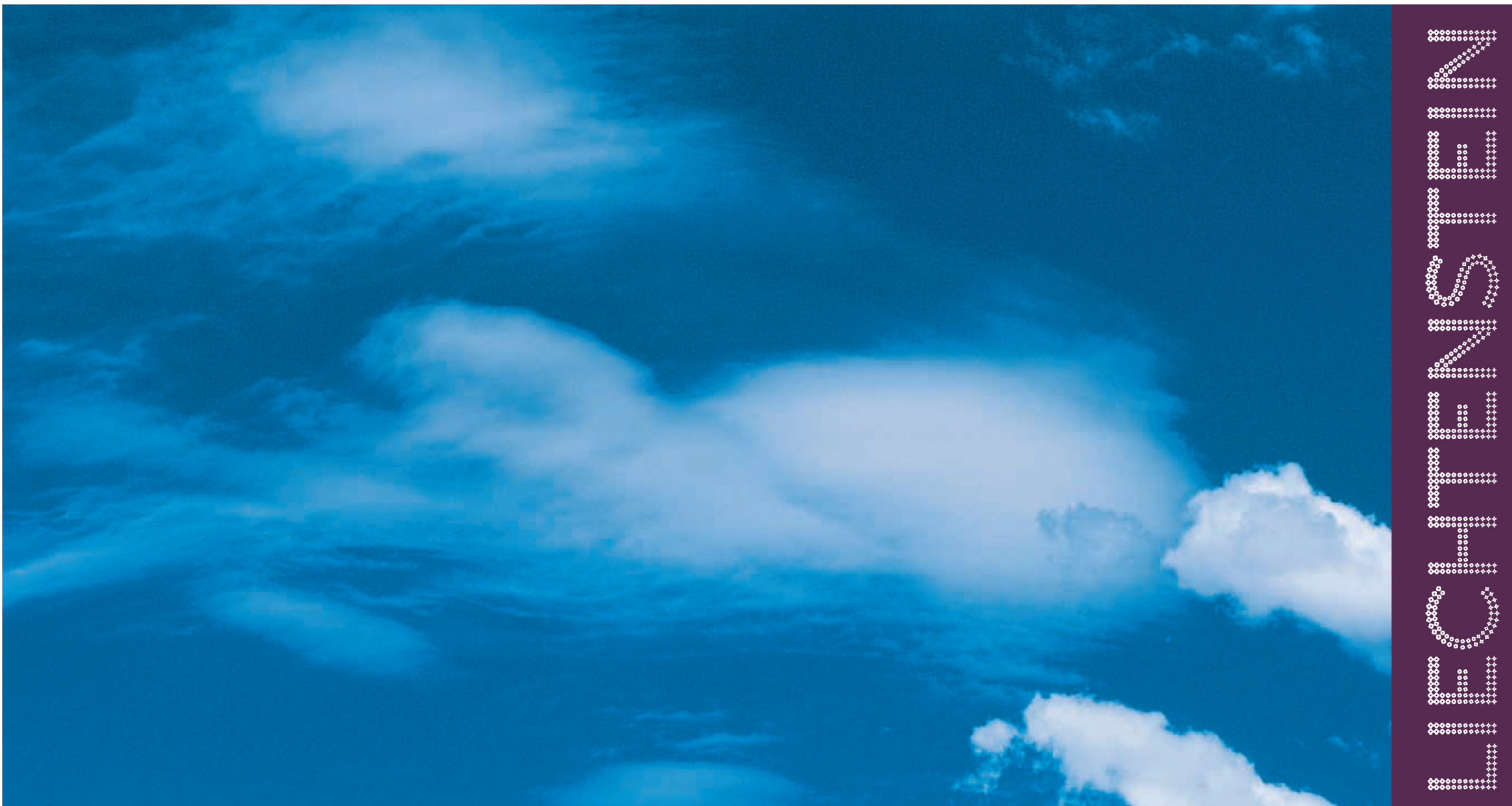
OFFICE OF ENVIRONMENTAL PROTECTION (OEP)
PRINCIPALITY OF LIECHTENSTEIN

Liechtenstein's Greenhouse Gas Inventory 1990 - 2004

National Inventory Report 2006

Submission of 22 December 2006
to the United Nations Framework Convention on Climate Change



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Glossary

ART	Agroscope Reckenholz-Tänikon Research Station (former name: Swiss Federal Research Station for Agroecology and Agriculture)
AVW	Amt für Volkswirtschaft (Office of Economic Affairs)
AWNL	Amt für Wald, Natur und Landschaft (Office of Forest, Nature and Landscape)
AZV	Abwasserzweckverband der Gemeinden Liechtensteins (Liechtenstein's wastewater administration union)
CH_4	Methane
CHP	Combined heat and power production
CO	Carbon monoxide
CO_2, CO_2 eq	Carbon dioxide (equivalent)
CRF	Common reporting format
dm	dry matter
FAL	Swiss Federal Research Station for Agroecology and Agriculture (since 2006: ART)
FCCC	Framework Convention on Climate Change
FOEN	Swiss Federal Office for the Environment (former name SAEFL)
Gg	Giga gramme (10^9 g = 1'000 tons)
GHFL	Genossenschaft für Heizöllagerung im Fürstentum Liechtenstein (Co-operation for the Storage of Gas Oil in the Principality of Liechtenstein)
GHG	Greenhouse gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbons (e.g. HFC-32 difluoromethane)
IPCC	Intergovernmental Panel on Climate Change
LFO	Light fuel oil (Gas oil)
LGV	Liechtensteinische Gasversorgung (Liechtenstein's gas utility)
LPG	Liquefied Petroleum Gas (Propane/Butane)
LULUCF	Land-Use, Land-Use Change and Forestry
LWA	Landwirtschaftsamt (Office of Agriculture)
MSW	Municipal solid waste
NIR	National Inventory Report
NIS	National Inventory System
NMVOC	Non-methane volatile organic compounds
N_2O	Nitrous oxide (laughing gas)
NO_x	Nitrogen oxides
OEA	Office of Economic Affairs

OEP	Office of Environmental Protection
PFC	Perfluorinated carbon compounds (e.g. Tetrafluoromethane)
SAEFL	Swiss Agency for the Environment, Forests and Landscape (former name of Federal Office for the Environment FOEN)
SF_6	Sulphur hexafluoride
SLP	Stabstelle für Landesplanung, Office of Land Use Planning
SO_2	Sulphur dioxide
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Inventory Preparation in Liechtenstein

In 1995, the Principality of Liechtenstein ratified the United Nations Framework Convention on Climate Change (UNFCCC). In 1995, 2001 and 2006, Liechtenstein submitted its National Communication Reports to the secretariat of the UNFCCC. Also, a first greenhouse gas inventory (without National Inventory Report) was submitted in the Common Reporting Format (CRF) in 2005. In 2006, two submissions took place, the first on 31 May and the second and current submission on 22 December, both including the national greenhouse gas inventory and a National Inventory Report. The current documents are annexed to the Initial Report under Article 7, paragraph 4 of the Kyoto Protocol.

In 2004, Liechtenstein ratified the Kyoto Protocol to the UNFCCC. A National Inventory System (NIS) according to Article 5.1 of the Kyoto Protocol has now been implemented.

The Office of Environmental Protection (OEP) is in charge of compiling the emission data and bears overall responsibility for Liechtenstein's national greenhouse gas inventory. In addition to the OEP, the Office of Economic Affairs (OEA), the Office of Agriculture (LWA), the Office of Forests, Nature and Landscape (AWNL) and the Office of Land Use Planning (SLP) participate directly in the compilation of the inventory. Several other administrative and private institutions are involved in inventory preparation.

Liechtenstein is a small central European State in the Alpine region with a population of 34'600 inhabitants (as of 31 December 2004) and with an area of 160 km^2. Its neighbours are therefore important partners: Liechtenstein and Switzerland form a customs and monetary union governed by a customs treaty. On the basis of this union, Liechtenstein is linked to Swiss foreign trade strategies, with few exceptions, such as trade with the European Economic Community: Liechtenstein – contrary to Switzerland – is a member of the Agreement of the European Economic Area. The Customs Union Treaty with Switzerland impacts greatly on environmental and fiscal strategies. Many Swiss taxes and regulations for special goods (for example, environmental standards) are also adapted and applied in Liechtenstein. For the determination of the GHG emissions, Liechtenstein appreciates having been authorised to adopt a number of Swiss methods and Swiss emission factors.

Chapter 1, the introduction, provides an overview of Liechtenstein's institutional arrangements for producing the inventory and the process and methodologies used for inventory preparation:

The activity data sources used to compile the national inventory and to estimate greenhouse gas emissions and removals are: The national energy statistics, separate statistics for the consumption of gasoline and diesel oil, agriculture, LULUCF and waste. The data is compiled and set up in line with the FCCC inventory guidelines (FCCC 2003). Emissions are calculated according to methodologies recommended by the IPCC and contained in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997a, 1997b, 1997c) and in the IPCC Good Practice Guidances (IPCC 2000, IPCC 2003). The data is finally implemented in the CRF Reporter.

All inventory data are assembled and prepared for input by an inventory group. It is responsible for ensuring the conformity of the inventory with UNFCCC guidelines.

Moreover, Chapter 1 provides information on key categories and uncertainties: 16 key categories are identified for 2004, where 11 are in the energy sector. An uncertainty analysis (Tier 1) estimates the level uncertainty of 11.3% and the trend uncertainty of 18.4% of total CO_2 equivalent emissions in 2004.

Chapter 2 provides an analysis of Liechtenstein's greenhouse gas emissions. The most important results are also reported further below in this Executive Summary.

Chapters 3 to 8 provide principal source and sink category estimates. Methods used are presented, activity data and emission factors are shown. The emissions are reported for the full time period 1990–2004.

Chapter 9 For the present GHG inventory, a fundamental effort has been accomplished to achieve the best possible data. A number of previous results have turned out to be rather different from the new results. The quality of the new results has much increased. The results are considered as reliable, whereas the former results are based on preliminary data.

Trend Summary: National GHG Emissions and Removals

In 2004, Liechtenstein emitted 271.3 Gg (kilotonnes) CO_2 equivalent, or 7.8 tonnes CO_2 equivalent per capita (CO_2 only: 6.9 tonnes per capita) to the atmosphere not including emissions and removals from Land Use, Land-Use Change and Forestry (LULUCF).

For 2004, 16 categories were identified as key categories in level and trend analysis for Liechtenstein, covering 96.2% of total greenhouse gas (GHG) emissions (CO_2 equivalent). 40.1% of total GHG emissions resulted from the two most important key categories: CO_2 from source category 1A3b Fuel Combustion – Transport/gasoline (23.2%) and CO_2 from source category 1A4a Fuel Combustion – Other Sectors; Commercial, Institutional/ liquid fuels (16.9%). Besides the energy sector, other key categories are found in source category 2 Industrial Processes and 4 Agriculture.

Figure 1 and Table 1 show Liechtenstein's annual GHG emissions by individual GHG for 1990 (base year) till 2004. Over this period, total annual GHG emissions increased by 17.8% (total excluding emissions from Land Use, Land-Use Change and Forestry, LULUCF).

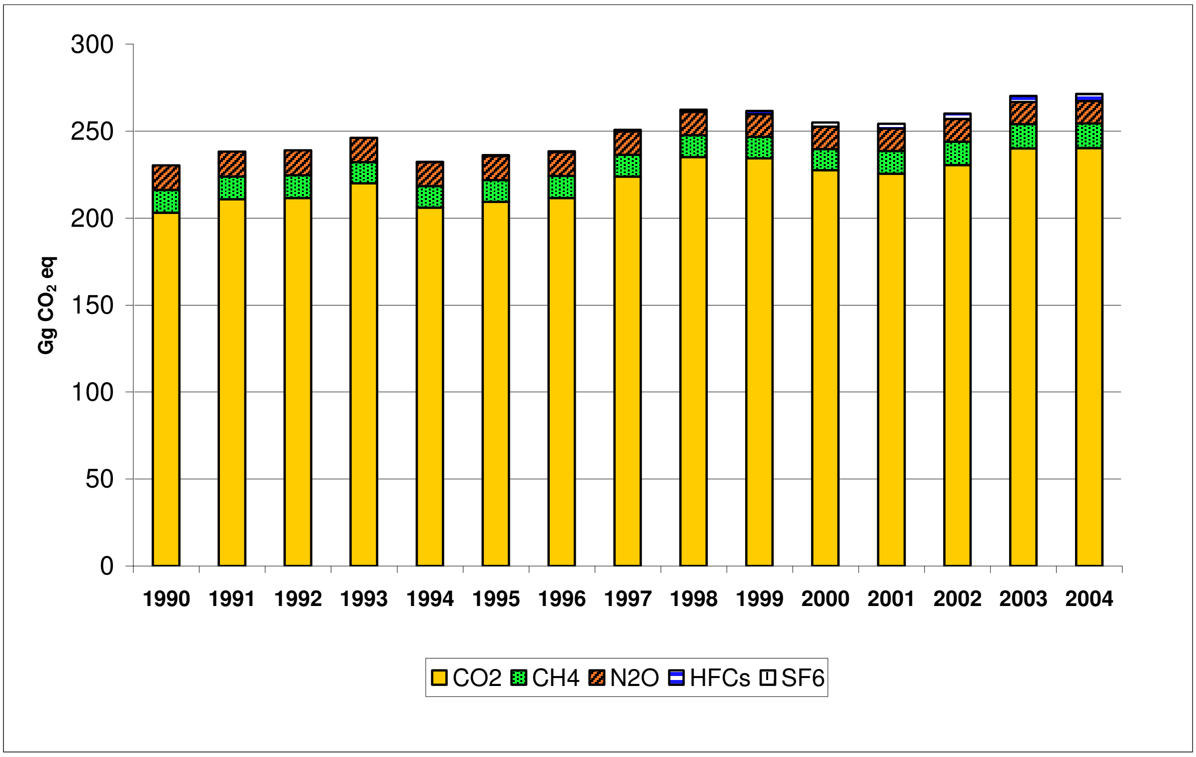

Figure 1 Trend of Liechtenstein's greenhouse gas emissions by gases1990–2004. CO_2 corresponds to the total CO_2 emissions excl. net CO_2 from LULUCF.

Greenhouse Gas Emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*1990→2004*
	CO_2 equivalent (Gg)															%
CO_2 emissions including net CO_2 from LULUCF	195.7	201.8	204.4	212.9	198.5	200.0	203.6	220.0	230.3	229.8	221.9	221.6	225.0	234.2	233.8	*19.5*
CO_2 emissions excluding net CO_2 from LULUCF	203.1	210.8	211.7	220.0	206.0	209.4	211.6	223.8	235.1	234.3	227.5	225.6	230.5	240.0	240.2	*18.3*
CH_4	13.2	13.0	12.9	12.2	12.4	12.5	12.6	12.4	12.5	12.4	12.2	12.9	13.5	13.9	14.3	*8.6*
N_2O	14.2	14.3	14.3	13.9	13.8	13.9	13.6	13.5	13.2	13.2	12.8	12.9	12.9	12.9	12.8	*-9.5*
HFCs	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.0	1.4	1.8	2.3	2.9	3.2	3.4	3.9	---
PFCs	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	---
S_{F6}	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	---
Total (incl. net CO_2 from LULUCF)	**223.1**	**229.2**	**231.7**	**239.1**	**224.9**	**226.8**	**230.5**	**247.0**	**257.4**	**257.2**	**249.3**	**250.4**	**254.6**	**264.4**	**265.0**	***18.8***
Total (excl. net CO_2 from LULUCF)	**230.4**	**238.2**	**238.9**	**246.1**	**232.4**	**236.2**	**238.4**	**250.8**	**262.3**	**261.7**	**254.9**	**254.4**	**260.1**	**270.3**	**271.3**	***17.8***
Total (excl. LULUCF Removals/Emissions)	**230.4**	**238.2**	**238.9**	**246.1**	**232.4**	**236.1**	**238.4**	**250.8**	**262.3**	**261.6**	**254.9**	**254.4**	**260.1**	**270.3**	**271.3**	***17.8***

Table 1 Summary of Liechtenstein's GHG emissions in CO_2 equivalent (Gg) by gas, 1990–2004 (CRF Table 10s5/10s5.2). The column on the far right (digits in italics) shows the percent change in emissions in 2004 as compared to the base year 1990.

With regard to the distribution of emissions by individual greenhouse gases, CO_2 is the largest single contributor to emissions, accounting for about 88.5% of total GHG emissions (without LULUCF) in 2004, 88.1% in 1990. The share of CH_4 decreased slightly from 5.7% (1990) to 5.3% (2004). Simultaneously, the share of N_2O decreased from 6.2% to 4.7%. The share of synthetic gases increased from 0.0% (1990) to 1.5% (2004). Figure 2 shows the share of 2004 emissions contributed by individual greenhouse gases. Since the shares of emissions contributed by the gases have remained relatively constant, the diagram is also representative for the base year 1990.

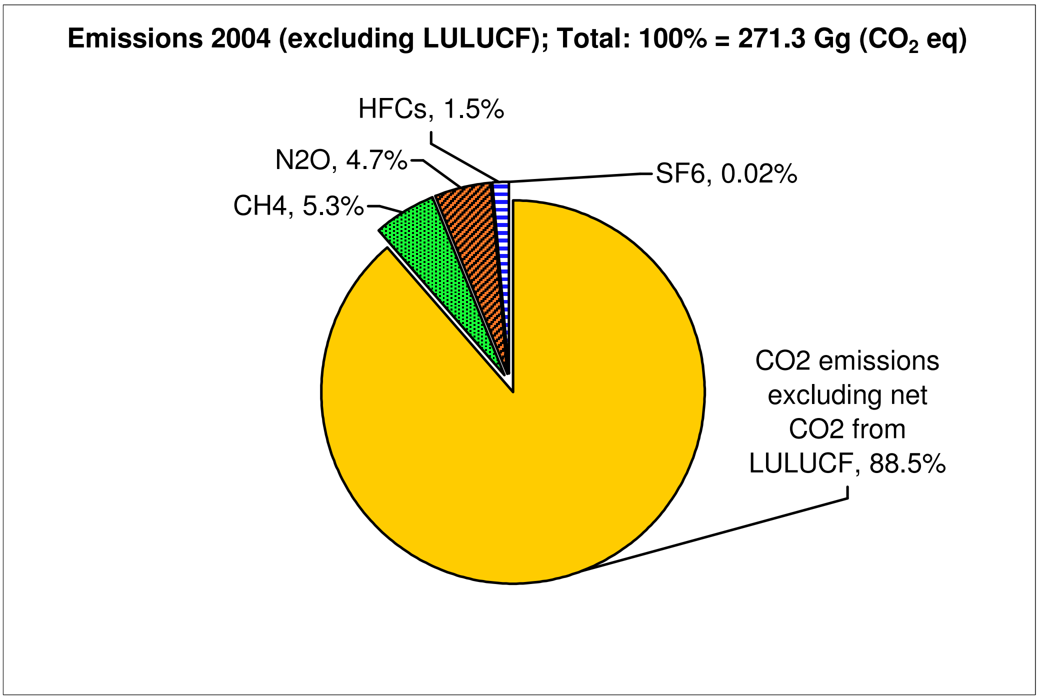

Figure 2 Liechtenstein's GHG emissions by gas (excluding LULUCF), 2004.

Overview of Source and Sink Category Estimates and Trends

Table 2 shows the GHG emissions and removals by categories. The Energy sector is the largest source of national emissions, contributing to 88.5% of the emissions. An increase of 19% is found for the Energy sector for the period 1990–2004. The emissions from industrial processes exclusively consist of synthetic gases, which have also increased. The emissions from agriculture have decreased by -6% during this period. The emissions from the waste sector have increased, but one has to note that it only contains a relatively small amount of emissions (mainly from composting). Liechtenstein's activities in the LULUCF sector form a net sink with the removals varying in the range between -3.8 to -9.9 Gg CO_2 eq.

Greenhouse Gas Source and	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*1990→2004*
Sink Categories	CO_2 equivalent (Gg)															*%*
1 Energy	203.4	211.4	212.6	221.0	207.1	210.6	212.9	225.4	236.7	236.0	229.4	227.3	232.2	241.8	242.0	*19.0%*
2 Industrial Processes	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.0	1.4	1.8	2.3	3.0	3.2	3.5	4.0	---
3 Solvent and Other Product Use	2.0	1.9	1.8	1.7	1.7	1.6	1.5	1.4	1.4	1.3	1.3	1.2	1.2	1.2	1.1	---
4 Agriculture	23.7	23.6	23.3	22.0	22.0	22.1	21.9	21.6	21.3	21.0	20.2	21.3	21.7	22.1	22.5	*-5.0%*
5 Land Use, Land-Use Change and Forestry	-7.3	-8.9	-7.2	-7.1	-7.5	-9.3	-7.9	-3.8	-4.9	-4.4	-5.6	-4.0	-5.5	-5.8	-6.4	*-13.2%*
6 Waste	1.3	1.3	1.3	1.3	1.5	1.4	1.5	1.4	1.5	1.5	1.7	1.5	1.7	1.7	1.7	*29.2%*
Total (including LULUCF)	**223.1**	**229.2**	**231.7**	**239.1**	**224.9**	**226.8**	**230.5**	**247.0**	**257.4**	**257.2**	**249.3**	**250.4**	**254.6**	**264.4**	**265.0**	***18.8%***

Table 2 Summary of Liechtenstein's GHG emissions by source and sink categories in CO_2 equivalent (Gg) 1990 and 2004. The most right column (in italics) shows the percent change in emissions in 2004 as compared to the base year 1990.

Acknowledgement

Liechtenstein's Office of Environmental Protection (OEP) highly appreciates the generous support by the members of the Swiss FOEN Inventory Core Group. The free use of methods and tools developed by the Swiss Federal Office for the Environment (FOEN) has been essential during the development of the completely revised Liechtenstein GHG inventory and the NIR. We also gratefully acknowledge the support of the Agroscope Reckenholz-Tänikon Research Station (ART). The free use of the worksheets developed by ART facilitated very much the modelling of the agricultural emissions. The personal and close contacts between the GHG specialists of Switzerland and Liechtenstein developed during this work laid the basis for a very promising and fruitful cooperation both on a technical and on a political level.

The OEP also thanks the data suppliers of Liechtenstein: Office of Agriculture, Office of Economic Affairs, Office of Forests, Nature and Landscape, Office of Land Use Planning, Liechtensteinische Gasversorgung, Liechtensteinische Kraftwerke, Genossenschaft für Heizöl-Lagerhaltung im Fürstentum Liechtenstein), Abwasserzweckverband der Gemeinden Liechtensteins (AZV), Rhein Helikopter AG, the sectoral experts and the NIR authors. Their effort made it possible to finalise the inventory and the NIR within the very ambitious time table set by the OEP.

1. Introduction

1.1. Background Information on Liechtenstein's Greenhouse Gas Inventory

In 1995, the Principality of Liechtenstein ratified the United Nations Framework Convention on Climate Change (UNFCCC). In 1995, 2001 and 2006, Liechtenstein submitted its National Communication Reports to the secretariat of the UNFCCC. Also, a first preliminary greenhouse gas inventory (without National Inventory Report) was submitted in the Common Reporting Format (CRF) in 2005. On 31 May 2006 Liechtenstein submitted two inventories for 1990 and 2004 in the CRF accompanied by Liechtenstein's first National Inventory Report (OEP 2006).

The current report is the second submission in 2006, which includes, beside a number of improvements and corrections, a complete time series 1990–2004 of all the sectors. It should be noted that the LULUCF sector has for the first time been calculated by means of the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2003), which has not been available yet for the submission in May 2006.

In 2004, Liechtenstein ratified the Kyoto Protocol to the UNFCCC. A National Inventory System (NIS) according to Article 5.1 of the Kyoto Protocol has now been implemented.

1.2. Institutional Arrangements for Inventory Preparation

The Office of Environmental Protection (OEP) is in charge of compiling the emission data and bears overall responsibility for Liechtenstein's national greenhouse gas inventory. In addition to the OEP, the Office of Economic Affairs (OEA), the Office of Agriculture (LWA), the Office of Forests, Nature and Landscape (AWNL) and the Office of Land Use Planning (SLP) participate directly in the compilation of the inventory. Several other administrative and private institutions are involved in inventory preparation.

Liechtenstein is a small central European State in the Alpine region state with a population of 34'600 inhabitants (as of 31 December 2004) and with an area of 160 km^2. Its neighbours are therefore important partners: Liechtenstein and Switzerland form a customs and monetary union governed by a customs treaty. On the basis of this union, Liechtenstein is linked to Swiss foreign trade strategies, with few exceptions, such as trade with the European Economic Community: Liechtenstein – contrary to Switzerland – is a member of the Agreement of the European Economic Area. The Customs Union Treaty with Switzerland impacts greatly on environmental and fiscal strategies. Many Swiss taxes and regulations for special goods (for example, environmental standards) are also adapted and applied in Liechtenstein. For the determination of the GHG emissions, Liechtenstein appreciates having been authorised to adopt a number of Swiss methods and Swiss emission factors.

As part of a comprehensive project, the Government mandated its Office of Environmental Protection in 2005 to design and establish the NIS in order to ensure full compliance with the reporting requirements of the UNFCCC and its Kyoto Protocol. With regard to the provisions of Art. 5.1 of the Kyoto Protocol, the project encompasses the following elements:

- Collaboration and cooperation of the different Offices involved in data collection,
- Upgrading and updating of central GHG emissions data base,
- Setting up a simplified quality control system,
- Official consideration and approval of the data.

1.3. *Process for Inventory Preparation*

Figure 3 gives a schematic overview of the institutional setting of the process of inventory preparation within the NIS.

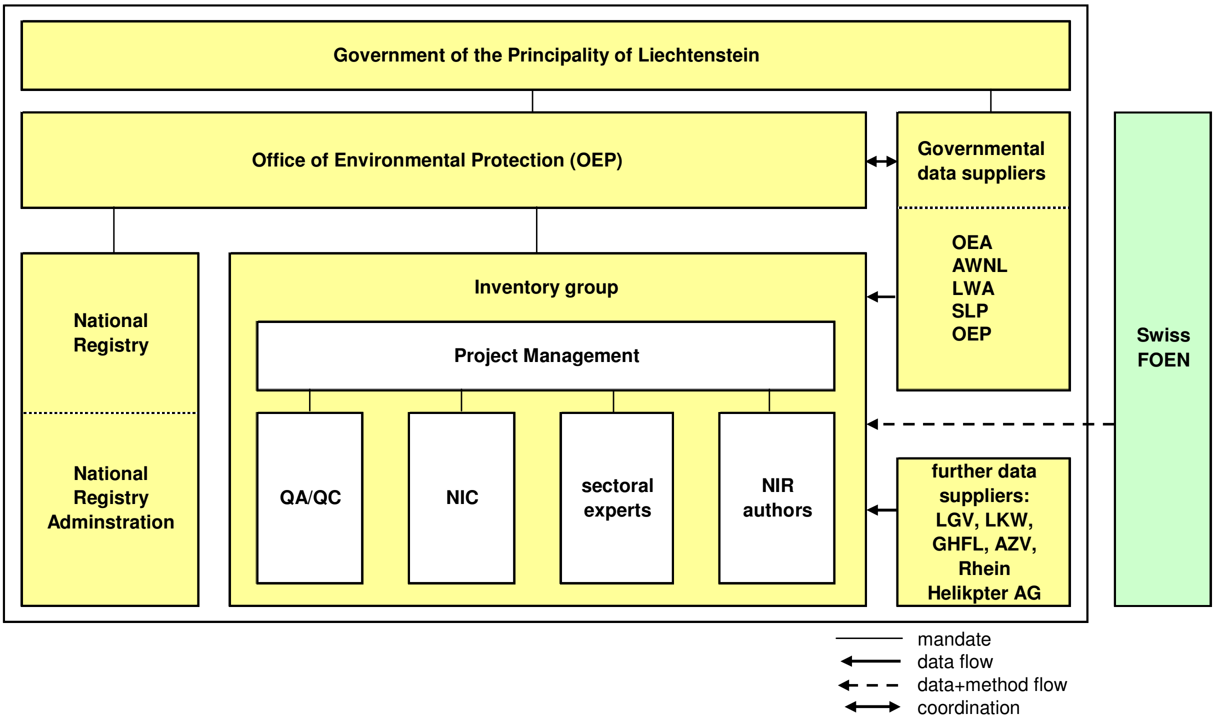

Figure 3 National Inventory System: Institutional setting.

The **Government of the Principality of Liechtenstein** bears the overall responsibility for the NIS. By the Air Pollution Control Act, the Office of Environmental Protection (OEP) is in charge of establishing emission inventories and is therefore also responsible for all aspects concerning the establishing of the National Inventory System (NIS) under the Kyoto Protocol. The responsibility of the OEP for establishing the NIS is also described in the report of the Government to the parliament for ratifying the Kyoto Protocol[1]. The Government mandated the realisation of the NIS to its Office of Environmental Protection.

The **Office of Environmental Protection (OEP)** plays a major role in the National Inventory System. Its representative, the head of the OEP, is the project manager of the inventory group and the National Registry Administrator. He also coordinates the data flow from the governmental data suppliers to the Inventory Group.

The **Inventory group** consists of the project manager, the responsible for the QC activities, the National Inventory Compiler (NIC), all represented by the head of the OEP. Furthermore several external experts belong to the Inventory Group: Sectoral specialists for modelling the greenhouse gas emissions and removals and the NIR authors .

Among the **governmental data suppliers** there are:

- Office of Economic Affairs (AVW)
- Office of Forest, Nature and Landscape (AWNL)
- Office of Agriculture (LWA)
- Office of Land Use Planning (SLP)

[1] Bericht und Antrag Nr. 76/2004 der Regierung an den Landtag

- Office of Environmental Protection (OEP)

Further data suppliers are

- Co-operation for the storage of gas oil in the Principality of Liechtenstein Genossenschaft für Heizöl-Lagerhaltung im Fürstentum Liechtenstein (GHFL);
- Liechtenstein's Gas Utility Liechtensteinische Gasversorgung (LGV)
- Electric power company Liechtensteinische Kraftwerke (LKW)
- Abwasserzweckverband (AZV)
- Heliport Balzers (Rhein Helikopter AG)

Swiss FOEN

The Swiss Federal Office for the Environment (FOEN) is the agency that has the lead within the Swiss federal administration regarding climate policy and its implementation. FOEN and OEP cooperate in the inventory preparation. Due to the customs treaty of the two states, the import statistics in the Swiss overall energy statistics[2] also includes the fossil fuel consumption of the Principality of Liechtenstein. FOEN therefore corrects its fuel consumption data by subtracting Liechtenstein's fuel consumption from the data provided in the Swiss overall energy statistics. To that aim, OEP calculates its energy consumption and provides FOEN with the data. FOEN, on the other hand, makes a number of methods and emission factors available to OEP (mainly transportation, agriculture, LULUCF). Liechtenstein has benefited to a large extend from the methodological support by the inventory core group within the Swiss Federal Office of the Environment (FOEN) and its readiness to share very openly data and spreadsheet-tools. Its kind support is herewith highly appreciated.

Figure 4 illustrates in a simplified manner the data flow leading to the CRF tables required for reporting under the UNFCCC. For roles and responsibilities of the actors see Figure 3.

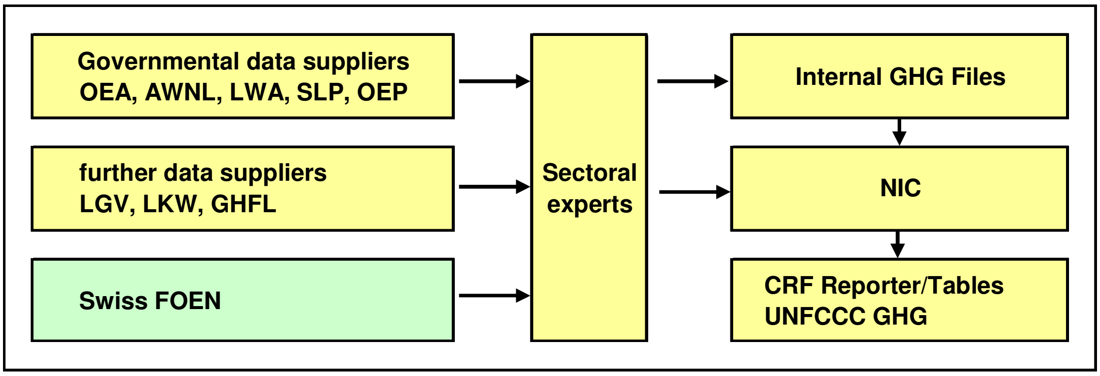

Figure 4 Data suppliers and data collection for setting up the UNFCCC GHG Inventory (see Glossary for abbreviations).

[2] Schweizerische Gesamtenergiestatistik 2004. Statistique globale Suisse de l'énergie 2004. Swiss Federal Office of Energy, Bern [in German and French].

1.4. Methodologies

1.4.1. General Description

The emissions are calculated based on the standard methods and procedures of the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC 1997a, 1997b, 1997c) and IPCC Good Practice Guidances (IPCC 2000, IPCC 2003) as adopted by the UNFCCC.

The emissions are modelled by using country-specific activity data. Country-specific emissions factors are applied if available. A number of default emission factors from IPCC are used. For a majority of emission sources, however, emission factors are adopted from the Swiss GHG inventory. It is noteworthy that there is a very close relationship between Liechtenstein and Switzerland based on the Customs Union Treaty between the two countries. The Customs Union Treaty with Switzerland has a significant impact on environmental and fiscal strategies. Many Swiss environmental provisions and climate-protection regulations are also applicable in Liechtenstein or are implemented into Liechtenstein law on the basis of specific international treaty rules.

For the present submission, the full time series has been calculated for the first time. The inventory is implemented using the CRF Reporter.

1 Energy

- Emissions from 1A Fuel Combustion Activities: Activity data is taken from the National Energy Statistics (including consistency modifications) and from census for the fuel sales of gasoline and diesel oil. Emission factors: Swiss country-specific and IPCC default values are applied.
- Emissions from 1B Fugitive Emissions from Fuels: Activity data is taken from the Liechtenstein's gas utility (LGV). Emission factors: Swiss country-specific.

2 Industrial Processes

- HFC emissions from 2F1 Refrigeration and Air Conditioning Equipment are reported and are calculated with the rule of proportion applied on the Swiss emissions using country-specific activity data as proxy for the conversion (e.g. no. of inhabitants).
- SF_6 emissions from 2F8 Electrical Equipment are reported based on country-specific data.
- CO and NMVOC emissions from 2A5 Asphalt Roofing and 2A6 Road Paving with Asphalt. The emissions are estimated from the Swiss emissions using the no. of inhabitants as a proxy for the conversion.
- Other emissions from industrial processes (CO_2, CH_4, N_2O, PFCs) are not occurring.

3 Solvent and Other Product Use

- Emissions 3A–3D are estimated from the Swiss emissions using the no. of inhabitants as a proxy for the conversion..

4 Agriculture

- Emissions are reported for 4A Enteric Fermentation, 4B Manure Management and 4D Agricultural Soils: Country-specific activity data, Swiss methods and Swiss emission factors are applied.

5 LULUCF

- Emissions and removals are reported for 5A to 5F. The methods are adopted from Switzerland. Country-specific activity data and Swiss emission (carbon) factors are used.

6 Waste

- Emissions from 6B Waste Water Handling 6C Waste Incineration and 6D Other are reported. Country-specific activity data and Swiss or IPCC default emission factors are used

1.4.2. Reference Approach for Sector 1 Energy

Liechtenstein forms a customs union with Switzerland and has therefore no specific statistics on imports/exports of liquid fuels. Furthermore, Liechtenstein does not have any refinery industry. Therefore, the Reference Approach is identical with the Sectoral Approach, and it has not explicitly been carried out in the CRF Reporter.

1.5. Key Categories

The key category analysis is performed according to the IPCC Good Practice Guidance (IPCC 2000, chapter 7): A Tier 1 level and trend assessment is applied with the proposed threshold of 95%.

For 2004, among a total of 121 categories, 16 have been identified as key categories with an aggregated contribution of 96.2% of the national total emissions. 14 among the 16 are key categories due to the level assessment, another 14 due to the trend assessment.

Of the 16 key categories, 11 are in sector “1 Energy”, contributing 87.6% to total CO_2 equivalent emissions in 2004. The other key categories are from sectors “2 Industrial Processes” (1.5%), “3 Solvent an other product use” (0.3%) and “4 Agriculture” (6.8%). There are two major key sources:

- 1A3b Energy, Fuel Combustion, Road Transportation, gasoline, CO_2, level contribution 23.2%,
- 1A4a Energy, Fuel Combustion, Other Sectors, Commercial/Institutional, liquid fuels, CO_2, level contribution 16.9%.

The complete Key Category Analysis is provided in Annex 1.

Table 3 List of Liechtenstein's 16 key categories 2004. Upper part sorted by category code, lower part sorted by contribution in level.

IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Assessm.	Trend Assessm.	Contrib. in Trend	Level assessm.	Trend assessm.
Sorted by category code						[Gg CO2eq]	[Gg CO2eq]	%		%		
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	0.12	2.79	1.03%	0.00830	2.6%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	22.09	8.14%	0.00838	2.6%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	15.18	5.60%	0.02155	6.8%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	20.40	7.52%	0.00942	3.0%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CO2	0.00	1.70	0.63%	0.00533	1.7%	-	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	62.89	23.18%	0.02625	8.2%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	26.27	9.68%	0.05015	15.7%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	45.82	16.89%	0.06703	21.0%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	22.36	8.24%	0.06075	19.1%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	15.18	5.60%	0.02156	6.8%	KC level	KC trend
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	3.02	1.11%	0.00075	0.2%	KC level	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			HFC	0.00	3.95	1.45%	0.01235	3.9%	KC level	KC trend
3	3. Solvent and Other Product Use				CO2	1.53	0.87	0.32%	0.00291	0.9%	-	KC trend
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	10.40	3.83%	0.00359	1.1%	KC level	KC trend
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	6.93	5.69	2.10%	0.00772	2.4%	KC level	KC trend
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.46	0.91%	0.00236	0.7%	KC level	-

Sorted by contribution in level												
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	62.89	23.18%	0.02625	8.2%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	45.82	16.89%	0.06703	21.0%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	26.27	9.68%	0.05015	15.7%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	22.36	8.24%	0.06075	19.1%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	22.09	8.14%	0.00838	2.6%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	20.40	7.52%	0.00942	3.0%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	15.18	5.60%	0.02155	6.8%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	15.18	5.60%	0.02156	6.8%	KC level	KC trend
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	10.40	3.83%	0.00359	1.1%	KC level	KC trend
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	6.93	5.69	2.10%	0.00772	2.4%	KC level	KC trend
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			HFC	0.00	3.95	1.45%	0.01235	3.9%	KC level	KC trend
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	3.02	1.11%	0.00075	0.2%	KC level	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	0.12	2.79	1.03%	0.00830	2.6%	KC level	KC trend
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.46	0.91%	0.00236	0.7%	KC level	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CO2	0.00	1.70	0.63%	0.00533	1.7%	-	KC trend
3	3. Solvent and Other Product Use				CO2	1.53	0.87	0.32%	0.00291	0.9%	-	KC trend

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

No formal QA/QC system exists for Liechtenstein's GHG inventory. It is important to take note of the **specific circumstances of the Principality of Liechtenstein**: Due to the smallness of the State, not every process, data flow and arrangement does need to be established by a formal agreement due to short "distances" within the administration and due to a high degree of acquaintance between the persons involved. Therefore, the National System manages with little number of written documents. The following QC activities are carried out:

- The annual cycle for inventory preparation contains several meetings of the Inventory Group and several meetings of governmental and other data suppliers with the OEP. On these meetings the activities, responsibilities and schedule for the inventory preparation process are being organised and determined.
- Regular meetings of the group "Umwelt und Raum" (environment and spacial planning). The group is formed by the heads of the OEP, SLP, AWNL and the minister for the environment. It prepares policy matters for the attention of the Government including climate affairs[3].
- The project manager, the sectoral experts and the NIR authors accomplish a number of QC activities:
  - The NIR authors check the emission results produced by the sectoral experts, for consistency of cross-cutting parameters, correctness of emissions aggregation, completeness of the GHG inventory. They compare the methods used with IPCC Good Practice Guidance, check the correct compiling of the methods in the NIR, the correct transcription of CRF data into NIR data tables and figures, the consistency between data tables and text in the NIR, the completeness of references in the NIR, and are responsible for the correctness of the key source and the uncertainty analysis.
  - The sectoral experts check the description of methods, numbers and figures in the NIR,
  - Further staff members of the OEP carry out a proof reading of single sectors.
  - The project manager executes an overall checking function for the GHG inventory and the NIR[4]: He monitors the GHG emission modelling and the key category analysis. He checks the NIR for correctness, completeness, transparency and quality, checks for the complete archiving of documents, and the completeness of the CRF submission document.

[3] like the election to not accounting for LULUCF activities under Article 3.4 of the Kyoto Protocol

[4] INFRAS: Minutes to the meeting of 24 Oct 2006 at OEP (Submission-Dec-06-Protokoll-061024.pdf)

1.7. *Uncertainty Evaluation*

A quantitative uncertainty analysis has been carried out following IPCC Good Practice Guidance Tier 1 methodology (IPCC 2000, p. 6.13ff.).

1.7.1. Data Used

Data on uncertainties is not provided explicitly for most key data sources. In this situation, the authors of the NIR chapters together with the involved experts generated first estimates of uncertainties based on IPCC Good Practice Guidance default values, expert estimates and uncertainty data from the Swiss NIR (FOEN 2006).

All uncertainty figures are to be interpreted as corresponding to half of the 95% confidence interval. Distributions are assumed to be symmetric.

Uncertainties in the GWP-values were not taken into account in inventory uncertainty estimates.

1.7.2. Results for Tier 1 Uncertainty Evaluation

The results of the Tier 1 uncertainty analysis for GHG emissions from key categories in Liechtenstein are summarized in Table 4.

Details on the uncertainty estimates of specific sources are provided in the sub-sections on "Uncertainties and Time-Series Consistency" in each of the chapters on source categories below.

The resulting Tier 1 uncertainty in the national total annual emissions in CO_2 equivalents is estimated to be about 11.3% for the level. Trend uncertainty is 18.4%.

The overall uncertainty is determined by the rather high activity data uncertainty of liquid fuels. This is due to the fact that Liechtenstein, forming a customs and monetary union with Switzerland, has no customs statistics of imports of oil products, and activity data has to be based on soundings with suppliers, being of heterogeneous quality.

Please note that the current results of the Tier 1 uncertainty analysis for GHG emissions from key sources in Liechtenstein do not (fully) take into account the following factors that may further increase uncertainties:

- Correlations that exist between source categories that have not been considered,
- Errors due to the assumption of constant parameters, e.g. of constant net calorific values for fuels for the entire period since 1990,
- Errors due to methodological shortcomings,
- Errors due to non-key category sources not contained in the uncertainty analysis.

Table 4 Tier 1 Uncertainty Calculation and Reporting for sources in Liechtenstein, 2004 (IPCC 2000, Table 6.1).

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions 1990	Year 2004 emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combinded uncertainty as % of total national emission in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	Calc/Input						
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%	%	%	%	%	%
1. CO2 emissions from Fuel Combustion												
1A 1. Energy A. Fuel Combustion Gaseous fuels	CO2	27.81	75.22	5.0	4.6	6.8	1.883	0.1841	0.3264	0.85	2.31	2.46
1A 1. Energy A. Fuel Combustion Liquid fuels	CO2	173.62	164.07	18.0	0.6	18.0	10.889	-0.1739	0.7120	-0.10	18.13	18.13
1A 1. Energy A. Fuel Combustion Solid fuels	CO2	0.09	0.02	20.0	5.0	20.6	0.002	-0.0004	0.0001	0.00	0.00	0.00
Total CO2 Emissions Fuel Combustion	CO2	201.53	239.31									

A	B	C	D	E	F	G	H	I	J	K	L	M
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%	%	%	%	%	%
2. Other Key Sources												
2F 2. Industrial Proc. F. Consumption of Halocarbons and SF6	HFC	0.00	3.95		13.8	13.8	0.201	0.0171	0.0171	0.24	0.00	0.24
3 3. Solvent and Other Product Use	CO2	1.53	0.87		80.0	80.0	0.256	-0.0040	0.0038	-0.32	0.00	0.32
4A 4. Agriculture A. Enteric Fermentation	CH4	9.80	10.40	20.0	12.7	23.7	0.909	-0.0050	0.0451	-0.06	1.28	1.28
4D1 4. Agriculture D. Agricultural Soils; Direct Soil Emissions	N2O	6.93	5.69	10.0	79.8	80.4	1.687	-0.0107	0.0247	-0.85	0.35	0.92
4D3 4. Agriculture D. Agricultural Soils; Indirect Emissions	N2O	2.73	2.46	15.0	*93.9*	95.1	0.864	-0.0033	0.0107	-0.31	0.23	0.38
Rest of sources	all	7.90	8.66	20.0	*34.6*	40.0	1.276	-0.0028	0.0376	-0.10	1.06	1.07
Total other Key Sources		28.89	32.02									

A	B	C	D				H					M
		Gg CO2 equivalent	Gg CO2 equivalent									
3. Total (combined uncertainty of 1. and 2.)												
Total Emissions	all	230.42	271.33									
Total Uncertainties						Overall uncertainty in the year (%)	**11.33**				Trend uncertainty (%)	**18.40**

A (continued)				B	N	O	P	Q
IPCC Source category				Gas	Emission factor quality indicator IPCC **D**efault, **M**easurement based, national **R**eferenced data	Activity data quality indicator IPCC **D**efault, **M**easurement based, national **R**eferenced data	Expert judgement reference numbers	Reference to section in NIR
1A	1. Energy	A. Fuel Combustion	Gaseous fuels	CO2	M	D		Section 3.2.3
1A	1. Energy	A. Fuel Combustion	Liquid fuels	CO2	M	R		Section 3.2.3
1A	1. Energy	A. Fuel Combustion	Solid fuels	CO2	D	D, R		Section 3.2.3
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6		HFC	R	R		Section 4.7.3
3	3. Solvent and Other Product Use			CO2	R	R		Section 5.2.3
4A	4. Agriculture	A. Enteric Fermentation		CH4	R	R		Section 6.2.3
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions		N2O	D	R		Section 6.5.3
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions		N2O	D	D		Section 6.5.3
	Rest of sources			All	R	R		Exp. est.

Table 5 Further information on the Tier 1 uncertainty calculation and reporting for sources in Liechtenstein, 2004 (IPCC 2000, Table 6.1 continued).

1.8. Completeness Assessment

Liechtenstein's current GHG inventory is now for the first time completed for all Kyoto gases. The emissions of precursors (NO_x, CO, NMVOC, SO_2) are in general not estimated and not reported (not mandatory). However, CO and NMVOC emissions from source category 3 Solvent and Other Product Use have been estimated in a preliminary way based on Swiss data.

2. Trends in Greenhouse Gas Emissions and Removals

This chapter gives an overview of Liechtenstein's GHG emissions and removals as well as their trends in the period 1990–2004.

2.1. *Aggregated Greenhouse Gas Emissions 2004*

In 2004, Liechtenstein emitted 271.3 Gg of CO_2 equivalents (excluding LULUCF) to the atmosphere. The largest contributor gas is CO_2, and the most important sources of emissions are fuel combustion activities in the Energy sector. Table 6 shows the emissions for individual gases and sectors in Liechtenstein for the year 2004. Fuel combustion within the Energy sector was by far the largest source of emissions of CO_2 in 2004. Emissions of CH_4 and N_2O originated mainly from Agriculture, and the synthetic gas emissions stemmed by definition from Industrial Processes.

Emissions 2004	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**Total**
	CO_2 equivalent (Gg)						
1 All Energy	239.3	1.6	1.1				**242.0**
2 Industrial Processes	NA,NO	NA,NO	NA,NO	3.9	NA,NO	0.1	**4.0**
3 Solvent Use	0.9		0.2				**0.2**
4 Agriculture (1 year average)		12.1	10.4				**22.5**
6 Waste	NA,NO	0.6	1.1				**1.7**
Total (excluding LULUCF)	**240.2**	**14.3**	**12.8**	**3.9**	**0.0**	**0.1**	**271.3**
5 LULUCF	-6.4	NO	NO				**-6.4**
Total (including LULUCF)	233.8	14.3	12.8	3.9	0.0	0.1	**265.0**
International Bunkers	*0.4*	*0.0*	*0.0*				***0.4***

Table 6 Summary of Liechtenstein's GHG emissions by gas and sector in CO_2 equivalent (Gg), 2004.

A breakdown of Liechtenstein's total emissions by gas is shown in Figure 5 below. Figure 6 is a bar chart of contributions to GHG emissions by gas and sector.

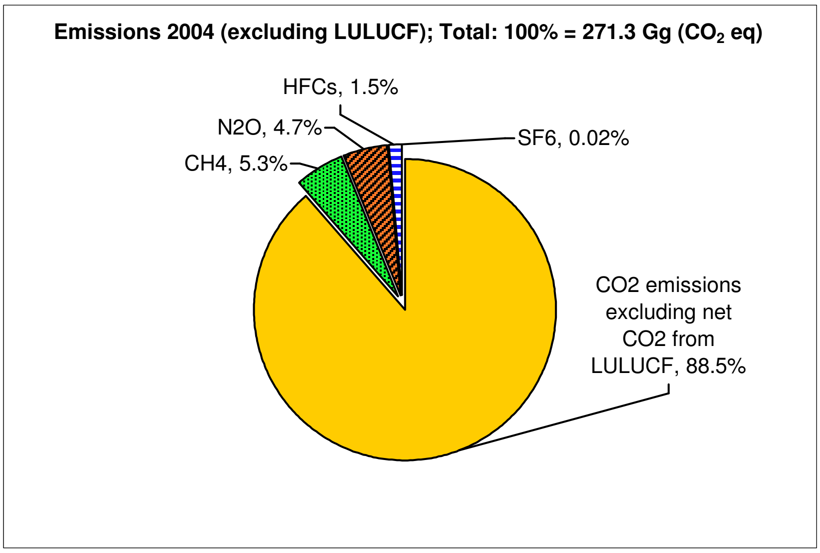

Figure 5 Liechtenstein's GHG emissions by gas (excluding LULUCF), 2004.

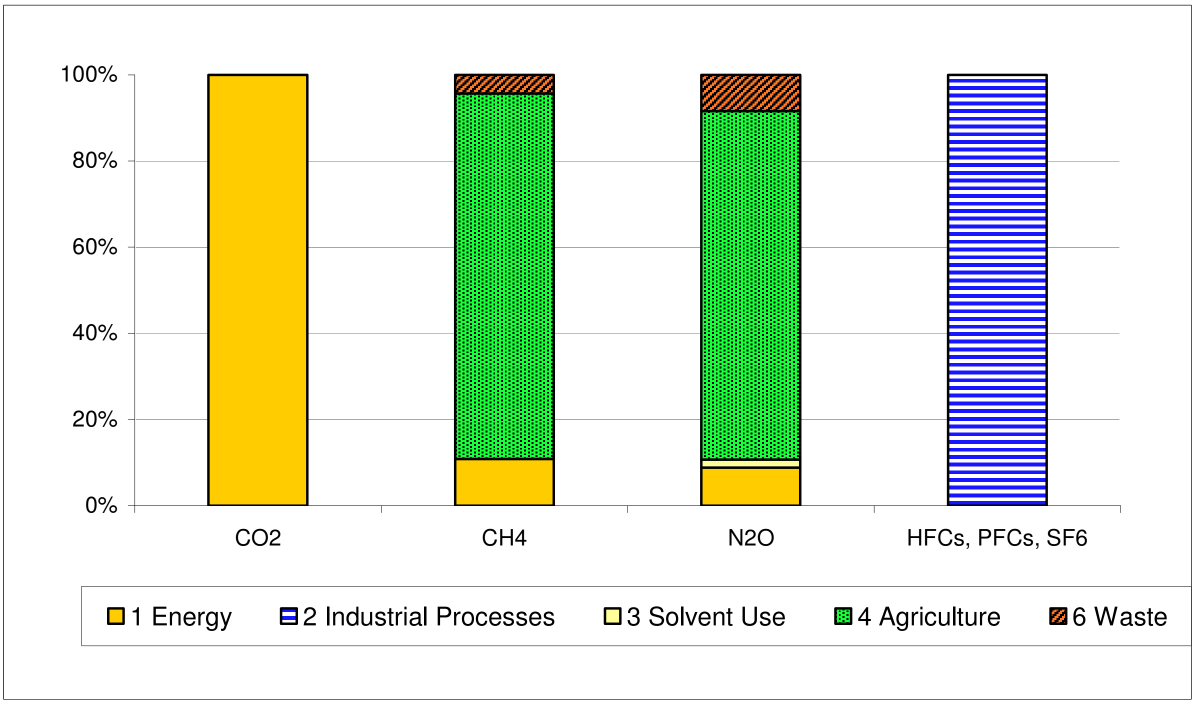

Figure 6 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions, 2004.

2.2. *Emission Trends by Gas*

Emission trends 1990/2004 by gas are summarised in the following Table 7 and in Figure 7.

Greenhouse Gas Emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*1990→2004*
	CO_2 equivalent (Gg)															%
CO_2 emissions including net CO_2 from LULUCF	195.7	201.8	204.4	212.9	198.5	200.0	203.6	220.0	230.3	229.8	221.9	221.6	225.0	234.2	233.8	*19.5*
CO_2 emissions excluding net CO_2 from LULUCF	203.1	210.8	211.7	220.0	206.0	209.4	211.6	223.8	235.1	234.3	227.5	225.6	230.5	240.0	240.2	*18.3*
CH_4	13.2	13.0	12.9	12.2	12.4	12.5	12.6	12.4	12.5	12.4	12.2	12.9	13.5	13.9	14.3	*8.6*
N_2O	14.2	14.3	14.3	13.9	13.8	13.9	13.6	13.5	13.2	13.2	12.8	12.9	12.9	12.9	12.8	*-9.5*
HFCs	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.0	1.4	1.8	2.3	2.9	3.2	3.4	3.9	---
PFCs	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	---
S_{F6}	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	---
Total (incl. net CO_2 from LULUCF)	**223.1**	**229.2**	**231.7**	**239.1**	**224.9**	**226.8**	**230.5**	**247.0**	**257.4**	**257.2**	**249.3**	**250.4**	**254.6**	**264.4**	**265.0**	***18.8***
Total (excl. net CO_2 from LULUCF)	**230.4**	**238.2**	**238.9**	**246.1**	**232.4**	**236.2**	**238.4**	**250.8**	**262.3**	**261.7**	**254.9**	**254.4**	**260.1**	**270.3**	**271.3**	***17.8***
Total (excl. LULUCF Removals/Emissions)	**230.4**	**238.2**	**238.9**	**246.1**	**232.4**	**236.1**	**238.4**	**250.8**	**262.3**	**261.6**	**254.9**	**254.4**	**260.1**	**270.3**	**271.3**	***17.8***

Table 7 Summary of Liechtenstein's GHG emissions in CO_2 equivalent (Gg) by gas, 1990/2004. The column on the far right (digits in italics) shows the percent change in emissions in 2004 as compared to the base year 1990. Note that the difference between the total excl. net CO_2 from LULUCF and the total excl. LULUCF is very small with maximum values of ca. 0.07 Gg CO_2 eq in 1995 and 1999 (the difference consist of 0.2 t N_2O from land-use conversion to cropland).

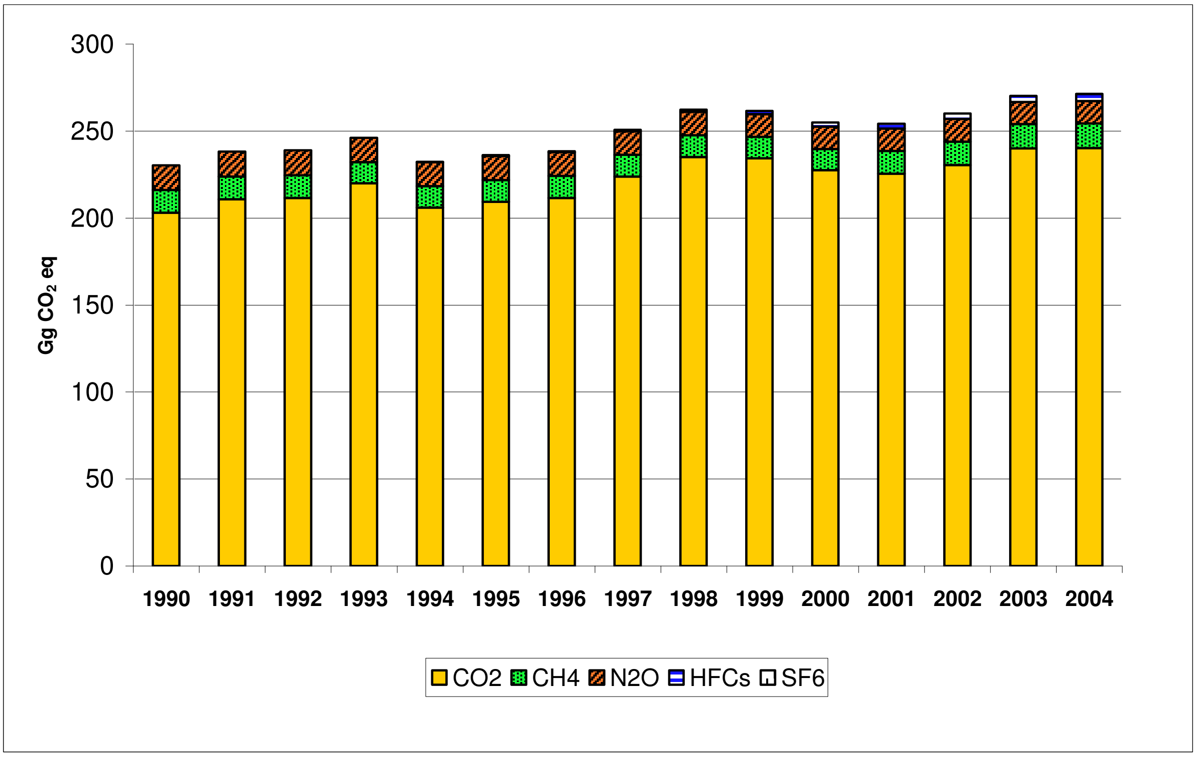

Figure 7 Trend of Liechtenstein's greenhouse gas emissions by gases1990–2004. CO_2 corresponds to the total CO_2 emissions excl. net CO_2 from LULUCF.

The emission trends for the individual gases are as follows:

- Total emissions excluding LULUCF Removals/Emissions increased from 1990 to 2004 by 17.8%.
- Total emissions including net CO_2 from LULUCF increased even more strongly by 18.8%.
- The total CO_2 (excl. net CO_2 from LULUCF) increased from 1990 to 2004 by 18.3%. It contributes the largest share of emissions, accounting for about 88.5% of the total in 2004 and 88.1% in 1990.
- CH_4 showed an increase of 8.6% which is the result of an increase in the sectors energy and waste. Its contribution to the total national emissions is 5.3%.
- N_2O emissions have decreased by 9.5% due to reduced input of mineral fertilizers and due to a reduction of organic soils. Its contribution to the total national emissions is 4.7%.
- HFC emissions (mainly from 2F1 Refrigeration and Air Conditioning Equipment) increased due to their role as substitutes for CFCs. SF_6 emissions stem from electrical transformation stations and plays a minor role for the total of synthetic gases. PFC emissions are not occurring.

2.3. Emission Trends by Sources and Sinks

Table 8 shows emission trends for all major source and sink categories. As the largest share of emissions originated from the energy sector, the table also shows the contributions of the energy sub-sectors (1A1-1A5, 1B).

Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*1990→2004*
	CO_2 equivalent (Gg)															*%*
1 Energy	**203.4**	**211.4**	**212.6**	**221.0**	**207.1**	**210.6**	**212.9**	**225.4**	**236.7**	**236.0**	**229.4**	**227.3**	**232.2**	**241.8**	**242.0**	***19.0***
1A1 Energy Industries	0.1	0.8	1.8	1.9	1.7	2.0	2.5	2.4	2.8	2.8	2.6	2.8	2.6	2.7	2.8	*2250*
1A2 Manufacturing Industries and Construction	35.3	34.2	34.2	36.0	34.2	34.4	34.3	35.9	38.2	37.6	34.3	34.6	34.3	38.3	37.4	*5.8*
1A3 Transport	76.4	89.7	89.1	87.0	79.6	81.7	82.9	86.6	86.2	91.9	95.9	92.3	95.9	87.3	86.0	*12.6*
1A4 Other Sectors	88.9	83.4	84.2	93.3	88.8	89.9	90.3	97.3	105.9	99.8	92.8	94.4	92.8	109.2	111.9	*25.9*
1A5 Other (Offroad)	2.4	2.9	2.9	2.4	2.3	2.2	2.3	2.5	3.0	3.1	3.0	2.6	3.0	3.4	3.1	*27.9*
1B Fugitive emissions from oil and natural gas	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.7	0.9	0.9	*188*
2 Industrial Processes	**0.0**	**0.0**	**0.0**	**0.1**	**0.2**	**0.4**	**0.7**	**1.0**	**1.4**	**1.8**	**2.3**	**3.0**	**3.2**	**3.5**	**4.0**	**---**
3 Solvent and Other Product Use	**2.0**	**1.9**	**1.8**	**1.7**	**1.7**	**1.6**	**1.5**	**1.4**	**1.4**	**1.3**	**1.3**	**1.2**	**1.2**	**1.2**	**1.1**	**---**
4 Agriculture	**23.7**	**23.6**	**23.3**	**22.0**	**22.0**	**22.1**	**21.9**	**21.6**	**21.3**	**21.0**	**20.2**	**21.3**	**21.7**	**22.1**	**22.5**	***-5.0***
6 Waste	**1.3**	**1.3**	**1.3**	**1.3**	**1.5**	**1.4**	**1.5**	**1.4**	**1.5**	**1.5**	**1.7**	**1.5**	**1.7**	**1.7**	**1.7**	***29.2***
Total (excl. LULUCF Removals/Emissions)	**230.4**	**238.2**	**238.9**	**246.1**	**232.4**	**236.1**	**238.4**	**250.8**	**262.3**	**261.6**	**254.9**	**254.4**	**260.1**	**270.3**	**271.3**	***17.8***
5 Land Use, Land-Use Change and Forestry	-7.3	-8.9	-7.2	-7.1	-7.5	-9.3	-7.9	-3.8	-4.9	-4.4	-5.6	-4.0	-5.5	-5.8	-6.4	*-13.2*
Total (incl. net CO_2 from LULUCF)	223.1	229.2	231.7	239.1	224.9	226.8	230.5	247.0	257.4	257.2	249.3	250.4	254.6	264.4	265.0	*18.8*

Table 8 Summary of Liechtenstein's GHG emissions by source and sink categories in CO_2 equivalent (Gg), 1990–2004. The column on the far right (digits in italics) shows the percent change in emissions in 2004 as compared to the base year 1990.

Figure 8 is a graphical representation of Table 8 data. For the development of the sub-sectors of source "1 Energy" see Chapter 3.

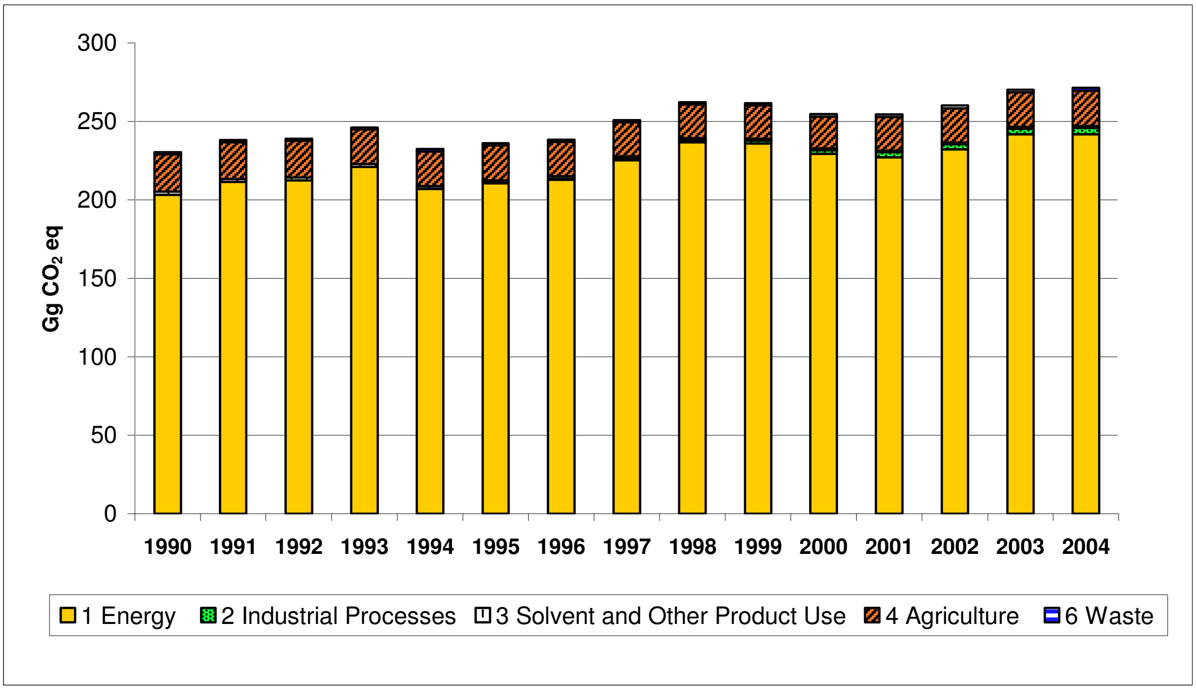

Figure 8 Trend of Liechtenstein's greenhouse gas emissions by main source categories in CO_2 equivalent (Gg), 1990/2004 (excl. net CO_2 from LULUCF).

The following emission trends in the sectors are found:

- 1 Energy: 89.2% of Liechtenstein's GHG emissions stem from the energy sector. In every of its sub-sectors, the emissions have increased between 1990 and 2004.
  - 1A1: The consumption of natural gas in co-generation plants has considerably increased.
  - 1A2: The consumption of natural gas by industries has strongly increased whereas gas oil has decreased.
  - 1A3: In line with a general increase of the road-vehicle kilometres of all vehicle categories, the fuel consumption and the emissions are increasing.

  - 1A4: Inhabitants and employment have increased by 20% in the period 1990-2004, which is reflected in a similar increase of energy consumption.
  - 1A5: The emissions reported under this category are all kind of vehicles from construction sites. The general construction activities have increased in Liechtenstein with a subsequent, fluctuating increase of diesel consumption and emissions.
  - 1B: In parallel with the built-up of Liechtenstein's gas supply network, the fugitive emissions have strongly increased over the period 1990-2004.

- 2 Industrial Processes: Due to the lack of industry in the (small!) state Liechtenstein, only synthetic gases contribute to sector 2. The increasing trend is determined by HFC emissions from 2F1 Refrigeration and Air Conditioning Equipment (substitutes for CFCs).
- 3 Solvent and other product use: Emissions have decreased due to reduction measures for NMVOCs resulting from legal restrictions and the introduction of the VOC-levy.
- 4 Agriculture: CH_4 emissions show a slight increase, but which is compensated by a decrease of N_2O emissions from agricultural soils.
- 5 LULUCF: Figure 9 shows the net removals (negative emissions) by sources and sinks from LULUCF categories in Liechtenstein. Whereas increase and decrease of living biomass in forests are the dominant categories and are relatively constant from 1990–2004, the other categories of land-use changes and soils are smaller and show more fluctuation.

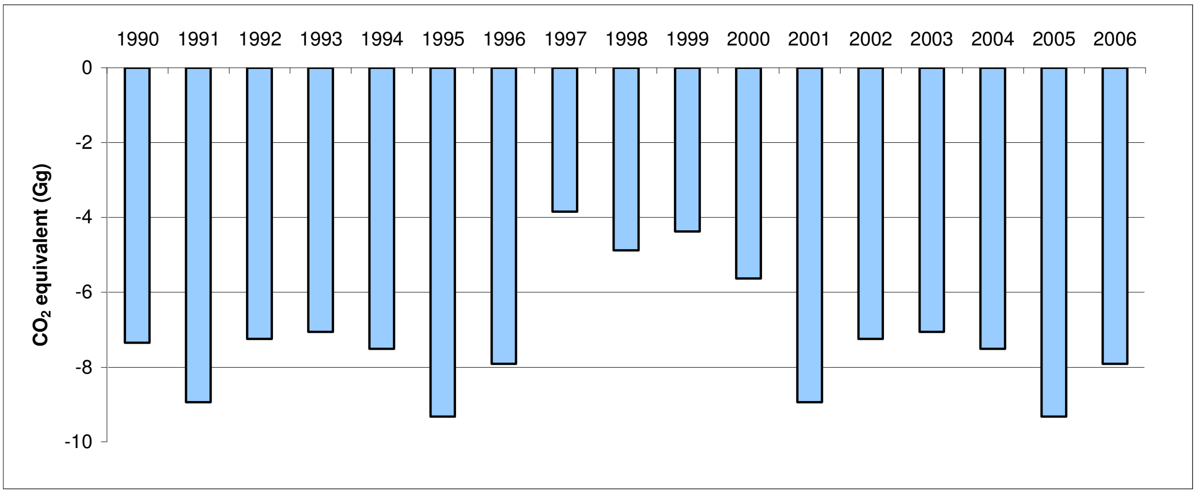

Figure 9 Net removals of CO_2 from LULUCF for 1990–2004.

- 6 Waste: In Liechtenstein only few emissions from the sector “Waste” are occurring, because all municipal solid waste is exported to a Swiss incineration plant. The increasing trend of the emissions remaining in Liechtenstein is determined by increasing composting activities and a slight increase in emissions from waste water handling.

2.4. Emission Trends for Indirect Greenhouse Gases and SO_2

The emissions of the indirect greenhouse gases are not yet reported for Liechtenstein.

3. Energy

3.1. Overview

3.1.1. Greenhouse Gas Emissions

This chapter contains information about the greenhouse gas emissions of source category "1 Energy". In Liechtenstein, the energy sector is the most relevant greenhouse gas source. In 2004, it emitted 242.0 Gg CO_2 equivalent which correspond to 89.2% of total emissions (271.3 Gg, without LULUCF). The emissions of the time period 1990–2004 are depicted in Figure 10.

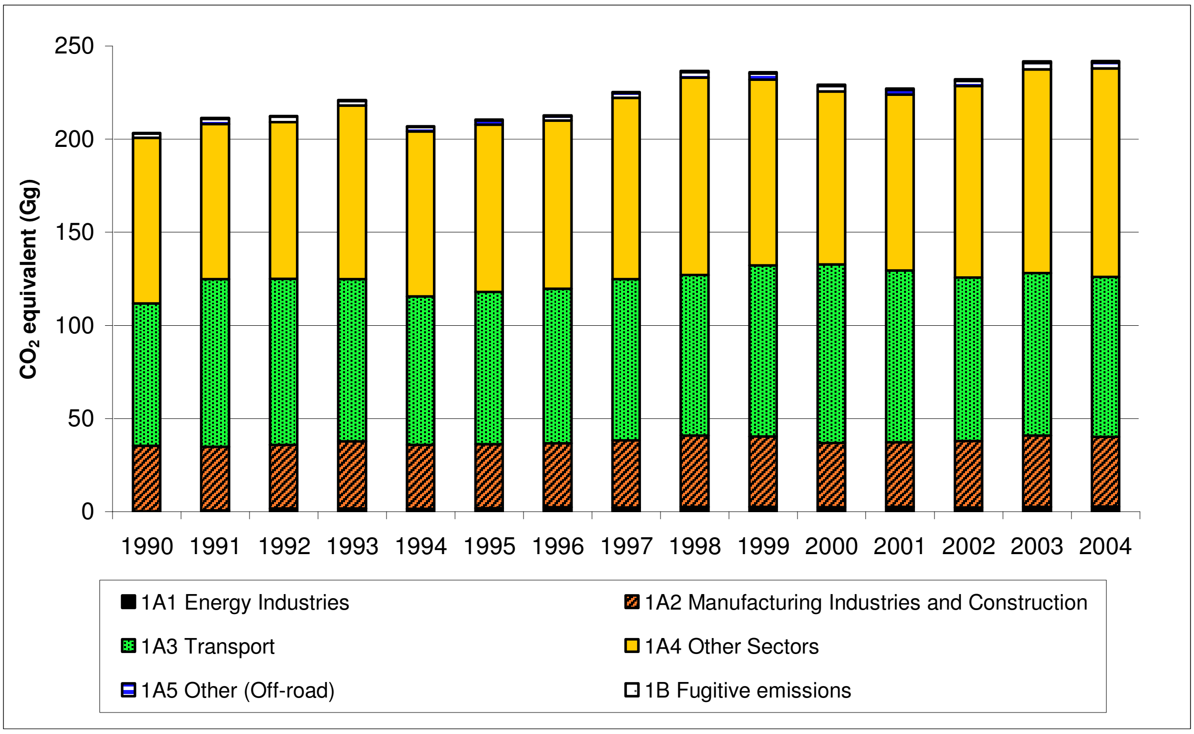

Figure 10 Liechtenstein's GHG emissions of the energy sector 1990–2004.

The following Table 9 summarises the emissions of the individual gases 1990–2004

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*1990→2004*
	CO_2 equivalent (Gg)															*%*
CO_2	201.5	209.3	210.3	218.7	204.8	208.1	210.4	222.7	234.1	233.2	226.5	224.6	229.6	239.1	239.3	*18.7*
CH_4	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.4	1.5	1.6	*48.6*
N_2O	0.8	1.0	1.1	1.2	1.2	1.4	1.4	1.5	1.4	1.4	1.5	1.4	1.3	1.2	1.1	*36.7*
Sum	**203.4**	**211.4**	**212.6**	**221.0**	**207.1**	**210.6**	**212.9**	**225.4**	**236.7**	**236.0**	**229.4**	**227.3**	**232.2**	**241.8**	**242.0**	***19.0***

Table 9 GHG emissions of source category "1 Energy" in Liechtenstein by gas in CO_2 equivalent (Gg), 1990–2004 and the relative increase 1990–2004 (last column).

Table 10 shows more details of the emissions of source category "1 Energy" in 2004. The table includes emissions from international bunkers (aviation) as well as biomass which are both not accounted for in the Kyoto Protocol.

Emissions 2004	CO_2	CH_4	N_2O	Total	
Sources	CO_2 equivalent (Gg)				%
1 Energy	**239.3**	**1.56**	**1.14**	**242.0**	***100.0***
1A Fuel Combustion	**239.3**	**0.63**	**1.14**	**241.1**	***99.6***
1A1 Energy Industries	2.8	0.03	0.00	**2.8**	***1.2***
1A2 Manufacturing Industries and Construction	37.3	0.05	0.05	**37.4**	***15.4***
1A3 Transport	85.1	0.16	0.76	**86.0**	***35.5***
1A4 Other Sectors	111.2	0.39	0.30	**111.9**	***46.2***
1A5 Other	3.0	0.00	0.03	**3.1**	***1.3***
1B Fugitive Emissions from Fuels	**NA,NO**	**0.93**	**NA,NO**	**0.9**	***0.4***
International Bunkers	0.4	0.0	0.0	**0.0**	***NE,NO***
CO_2 Emissions from Biomass	10.0	0.0	0.0	**10.0**	**---**

Table 10 Summary of source category “1 Energy”, emissions in 2004 in Gg CO_2 equivalent (rounded values).

The most obvious features of the energy emissions may be characterised as follows:

- For the total emissions of the energy sector, an increase of 19% may be observed between 1990 and 2004. This fact will become important for the emission reduction policy with respect to Liechtenstein's obligations of the Kyoto Protocol.
- The three sub-categories 1A2, 1A3 and 1A4 dominate the emissions of 1 Energy and cover together 97.2% of its emissions:
    - 1A2 Manufacturing Industries and Construction contribute 15.4% of the emissions.
    - 1A3 Transport is responsible for 35.5% of the emissions.
    - 1A4 Other Sectors (commercial/institutional, residential) is the largest source with 46.2% of the emissions.
    - 1A1 Energy Industries, 1A5 Other (Off-road) and 1B Fugitive Emissions only play a minor role. In 2004, they cover 1.2%, 1.3% and 0.4%, respectively, of the total emissions of “1 Energy”.
- The only bunker emissions occurring stem from a helicopter basis in Balzers, Liechtenstein. Only few flights are domestic, most of them are business flights to Switzerland and Austria, producing bunker emissions. The emissions are 0.4 Gg CO_2 eq.
- CO_2 emissions from biomass add up to 10 Gg. It includes wood burning (heating) and the burning of gas from sewage treatment (heating, power).
- The far most important gas emitted from source category “1 Energy” is CO_2. It accounts for 99.1% of the category in 1990 and for 98.9% in 2004.
- In 2004, CH_4 emissions contributed 0.65% to the total emissions of the energy sector. The Increasing trend since 1990 (0.52%) is the result of the extended consumption of natural gas and the subsequent increase of fugitive emissions of methane (increase of factor of 3). As well, the CH_4 emissions of 1A4 have doubled in the same period. The emissions from road transportation have actually decreased by a factor of 3 mainly due to the growing number of gasoline passenger cars with catalytic converters.
- N_2O contributed 0.41% (1990) and 0.47% (2004) to the total emissions of the energy sector. The changes in N_2O emissions may be explained by changes in the emission of

passenger cars due to catalytic converters.

The Liechtenstein greenhouse gas inventory identifies 16 key sources (see Chapter 1.5), 11 of which belong to the energy sector. These are depicted in Figure 11. Most dominant are the CO_2 emissions from 1A3b Transport (gasoline), 1A4a Other Sectors, Commercial/Institutional (liquid and gaseous fuels).

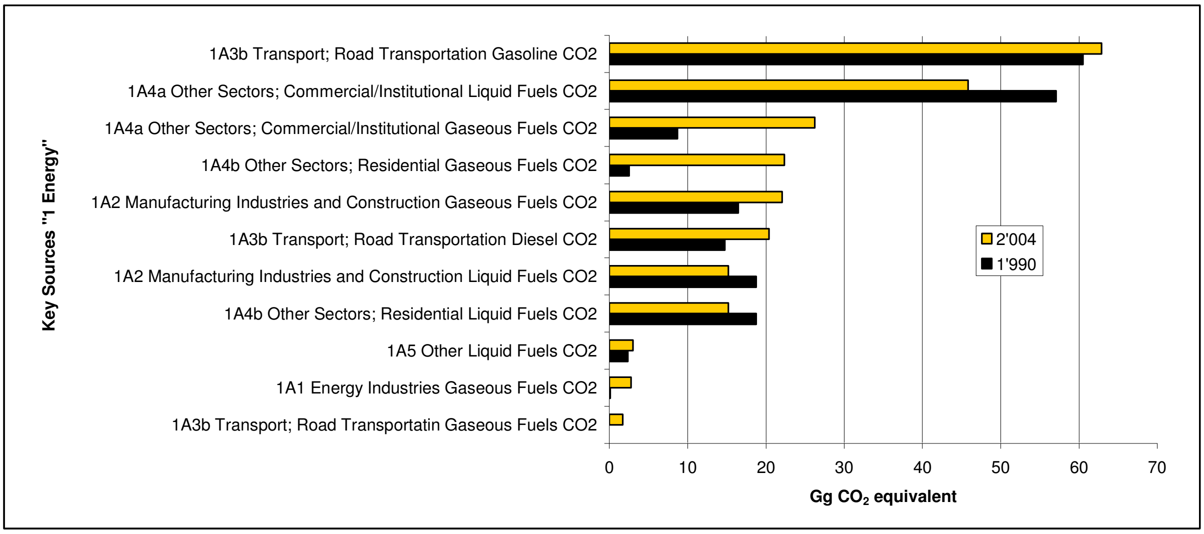

Figure 11 Key sources in the Liechtenstein GHG inventory pertaining to the energy sector.

3.1.2. CO_2 Emission Factors

The CO_2 emission factors used for the calculation of the emissions of 1 Energy are shown in Table 11.

CO_2 Emission Factors				
Fuel	t CO_2 / TJ	t CO_2 / t	t CO_2 / volume	data source
Gasoline (Petrol)	73.9	3.14	2.34 t / 1000 litre	NIR CH (FOEN 2006)
Natural Gas	55.0	2.56	2.00 t / 1000 Nm^3	
Diesel Oil	73.6	3.15	2.61 t / 1000 litre	
Gas Oil	73.7	3.14	2.65 t / 1000 litre	
Hard Coal	94.0	2.64	---	
Propane/Butane (LPG)	65.5	---	---	

Table 11 CO_2 emission factors for fuels. The values are assumed to be constant over the period 1990-2004. The value for natural gas also holds for CNG (compressed natural gas).

3.1.3. Energy Statistics (Activity Data)

a) National Energy Statistics and Modifications

In general, the data is taken from Liechtenstein's energy statistics (AVW 2005b). A more detailed analysis revealed that the data from the national energy statistics included some inconsistencies and could not simply be copied, but had to be revised in an adequate way as will be explained in the following sections. The revised data is summarised in Table 12.

Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	TJ														
Gasoline	819	916	957	947	878	903	909	954	896	940	1'040	1'007	920	879	851
Diesel	250	339	288	261	230	230	242	252	311	347	298	267	284	330	339
Gas Oil	1'272	1'116	1'077	1'189	1'095	1'065	988	1'125	1'208	1'060	931	885	1'001	1'061	1'030
Natural Gas	506	614	688	742	754	824	943	914	1'008	1'084	1'067	1'181	1'210	1'294	1'368
LPG	13.3	8.1	15.5	12.1	9.5	8.1	9.8	7.0	7.2	5.8	5.5	3.9	4.2	4.6	4.1
Hard Coal	1.0	0.9	1.1	1.0	0.7	0.7	0.5	0.5	0.6	0.3	0.6	0.3	0.3	0.3	0.3
Kerosene	6.9	6.9	6.9	6.9	6.9	6.9	7.0	7.2	7.4	7.6	7.7	7.9	7.3	7.9	5.7
Sum	**2'868**	**3'000**	**3'033**	**3'160**	**2'974**	**3'038**	**3'099**	**3'259**	**3'437**	**3'445**	**3'349**	**3'352**	**3'427**	**3'578**	**3'597**
1990=100%	100%	105%	106%	110%	104%	106%	108%	114%	120%	120%	117%	117%	119%	125%	125%
Biomass															
Wood	45	31	45	40	51	38	35	42	48	52	92	56	59	77	85
Klärgas	16	16	17	17	19	17	18	18	20	21	22	21	20	21	22
Sum Biomass	60	47	62	58	70	55	53	61	67	74	113	77	79	98	106

Table 12 Time series of Liechtenstein's fuel consumption due to the sales principle, including bunker fuel consumption (AVW 2005b, OEP 2006).

The following modifications on the original energy statistics data have been carried out:

Gas oil: The "consumption" of gas oil in Liechtenstein's energy statistics reflects the amount of gas oil supplied annually to customers in Liechtenstein by oil transport companies. These customers include (i.) final consumers as well as (ii.) *Liechtenstein's main storage facility* for gas oil, located in Schaan. Gas oil supplied to final consumers in Liechtenstein stems both from sources in Switzerland as well as from Liechtenstein's storage. In order to avoid double counting, the amount of gas oil supplied to the storage facility has to be subtracted from the overall amount of gas oil supplied as provided by the energy statistics.

Therefore, data on the amount of gas oil supplied to Liechtenstein's storage facility has been collected from the Co-operation for the Storage of Gas Oil in the Principality of Liechtenstein (GHFL 2006). Actual consumption of gas oil in Liechtenstein has been calculated based on the total amount supplied according to national energy statistics minus supply to the stock (see Table 13).

Year	Total supply	Supplied to stock	Consumption 1	Assumed density	Consumption	Actual density	Consumption 2	Consumption
Source	Energy Statistics	GHFL 2006	Calculated	OEA-LIE	Calculated	FOEN 2006	Calculated	Calculated
	Gas oil [t]	Gas oil [t]	Gas oil [t]	Gas oil [t/m3]	Gas oil [m3]	Gas oil [t/m3]	Gas oil [t]	Gas oil [TJ]
1990	35'484	5'813	29'671	0.840	35'323	0.845	29'848	1'272
1991	29'240	3'207	26'033	0.840	30'991	0.845	26'188	1'116
1992	26'083	961	25'122	0.840	29'907	0.845	25'271	1'077
1993	28'531	792	27'739	0.840	33'023	0.845	27'904	1'189
1994	26'931	1'380	25'551	0.840	30'418	0.845	25'704	1'095
1995	25'004	159	24'845	0.840	29'578	0.845	24'993	1'065
1996	23'053	0	23'053	0.840	27'444	0.845	23'190	988
1997	26'443	200	26'243	0.840	31'241	0.845	26'399	1'125
1998	28'701	520	28'181	0.840	33'549	0.845	28'349	1'208
1999	24'774	45	24'729	0.840	29'439	0.845	24'876	1'060
2000	21'931	216	21'715	0.840	25'851	0.845	21'844	931
2001	21'098	435	20'663	0.840	24'599	0.845	20'786	885
2002	24'218	859	23'359	0.840	27'808	0.845	23'498	1'001
2003	24'871	116	24'755	0.840	29'471	0.845	24'903	1'061
2004	24'036	0	24'036	0.840	28'614	0.845	24'179	1'030

Table 13 Total supply of gas oil as provided by Liechtenstein's energy statistics and fraction of supply that is supplied to Liechtenstein's stock (and may be further supplied to final consumers). Gas oil *consumption 1* is the difference of total supply minus supply to stock (*Consumption 1* = *Total supply* - *Supplied to stock*).
This consumption is then corrected for actual density, resulting in *consumption 2*. The latter is then used for Liechtenstein's GHG Inventory. (*Consumption 2* = *Consumption 1 * 0.845 / 0.840*).

Gas oil supply is measured in volume units (litres, m^3) and later reported to the office of the environment in mass units (t). This conversion is made with a (rounded) density of 0.84*0* t/m^3, whereas the more correct density is 0.84*5* t/m^3 (FOEN 2006) Therefore, the *Consumption 1* is corrected accordingly, resulting in *Consumption 2*, as is shown in Table 13.

Using a net calorific value of 42.6 GJ/t (FOEN 2006), the actual consumption in energy units, used in Liechtenstein's GHG inventory, results.

Natural gas: Natural gas consumption as published in the energy statistics is based on net natural gas imports. The amount of natural gas that leaks from the distribution network (reported under 1B2b) and is not burned at the final consumer's combustion system, is subtracted from the net imports in order to determine final consumption in 1A.

Gasoline / **Diesel oil:** Due to the census carried out by the Office of Economic Affairs OEA (AVW), the fuel consumption has large uncertainties. A number of distributors of gasoline and diesel annually report the amount of gasoline and diesel provided to domestic gasoline stations. Since not all distributors are known (they may come from any Swiss place and may differ every year), the census may not provide a complete statistics. Therefore, in 2000, the Office of Environmental Protection started a second census by direct questioning of all public gasoline stations. The results of this new census may be considered as a complete overview of all gasoline and diesel oil sold to passenger cars (including also "tank tourism"[5]), but it covers only the years 2000-2004. For the years 1990-1999 (diesel: 1990-2001 see below), the data compiled by OEA were collected in their original units (mass and volume units were used) and transformed into energy units by using the following densities and NCV

Parameter	unit	Gasoline	Diesel oil
Density	kg/litre	0.745	0.830
NCV	GJ/t	42.5	42.8

Table 14 Values used for 1990 and 2004 (OEP 2006b).

For gasoline, in 1990 the value of the energy statistics is used. For the years 1991-1999, a 3-years-mean is carried out (e.g. 1991: arithmetic mean of 1990, 1991, 1992). From 2000 to 2004, the values of the second census are used. The result of this modification is shown in Table 12 (row gasoline).

For diesel oil the amount sold at gasoline station does not yet cover the whole amount consumed. There are private diesel stations, which are not part of the OEP census of public accessible gasoline stations. The holders of these private stations are mainly transport companies with heavy duty vehicles, construction companies with construction vehicles and farmers with agricultural machinery/vehicles. Because the diesel oil containers are subject to registration, the holders of these private diesel stations are known to the OEP. Based on these registration data, the OEP in 2002 started a further census of the diesel consumption by these private stations. Finally, the agriculture part is known by another way: Farmers declare their purchase of diesel fuel and claim refund of the fuel tax at the General Directorate of Swiss Customs, which is the collecting and refunding institution of fuel taxes for fuel purchase in Switzerland and Liechtenstein, and which provides the OEP with the information about the amount declared annually by Liechtenstein's farmers. The OEP census for diesel oil therefore encompasses three parts: diesel oil of public gasoline stations (in census since 2000), diesel oil consumption of private stations (in census since 2002) and diesel oil consumption by farmers (data available for all years since 1990). The sum of these three parts, as available since 2002, is the total of diesel oil consumption.

[5] Like in Switzerland, gasoline stations sell relevant amounts of gasoline to foreign car owners due to fuel price differences between Liechtenstein/Switzerland (same prices) and Austria, Germany (higher gasoline prices). This amount of fuel is mainly consumed abroad (Therefore called "tank tourism"), but the whole amount must be reported as national under 1A3b Road transportation. For Diesel oil, a similar tourism holds but inverse (import), because diesel oil is cheaper in Austria and Germany.

For diesel oil, in 1990, the value is taken from the energy statistics. For the years 1991-2001, a 3-years-mean is carried out (e.g. 1991: arithmetic mean of 1990, 1991, 1992), because of low data quality. From 2002 to 2004, the values of the OEP census are used, because for these years data of high quality is available. The result of this modification is shown in Table 12 (line “diesel”).

Kerosene: The fuel sales at the single helicopter base have been reported in detail (domestic, bunker) for 2001 and 2002 and less detailed for 1995. For the other years in the period 1990–2004, adequate assumptions were made (see Section 3.2.2.c)

b) Energy Statistics and Contribution to the IPCC Source Categories

b1) Gas oil

No data on the specific contribution of Source Categories 1A2, 1A4 a and 1A4b to total gas oil consumption in 1A Fuel Combustion Activities is currently available. Therefore, the following rough estimated shares based on expert judgement are assumed for all years from 1990 to 2004:

Source category		Share in consumption (1990-2004)
1A2	Manufaturing Industries and Contruction	20%
1A4a	Other Sectors - Commercial/Institutional	60%
1A4b	Other Sectors - Residential	20%
Total 1A		100%

Table 15 Estimated share of source categories in total consumption of gas oil in 1A Fuel Combustion Activities.

The data on total consumption of natural gas in Liechtenstein is provided by the gas utility (LGV 2005) and published in the national energy statistics (refers to the net import). It is corrected for natural gas leakage in the distribution network within the country (which is reported under 1B2b).

For the partition of natural gas consumption between the different combustion activities in 1A, only limited data is available. Even though the gas utility publishes statistics of natural gas consumption of different groups of its customers, the definition of these groups is not fully in line with IPCC source categories and appears also somewhat arbitrary. The following tentative attribution is used:

IPCC Source Category		Corresponding category in NG statistics	
		(English)	*(German)*
1A1a	Public Electricity and Heat Production	Co-generation	Blockheizkraftwerke
1A2	Manufacturing Industries and Construction	Industry	Industrie
1A3b	Road Transportation	Fuel for transportation	Treibstoff
1A4a	Other Sectors - Commercial/Institutional	Services	Gewerbe/Dienstleistungen und Öffentliche Hand
1A4b	Other Sectors - Residential	Residential/Households	Wohnungen/Haushalt

Table 16 Tentative correspondence between IPCC source categories and categories in Liechtenstein's natural gas (NG) consumption statistics.

b3) Gasoline

The whole amount of gasoline sold is attributed to 1A3b Road Transportation.

b4) Diesel oil

The diesel consumption, which stems from three different data sources, is attributed to the source categories according to the following assumptions (private diesel tanks: see Section a) Energy Statistics and modification above).

Data source	1A3b Road Transportation	1A4c Other Sect./Agriculture	1A5a Other/Stationary	1A5b Other/Mobile	Sum
Census gasoline stations	100%	0%	0%	0%	100%
Private diesel tanks agriculture	0%	100%	0%	0%	100%
Private diesel tanks non-agriculture	75%	0%	0%	25%	100%

Table 17 Data sources for the diesel consumption and its attribution to IPCC source categories (Acontec 2006).

Note

Please note that for the Swiss greenhouse gas inventory, the data for source category 1A Fuel Combustion from the Swiss Overall Energy Statistics (in TJ) is corrected for the fuel consumption in Liechtenstein (FOEN 2006). In the Swiss GHG Inventory, the fuel consumption in Liechtenstein is subtracted from the fuel consumption from the Swiss Overall Energy Statistics (that includes Liechtenstein's consumption). Therefore, a potential overestimation (underestimation) of fuel consumption in Liechtenstein is fully compensated by a related underestimation (overestimation) of fuel consumption in Switzerland.

3.2. Source Category 1A – Fuel Combustion Activities

3.2.1. Source Category Description

a) Energy Industries (1A1)

Key categories 1A1
CO_2 from the combustion of Gaseous Fuels in Energy Industries (1A1) are key categories regarding level and trend.

According to IPCC guidelines, source category 1A1 “Energy Industries” comprises emissions from fuels combusted by fuel extraction and energy producing industries.

In Liechtenstein, fuel extraction is not occurring and 1A1 includes only emissions from the production of heat and/or electricity for sale to the public. Auto-producers in industry are included in category 1A2 “Manufacturing Industries and Construction”. Waste incineration plants do not exist in Liechtenstein, municipal solid waste is exported to Switzerland for incineration.

1A1	Source	Specification	Data Source
1A1 a	Public Electricity and Heat Production	This source consists of natural gas fuelled public co-generation units.	AD: Energy Statistics 2004 EF: FOEN 2006
1A1 b	Petroleum Refining	Not occurring	-
1A1 c	Manufacture of Solid Fuels and Other Energy Industries	Not occurring	-

Table 18 Specification of source category 1A1 “Energy Industries” (AD: activity data; EF: emission factors)

In Liechtenstein, 80% of electricity consumption is imported and 20% is produced domestically (see Table 19).

	(MWh)	
Total consumption Liechtenstein 2004	344'715	100%
Power generation in Liechtenstein 2004	68'915	20%
Hydro power	64'387	
Natural gas co-generation	3'196	
Bio gas co-generation	1'180	
Photovoltaic	152	
Imports	275'800	80%

Table 19 Electricity consumption, generation and imports in Liechtenstein in 2004 (source Energy Statistics 2004).

Domestic power generation is dominated by hydroelectric power plants (see Figure 12). Other power sources are (fossil and bio fueled) combined heat and power generation, and power generation from photovoltaic plants.

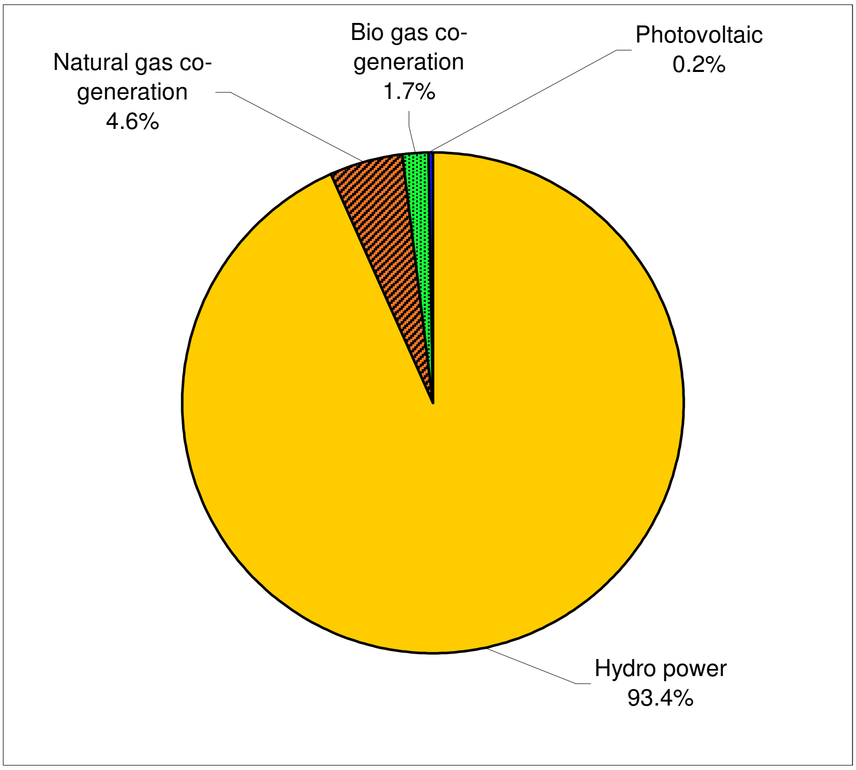

Figure 13 Structure of power generation in Liechtenstein 2004 (source Energy Statistics 2004).

Overall, renewable sources account for over 95% of domestic power generation in Liechtenstein.

b) Manufacturing Industries and Construction (1A2)

Key categories 1A2
CO_2 from the combustion of Gaseous Fuels and Liquid Fuels in Manufacturing Industries and Construction (1A2) is a key category regarding both level and trend.

The source category 1A2 “Manufacturing Industries and Construction” comprises all emissions from the combustion of fuels in stationary boilers, gas turbines and engines within manufacturing industries and construction. This includes industrial autoproduction of heat and electricity. Not included are combustion installations in the commercial/institutional and the residential sector as well as in agriculture/forestry. These are included in category 1A4 (“Other Sectors”).

Iron and Steel, Nonferrous Metals industry, Chemicals and Pulp and Paper production are not occurring in Liechtenstein.

Because data needed for the disaggregation of fuel consumption between the categories 1A2e to 1A2f is currently not available, all emissions related to Manufacturing Industries and Construction are reported under 1A2f Other.

1A2	Source	Specification	Data Source
1A2 a	Iron and Steel	Not occurring.	-
1A2 b	Non-ferrous Metals	Not occurring.	-
1A2 c	Chemicals	Not occurring.	-
1A2 d	Pulp, Paper and Print	Not occurring.	-
1A2 e	Food Processing, Beverages and Tobacco	Included in 1A2f.	-
1A2 f	Other (Combustion Installations in Industries)	Category 1A2 f contains all emissions related to 1A2.	AD: Energy Statistics 2004 EF: EMIS, SAEFL 2000a

Table 20 Specification of source category 1A2 “Manufacturing Industries and Construction” (AD: activity data; EF: emission factors)

c) Transport (1A3)

Key categories 1A3b
CO_2 from the combustion of gasoline (level and trend)
CO_2 from the combustion of diesel (level and trend)
CO_2 from the combustion of gaseous fuels (trend)

The source contains road transport and national civil aviation. Civil aviation in fact is only a very small contribution resulting from one only helicopter base in Liechtenstein. Railway is not producing emissions (see below), navigation and other transportation are not occurring. Further off-road transportation is included in category 1A4 Other Sectors (off-road transport in agriculture and forestry) and in 1A5 Other (off-road, e.g. construction).

1A3	Transport	Specification	Data Source
1A3a	Civil Aviation (National)	Helicopters only	AD: Rhein Helikopter AG 2006 Acontec 2006 EF: FOEN 2006, IPCC 1997c
1A3b	Road Transportation	Light and heavy motor vehicles, coaches, two-wheelers	AD: AVW 2005b, OEP 2006, EF: NIR CH (FOEN 2006), IPCC 1997c
1A3c	Railways	Fully electrified system, no electricty infeed, no diesel locomotives, shunting yards	---
1A3d-e	Navigation, military aviation	Not occurring	---

Table 21 Specification of Liechtenstein's source category 1A3 “Transport” (AD: activity data; EF: emission factors).

d) Other Sectors (1A4 – Commercial/Institutional, Residential, Agriculture/ Forestry)

Key categories 1A4a, 1A4b
CO_2 from the combustion of gaseous and liquid fuels in the Commercial/Institutional Sector (1A4a) and in the Residential Sector (1A4b) are key categories regarding both level and trend.

Source category 1A4 “Other sectors” comprises emissions from fuels combusted in commercial and institutional buildings, and in households, as well as emissions from fuel combustion for grass drying and off-road machinery in agriculture.

1A4	Source	Specification	Data Source
1A4 a	Commercial/ Institutional	Emission from fuel combustion in commercial and institutional buildings	AD: Energy statistics 2004 EF: EMIS, SAEFL 2000a; SFOE 2001
1A4 b	Residential	Emissions from fuel combustion in households	AD: Energy statistics 2004 EF: EMIS, SAEFL 2000a; SFOE 2001
1A4 c	Agriculture/ Forestry/ Fishing	Comprises fuel combustion for agricultural machinery.	AD: Energy statistics 2004 EF: EMIS, SAEFL 2000a; SFOE 2001; SAEFL 2005a

Table 22 Specification of source category 1A4 “Other sectors” (AD: activity data; EF: emission factors).

e) Other – Off-road: Construction, Hobby, Industry and Military (1A5)

Key source 1A5b
CO_2 from the combustion of liquid fuels in 1A5 Other – Off-road is a key source regarding level.

In Liechtenstein, the sub-sources are defined according to the next table. The IPCC category structure distinguishes stationary (1A5a) and mobile (1A5b) sources. In Liechtenstein, the main sources are construction and industrial vehicles. All emissions are therefore reported under 1A5b Mobile. 1A5a Stationary sources are not reported. Should some of them occur in reality, their emissions would not be neglected but would appear under 1A5b since the emission of the total amount of fuel sold is included in the modelling.

1A5b	Off-road	Specification	Data Source
	Construction	Construction vehicles and machinery	EF: SAEFL 2005a AD: AVW 2005b, OEP 2006
	Industry	Industrial off-road vehicles and machinery	

Table 23 Specification of Liechtenstein's source category 1A5b “Other, Mobile” (off-road).

3.2.2. Methodological Issues

General Issues

National and Reference Approach

The Sectoral (National) Approach uses Tier 1 methods for the different source categories of the energy sector.

Liechtenstein forms a customs union with Switzerland and has therefore no specific statistics on imports/exports of liquid fuels. Furthermore, Liechtenstein does not have any refinery industry. Therefore, the Reference Approach is identical with the Sectoral Approach.

Emission factors

Due to the close relations with Switzerland, similar economic structures, the same liquid/gaseous fuels and a similar vehicle fleet composition, a large number of emission factors, especially for CO_2, are taken from the Swiss greenhouse gas inventory.

Oxidation Factors

For the calculation of CO_2 emissions, an oxidation factor of 100% is assumed for all fossil fuel combustion processes (including coal), because technical standards for combustion installations in Liechtenstein are relatively high. Coal plays a negligible role in Liechtenstein (coal emissions were 0.02 Gg CO_2 in 2004).

As the consumption of liquid fuels slightly decreased (1990 to 2004: -6% to 2225 TJ) and gaseous fuels strongly increased (1990 to 2004: +170% to 1368 TJ), overestimating of oxidation factors tends to overestimate emission increase and is therefore conservative.

a) Energy Industries (1A1)

Key categories 1A1
CO_2 from the combustion of Gaseous Fuels in Energy Industries (1A1) is a key category regarding both level and trend.

In Liechtenstein, Energy Industries (source category 1A1) consists solely of natural gas fuelled public co-generation units in Public Electricity and Heat Production in 1A1a.

Petroleum Refining (1A1b) and Manufacture of Solid Fuels and Other Energy Industries (1A1c) do not occur.

Public Electricity and Heat Production (1A1a)

Methodology

For fuel combustion in Public Electricity and Heat Production (1A1a) a Tier 2 method is used. Aggregated fuel consumption data from the energy statistics is used to calculate emissions. These sources are characterised by rather similar industrial combustion processes and the same emission factors are applied throughout these sources. Emissions of GHGs are calculated by multiplying fuel consumption (in TJ) by emission factors.

Emission Factors

The emission factors for CO_2, CH_4, and N_2O for co-generation (lean fuel-air-ratio) have been taken from Switzerland (SAEFL 2005).

The following table presents the emission factors used in 1A1a:

Source/fuel	CO_2 t/TJ	CO_2 bio. t/TJ	CH_4 kg/TJ	N_2O kg/TJ	NO_x kg/TJ	CO kg/TJ	NMVOC kg/TJ	SO_2 kg/TJ
1A1a Public Electricity/Heat								
Natural gas	55.00	NO	25	0.1	NE	NE	NE	NE

Table 24 Emission Factors for 1A1a Public Electricity and Heat Production in Energy Industries for all years 1990 - 2004 (public co-generation).

Activity Data

Activity data on fuel consumption (TJ) for Public Electricity and Heat Production (1A1a) is extracted from the energy statistics.

Source/fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A1a Public Electricity/Heat Fuel Consumption											
Natural gas	TJ	2.16	14.04	32.40	33.48	31.32	35.64	44.64	43.56	50.40	50.40

Source/fuel	Unit	2000	2001	2002	2003	2004
1A1a Public Electricity/Heat Fuel Consumption						
Natural gas	TJ	47.52	50.40	43.20	48.60	50.76

Table 25 Activity data in 1A1a Public Electricity/Heat Production.

The table above documents the increase of Gaseous Fuel consumption by 2350% from 1990 to 2004. This increase is the reason for category 1A1 Gaseous Fuels being a key category regarding trend.

b) Manufacturing Industries and Construction (1A2)

Key categories 1A2

CO_2 from the combustion of Gaseous Fuels and Liquid Fuels in Manufacturing Industries and Construction (1A2) is a key category regarding both level and trend.

Methodology

For fuel combustion in Manufacturing Industries and Construction (1A2) a Tier 2 method is used.

A top-down method based on aggregated fuel consumption data from the energy statistics is used to calculate CO_2 emissions of 1A2f. All emissions from 1A2 are reported under 1A2f. The sources are characterised by rather similar industrial combustion processes and assumingly homogenous emission factors, where a top-down approach is feasible. Identical emission factors for each fuel type are applied throughout these sources. The unit of emission factors refers to fuel consumption (in TJ).

Emissions of GHGs are calculated by multiplying levels of activity by emission factors.

An oxidation factor of 100% is assumed for all combustion processes and fuels (see sub-section on oxidation factors in the beginning of Section 3.2.2).

Emission factors

The emission factors for CO_2 and SO_2 are based on measurements and analysis of fuel samples carried out by the Swiss Federal Laboratories for Materials Testing and Research EMPA (carbon emission factor documented in SFOE 2001, Table 45, p. 51; net calorific values on p. 61. See also Annex 2.1).

Emission factors for CH_4, and N_2O are based on comprehensive life cycle analysis of industrial boilers in Switzerland, documented in SAEFL 2000a (pp. 14-27).

The following table presents the emission factors used for the sources in category 1A2f:

Source/fuel	CO_2 t/TJ	CH_4 kg/TJ	N_2O kg/TJ	NO_x kg/TJ	CO kg/TJ	NMVOC kg/TJ	SO_2 kg/TJ
1A2 f Other							
Gas oil	73.7	1.0	0.6	NE	NE	NE	NE
Gas	55.0	6.0	0.1	NE	NE	NE	NE

Table 26 Emission factors for sources in 1A2f for all years 1990 - 2004.

Activity data

Activity data on fuel consumption (TJ) are based on aggregated fuel consumption data from the energy statistics (see Section 3.1.3).

The resulting disaggregated fuel consumption data for 1990 to 2004 is provided in Table 27.

Source	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1A2f Other	TJ	554	545	546	572	546	551	556	574	611	611	560	581	610	654	639
Gas oil	TJ	254	223	215	238	219	213	198	225	242	212	186	177	200	212	206
Natural gas	TJ	300	322	331	334	327	338	358	349	370	399	374	390	379	410	402
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	14	31	32	31

Table 27 Activity data fuel consumption in 1A2f Manufacturing Industries and Construction 1990 to 2004.

Table 27 documents the increase of Natural Gas consumption for manufacturing industries by +43% from 1990 to 2004 as well as the net decrease of gas oil consumption by -19% over the period. This shift in fuel mix is the reason for CO_2 emissions from the use of Gaseous, and Liquid Fuels in category 1A2 being a key category regarding trend.

c) Transport (1A3)

Key categories 1A3b
CO_2 from the combustion of gasoline (level and trend)
CO_2 from the combustion of diesel (level and trend)
CO_2 from the combustion of gaseous fuels (trend)

In Liechtenstein, 1A3 Transport mainly consists of sub-category 1A3b Road Transportation and a minor contribution of 1A3a Civil Aviation.

Aviation (1A3a)

Methodology

The emissions are estimated based on the fuel consumption, flying hours and the fleet composition of Liechtenstein's single helicopter base.

It must be noted, that these emissions are also reported in the Swiss GHG inventory. Since Switzerland and Liechtenstein form a customs union, all imports of kerosene appear in the Swiss overall energy statistics. The Swiss Federal Office of Civil Aviation (FOCA) carries out an extended Tier 3a method to determine the domestic (and bunker) emissions of civil aviation. Within this calculation, all fuel consumption of helicopters is accounted for. The helicopter basis in Balzers/Liechtenstein is included in this modelling scheme. All resulting emissions from helicopters are reported in the Swiss inventory as domestic emissions. The amount of emissions from the Balzers helicopter basis is very small compared to the total of Swiss helicopter emissions. Therefore, Switzerland disclaimed to subtract the small contribution of emissions from its inventory. Nevertheless, for Liechtenstein these emissions are not negligible. They are calculated using a Tier 1 method.

Emission Factors

Emission factors	**CO_2** t/TJ	**CH_4** kg/TJ	**N_2O** kg/TJ
1A3a Civil aviation/ helicopters	73.2	0.5	2.3
data source	FOEN 2006	IPCC 1996	IPCC 1996

Table 28 Emission factors used for estimating emissions of helicopters. The values are used for the entire time series 1990-2004.

Activity Data

The two operating companies of the helicopter base provided the fuel consumption for 1995, 2001–2004 as well as detailed flying hours, shares of domestic and international flights as well as specific consumption of the helicopter fleet for 2001–2002 (Rhein Heli 2006).

Company Rhein-Helikopter AG: Helikopter AS 350 B-3 Ecureuil, 180 litre/hour
Rotex Helicopter AG: Helikopter Kamax K 1200, 320 litres/hour

From the shares of domestic flights in 2001 (14%) and in 2002 (16%), a mean share of 15% was adopted for all other years in the period 1990–2000, 2003–2004. The consumption 1990–1994, which is not available any more, is assumed to be constant and equal to 1995. The consumption for 1996–2000 was linearly interpolated between 1995 and 2001.

Kerosene	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
								TJ							
domestic	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.22	0.22	0.23	0.24	0.17

Table 29 Activity data for civil aviation (domestic): Kerosene consumption 1990-2004 in TJ.

Road Transportation (1A3b)

Key categories 1A3b
CO_2 from the combustion of gasoline (level and trend)
CO_2 from the combustion of diesel (level and trend)
CO_2 from the combustion of gaseous fuels (trend)

Methodology

The emissions are calculated with a tier 1 method (top-down) as suggested by IPCC Good Practice Guidance using Swiss emission factors. The CO_2 emission factors are derived from the carbon content of fuels (see Table 11). For CH_4 and N_2O , the implied emission factors of the Swiss greenhouse gas inventory are applied. The activity data corresponds to the amounts of gasoline and diesel fuel sold in Liechtenstein (sales principle). These numbers are taken from the national energy statistics modified as mentioned in Chapter 3.1.3. For Liechtenstein, "tank tourism" is a very important feature of the gasoline sales, since the prices in the neighbouring Austria are much higher than in Liechtenstein and Switzerland (which both have the same price due to the Customs Union Treaty) and an enormous number of Austrian and German people are working in Liechtenstein (34’006 inhabitants, 13’911 commuters, where 7’463 are non-Swiss commuters) and buying their gasoline in Liechtenstein. The method of reporting the fuel sold at all gasoline stations in the country guarantees that indeed the sales principle is applied and not a territorial principle as might be the case by applying a traffic model, which, for Liechtenstein, would considerably underestimate the fuel sold.

Emission Factors

The emission factors for gasoline and diesel oil are adopted from Switzerland:

- CO_2 for gasoline, diesel oil and natural gas: The emission factors are taken from Table 11.
- CH_4, N_2O for gasoline and diesel oil: The implied emission factors of the Swiss CRF Table1.A(a)s3 (rows 1A3b Road Transportation Gasoline / Diesel oil) are used. The fleet composition of the two countries are very similar, the CO_2 emissions of light motor vehicles (passenger cars, light duty vehicles, motorcycles) and heavy motor vehicles (heavy duty vehicles, buses, coaches) are similar in Liechtenstein and Switzerland. A quantitative analysis based on the traffic models of Switzerland (SAEFL 2004a, Annex A5) and of Liechtenstein (OEP 2002, Table 7, p. 16) shows: The contribution of light motor vehicles to the CO_2 emissions of the total (light and heavy motor vehicles) is 80% in Liechtenstein and 85% in Switzerland. Note that these results are derived on the territorial principle. From the viewpoint of sales principle, both numbers would be higher due to tank tourism, but in Liechtenstein, the increase would be stronger since the tank tourism is more pronounced in Liechtenstein than in Switzerland. It may therefore be expected that the two numbers 80% and 85% would even be closer together. This comparison may serve as an argument for the applicability of Swiss implied emission factors for Liechtenstein.
- CH_4, N_2O for natural gas: There are no implied emission factors available in the Swiss CRF. Therefore, the IPCC default emission factors for CH_4 and N_2O are applied.

Gas	unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Gasoline																
CO_2	t/TJ	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9
CH_4	kg/TJ	28.3	25.2	22.1	19.7	17.4	15.6	14.0	12.8	11.6	10.7	9.8	9.0	8.2	7.6	7.1
N_2O	kg/TJ	1.9	2.3	2.7	3.0	3.2	3.7	3.6	3.6	3.6	3.5	3.3	3.1	2.9	2.7	2.5
Diesel																
CO_2	t/TJ	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6
CH_4	kg/TJ	2.0	2.0	1.9	1.7	1.6	1.6	1.5	1.4	1.3	1.3	1.2	1.0	0.9	0.9	0.8
N_2O	kg/TJ	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.2	1.3
Gaseous fuels																
CO_2	t/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	55.0	55.0	55.0	55.0
CH_4	kg/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	49.9	50.0	49.9	50.1
N_2O	kg/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.1	0.1	0.1	0.1

Table 30 Emission factors for road transport. The values for gasoline and diesel oil are adopted from the Swiss GHG inventory (implied emission factors from CRF Table1.A(a)s3, 1990, 1995, 2004 (NIR CH, FOEN 2006). For gaseous fuels, IPCC default values are used (IPCC 1997c).

The following paragraph gives a couple of explanations to the origin of the Swiss emission factors for road transportation:

Swiss emission factors (excerpt from NIR CH, chp 3.2.2.c, FOEN 2006): *The emission factors for CO_2 are country-specific and based on measurements and analyses of fuel samples. Emission factors for the further gases are derived from "emission functions" which are determined from measurements of a large number of driving patterns within an international measurement program of Switzerland together with Austria, Germany and the Netherlands. The method has been developed in 1990-1995 and has been extended and updated in 2000 and 2004. The latest version is presented and documented on the website http://www.hbefa.net/. Several reports may be downloaded from there:*

- *Documentation of the general emission factor methodology, SAEFL 2004c (in German),*
- *Emission Factors for Passenger Cars and Light Duty Vehicles Switzerland, Germany, Austria, INFRAS 2004 (in English).*
- *Update of the Emission Factors for Heavy Duty Vehicles, TUG 2002 (in English),*
- *Update of the Emission Factors for Two-wheelers, RWTÜV 2003 (in German)*

The resulting emission factors are published on CD ROM ("Handbook of emission factors for Road Transport", SAEFL 2004b). The underlying database contains a dynamic fleet compositions model simulating the release of new exhaust technologies and the dying out of old technologies. Corrective factors are provided to account for future technologies. Further details are shown in Annex 3.2 of FOEN 2006.

The CO_2 factors are constant over the whole period 1990–2004. Changes in the carbon content of the fuels have not been considered so far due to (approximately) constant fuel qualities. For the other gases, more or less pronounced decreases of the emission factors occur due to new emission regulations and subsequent new exhaust technologies (mandatory use of catalytic converters for gasoline cars and lower limits for sulphur content in diesel fuels). Early models of catalytic converters have been substantial sources of N_2O, leading to an emission increase until 1998. Recent converter technologies have overcome this problem resulting in a decrease of the (mean) emission factor. It should be noted that the N_2O emission factors are much smaller than the IPCC default values. The factors used in Switzerland are taken from a recent Dutch measurement programme (TNO 2002a-b, TNO 2003).

It may be added that cold start and evaporative emissions are included in the Swiss modelling scheme.

Activity Data

The amount of gasoline and diesel fuel sold in Liechtenstein serves as the activity data for the calculation of the CO_2 emissions. For gasoline, the numbers are identical with Table 12 line "gasoline". For diesel, around 80% of the value for “diesel” in the national statistics of Table 12 is consumed in 1A3b Road Transportation, the remaining amount in 1A5b (construction) and 1A4c Other Sectors, agricultural machinery (see also Table 31 and Table 37). For gaseous fuels, the amount reported by gasoline stations is used.

Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	TJ														
Gasoline	819	916	957	947	878	903	909	954	896	940	1'040	1'007	920	879	851
Diesel	201	282	231	211	182	184	195	199	253	287	240	214	229	264	277
Natural Gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	14	31	32	31
Sum	1'020	1'198	1'188	1'159	1'060	1'087	1'104	1'152	1'149	1'226	1'279	1'235	1'179	1'175	1'159

Table 32 Activity data for 1A3b Road Transportation.

The share of gasoline has decreased from 80% in 1990 to 73% in 2004. In the same period, the consumption of diesel has increased from 10% to 24%.

Railways (1A3c)

There is a railway line crossing the country, where Austrian and Swiss railways are passing. Liechtenstein has no own railway. The railway line is owned and maintained by the Austrian Federal Railway. The line in Liechtenstein is fully electrified. There are no diesel sales to railway locomotives, therefore there are no emissions occurring, which are relevant for the GHG inventory.

Navigation (1A3d)

Navigation is not occurring in Liechtenstein, because there are no lakes, and the river Rhine is not navigable within Liechtenstein. Therefore, there are no emissions occurring.

d) Other Sectors (Commercial, Residential, Agriculture, Forestry; 1A4)

Key categories 1A4a, 1A4b
CO_2 from the combustion of gaseous and liquid fuels in the Commercial/Institutional Sector (1A4a) and in the Residential Sector (1A4b) are key categories regarding both level and trend.

“Other Sectors” (source category 1A4) comprises

- “Commercial/ Institutional” (1A4a)
- “Residential” (1A4b)
- “Agriculture/Forestry/Fisheries” (1A4c)

Commercial/ Institutional (1A4a) and Residential (1A4b)

Methodology

For Fuel Combustion in Commercial and Institutional Buildings (1A4a) and in Households (1A4b), a Tier 2 method is used. A top-down method based on aggregated fuel consumption data from the energy statistics is used to calculate emissions. These sources are characterised by rather similar combustion processes and the same emission factors are assumed for 1A4a and 1A4b. Emissions of GHGs are calculated by multiplying levels of activity by emission factors. An oxidation factor of 100% is assumed for all combustion processes and fuels (see sub-section on oxidation factors in the beginning of Section 3.2.2).

Emission Factors

The emission factors for CO_2 are based on measurements and analysis of fuel samples carried out by the Swiss Federal Laboratories for Materials Testing and Research EMPA (carbon emission factor documented in SFOE 2001, Table 45, p. 51; net calorific values on p. 61. See also Annex A2.1 of the NIR in hand).

The coal emission factor for CO_2 is a mixed emission factor that results as a weighted average of the hard coal and lignite emission factors in Switzerland (FOEN 2006), where similar conditions prevail.

Emission factors for CH_4, and N_2O are based on comprehensive life cycle analysis of combustion boilers in the residential, commercial institutional and agricultural sectors, documented in SAEFL 2000a (pp. 42-56) and SAEFL 2005.

Emission factor for CH_4 emissions from Liquefied Petroleum Gas (LPG) is from UBA 2004.

All emission factors for biomass are based on SAEFL 2000a (pp. 26ff).

Since the fraction of stationary engines in total fuel consumption is rather small, emission factors for combustion boilers are used for all sources and fuels considered (see also Section 3.2.6 on planned improvements).

Table 33 presents the emission factors used in 1A4a and 1A4b:

Source/fuel	CO_2 t/TJ	CO_2 bio. t/TJ	CH_4 kg/TJ	N_2O kg/TJ	NO_x kg/TJ	CO kg/TJ	NMVOC kg/TJ	SO_2 kg/TJ
1A4 a+b Other Sectors: Commercial/Institutional and Residential								
Gas oil	73.7		1	0.6	NE	NE	NE	NE
LPG	65.5		2.5	0.1	NE	NE	NE	NE
Coal	94.0		300	1.6	NE	NE	NE	NE
Natural gas	55.00		6	0.1	NE	NE	NE	NE
Biomass (1A4a)		92	8	1.6	NE	NE	NE	NE
Biomass (1A4b)[6]		92	350	1.6	NE	NE	NE	NE

Table 33 Emission Factors for 1A4a and 1A4b: Commercial/Institutional and Residential in “Other Sectors” for all years 1990 - 2004.

Activity Data

Activity data on fuel consumption (TJ) are based on aggregated fuel consumption data from the energy statistics. A description of the modifications and the disaggregation of data from energy statistics is provided in Section 3.1.

The resulting disaggregated fuel consumption data from 1990–2004 is provided in.Table 34.

Source/Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A4a Commercial/Institutional	TJ	977	908	910	997	962	950	961	1'024	1'121	1'042
Gas oil	TJ	763	669	646	713	657	639	593	675	725	636
LPG	TJ	13	8	15	12	9.5	8.1	10	7.0	7.2	5.8
Natural gas	TJ	158	196	205	230	246	264	319	298	340	348
Coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	42	35	44	42	49	40	39	44	48	53
1A4b Residential	TJ	319	319	354	401	391	417	434	467	510	522
Gas oil	TJ	254	223	215	238	219	213	198	225	242	212
Natural gas	TJ	46	82	120	146	150	188	222	224	249	289
Coal	TJ	1.0	0.9	1.1	1.0	0.7	0.7	0.5	0.5	0.6	0.3
Biomass	TJ	18	12	18	16	20	15	14	17	19	21

Source/Fuel	Unit	2000	2001	2002	2003	2004
1A4a Commercial/Institutional	TJ	998	984	1'077	1'144	1'172
Gas oil	TJ	558	531	601	637	618
LPG	TJ	5.5	3.9	4.2	4.6	4.1
Natural gas	TJ	357	394	417	435	478
Coal	TJ	NO	NO	NO	NO	NO
Biomass	TJ	77	54	55	67	72
1A4b Residential	TJ	513	534	565	612	647
Gas oil	TJ	186	177	200	212	206
Natural gas	TJ	290	334	341	369	407
Coal	TJ	0.6	0.3	0.3	0.3	0.3
Biomass	TJ	37	22	23	31	34

Table 34 Activity data in 1A4a Commercial/Institutional and 1A4b Residential.

The table above documents the increase of natural gas consumption by three times (1A4a) and almost nine times (1A4b) from 1990 to 2004 with the built-up of Liechtenstein's gas

[6] The CH_4 emission factor of 350kg/TJ in 1A4b Residential is an average value over emission factors for open fireplaces (700 kg /TJ), old closed stoves (450 kg/TJ), modern closed stoves (130 kg/TJ), and modern closed stoves with ventilation (70 kg/TJ).

supply network. Also a the net decrease of gas oil consumption by -19% (both 1A4a and 1A4b) over the period can be detected. This shift in fuel mix is the reason for CO_2 emissions from the use of gaseous and liquid fuels in category 1A4a/b being key categories regarding trend.

Agriculture/Forestry (1A4c)

Methodology

For source category 1A4c, a Tier 1 method is used. Emissions stem from fuel combustion in agricultural machinery. Implied emission factors from a Swiss off-road study are used. The activity data follows from the information provided by the General Directorate of Swiss Customs (refunding institution of fuel taxes, see above in Section 3.1.3a) .

Emission Factors

Emission factors for the use of Diesel in off-road machinery are the same as in 1A4b (see Table 36).

Activity Data

Off-road machinery: Activity data (Diesel consumption) is shown in Table 35.

1A4c Fuel cons	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	TJ														
Diesel	17.7	18.1	17.8	17.2	17.3	16.8	16.5	18.5	17.4	18.8	17.7	18.4	18.5	19.9	20.5

Table 35 Activity data in 1A4c Agriculture/Forestry.

e) Other – Off-road: Construction, Industry (1A5b)

Key source 1A5b
CO_2 from the combustion of liquid fuels in 1A5 Other – Off-road is a key source regarding level.

Methodology

For source category 1A5, a Tier 1 method is used. Due to Table 17, among private diesel tanks non-agriculture, the amount of 25% of the consumption is attributed to 1A5b Other/Mobile (off-road) activity: Construction vehicles and machinery; Industrial off-road vehicles and machinery. Emission factors are taken from the latest Swiss off-road study (SAEFL 2005a).

Emission Factors

The emission factors are based on a query on the new Swiss off-road database for construction machinery (SAEFL 2005a). They correspond to implied emission factors: The total of emissions of the whole fleet of construction vehicles was divided by the fuel consumption (in TJ). For the application in the Liechtenstein inventory, it is assumed, that the fleet composition is similar to the Swiss fleet composition (vehicle category, size class, age distribution).

Gas	unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
liquid fuels																
CO_2	t/TJ	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6
CH_4	kg/TJ	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.46	0.46
N_2O	kg/TJ	2.15	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.17	2.17	2.17	2.17	2.17	2.17	2.17

Table 36 Emission factors used for 1A5b Other – Off-road / mobile sources. Data are based on Swiss off-road database (SAEFL 2005a).

Activity Data

The activity data includes the consumption of diesel oil as mentioned in the paragraph “Methodology” above.

1A5 Fuel cons.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	TJ														
Diesel	32.1	38.8	39.6	32.7	30.7	29.7	30.4	34.3	39.8	42.1	40.3	34.4	37.2	46.3	41.1

Table 37 Activity data (diesel oil consumption) for 1A5b Other – Off-road / mobile sources.

3.2.3. Uncertainties and Time-Series Consistency

A quantitative Tier 1 analysis (following Good Practice Guidance; IPCC 2000, p. 6.13ff) is used to estimate uncertainties of key categories in the NIR. First, uncertainties of activity data and emission factors are estimated separately. The combined uncertainty for each source is then calculated using a Rule B approximation (IPCC 2000 p. 6.12). Further, the Rule A approximation is used to arrive at the overall uncertainty in national emissions and the trend in national emissions between the base year and the current year.

a) Uncertainties

Uncertainty in aggregated fuel consumption activity data (1A Fuel Combustion)

Liechtenstein and Switzerland form a customs and monetary union governed by a customs treaty. Therefore, no customs statistics exist that would provide reliable data on (liquid and solid) fuels imports into Liechtenstein.

The level of disaggregation that has been chosen for the key category analysis provides a rather fine disaggregation of combustion related CO_2 emissions in category 1 Energy. E.g. the key category analysis distinguishes between Emissions from Commercial/Institutional (1A4a), Residential (1A4b), and Agriculture/Forestry (1A4c).

However, the data on fuel consumption originates at the aggregated level of sales data. It is only later disaggregated using simple expert judgement leading to the consumption in different branches (see Section 3.1.3). In order to avoid errors that are introduced in the process of disaggregation, but do not apply to the aggregated emissions on the national level, the analysis of uncertainties for CO_2 emissions from fuel combustion is carried out on the level of aggregated total national emissions (1A) for Gaseous, Liquid and Solid fuels.

Details of uncertainty analysis of activity data (fuel consumption) in 1A are based on expert judgement. The dominant contributor to overall uncertainty is liquid fuel consumption. Because customs statistics of imports of oil products do not exist, this data is based on surveys with oil suppliers carried out earlier by AVW and in recent years by OEP. The methodology and completeness of the surveys has been improved over the years. Therefore it is assumed that the uncertainty in activity data for liquid fuels around 1990 is rather high, whereas recent data is of medium to low uncertainty. From this, a global uncertainty for liquid fuels of 18% has been estimated.

Uncertainty in CO_2 emission factors in fuel combustion (1A)

Liechtenstein and Switzerland form a customs and monetary union governed by a customs treaty. E.g. all Gas oil is supplied by Swiss suppliers and no taxation accrues at the borders for the import to Liechtenstein. It may therefore be assumed that fuel has the same properties as the fuels sold on the Swiss market. Therefore, the emission factors and their uncertainties have been taken from Switzerland, and are documented in the Swiss NIR (FOEN 2006).

Table 38 below provides the results of the quantitative Tier 1 analysis (following Good Practice Guidance; IPCC 2000, p. 6.13ff) estimating uncertainties of CO_2 emissions from fuel combustion activities.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions 1990	Year 2004 emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combinded uncertainty as % of total CO2 combustion emission in year t	Type A sensitivity (CO2 from combustion)	Type B sensitivity (CO2 from combustion)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (CO2 from combustion)	Uncertainty in trend in national emissions introduced by activity data uncertainty (CO2 from combustion)	Uncertainty introduced into the trend in total CO2 combustion emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%	%	%	%	%	%
1A Gaseous fuels	CO2	27.81	75.22	5.0	4.6	6.8	2.135	0.2091	0.3732	0.96	2.64	2.81
1A Liquid fuels	CO2	173.62	164.07	18.0	0.55	18.01	12.347	-0.2071	0.8141	-0.11	20.72	20.72
1A Solid fuels	CO2	0.09	0.02	20.0	5.0	20.6	0.002	-0.0004	0.0001	0.00	0.00	0.00
1A Other fuels	CO2	NA,NO	NA,NO									
Total CO2 Emissions Fuel		201.53	239.31									
Overall uncertainty CO2 combustion emissions in the year (%):							12.53	CO2 combustion emissions trend uncertainty (%):				20.91

Table 38 Results from Tier 1 uncertainty calculation and reporting for CO_2 emissions in 1A Fuel Combustion.

The analysis results in an overall uncertainty of the CO_2 emissions from 1A Fuel Combustion of 12.53% for the year 2004 and in a trend uncertainty for the period 1990 to 2004 of 20.91%.

The overall uncertainty is determined by the rather high activity data uncertainty of liquid fuels.

Qualitative estimate of uncertainties of non-key category emissions in 1A Fuel Combustion

Non-CO_2 emissions in Energy Industries (1A1), Manufacturing Industries and Construction (1A2) and Other Sectors (Commercial, Residential, Agriculture, Forestry; 1A4):
Uncertainty in emissions of non-CO_2 gases is estimated to be medium.

Other source categories in 1A
Uncertainty: No estimates of the uncertainties have been performed.

b) Consistency and Completeness in 1A Fuel Combustion

Consistency:
The method for the calculation of GHG emissions are the same for the years 1990 to 2004; time series are consistent

Completeness:
For the first time, the emissions for the full time series 1990–2004 have been calculated and reported. The data on emissions of the six Kyoto gases (CO_2, CH_4, N_2O, HFC, PFC, SF_6) are therefore complete. The precursor emissions from Energy have not been estimated.

3.2.4. Source-Specific QA/QC and Verification

No formal QA/QC process has been carried out. Nevertheless, the inputs and the results were checked by the sectoral expert, who also feeds the CRF Reporter and independently by the NIR authors as well as by the specialists of the OEP.

3.2.5. Source-Specific Planned Improvements

There are no source-specific planned improvements.

3.3. Source Category 1B – Fugitive Emissions from Fuels

3.3.1. Source Category Description

Source category 1B “Fugitive Emissions from Fuels” is **not a key category.**

Fugitive emissions arise from the production, processing, transmission, storage and use of fuels. According to IPCC guidelines, emissions from flaring at oil and gas production facilities are included while emissions from vehicles are not included in 1B.

Source Category 1B “Fugitive Emissions from Fuels” comprises the following sub-categories:

- Solid fuels (1B1)
- Oil and Natural Gas (1B2)

a) Solid fuels (1B1)

Coal mining is not occurring in Liechtenstein.

b) Oil and Natural Gas (1B2)

1B2	Source	Specification	Data Source
1B2 a	Oil	Refining of oil is not occurring	-
1B2 b	Natural Gas	Emissions from gas pipelines	AD: LGV 2005 EF: FOEN 2006
1B2 c	Venting / Flaring	Not occurring	-

Table 39 Specification of source category 1B2 “Fugitive Emissions from Oil and Natural Gas” (AD: activity data; EF: emission factors)

3.3.2. Methodological Issues

a) Oil and Natural Gas (1B2)

Methodology

For source 1B2b Natural Gas, the emissions of CH_4 leakages from gas pipelines are calculated with a Tier 3 method, adapted from the Swiss NIR (FOEN 2006). The method considers the length, type and pressure of the gas pipelines. The distribution network components (regulators, shut off fittings and gas meters), the losses from maintenance and extension as well as the end user losses are taken into account. NMVOC leakages are not estimated.

Emission factors

The emission factors for gas distribution losses (source 1B2b) depend on the type and pressure of the natural gas pipeline (see Table 40; sources cited in FOEN 2006: Battelle 1994, Xinmin 2004). The CH_4-emissions due to gas meters are considered with an emission factor of 5.11 m^3 CH_4 per gas meter and year.

1B2 Fugitive Emissions from Oil and Natural Gas [m^3/h/km]	< 100 mbar	100-1000 mbar	1- 5 bar	> 5 bar
Steel cath.	-	-	-	0.028
HDPE (Polyethylene)	0.00800	0.01600	0.00062	-

Table 40 CH_4-Emission Factors for 1B2 “Fugitive Emissions from Oil and Natural Gas” (Battelle 1994, Xinmin 2004)

Activity data

The activity data such as length and type of pipes in the distribution network for the calculation of methane leaks have been extracted from the annual reports of Liechtenstein's Gas Utility (LGV 2005).

3.3.3. Uncertainties and Time-Series Consistency

No uncertainty estimate has been carried out for 1B.

The time series is consistent.

3.3.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

3.3.5. Source-Specific Recalculations

No recalculations have been carried out.

3.3.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

3.4. Source Category International Bunker Fuels

For Liechtenstein, the only source of international bunker emissions is civil aviation (one helicopter-base). Total emissions of civil aviation are calculated as described in Section 3.2.2.c) with Tier 1 method. The share of consumption for international flights is provided by the two operating companies of the helicopter base (Rhein-Helikopter AG, Rotex Helicopter AG) for 2001 (84%) and 2002 (86%). For all other years, the mean (85%) is used.

Kerosene	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
	TJ														
total	6.87	6.87	6.87	6.87	6.87	6.87	7.04	7.21	7.39	7.56	7.74	7.91	7.26	7.93	5.67
domestic	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.14	1.19	0.85
internat. (bunker)	5.84	5.84	5.84	5.84	5.84	5.84	6.00	6.16	6.33	6.49	6.66	6.82	6.12	6.74	4.82

Table 41 Kerosene consumption for civil aviation: Total, domestic (1A4a) and international bunker (memo item) contribution.

Marine bunker emissions are not occurring.

3.5. CO_2 Emissions from Biomass

A description of the methodology for calculating CO_2 emissions from the combustion of biomass is included in the relevant Chapters 3 (Energy) and 8 (Waste).

4. Industrial Processes

4.1. *Overview*

According to IPCC guidelines, emissions within this sector comprise greenhouse gas emissions as by-products from industrial processes and also emissions of synthetic greenhouse gases during production, use and disposal. (Emissions from fuel combustion in industry are reported under category 1 Energy.)

Only few IPCC source categories among the sector Industrial Processes occur in Liechtenstein. Sources in the categories 2B, 2C, 2D, 2E and 2G are not occurring at all.

With the present submission, a first attempt has been made to quantify potential emissions from sources to be found in category 2A. Also, sources in category 2F are occurring and are partly estimated: HFC emissions have been estimated from refrigeration and air conditioning equipment as well as some SF_6 emissions from electrical equipment. The emissions have increased in 2004 compared to 1990 as Table 42 shows. PFC emissions are not occurring in Liechtenstein.

Gas	**2F Consump. of Halocarbons and SF_6**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
		Gg CO2 eq														
HFC	2F1, 2F4	8.E-06	2.E-03	0.01	0.05	0.15	0.39	0.66	1.04	1.38	1.81	2.31	2.92	3.16	3.44	3.95
PFC		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	2F8	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.02	0.04	0.05	0.05	0.06
Sum	**2F**	**8.E-06**	**2.E-03**	**0.01**	**0.05**	**0.15**	**0.39**	**0.66**	**1.04**	**1.38**	**1.81**	**2.32**	**2.96**	**3.21**	**3.49**	**4.00**
	2A Mineral Products	**Gg**														
CO	2A5, 2A5	0.020	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.017	0.016	0.014
NMVOC	2A6	0.028	0.027	0.025	0.024	0.023	0.021	0.020	0.019	0.019	0.019	0.018	0.016	0.015	0.014	0.014

Table 42 GHG emissions of source category 2 “Industrial Processes” 1990 an 2004 by gases in CO2 equivalent (Gg)..

4.2. *Source Category 2A – Mineral Products*

4.2.1. Source Category Description

Source category 2A "Mineral Products" is **not a key category.**

Details on source category 2A “Mineral Products” are provided in the table below:

2A	Source	Specification	Data Source
2A1	Cement Production	Not occurring in Liechtenstein.	-
2A2	Lime Production	Not occurring in Liechtenstein.	-
2A3	Limestone and Dolomite Use	Not occurring in Liechtenstein.	-
2A4	Soda Ash Production and Use	Not occurring in Liechtenstein.	-
2A5	Asphalt Roofing		AD: AVW 2005a EF: FOEN 2006
2A6	Road Paving with Asphalt		AD: AVW 2005a EF: FOEN 2006
2A7	Other	Not occurring in Liechtenstein.	-

Table 43 Specification of source category 2A "Mineral Products"

4.2.2. Methodological Issues

Asphalt Roofing (2A5) and Road Paving with Asphalt (2A6)

Methodology

For the determination of CO and NMVOC emissions from Asphalt Roofing and NMVOC emissions from Road Paving with Asphalt data available in Liechtenstein is very limited. Up to now, Liechtenstein has not established an inventory of these emissions.

In order to establish rough estimates of emissions for Liechtenstein, the specific emissions per inhabitant in Switzerland are used as a proxy:

Emissions of CO and NMVOC from 2A5 and 2A6 in Liechtenstein are the product of *the specific emissions per inhabitant in Switzerland* times *the number of inhabitants in Liechtenstein*.

This allows for a first preliminary estimate of emissions. The rationale behind this simple approach is that the general characteristics of Liechtenstein and Switzerland determining emissions are roughly similar.

Emission Factors

Emission factors for CO and NMVOC, the specific emissions per inhabitant, are calculated by dividing the emissions from Asphalt Roofing (2A5) and Road Paving with Asphalt (2A6) from the Swiss national inventory (FOEN 2006) by the number of inhabitants in Switzerland, as given below.

Activity Data

The activity data consist in the number of inhabitants in Liechtenstein as provided in the Table below.

Inhabitants	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Liechtenstein	**29'032**	**29'386**	**29'868**	**30'310**	**30'629**	**30'923**	**31'143**	**31'320**	**32'015**	**32'426**
Switzerland	6'796'000	6'880'000	6'943'000	6'989'000	7'037'000	7'081'000	7'105'000	7'113'000	7'132'000	7'167'000
Liechtenstein/Switzerland	0.427%	0.427%	0.430%	0.434%	0.435%	0.437%	0.438%	0.440%	0.449%	0.452%

Inhabitants	2000	2001	2002	2003	2004
Liechtenstein	**32'863**	**33'525**	**33'863**	**34'294**	**34'600**
Switzerland	7'209'000	7'209'000	7'209'000	7'209'000	7'209'000
Liechtenstein/Switzerland	0.456%	0.465%	0.470%	0.476%	0.480%

Table 44 Inhabitants in Liechtenstein 1990 – 2004 (AVW 2005a) and Inhabitants of Switzerland for comparison.

4.2.3. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment results in low confidence in emission estimates.

The time series is consistent.

4.2.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

4.2.5. Source-Specific Recalculations

Time series have been calculated for the first time with this submission. See Chapter 9.

4.2.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

4.3. Source Category 2B – Chemical Industry

4.3.1. Source Category Description

Source Category 2B Chemical Industry is **not a key category.**

Details on source category 2B “Chemical Industry” are provided in the table below:

2B	Source	Specification
2B1	Ammonia Production	Not occurring in Liechtenstein
2B2	Nitric Acid Production	Not occurring in Liechtenstein
2B3	Adipic Acid Production	Not occurring in Liechtenstein
2B4	Carbide Production	Not occurring in Liechtenstein
2B5	Other (Emissions from the production of Organic Chemicals (Ethylene, PVC, Formaldehyde, Acetic Acid))	Not occurring in Liechtenstein

Table 45 Specification of source category 2B “Chemical Industry”

GHG emissions from source category 2B are not occurring in Liechtenstein.

4.4. Source Category 2C – Metal Production

4.4.1. Source Category Description

Source category 2C "Metal Production" is **not a key category.**

Details on source category 2C “Metal Production” are provided in the table below:

2C	Source	Specification
2C1	Iron and Steel Production	Not occurring in Liechtenstein
2C2	Ferroalloys Production	Not occurring in Liechtenstein
2C3	Aluminium Production	Not occurring in Liechtenstein
2C4	Use of SF_6 in Aluminium and Magnesium Foundries	Not occurring in Liechtenstein
2C5	Other	Not occurring in Liechtenstein

Table 46 Specification of source category 2C “Metal Production”.

GHG emissions from source category 2C are not occurring in Liechtenstein.

4.5. Source Category 2D – Other Production

Source category 2D "Other Production" is **not a key category.**

GHG emissions from source category 2D are not occurring in Liechtenstein.

4.6. Source Category 2E – Production of Halocarbons and SF_6

Source category 2E "Production of Halocarbons and SF_6" is **not a key category.**

There is no production of HFC, PFC or SF_6 in Liechtenstein. GHG emissions from source category 2E are not occurring in Liechtenstein.

4.7. Source Category 2F – Consumption of Halocarbons and SF_6

4.7.1. Source Category Description

Key category 2F
HFC from consumption of halocarbons and SF6 is a key category regarding level and trend (see Table 3)

Source category 2F comprises HFC and SF_6 emissions from consumption of the applications listed below. Other applications are not occurring in Liechtenstein. PFC emissions from this source category are not occurring within Liechtenstein.

2F	Source	Specification	Data Source
2F1	Refrigeration and Air Conditioning Equipment	Emissions from Refrigeration and Air Conditioning Equipment	AD: Number of households, employees, passenger cars EF: Industry data for Switzerland (FOEN 2006)
2F7	Electrical Equipment	Emissions from use in electrical equipment	AD: Industry data EF: Industry data

Table 47 Specification of source category 2F "Consumption of Halocarbons and SF_6" (AD: activity data; EF: emission factors).

4.7.2. Methodological Issues

2F1 Refrigeration and Air Conditioning Equipment

Methodology

Liechtenstein does not have the relevant import statistics or industry data which would allow to develop specific data models to estimate the emissions under source category 2F1. Therefore the emissions for Liechtenstein are estimated by applying the rule of proportion on basis of the emissions reported by Switzerland and specific indicators such as number of households, number of employees, number of cars, etc. As it can be assumed that the consumption patterns for industry, service sector and household sector of Liechtenstein are very similar to Switzerland, this approach will result in reliable figures for Liechtenstein. While the emission factors are assumed to be identical for both countries, the specific indicators for the rule of proportion calculation are chosen under the criteria that they shall be suitable to derive the activity data for Liechtenstein on basis of data for Switzerland.

More details of the underlying data models can be seen from the National Inventory Report for Switzerland (FOEN 2006).

Manufacturing of refrigeration and air conditioning equipment is not occurring in Liechtenstein, whereas product life emissions and disposal losses are estimated on basis of the rule of proportion applied onto the sum of emissions for Switzerland including manufacturing, product life emissions and disposal losses (for more precision, the Swiss manufacturing emissions should be excluded from the calculation; since the manufacturing emissions in Switzerland are of low relative importance, the bias is neglected).

The inventory under this sub-source category includes the following types of equipment: domestic refrigeration, commercial and industrial refrigeration, transport refrigeration, stationary air conditioning and mobile air conditioning. The indicators used for the rule of proportion calculations are summarised in the following table.

Application	**Refrigerant**	**Base value**	**Indicator for calculation by rule of proportion**
Domestic Refrigeration	HFC-134a	Total emissions reported for Switzerland	Number of households
Commercial Refrigeration	HFC-125 HFC-134a HFC-143a	Total emissions reported for Switzerland	Number of persons employed in industrial and service sector
Transport Refrigeration	HFC-125 HFC-134a HFC-143a	Total emissions reported for Switzerland	Number of inhabitants
Industrial Refrigeration	Included in commercial refrigeration		
Stationary Air Conditioning	HFC-32 HFC-125 HFC-134a HFC-143a	Total emissions reported for Switzerland	Number of persons employed in industrial and service sector
Mobile Air Conditioning	HFC-134a	Total emissions reported for Switzerland (cars, trucks, railway)	Number of registered cars

Table 48 Indicators used in calculating Liechtenstein's emissions for source category 2F1 on basis of Switzerland's emissions by applying rule of proportion.

Emission Factors

Due to the approach chosen, the emission factors as reported in the Swiss National Inventory Report (FOEN 2006) are applicable.

The data reported in Table 49 is taken from FOEN 2006 and shows details to the emission factors. No manufacturing of refrigeration and air conditioning equipment is occurring in Liechtenstein.

Equipment type	Product life time [a]	Initial charge of new product [kg]	Manufacturing emission factor [% of initial charge]	Product life emission factor [% per annum]	Charge at end of life [% of initial charge of new product] *)	Disposal loss emission factor [% of remaining charge
Domestic Refrigeration	12	0.1	NO	0.5	92	37
Commercial and Industrial Refrigeration	12	NR	NO	10 (5)	100	10
Transport Refrigeration / Trucks	8	1.8 … 7.8	NO	15	100	20
Transport Refrigeration / Railway	NA	NR	NO	10	100	20
Stationary Air Conditioning (direct / indirect cooling system)	10 / 15	1.6 … 3.1 / 18.5	NO	10 (3) / 6 (4)	100	28 / 19
Mobile Air Conditioning / Cars	12	0.78	NO	8.5 (3)	60	100 (30)
Mobile Air Conditioning / Trucks	10	1.1	NO	10 (8.5)	35	100 (30)
Mobile Air Conditioning / Railway	12	20	NO	4	100	10

*) takes into account refill of losses during product life where applicable

NA = not available
NR = not relevant as only aggregate data is used
NO = Not occurring (only import of charged units)

Table 49 Typical values on life time, charge and emission factors used in model calculations for Refrigeration and Air Conditioning Equipment. Where values in brackets are provided, the first value shows the assumption for 1995 while the second value (in brackets) shows the assumption for 2010. Data between 1995 and 2010 is linearly interpolated. Source: FOEN 2006, Carbotech 2006.

Activity Data

Activity data for Liechtenstein is calculated based on activity data for Switzerland with the methodology as described above. The following figures have been used for the indicators:

	1990		2004	
Number of households				
Liechtenstein	10'556	Source: National census 1990	14'418	Source: National census 2000 with trend extrapolation
Switzerland	2'859'766	Source: National census 1990	3'313'619	Source: National census 2000 with trend extrapolation
Conversion Factor CH→LIE	0.00369		0.00435	
Number of employees in industrial and service sector				
Liechtenstein	19'554	Source: National census of enterprises 1990	29'148	Source: National census of enterprises 2004
Switzerland	3'664'214	Source: National census of enterprises 1985 and 1991, interpolated	3'796'901	Source: National census of enterprises 1998 and 2001, extrapolated
Conversion Factor CH→LIE	0.00534		0.00768	
Number of registered cars				
Liechtenstein	16'891	Source: National motor car statistic for Liechtenstein	22'935	Source: National motor car statistic for Liechtenstein
Switzerland	2'985'399	Source: www.statweb.admin.ch	3'791'540	Source: www.statweb.admin.ch
Conversion Factor CH→LIE	0.00566		0.00605	

Table 50 Figures used as indicators for calculation of activity data by applying rule of proportion.

2F7 Electrical Equipment

Methodology

The only SF_6 emissions in Liechtenstein stem from the transformers operated by the utility Liechtensteinische Kraftwerke (LKW). The LKW reports on activity data and emissions. No production of equipment with SF_6 is occurring.

Emission Factors

Emission factors for this sub-source category are based on industry information.

Activity Data

Activity data is based on industry information. Before 1995/1996 a different technology was applied which did not use SF_6.

4.7.3. Uncertainties and Time-Series Consistency

For source category 2F1 Refrigeration and Air Conditioning Equipment no specific uncertainties have been determined. For the Swiss GHG inventory, the uncertainties of the emissions of source category 2F1 were estimated at approx. 14% (Monte Carlo simulation). For Liechtenstein's uncertainty analysis, this value was adopted although it will be somewhat higher due to the conversion of Swiss into Liechtenstein data.

The methods for calculating the emissions of the full time series 1990–2004 are consistent.

For source category 2F7 Electrical Equipment, no uncertainty estimation has been carried out. The results for the full time period 1990–2004 are consistent.

4.7.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

4.7.5. Source-Specific Recalculations

No recalculations have been carried out.

4.7.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

4.8. Source Category 2G – Other

Source category 2G "Other" is **not a key category.**

GHG emissions from source category 2G are not occurring in Liechtenstein.

5. Solvent and Other Product Use

5.1. Overview

Emissions within this sector comprise NMVOC emissions from the use of solvents and other related compounds. It also includes indirect CO_2 emissions from the atmospheric decomposition of NMVOC.

Further included are evaporative emissions of N_2O arising form other types of product use and from medical use. The disposal of solvents is reported in category 6 Waste (in Chapter 8). Emissions from the use of halocarbons and sulphur hexafluoride are reported in the Industrial Processes Chapter under 2F. Other non-energy emissions not included under Industrial Processes are reported in this chapter.

Key category 3

Emissions of CO_2 from source category 3 “Solvent and Other Product Use” are key categories regarding trend.

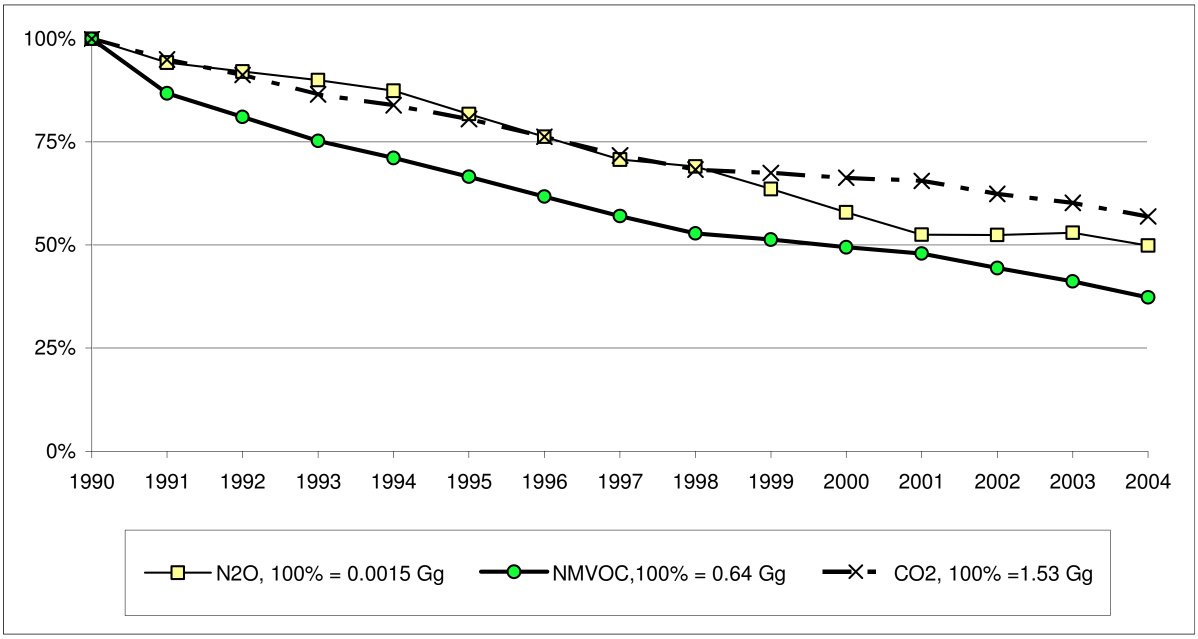

Figure 14 Overview over emissions in category 3 Solvent and Other Product Use in Liechtenstein.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Gg														
CO_2	1.53	1.45	1.39	1.32	1.28	1.23	1.16	1.09	1.04	1.03	1.01	1.00	0.95	0.92	0.87
N_2O	0.0015	0.0014	0.0014	0.0013	0.0013	0.0012	0.0011	0.0011	0.0010	0.0010	0.0009	0.0008	0.0008	0.0008	0.0007
NMVOC	0.64	0.56	0.52	0.48	0.46	0.43	0.40	0.37	0.34	0.33	0.32	0.31	0.28	0.26	0.24

Table 51 Emissions of source category 3 Solvent and Other Product Use.

The emissions of NMVOC, CO_2 and N_2O are all calculated from the corresponding Swiss emissions by using the specific emission per inhabitant as conversion factors. Two reduction efforts are responsible for the decrease of the emissions: The limitation of the application of NMVOC brought by the legal restrictions (Government 1986 and 2003) and the introduction of the VOC-levy in 2000 in Liechtenstein and Switzerland (based on the Customs Union Treaty the Swiss VOC-levy is also applicable in Liechtenstein). Also CO_2 and N_2O emissions decreased significantly.

5.2. Source Category 3A – Paint Application

5.2.1. Source Category Description

Source category 3A "Paint Application" comprises NMVOC emissions from paints, lacquers, thinners and related materials used in coatings in industrial, commercial and household applications. Also, it includes indirect CO_2 emissions resulting from post-combustion of NMVOCs to reduce NMVOCs in exhaust gases.

	Source	Specification	Data Source
3A	Paint Application	Paint application in households, industry and construction	AD: AVW 2005a EF: FOEN 2006

Table 52 Specification of source category 3A "Paint Application".

5.2.2. Methodological Issues

Methodology

Up to now, Liechtenstein has not established an inventory of these emissions, and data availability is very limited.

In order to establish rough estimates of emissions for Liechtenstein, the specific emissions per inhabitant in Switzerland are used as a proxy:

Emissions of the source category in Liechtenstein are the product of *the specific emissions per inhabitant in Switzerland* times *the number of inhabitants in Liechtenstein*.

This allows for a first preliminary estimate of emissions. The rationale behind this simple approach is that the general characteristics of Liechtenstein and Switzerland determining emissions are roughly similar.

Emission Factors

Source	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3A. Paint Application											
CO_2	g/inhabitant	14'612	14'222	13'804	13'226	12'605	11'874	11'067	10'214	9'281	8'866
NMVOC	g/inhabitant	6'176	5'953	5'719	5'469	5'185	4'875	4'532	4'167	3'766	3'584

Source	Unit	2000	2001	2002	2003	2004
3A. Paint Application						
CO_2	g/inhabitant	8'444	8'021	6'816	5'592	4'188
NMVOC	g/inhabitant	3'404	3'225	2'724	2'201	1'615

Table 53 Emission factors - specific emissions per inhabitant, 1990 to 2004 (Source: Swiss emissions from FOEN 2006; inhabitants see Section 4.2.2).

The emission factor for the indirect CO_2-emissions from NMVOC for 3A is 2.35 Gg CO_2/Gg NMVOC [RIVM 2005: p. 5-2ff.].

Activity Data

The development of the number of inhabitants in Lichtenstein is provided in Section 4.2.2.

5.2.3. Uncertainties and Time-Series Consistency

The uncertainty of total CO_2 emissions from the entire category 3 Solvent and Other Product Use is estimated to be 80% (expert estimate based on uncertainty of Swiss data).

The time series is consistent.

5.2.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

5.2.5. Source-Specific Recalculations

Time series have been calculated for the first time with this submission. See Chapter 9.

5.2.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

5.3. Source Category 3B – Degreasing and Dry Cleaning

5.3.1. Source Category Description

Source category 3B "Degreasing and Dry Cleaning" comprises NMVOC emissions from degreasing, dry cleaning and cleaning in electronic industry. Also, it includes indirect CO_2 emissions resulting from post-combustion of NMVOCs to reduce NMVOCs in exhaust gases.

	Source	**Specification**	**Data Source**
3B	Degreasing and Dry Cleaning	Degreasing, Dry Cleaning, Cleaning of electronic components, cleaning of parts in metal processing, other industrial cleaning, if applicable in Liechtenstein.	AD: AVW 2005a EF: FOEN 2006

Table 54 Specification of source category 3B "Degreasing and Dry Cleaning".

5.3.2. Methodological Issues

Methodology

Up to now, Liechtenstein has not established an inventory of these emissions, and data availability is very limited.

In order to establish rough estimates of emissions for Liechtenstein, the specific emissions per inhabitant in Switzerland are used as a proxy:

Emissions of the source category in Liechtenstein are the product of *the specific emissions per inhabitant in Switzerland* times *the number of inhabitants in Liechtenstein*.

This allows for a first preliminary estimate of emissions. The rationale behind this simple approach is that the general characteristics of Liechtenstein and Switzerland determining emissions are roughly similar.

Emission Factors

Source	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3B. Degreasing and Dry Cleaning											
CO_2	g/inhabitant	4'101	3'722	3'382	3'068	2'761	2'471	2'203	1'951	1'709	1'599
NMVOC	g/inhabitant	1'833	1'664	1'509	1'366	1'229	1'099	980	867	759	710

Source	Unit	2000	2001	2002	2003	2004
3B. Degreasing and Dry Cleaning						
CO_2	g/inhabitant	1'488	1'380	1'323	1'278	1'228
NMVOC	g/inhabitant	660	612	586	566	545

Table 55 Emission factors - specific emissions per inhabitant, 1990 to 2004 (Source: Swiss emissions from FOEN 2006; inhabitants see Section 4.2.2).

The emission factor for the indirect CO_2-emissions from NMVOC for 3B is 2.24 Gg CO_2 per Gg NMVOC [RIVM 2005[7]: p. 5-2ff.].

Activity Data

The development of the number of inhabitants in Lichtenstein is provided in Section 4.2.2.

5.3.3. Uncertainties and Time-Series Consistency

The uncertainty of total CO_2 emissions from the entire category 3 Solvent and Other Product Use is estimated to be 80% (expert estimate based on uncertainty of Swiss data).

The time series is consistent.

5.3.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

5.3.5. Source-Specific Recalculations

Time series have been calculated for the first time with this submission. See Chapter 9.

5.3.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

5.4. Source Category 3C – Chemical Products, Manufacture and Processing

5.4.1. Source Category Description

Source category 3C “Chemical Products, Manufacture and Processing” comprises NMVOC emissions from manufacturing and processing chemical products. Also, it includes indirect

[7] There seems to be a typo in the relevant section of the RIVM 2005 regarding the Emission Factor for the indirect CO_2-emissions from NMVOC for 3B.

CO_2 emissions resulting from post-combustion of NMVOCs to reduce NMVOCs in exhaust gases.

	Source	Specification	Data Source
3C	Chemical Products, Manufacture and Processing	Handling and storage of solvents; fine chemical production; production of pharmaceuticals; manufacturing of paint, inks, glues, adhesive tape, rubber; processing of PVC, polystyrene foam, polyurethane and polyester; if applicable in Liechtenstein.	AD: AVW 2005a EF: FOEN 2006

Table 56 Specification of source category 3C “Chemical Products, Manufacture and Processing”.

5.4.2. Methodological Issues

Up to now, Liechtenstein has not established an inventory of these emissions, and data availability is very limited.

In order to establish rough estimates of emissions for Liechtenstein, the specific emissions per inhabitant in Switzerland are used as a proxy:

Emissions of the source category in Liechtenstein are the product of *the specific emissions per inhabitant in Switzerland* times *the number of inhabitants in Liechtenstein*.

This allows for a first preliminary estimate of emissions. The rationale behind this simple approach is that the general characteristics of Liechtenstein and Switzerland determining emissions are roughly similar.

Emission Factors

Source	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3C. Chemical Products, Manufacture and Processing											
CO_2	g/inhabitant	11'395	9'759	8'378	6'944	6'524	5'999	5'495	5'140	4'884	4'911
NMVOC	g/inhabitant	4'161	3'366	2'643	1'952	1'742	1'512	1'291	1'137	965	906

Source	Unit	2000	2001	2002	2003	2004
3C. Chemical Products, Manufacture and Processing						
CO_2	g/inhabitant	4'707	4'559	4'680	4'769	4'892
NMVOC	g/inhabitant	803	731	706	690	661

Table 57 Emission factors - specific emissions per inhabitant, 1990 to 2004 (Source: Swiss emissions from FOEN 2006; inhabitants see Section 4.2.2).

The emission factor for the indirect CO_2 emissions from NMVOC for 3C is 2.31 Gg CO_2 per Gg NMVOC [RIVM 2005: p. 5-2ff.].

Activity Data

The development of the number of inhabitants in Lichtenstein is provided in Section 4.2.2.

5.4.3. Uncertainties and Time-Series Consistency

The uncertainty of total CO_2 emissions from the entire category 3 Solvent and Other Product Use is estimated to be 80% (expert estimate based on uncertainty of Swiss data).

The time series is consistent.

5.4.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

5.4.5. Source-Specific Recalculations

Time series have been calculated for the first time with this submission. See Chapter 9.

5.4.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

5.5. Source Category 3D – Other

5.5.1. Source Category Description

Source category 3D "Other" comprises emissions from many different solvent applications. Besides NMVOC also emissions of N_2O are relevant. Also, 3D includes indirect CO_2 emissions resulting from post-combustion of NMVOCs to reduce NMVOCs in exhaust gases.

The application of N_2O in households and hospitals and CO2 from the use of fireworks are the only direct greenhouse gas emission considered in this category.

	Source	**Specification**	**Data Source**
3D	Other	Use of spray cans in industry and households; domestic solvent use application of glues and adhesives; use of concrete additives; removal of paint and lacquer; car underbody sealant; use of cooling lubricants and other lubricants; use of pesticides; use of pharmaceutical products in households; house cleaning industry/craft/services; hairdressers; scientific laboratories; industrial production; cosmetic institutions; use of tobacco products; wood preservation; medical practitioners; other health care institutions; no-attributable solvent emissions; use of N_2O in households and in hospitals; other use of gases; use of fireworks; if applicable in Liechtenstein..	AD: AVW 2005a EF: FOEN 2006

Table 58 Specification of source category 3D "Other".

5.5.2. Methodological Issues

Methodology

Up to now, Liechtenstein has not established an inventory of these emissions, and data availability is very limited.

In order to establish rough estimates of emissions for Liechtenstein, the specific emissions per inhabitant in Switzerland are used as a proxy:

Emissions of the source category in Liechtenstein are the product of *the specific emissions per inhabitant in Switzerland* times *the number of inhabitants in Liechtenstein*.

This allows for a first preliminary estimate of emissions. The rationale behind this simple approach is that the general characteristics of Liechtenstein and Switzerland determining emissions are roughly similar.

Emission Factors

Source	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3D1. Other. Use of N_2O for Anaesthesia											
N_2O	g/inhabitant	43	39	37	34	33	30	27	24	22	20
3D3. Other. N_2O from Aerosol Cans											
N_2O	g/inhabitant	9	9	9	10	10	10	10	10	10	10
3D. Other. Other. Spray cans, cosmetic institutions, etc.											
CO_2	g/inhabitant	22'425	21'573	21'015	20'283	19'896	19'363	18'570	17'600	16'649	16'365
NMVOC	g/inhabitant	9'951	7'981	7'551	7'153	6'749	6'340	5'931	5'527	5'105	4'957

Source	Unit	2000	2001	2002	2003	2004
3D1. Other. Use of N_2O for Anaesthesia						
N_2O	g/inhabitant	17	14	14	14	12
3D3. Other. N_2O from Aerosol Cans						
N_2O	g/inhabitant	10	10	10	10	9
3D. Other. Other. Spray cans, cosmetic institutions, etc.						
CO_2	g/inhabitant	16'124	15'869	15'278	15'132	14'762
NMVOC	g/inhabitant	4'795	4'621	4'399	4'248	4'103

Table 59 Emission factors - specific emissions per inhabitant, 1990 to 2004 (Source: Swiss emissions from FOEN 2006; inhabitants see Section 4.2.2).

The emission factor for the indirect CO_2-emissions from NMVOC for 3D is 2.53 Gg CO_2/Gg NMVOC [RIVM 2005: p. 5-2ff.].

Activity Data

The development of the number of inhabitants in Lichtenstein is provided in Section 4.2.2.

5.5.3. Uncertainties and Time-Series Consistency

The uncertainty of total CO_2 emissions from the entire category 3 Solvent and Other Product Use is estimated to be 80% (expert estimate based on uncertainty of Swiss data).

The time series is consistent.

5.5.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

5.5.5. Source-Specific Recalculations

Time series have been calculated for the first time with this submission. See Chapter 9.

5.5.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

6. Agriculture

6.1. Overview

This chapter provides information on the estimation of the greenhouse gas emissions from the agriculture sector (Sectoral Report for Agriculture, Table 4 in the Common Reporting Format). The following source categories are reported:

- CH_4 emissions from enteric fermentation in domestic livestock,
- CH_4 and N_2O emissions from manure management,
- N_2O emissions from agricultural soils.

Total greenhouse gas emissions from agriculture in 2004 were 22.5 Gg CO_2 equivalents in total, which is a contribution of 8.3% to the total of Liechtenstein's greenhouse gas emissions (excluding net CO_2 from LULUCF). Main agricultural sources of greenhouse gases in 2004 were enteric fermentation emitting 10.4 Gg CO_2 equivalents, followed by agricultural soils with 8.8 Gg CO_2 equivalents. With the exception of CH_4 emissions from enteric fermentation, emissions declined compared to 1990.

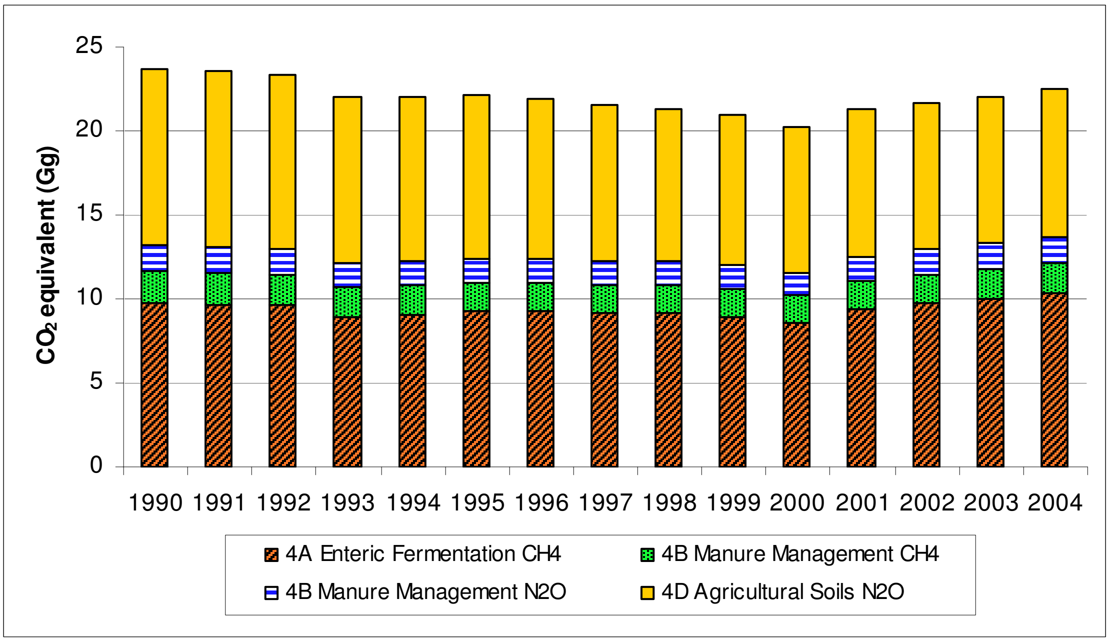

Figure 15 Greenhouse gas emissions in Gg CO_2 equivalents of agriculture 1990-2004.

No CO_2 emissions are reported in the agricultural sector. CO_2 emissions from energy use in agriculture are reported under Energy, Other Sectors (1A4c).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*1990→2004*
	CO_2 equivalent (Gg)															%
CH_4	11.7	11.6	11.4	10.7	10.8	11.0	11.0	10.8	10.8	10.6	10.2	11.1	11.5	11.8	12.1	*3.6*
N_2O	12.0	12.0	11.9	11.3	11.2	11.1	10.9	10.8	10.5	10.4	10.0	10.2	10.2	10.3	10.4	*-13.4*
Sum	**23.7**	**23.6**	**23.3**	**22.0**	**22.0**	**22.1**	**21.9**	**21.6**	**21.3**	**21.0**	**20.2**	**21.3**	**21.7**	**22.1**	**22.5**	***-5.0***

Table 60 Greenhouse gas emissions in Gg CO_2 equivalents of agriculture 1990-2004.

CH_4 emissions are slightly increasing since 2000 and are now higher than 1990 due to higher emission factors for dairy cattle and an increase of the number of some animal populations.

N_2O emissions decreased mainly due to a reduced input of mineral fertilizers and due to a reduction of organic soils.

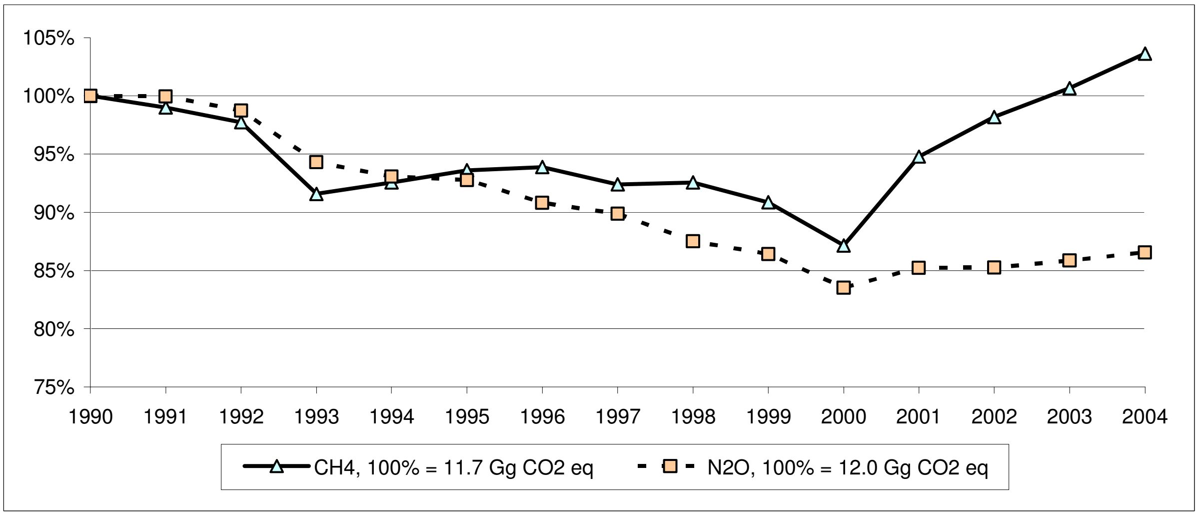

Figure 16 Trend of greenhouse gases of the agricultural sector 1990-2004. The base year 1990 represents 100%.

Among the key sources of the inventory, three are out of the agricultural sector: CH_4 emissions from enteric fermentation, direct N_2O emissions from agricultural soils and indirect N_2O emissions from agricultural soils.

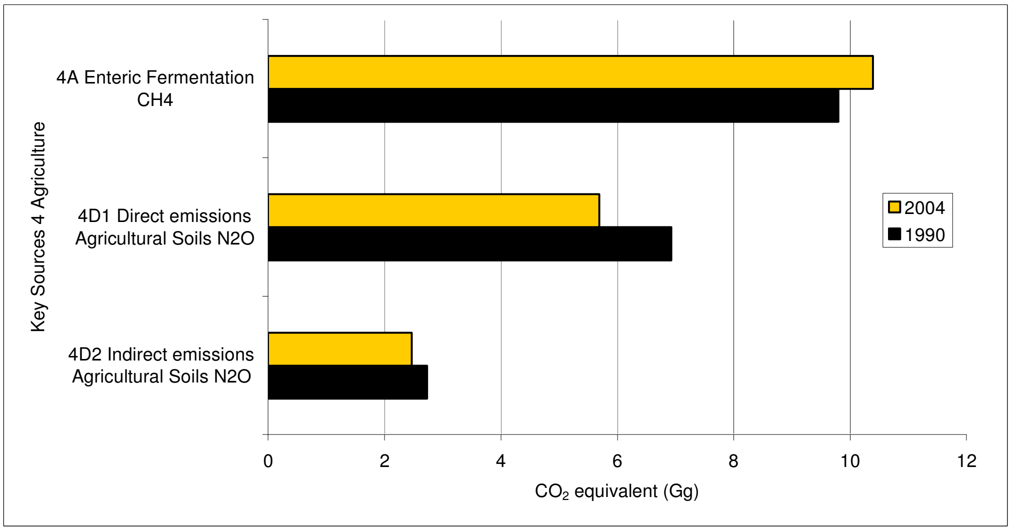

Figure 17 Key sources in Agriculture (emissions in CO_2 equivalents per source category).

6.2. Source Category 4A – Enteric Fermentation

6.2.1. Source Category Description

Key source 4A
The CH_4 emissions from 4A Enteric Fermentation are a key source by level and trend.

CH_4 emissions are slightly increasing since 1990 due to different reasons. One reason is a higher emission factor for dairy cattle which leads to higher emission despite a decrease in the number of dairy cattle. Another reason is the increase of the animal population of young and non-dairy cattle. Emissions from cattle contribute to approximately 88% of the emissions from enteric fermentation.

4A	Source	Specification	Data Source
4A1	Cattle	Emissions from mature dairy cattle, mature non-dairy cattle, young cattle and breeding cattle (more than one year)	AD: Livestock data from LWA 2004, AVW 1992 Data on energy intakes from SBV 2005 and RAP 1999 EF: Soliva 2006a
4A3 4A4	Sheep Goats		AD: Livestock data from LWA 2004, AVW 1992 Data on net energy and feed intake losses from SBV 2005 EF: Soliva 2006a
4A6 4A8	Horses Swine		AD: Livestock data from LWA 2004, AVW 1992 Data on digestible energy and feed intake losses from SBV 2005 EF: Soliva 2006a
A47	Mules and asses		AD: Livestock data from LWA 2004, AVW 1992 Data on digestible energy and feed intake losses from SBV 2005 EF: Soliva 2006a
4A9	Poultry		AD: Livestock data from LWA 2004, AVW 1992 Data on metabolisable energy and feed intake losses from SBV 2005 EF: Soliva 2006a

Table 61 Specification of source category 4A “Enteric Fermentation”. AD: activity data; EF: emission factors.

6.2.2. Methodological Issues

Methodology

Liechtenstein adopted the Swiss calculation methodology, Tier 2, for CH_4 emissions in agriculture by applying the same calculation and therefore the same values for the gross energy intake (except for dairy cattle) and by adjusting the activity data.

The following paragraph gives some further explanations about the Swiss calculation of CH_4 emissions from enteric fermentation.

Swiss methodology (excerpt from NIR CH, chp 6.2.2, FOEN 2006):

The calculation is based on methods described in the IPCC Good Practice Guidance (IPCC 2000, equation 4.14). CH_4 emissions from enteric fermentation of the livestock population have been estimated using Tier 2 methodology. This means that detailed country-specific data on nutrient requirements, feed intake and CH4 conversion rates for specific feed types are required.

*For calculating the **gross energy intake** a country specific method based on available data on net energy (lactation, growth), digestible energy and metabolisable energy has been applied. Data on energy intakes are taken from SBV 2005 and from RAP 1999. The method is described in detail in Soliva 2006a.*

Different energy levels (Figure 18) are used to express the energy conversion from energy intake to the energy required for maintenance and performance.

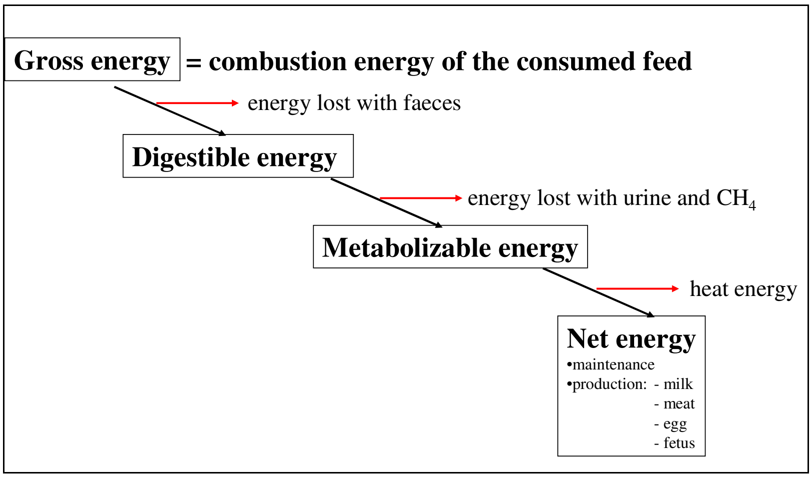

Figure 18 Levels of feed energy conversion. Reference: Soliva 2006a.

Net energy (NE) is used to express the energy required by the ruminants such as cattle, sheep and goats. NE in cattle feeding is further sub-divided into NE for lactation (NEL) and NE for growth (NEV). Exceptions in the cattle category are the calves, whose requirements for energy are expressed as metabolisable energy (ME). Horses, mules, asses and swine are fed on the basis of digestible energy (DE), whereas poultry are fed according to metabolisable energy (ME).

In the energy estimation also some feed energy losses are integrated. Feed losses are defined as the feed not eaten by the animal and therefore represent a loss of net energy. Calculation for NE, DE and ME consumption was used for the livestock categories sheep, goats, horses, mules and asses, swine and poultry, respectively.

For the livestock category cattle detailed estimations for NE are necessary. As the Swiss Farmers Union does not calculate the NE for detailed cattle sub-categories, NE data for each cattle sub-category was calculated individually according to the animal's requirements following the feeding recommendations of RAP 1999. These RAP recommendations are also used by the Swiss farmers as basis for their cattle feeding regime and for filling in application forms for subsidies for ecological services, and are therefore highly appropriate. In the calculation of the NE data, the animal's weight, daily growth rate, daily feed intake (DM), daily feed energy intake, and energy required for milk production for the respective sub-categories were considered.

For estimating the gross energy intake out of the available data on net energy, metabolisable energy and digestible energy, the following conversion factors were applied:

Livestock Category		***Conversion Factors***	
Cattle			
	Mature dairy cattle	*NEL to GE*	*0.318*
	Mature non-dairy cattle (suckler cow)	*NEL to GE*	*0.275*
	Young cattle		
	Milk-fed calf	*ME to GE*	*0.930*
	Suckler cow calf	*NEL to GE*	*0.291*
	Breeding calf	*NEL to GE*	*0.341*
	Breeding cattle (4-12 months)	*NEL to GE*	*0.322*
	Fattening calf	*NEV to GE*	*0.350*
	Fattening cattle	*NEV to GE*	*0.401*
	Breeding cattle (more than one year)	*NEL to GE*	*0.313*
Sheep	*Sheep (breeding)*	*NEL to GE*	*0.287*
	Sheep (fattening)	*NEV to GE*	*0.350*
Goats		*NEL to GE*	*0.283*
Horses, mules, asses		*DE to GE*	*0.560*
Swine		*DE to GE*	*0.682*
Poultry		*ME to GE*	*0.700*

Table 62 *Conversion factors used for calculation of energy requirements of individual livestock categories. Reference: Soliva 2006a: p.3. GE: Gross energy; DE: Digestible Energy; ME: Metabolisable Energy; NEL: Net energy for lactation; NEV: Net energy for growth..*

*For the **methane conversion rate Ym** (%) only few country-specific data exist. Therefore mainly default values recommended by the IPCC for developed countries in Western Europe were used (IPCC 1997b: Reference Manual: p. 4.32–4.35 and IPCC 2000: p. 4.27). For poultry a country specific value ($Y_{poultry}$ = 0.1631) was used since no default value is given by the IPCC. This value was evaluated in an in vivo trial with broilers (Hadorn and Wenk 1996).*

Emission factors

All emission factors for enteric fermentation are country specific emission factors of Switzerland. They are based on IPCC equation 4.14 IPCC 2000, p. 4.26.

$$EF = \frac{GE * Y_m * 365\, days / y}{55.65\ MJ / kg\, CH_4}$$

GE: Gross energy intake

Y_m = Methane conversion rate

55.65 MJ/kg = energy content of methane.

The following calculated gross energy intakes are used:

Gross Energy Intake	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	MJ/head/day														
Cattle															
Mature dairy cattle	282.1	282.6	284.3	285.5	281.7	283.7	284.1	287.9	290.6	292.0	296.4	303.6	305.5	306.3	311.4
Mature non-dairy cattle	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1
Young cattle (average)	48.9	47.9	47.2	46.2	46.2	45.8	45.0	44.6	43.6	43.4	41.9	46.4	52.0	50.4	53.0
Milk-fed calf	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6
Suckler cow calf	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7
Breeding calf	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9
Breeding cattle (4-12 months)	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2
Fattening calf	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6
Fattening cattle	124.5	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6
Breeding cattle (more than one year)	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1
Sheep	20.8	21.4	21.7	21.1	23.2	24.3	21.4	21.8	21.6	22.8	22.1	22.8	22.6	22.5	23.0
Goats	31.7	32.0	32.3	32.3	33.2	34.8	32.4	29.3	29.2	28.9	31.9	31.9	30.9	31.4	30.9
Horses	145.3	135.1	133.4	125.2	153.3	176.8	131.9	133.9	134.1	134.1	134.1	139.4	139.2	139.6	139.7
Ponies, Mules and Asses	162.0	158.1	159.7	152.9	161.0	156.1	118.3	115.0	110.3	101.7	100.9	98.9	95.3	92.0	89.2
Swine	35.2	36.0	36.2	36.1	36.8	40.4	43.0	37.0	36.5	37.4	36.4	35.2	34.9	34.9	35.1
Poultry	1.8	1.9	1.9	1.7	1.7	1.8	1.7	1.8	1.7	1.6	1.7	1.7	1.7	1.7	1.6

Table 63 Gross energy intake of different livestock groups. Calculation is based on the parameters net energy, digestible energy, metabolisable energy according to Soliva 2006. Input data on net energy, digestible energy and metabolisable energy is taken from SBV 2005 and RAP 1999. The gross energy intake for young cattle is an average value of the sub-categories mentioned under young cattle.

The gross energy intake per head for some animal categories revealed some fluctuations during the inventory period. The energy intake for all cattle categories (except dairy cattle) is estimated to be constant. The value for dairy cows increased which is mainly a result of higher milk production (Milk production was 5’792 kg per head and year in 1990 and 6’875 kg per year in 2004). The gross energy intake for the horse categories showed higher values for 1994 and 1995. According to the Swiss Farmers Union data comparison of these years can be made only partially due to changes in livestock survey methods (SBV 1998).

Activity data

The activity data input has been obtained from the Office of Agriculture (LWA 2004) and from the Office of Economic Affairs (AVW 1992).

Population Size	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	head														
Cattle	6'117	5'950	5'947	5'545	5'675	5'814	5'748	5'657	5'546	5'461	5'229	5'270	5'380	5'733	6'047
Mature dairy cattle	2'850	2'843	2'747	2'601	2'677	2'643	2'652	2'622	2'614	2'589	2'440	2'639	2'705	2'737	2'739
Mature non-dairy cattle	20	25	31	36	42	47	52	58	63	69	74	112	149	199	279
Young cattle	1'713	1'647	1'683	1'642	1'780	1'850	1'830	1'890	1'840	1'931	1'804	1'652	1'529	1'781	2'084
Milk-fed calf	40	47	54	62	69	76	83	90	98	105	112	92	71	89	87
Suckler cow calf	25	24	22	21	19	18	17	15	14	12	11	56	101	141	252
Breeding calf	280	302	323	345	366	388	410	431	453	474	496	386	276	262	219
Breeding cattle (4-12 months)	856	725	697	590	664	669	584	580	464	491	299	360	451	493	663
Fattening calf	205	225	244	264	284	304	323	343	363	382	402	283	164	290	287
Fattening cattle	307	325	342	360	378	396	413	431	449	466	484	475	466	506	576
Breeding cattle (more than one year)	1'534	1'434	1'486	1'266	1'177	1'274	1'213	1'087	1'029	873	911	868	997	1'016	945
Sheep	2'781	2'689	2'878	2'641	2'627	2'632	3'352	3'234	3'608	3'264	3'319	3'319	3'201	3'070	3'149
Goats	171	213	277	181	136	145	275	269	287	313	239	210	205	241	286
Horses	156	178	183	202	190	204	220	218	227	231	153	284	196	220	255
Ponies, Mules and Asses	50	58	66	75	83	91	99	107	115	124	132	140	148	127	159
Swine	3'251	3'543	2'902	3'236	2'787	2'429	2'392	2'128	2'056	2'122	2'013	2'248	2'101	1'979	990
Poultry	4'386	4'049	3'712	3'375	3'037	2'700	3'592	4'484	5'376	6'268	7'159	8'772	10'384	10'408	11'130

Table 64 Activity for calculating methane emissions from enteric fermentation. (LWA 2004, AVW 1992)

The number of swine was constantly declining during the last 14 years whereas the number of sheep, goats, horses and poultry were increasing. The drastic decrease of the swine population between 2003 and 2004 was caused by a disease.

6.2.3. Uncertainties and Time-Series Consistency

The relative uncertainties, 24% in the emissions of CH_4 were taken from the uncertainty analysis of the Swiss GHG inventory (FOEN 2006). For further results see Section 1.7.

Time series between 1990 and 2004 is consistent.

6.2.4. Source-Specific QA/QC and Verification

A documentation about the calculation method of Switzerland assures transparency and traceability (Soliva 2006a). Additionally a document in German lists all the methodological differences between the former calculations and the current methodology (Soliva 2006b).

Calculations were made by Acontec. A quality control was done by INFRAS by a counter-check of the calculation sheets. This countercheck lead to some adjustments of the calculation sheets.

Source-specific activities have not been carried out.

6.2.5. Source-Specific Recalculations

In the former submission only emissions for the years 1990 and 2004 were estimated. In this submission time series were calculated for the first time. This lead to a recalculation of all emissions, including the ones from enteric fermentation.

Additionally the former Swiss calculation method was revised in detail (Soliva 2006a and Soliva 2006b). This revision was also adopted by Liechtenstein, which made a recalculation necessary.

6.2.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

6.3. Source Category 4B – Manure Management

6.3.1. Source Category Description

Key source 4B Source category 4B Manure Management CH_4 and N_2O are not key sources.

CH_4 and N_2O emissions from manure management are reported. CH_4 emissions decreased in 2004 compared to 1990 mainly due to the reduction of the swine population. N_2O emissions from manure management were also slightly decreasing due to the reduction of the swine population and due to lower N excretion rates of different animal categories.

4B	Source	Specification	Data Source
4B1 4B3 4B4 4B6 4B8	Cattle Sheep Goats Horses Swine	Mature dairy cattle, mature non-dairy cattle, young cattle and breeding cattle (more than one year)	AD: LWA 2004, AVW 1992 EF: IPCC 2000; IPCC 1997b; FAL/RAC 2001
4B7	Mules and Asses		AD: LWA 2004, AVW 1992 EF: IPCC 2000; IPCC 1997b; FAL/RAC 2001
4B9	Poultry		AD: LWA 2004, AVW 1992 EF: IPCC 2000; IPCC 1997b; FAL/RAC 2001

Table 65 Specification of source category 4B “Manure Management (CH_4)”. (AD: Activity data; EF: Emission factors).

4B	Source	Specification	Data Source
4B11 4B12	Liquid Systems Solid storage and dry lot		AD: LWA 2004, AVW 1992 FAL/RAC 2001 (for N excretion); Menzi et al. 1997 (for split of manure management systems and ammonia emissions) EF: IPCC 2000

Table 66 Specification of source category 4B “Manure Management (N_2O)”. (AD: Activity data; EF: Emission factors).

6.3.2. Methodological Issues

Liechtenstein adopted the Swiss calculation methodology, Tier 2, for emissions from manure management by adjusting the activity data.

For calculation of CH_4 and N_2O emissions slightly different livestock sub-groups are used. Nevertheless there is no inconsistency in the total number of animals as they are the same both for CH_4 and N_2O emissions.

Calculation of CH_4 emissions is based on the domestic livestock populations mature dairy cattle, mature non-dairy cattle (suckler cows), young cattle (milk-fed calf, suckler cow calf, breeding calf, breeding cattle (4-12 months), fattening calf, fattening cattle), breeding cattle (more than one year), sheep, goats, horses, mules, asses, swine and poultry as reported for enteric fermentation.

Calculation of N_2O emissions is based on a slightly different livestock population break down with the following sub-groups: mature dairy cattle, mature non-dairy cattle (suckler cows), young cattle (milk-fed calf, suckler cow calf, breeding calf, breeding cattle (4-12 months), fattening calf, fattening cattle), breeding cattle (more than one year), fattening pig places, breeding pig places, sheep places, goat places, horses (foals < 1 year, foals 1-2 years, other horses), ponies, mules and asses and poultry (laying hens, young hens < 18 weeks, broilers, other poultry).

The following paragraph gives some further explanations about the reason for the Swiss specific calculation of N_2O emissions from manure management.

Swiss methodology (excerpt from NIR CH, chp 6.3.2, FOEN 2006):

This calculation is chosen because more detailed data on N excretion for the particular animal categories are available (FAL/RAC 2001).The categories for sheep, pigs and goats as provided by FAL/RAC 2001 do not correspond to the categories of the Swiss Farmers Union (SBV 2005). The conversion from the FAL/RAC 2001 classification to the available livestock categories according to SBV is done as follows (Schmid et al. 2000):

- *One fattening pig place corresponds to one fattening pig over 25 kg, 1/6 fattening pig place to one young pig below 30 kg.*
- *One breeding pig place corresponds to one sow, 1/2 breeding pig place to one boar.*
- *One sheep place corresponds to one ewe over one year. Other sheep such as lambs or rams are not included.*
- *One goat place corresponds to one (female) goat older 1.5 years. All goats younger than 1.5 years are not included[8].*

a) CH_4 Emissions

Methodology

Calculation of CH_4 emissions from manure management is based on IPCC Tier 2 (IPCC 2000, equation 4.17).

Emission factor

Liechtenstein is using Swiss emission factors for CH_4 emissions from manure management. The following paragraph gives explanations to the origin of the Swiss emission factor for manure management.

Swiss emission factor (excerpt from NIR CH, chp 6.3.2, FOEN 2006):

Calculation of the emission factor is based on the parameters volatile substance excreted (VS), the maximum CH_4 producing capacity for manure (B_o) and the CH_4 conversion factors for each manure management system (MCF).

*No country-specific values for the **daily excretion of VS** are available in Switzerland. For the livestock categories swine, sheep, goats, horses, mules and asses, and poultry default values from IPCC 1997b: Reference Manual: p. 4.41 to 4.47 were taken. The VS for cattle sub-categories were estimated according to IPCC 2000: equation 4.16: p. 4.31.*

*The **ash content** of cattle manure is assumed to amount to 8% on average (IPCC 1997b: Reference Manual: p. 4.47). The digestible energy of the feed for cattle is assumed to be 60% on average (IPCC 1997b: Reference Manual: p. 4.47). The calculation of gross energy intake per head is described in detail in chapter 6.2.2.*

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[8] Since the number of (female) goats older than 1.5 years are not known, the following approximation is used: GP = DG + 0.3508*OFG. GP goat places, DG dairy goats, OFG other female goats older than 1 year.

*For the Methane Producing Potential (**B_o**) default values are used (IPCC 1997b: Reference Manual: p. 4.41 to 4.47).*

*For the Methane Conversion Factor (**MCF**) IPCC default values are used (IPCC 2000, p. 4.36 and IPCC 1997b: Reference Manual: p. 4.25). In Switzerland mainly two manure management systems exist, solid storage and liquid/slurry storage. Calves are mainly kept in deep litter systems and there are also specific MCF values for pasture and poultry systems: The following MCF's were used:*

Table 67 Manure management systems and Methane conversion factors (MCFs). References: IPCC 2000, p. 4.36 and IPCC 1997b: p. 4.25 (for liquid/slurry).

Manure management system	***Description***	***MCF***
Solid manure	*Dung and urine are excreted in a barn. The solids (with and without litter) are collected and stored in bulk for a long time (months) before disposal.*	*1%*
Liquid/slurry	*Combined storage of dung and urine under animal confinements for longer than 1 month.*	*10%*
Pasture	*Manure is allowed to lie as it is, and is not managed (distributed, etc.).*	*1%*
Deep litter	*Dung and urine is excreted in a barn with lots of litter and is not removed for a long time (months). This is applied for the cattle sub-categories of milk-fed calves and fattening calves, and for sheep and goats.*	*39%*
Poultry system	*Manure is excreted on the floor with or without bedding.*	*1.5%*

*The fraction of animal's manure handled using different manure management systems (**MS**) was separately calculated for each livestock category and the respective manure management systems. The information about the percentage of a livestock category kept in a specific housing system is based on FAL/RAC 2001. The percentages of solid manure or slurry produced by different animals within specific housing systems were obtained from Menzi et al. 1997, as were the percentages of the grazing time for each livestock category.*

Activity data

Data on population sizes are taken from the Office of Agriculture (LWA 2004) and the Office of Economic Affairs (AVW 1992). For details please refer to chapter 6.2.2.

b) N_2O Emissions

Methodology

Liechtenstein follows the Swiss approach for calculating N_2O emissions from manure management using a Tier 2 method. The Swiss methodology is explained in the following paragraph.

Swiss methodology (excerpt from NIR CH, chp 6.3.2, FOEN 2006):

For calculation of N_2O emissions the country specific method IULIA is applied. IULIA is an IPCC-derived method for the calculation of N_2O emissions from agriculture that basically uses the same emission factors, but adjusts the activity data to the particular situation of

Switzerland. Further information is provided under the chapter 6.5.2. IULIA is described in detail in Schmid et al. 2000.

For calculation of emissions from manure management IULIA applies other values for the nitrogen excretion per animal category than IPCC (refer to information about activity data) and differentiates the animal waste management systems Liquid systems and Solid storage. The combined systems (liquid/slurry) are split up into Liquid systems and Solid storage. N_2O emissions from pasture range and paddock appears under the category „D Agricultural soils, subcategory 2 animal production". IPCC categories „daily spread" and „other systems" are not occurring. The basic animal waste management systems included in IULIA are defined in Menzi et al. 1997.

Emission factors

IPCC default emission factors are used for the two animal waste management systems (IPCC 2000, p.4.43).

Source	**Emission factor per animal waste management system (kg N_2O-N / kg N)**
Liquid systems	0.001
Solid storage	0.020

Table 68 Emission factors for calculating N_2O emissions from manure management (IPCC 2000, p. 4.43).

Activity data

Input data on all livestock groups are taken from LWA 2004 and AVW 1992. Data are converted into the following livestock categories.

Population Size	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
	head														
Cattle	6'117	5'950	5'947	5'545	5'675	5'814	5'748	5'657	5'546	5'461	5'229	5'270	5'380	5'733	6'047
Mature dairy cattle and non-dairy cattle	2'870	2'868	2'778	2'637	2'719	2'690	2'704	2'680	2'677	2'658	2'514	2'751	2'854	2'936	3'018
Young cattle	1'713	1'647	1'683	1'642	1'780	1'850	1'830	1'890	1'840	1'931	1'804	1'652	1'529	1'781	2'084
Milk fed calf, suckler cow calf, breeding calf and breeding cattle less than one year	1'201	1'098	1'097	1'017	1'118	1'151	1'094	1'117	1'028	1'082	918	894	899	985	1'221
Fattening calf	205	225	244	264	284	304	323	343	363	382	402	283	164	290	287
Fattening cattle	307	325	342	360	378	396	413	431	449	466	484	475	466	506	576
Breeding cattle (more than one year)	1'534	1'434	1'486	1'266	1'177	1'274	1'213	1'087	1'029	873	911	868	997	1'016	945
Sheep (Sheep places)	1'391	1'345	1'439	1'321	1'314	1'316	1'676	1'617	1'804	1'632	1'660	1'660	1'601	1'535	1'575
Goats (Goat places)	94	117	152	100	75	80	151	148	158	172	131	116	113	133	157
Horses	156	178	183	202	190	204	220	218	227	231	153	284	196	220	254
Foals (< 1 year)	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	1	5
Foals (1-2 years)	16	16	17	17	18	18	18	19	19	20	20	12	4	10	18
Other horses	140	161	166	184	173	186	202	199	207	211	133	272	192	209	231
Ponies, Mules and Asses	50	58	66	75	83	91	99	107	115	124	132	140	148	127	159
Swine															
Fattening pig places	1'983	2'097	1'717	2'003	1'720	1'449	1'488	1'169	1'200	1'208	1'221	1'306	1'329	1'240	654
Breeding pig places	273	394	324	228	204	253	158	373	254	308	180	287	106	117	8
Poultry	4'386	4'049	3'712	3'375	3'037	2'700	3'592	4'484	5'376	6'268	7'159	8'772	10'384	10'408	11'130
Laying hens	4'118	3'802	3'486	3'170	2'854	2'538	3'403	4'268	5'133	5'998	6'863	8'449	10'034	10'113	10'549
Young hens	105	96	88	79	70	61	53	44	35	26	18	9	0	11	9
Broilers	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	36	71	107	143	179	214	250	250	520
Other poultry	163	151	138	126	113	101	101	101	101	100	100	100	100	34	52

Table 69 Activity data for calculating N_2O emissions from manure management (LWA 2004, AVW 1992). For calculation of sheep places, goat places, fattening pig places and breeding pig places, please refer to this chapter above.

No national data on nitrogen excretion per animal category (kg N/head/year) are available in Liechtenstein (except the ones for dairy cattle, which are calculated based on country specific milk production data). Therefore Swiss data is taken from FAL/RAC 2001, p. 48/49 (see Annex 3.1). These data are calculated according to the method IULIA. Unlike IPCC, IULIA distinguishes the age structure of the animals and the different use of the animals (e.g. fattening and breeding). Calculation of nitrogen excretion of dairy cattle is based on milk production reported. This more disaggregated approach leads to 30% lower calculated nitrogen excretion rates compared to IPCC, which therefore also implies to lower total N_2O emissions from manure management.

The split of nitrogen flows into the different animal waste management systems including ammonia emissions are taken from Menzi et al. 1997.

6.3.3. Uncertainties and Time-Series Consistency

No uncertainty assessment has been carried out.

The time series 1990-2004 is consistent.

6.3.4. Source-Specific QA/QC and Verification

For CH_4 documentation about the calculation method of Switzerland assures transparency and traceability (Soliva 2006a). Additionally a document in German lists all the methodological differences between the former calculations and the current methodology (Soliva 2006b). For N2O estimations an internal Swiss documentation of the Agroscope Reckenholz-Tänikon Research Station (ART) is available (Berthoud 2004).

Calculations were made by Acontec. A quality control was done by INFRAS by a countercheck of the calculation sheets. This countercheck lead to some adjustments of the calculation sheets.

6.3.5. Source-Specific Recalculations

In the former submission only emissions for the years 1990 and 2004 were estimated. In this submission time series were calculated for the first time. Additionally, the former CH4 calculation was revised in detail for this submission (Soliva 2006a and Soliva 2006b). Therefore, recalculations for the whole time series have been carried out.

6.3.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

6.4. Source Category 4C – Rice Cultivation

Rice Cultivation does not occur in Liechtenstein.

6.5. Source Category 4D – Agricultural Soils

6.5.1. Source Category Description

Key source 4D1, 4D3 Direct (4D1) N_2O emissions from agricultural soils are key sources by level and trend. Indirect (4D3) N_2O emissions from agricultural soils are key sources by level.

The source category 4D includes the following emissions: Direct N_2O emissions from soils and from animal production (emission from pasture range and paddock manure) and indirect N_2O emissions.

Direct N_2O emissions were decreasing since 1990, mainly due to a reduced input of mineral fertilizer and due to a reduction of organic soils. Indirect emissions remained more or less constant.

4D	Source	Specification	Data Source
4D1	Direct soil emissions	Includes emissions from synthetic fertilizer, animal manure, crop residue, N-fixing crops, organic soils, residues form pasture range and paddock, N-fixing pasture range and paddock	AD: LWA 2000, LWA 2003, LWA 2005, FAL/RAC 2001; Leifeld et al. 2003 EF: IPCC 1997b (N_2O) and Schmid et al. 2000
4D2	Pasture, range and paddock manure		AD: LWA 2004, LWA 2005, AVW 1992 , FAL/RAC 2001; Menzi et al. 1997 EF: IPCC 1997b
4D3	Indirect emissions	Leaching and run-off, N deposition air to soil	AD: LWA 2005, FAL/RAC 2001; Prasuhn and Braun 1994, Braun et al. 1994. EF: IPCC 1997b

Table 70 Specification of source category 4D “Agricultural Soils”. (AD: Activity data; EF: Emission factors).

6.5.2. Methodological Issues

Methodology

Liechtenstein applies the Swiss method IULIA for calculating N_2O emissions. The methodology as well as differences between IULIA and the IPCC method are described in the following paragraph:

Swiss methodology (excerpt from NIR CH, chp 6.5.2, FOEN 2006):

For calculation of N_2O emissions from agricultural soils the national method IULIA is applied. IULIA is an IPCC-derived method for the calculation of N_2O emissions from agriculture that basically uses the same emission factors, but adjusts the activity data to the particular situation of Switzerland (Schmid et al. 2000). According to expert judgement IULIA has been proven to be an adequate method for calculation of N_2O emissions under Swiss circumstances. There is no indication that the adoption of the IPCC method would lead to a better estimation of the N_2O emissions in Switzerland.

Main differences between the IULIA method and IPCC are (Schmid et al. 2000, p. 74):

- *IULIA estimates lower nitrogen excretion per animal category, especially due to the lower excretions of cattle (refer to chapter 6.3.2).*
- *The amount of losses to the atmosphere from the excreted nitrogen is more than 50% higher compared to IPCC.*

- *The amount of leaching (of nitrogen excreted and of synthetic fertilizers) is lower by 1/3 compared to IPCC.*
- *The share of solid storage out of the total manure is more than twofold; the share of excretion on pasture range and paddock is lower by 1/3.*
- *The nitrogen inputs from biological fixation are higher by a factor of 30 since fixation on meadows and pastures are also considered. The consideration of nitrogen fixation from grassland is one of the major advantages of the method IULIA as the grassland accounts for the majority on nitrogen fixed in Swiss agricultural soils.*
- *The nitrogen inputs from crop residues are only 25% higher although emissions from plant residue returned to soils on meadows and pastures are considered. This is explained by the fact that the emissions from crop residue are estimated 50% below the IPCC defaults.*

Despite the different assumptions of the two methods, differences at the level of the N_2O emissions are quite moderate. In total IULIA estimations of the N_2O emissions from agriculture are 14% lower than the IPCC estimations (Schmid et al. 2000, p. 75).

Direct emissions from soil (4D1):

Calculation of direct N_2O emissions from soil is based on IPCC Tier 1b. Liechtenstein follows the Swiss method IULIA by using the same rates (e.g. N excretion per animal category) and standard values but using national activity data.

- Emissions from **synthetic fertilizer** include mineral fertilizer, compost and sewage sludge. For calculation of the amount of nitrogen in synthetic fertilizer and compost Swiss data from the Swiss Farmers Association were taken and adjusted to Liechtenstein by a rule of three (by estimating the nitrogen input per hectare of the agricultural area) (SBV 2005). The amount of nitrogen in sewage sludge is taken from the Office of Agriculture (LWA 2005). From the amount of nitrogen in fertilizer losses to the atmosphere in form of NH3 and NOx are subtracted and the rest is multiplied with the corresponding emission factor. According to the Swiss method IULIA losses to the atmosphere are set to 6% (NH3) and 0.7% (NOx, according to EMEP/CORINAIR, EEA 2005) instead of the IPCC value of 10% for NH3 and NOx. (Schmid et al. 2000, p. 63 and IPCC 1997c, p. 4.94).
- To model the emissions of **pasture range and paddock manure**, nitrogen input from manure applied to soils is calculated. This is calculated by the total N excretion minus N excreted on pastures minus ammonia volatilization from solid and liquid manure and excretion on pastures. Following the Swiss method IULIA the losses (to the atmosphere) as ammonia are specified for each management category instead of using a fixed ratio of 20% (Schmid et al. 2000, p. 66). The loss as NO_x is set to 0.7% of the excreted N (EMEP/CORINAIR, EEA 2005). For details regarding the volatized N refer to Table 72.
- Emissions from **crop residues** are based on the amount of nitrogen in crop residues returned to soil. According to IULIA (Schmid et al. 2000, p. 68 and p. 100) this amount is based on data reported on crop yields (LWA 2005), the standard values for arable crop yields for Switzerland (FAL/RAC 2001) and standard amounts of nitrogen in crop residues returned to soils for Switzerland (FAL/RAC 2001). The calculation of the amount of nitrogen in crop residues returned to soil according to IULIA is as follows (Schmid et al. 2000, p. 101):

  $$F_{CR} = \sum_{Cr} E_{Cr} * \frac{NR_{Cr}}{Y_{Cr}}$$

  F_{CR}: Amount of nitrogen in crop residues returned to soils (t N)

E_{Cr}: Amount of crop yields for culture Cr (t)
Y_{Cr}: Standard values for arable crop yields for culture Cr (t/ha)
NR_{Cr}: Standard amount of nitrogen in crop residues returned to soils (t)

From 2001 on updated standard values and amounts of nitrogen returned to soil are used. In addition to the N transfer from crop residues, IULIA also takes into account the plant residue returned to soils on meadows and pastures (Schmid et al. 2000). The grassland area in Liechtenstein is almost as big as the agricultural. Input data on the managed area of meadows and pastures are taken from (LWA 2005).

- For calculation of emissions from **N-fixing crops**, the Swiss method IULIA assumes that 60% of the nitrogen in crops is caused by biological nitrogen fixation (Schmid et al. 2000, p. 70). The total amount of nitrogen is calculated according to the calculation of nitrogen in crop residues. In addition, IULIA takes biological nitrogen fixation on meadows and pastures into account, assuming 3.5% of N in the dry matter of clover and 80% of the N in clover stemming from biological nitrogen fixation, and using statistical data for the dry matter production of clover on pastures and meadows (Schmid et al. 2000, p. 70). The following table gives an overview of the calculation of emissions from N-fixing crops.

Fixation	Share of N caused by fixation	Share of N in Dry matter
Leguminous (N-fixing crops)	0.6	
Clover (Fixation meadows and pastures)	0.8	0.035

Table 71 Input values for calculation of emissions from N-fixing crops according to IULIA (Schmid et al. 2000, p. 70).

- Emissions from **cultivated organic soils** are based on estimations on the area of cultivated organic soils (LWA 2005) and the IPCC default emission factor for N_2O emissions from cultivated organic soils (IPCC 1997b).

Emissions from pasture, range and paddock manure (4D2)

Calculation of these emissions is also based on the Swiss method IULIA. This equation is similar to equation 4.18, IPCC 2000, p. 4.42, but applies Swiss N excretion rates. For calculation of the N excretion per animal category, please refer to chapter 6.3.2.

Other emissions from animal production are reported under Manure Management. The relevant input data are taken from Swiss statistics (FAL/RAC 2001, p. 48/49 for the nitrogen excretion in kg N/head/yr and Menzi et al. 1997 for the fraction of animal waste management system).

Indirect emissions (4D3)

Calculation of the indirect emissions is based on IPCC Tier 1b.

- For calculation of N_2O emissions from **leaching and run-off**, N from fertilizers and animal wastes has to be estimated. The data for the cultivated area is taken from (LWA 2005). Other relevant input data such as the information on leaching and run-off is taken from the Swiss statistics FAL/RAC 2001, Prasuhn and Braun 1994 and Braun et al. 1994. $Frac_{Leach}$ is set as 0.2 instead of the IPCC default of 0.3 (Prasuhn and Mohni 2003). This value is extrapolated from long-term monitoring and modelling studies from the canton of Berne. According to Schmid et al. 2000, p. 71, the default value of IPCC leads to an overestimation of the emissions from leaching and run-off. The default value is based on a model which assumes that 30% of nitrogen from synthetic fertilizer and deposition is reaching water bodies. According to Schmid et al. 2000 this amount cannot be applied to the N-excretion of animals for production.

- N_2O emissions from **deposition** are based on NH_3 and NO_x emissions. Losses to the atmosphere are calculated according to Menzi et al. 1997. For NH_3 emissions losses for all livestock categories are assumed. Furthermore, it is estimated that 6% of nitrogen in mineral fertilizer is emitted as NH_3, 1.5 kg NH_3 -N/ha agricultural soil is produced during decomposition of organic material and 0.7% of nitrogen excretion from livestock and mineral fertilizer is emitted as NO_x (Schmid et al. 2000, p. 66, EMEP/CORINAIR, EEA 2005). Details about the amount of volatized N (NH_3 and NO_x) are provided in the following table.

	N excretion (t N) / N content 2004	Losses NH3 (%)	Emissions NH3 (t N) 2004	Losses NOx (%)	Emissions NOx (t N) 2004	Volatized N total (NH3, NOx in t) 2004
Cattle						
Mature dairy cattle and non-dairy cattle	346.5	32%	110.9	0.7%	2.4	113.3
Young cattle				0.7%	0.0	0.0
Milk fed calf, suckler cow calf, breeding calf and breeding cattle less than one year	26.5	22%	5.8	0.7%	0.2	6.0
Fattening calf	0.6	37%	0.2	0.7%	0.0	0.2
Fattening cattle	19.0	37%	7.0	0.7%	0.1	7.2
Breeding cattle (more than one year)	43.1	22%	9.5	0.7%	0.3	9.8
Sheep (Sheep places)	18.9	14%	2.6	0.7%	0.1	2.8
Goats (Goats places)	2.5	29%	0.7	0.7%	0.0	0.7
Horses						
Foals (< 1 year)	0.1	32%	0.0	0.7%	0.0	0.0
Foals (1-2 years)	0.8	32%	0.2	0.7%	0.0	0.2
Other horses	10.2	32%	3.3	0.7%	0.1	3.3
Ponies, Mules and Asses	4.1	32%	1.3	0.7%	0.0	1.4
Swine						
Fattening pig places	8.5	46%	3.9	0.7%	0.1	4.0
Breeding pig places	0.3	46%	0.1	0.7%	0.0	0.1
Poultry						
Laying hens	7.5	54%	4.0	0.7%	0.1	4.1
Young hens (< 18 weeks)	0.0	54%	0.0	0.7%	0.0	0.0
Broilers	0.0	48%	0.0	0.7%	0.0	0.0
Other poultry (turkeys)	0.1	48%	0.0	0.7%	0.0	0.0
Total animals			**149.8**		**3.4**	**153.2**
Mineral fertilizer, compost and sewage sludge (t N)	176.3	6%	10.6	0.7%	1.2	11.8
NH3 emissions from cropland (ha)	5'476	1.5 kg/ha	8.2			8.2
Total			**168.6**		**4.7**	**173.2**

Table 72 Overview of the volatized N (NH_3 and NO_X) from animal wastes and fertilizer for 2004. The total amount of volatized N appears under the indirect emissions (atmospheric deposition) in the CRF, table 4D.

The estimations of the ammonia emissions is based on a Swiss study, which takes into account the specific farming and manure systems (Menzi et al. 1997, p. 37). Emission factors are lower for cattle, sheep, goats and horses due to the grazing regime. Higher emission factors are estimated under stall feeding conditions.

Emission factors

The following IPCC default emission factors for calculating N_2O emissions from agricultural soils are used.

Emission source	Emission factor
Direct emissions	
Synthetic fertilizer	0.0125 kg N_2O -N/kg N
Animal excreta nitrogen used as fertilizer	0.0125 kg N_2O -N/kg N
Crop residue	0.0125 kg N_2O -N/kg N
N-fixing crops	0.0125 kg N_2O -N/kg N
Organic soils	8 kg N_2O-N/ha/year
Residues pasture, range and paddock	0.0125 kg N_2O -N/kg N
N-fixing pasture, range and paddock	0.0125 kg N_2O -N/kg N
Indirect emissions	
Leaching and run-off	0.025 kg N_2O -N/kg N
Deposition	0.01 kg N_2O -N/kg N
Pasture, range and paddock manure	
Pasture, range and paddock	0.02 kg N_2O -N/kg N/a
Other (sewage sludge and compost used for fertilizing)	0.0125 kg N_2O –N/kg N

Table 73 Emission factors for calculating N_2O emissions from agricultural soils (IPCC 1997c, tables 4.18 (direct emissions) and 4.23 (indirect emissions)).

Activity data

Activity data for calculation of direct soil emissions has been provided by

- the Office of Agriculture (LWA 2005): Use of synthetic fertilizer[9], crops produced, area of pasture range and paddock, area of cultivated organic soils
- and by FAL/RAC 2001 (p. 48/49): Nitrogen excretion.

[9] As already mentioned in the paragraph about methodological issues of direct soil emissions, data on nitrogen in mineral fertilizer and compost were not available for Liechtenstein. Therefore the amounts of nitrogen were estimated by taking Swiss data from the Swiss Farmers Association and adjusting them to Liechtenstein by a rule of three. The amount of nitrogen in sewage sludge is taken from the Office of Agriculture (LWA 2005)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Related activity data	Value														
Direct emissions																
Fertilizer (t N/yr)		233	236	236	221	211	204	186	188	166	172	173	187	182	175	176
	Mineral fertilizer (t N/yr)	202	192	199	180	173	172	164	164	145	156	162	180	176	169	176
	Sewage sludge (t N/yr)	30	44	37	41	38	31	21	24	21	16	11	6	5	6	0
	Compost (t N/yr)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.5	0.5	0.4
Animal manure	Nitrogen input from manure applied to soils (t N/yr)	281	283	276	262	261	262	263	263	262	260	248	257	261	269	274
N-fixing crops	Peas, dry beans, soybeans and leguminous vegetables produced (t N/yr)	143	146	150	153	158	164	161	162	164	165	167	169	171	177	180
Crop residue	Dry production of other crops (t N/yr)	193	200	201	203	206	209	203	202	200	198	197	197	198	202	201
Organic soils	Area of cultivated organic soils (ha)	471	450	429	408	387	366	345	324	303	282	261	240	219	198	177
Residues pasture range and paddock	Area of pasture range and paddock (ha)	4'181	4'202	4'224	4'245	4'267	4'288	4'298	4'307	4'317	4'326	4'336	4'368	4'400	4'543	4'670
N-fixing pasture range and paddock	Area of pasture range and paddock (ha)	4'181	4'202	4'224	4'245	4'267	4'288	4'298	4'307	4'317	4'326	4'336	4'368	4'400	4'543	4'670
Indirect emissions																
Leaching and run-off	N excretion of all animals (t N/yr)	519	519	509	480	477	481	482	480	478	470	448	459	468	481	489
	Fertilizer (t N/yr)	233	236	236	221	211	204	186	188	166	172	173	187	182	175	176
	N from fertilizers and animal wastes that is lost through leaching and run off (t N/yr)	150	151	149	140	138	137	134	134	129	129	124	129	130	131	133
Deposition	Emissions NH3 from fertilizers, animal wastes and cropland	180	182	177	169	167	167	166	166	164	164	157	163	164	168	169
	Emissions NOx from fertilizers and animal wastes	5	5	5	5	5	5	5	5	5	4	4	5	5	5	5
	Sum of volatized N (NH3 and NOx) from fertilizers, animal wastes and cropland (t N/yr)	185	187	182	174	172	171	170	171	169	169	161	167	169	173	174
Pasture, range and paddock manure																
Pasture, range and paddock	N excretion on pasture range and paddock (t N/yr)	84	81	83	75	74	76	77	74	73	68	65	62	65	66	67

Table 74 Activity data for calculating N_2O emissions from agricultural soils. For the sake of completeness, values for mineral fertilizer, sewage sludge and compost are displayed. For calculation of the emissions only the total amount of synthetic fertilizer is used.

6.5.3. Uncertainties and Time-Series Consistency

The uncertainty analysis carried out and documented in NIR of submission 31 May 2006 has not been updated. The relative uncertainties, 80% (4D1) and 95% (4D3) in the emissions of N_2O were taken from the uncertainty analysis of the Swiss GHG inventory (FOEN 2006). For further results see Section 1.7.

Time series between 1990 and 2004 is consistent.

6.5.4. Source-Specific QA/QC and Verification

No source-specific activities have been carried out. An internal documentation of the Agroscope Reckenholz-Tänikon Research Station (ART) about the calculation of the greenhouse gas emissions in agriculture assures transparency and traceability of the calculation methods (Berthoud, 2004).

6.5.5. Source-Specific Recalculations

In the former submission only emissions for the years 1990 and 2004 were estimated. In this submission time series were calculated for the first time. Therefore, recalculations for the whole time series have been carried out.

6.5.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

6.6. Source Category 4E – Burning of savannas

Burning of savannas does not occur (NO) in Liechtenstein.

6.7. Source Category 4F – Field Burning of Agricultural Residues

Field burning of agricultural residues is not occurring in Liechtenstein.

7. Land Use, Land-Use Change and Forestry

7.1. Overview

This chapter includes information about the estimation of greenhouse gas emissions and removals from land use, land-use change and forestry (LULUCF). The data acquisition and calculations are based on the Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2003). They are completed by country-specific methodologies from Switzerland, which were almost fully adopted to Liechtenstein.

The land areas from 1990 to 2004 are represented by geographically explicit land-use data with a resolution of one hectare (following a Tier 3 approach; IPCC 2003). Direct and repeated assessment of land use with full spatial coverage also enables to calculate spatially explicit land-use change matrices. Land-use statistics for Liechtenstein are available for the years 1984, 1996 and 2002. They are based on the same methodology as the Swiss land-use statistics. The 2002 data are based on a newly designed set of land-use and land-cover categories of Switzerland (SFSO 2006a). The two earlier land-use statistics were re-evaluated according to the new approach.

In Liechtenstein, Swiss country-specific emission factors and carbon stock values for forests and partially for agricultural land and grassland were implied. For other land use categories, IPCC default values or expert estimates are used.

The six main land categories required by IPCC (2003) are: A. Forest Land, B. Cropland, C. Grassland, D. Wetlands, E. Settlements and F. Other Land. These categories were further divided in 18 sub-divisions of land use (see Table 76). A further spatial stratification reflects the criteria ‘altitude’ (3 zones) and ‘soil type’ (mineral, organic).

Figure 19 shows the net CO_2 removals of the LULUCF sector. Table 75 and Figure 20 summarize the CO_2 equivalent emissions and removals in consequence of carbon losses and gains for the years 1990-2004. The total net removals/emissions of CO_2 equivalent vary between -3.9 Gg (2001) and -9.4 Gg (1995) from 1990 to 2004. Three components of the CO_2 balance are shown separately

- Increase of living biomass on forest land: this is the growth of biomass on forest land remaining forest land; it is the largest sink of carbon.
- Decrease of living biomass on forest land: this is the decrease of carbon in living biomass (by harvest and mortality) on forest land remaining forest land; it is the largest source of carbon.
- Land-use change and soil: this is all the rest including carbon removals/emissions due to land-use changes and use of soils, especially of organic soils.

In all the years, growth of biomass exceeds the harvesting and mortality rate. Compared to these biomass changes in forests, the net CO_2 equivalent emissions arising from all land-use changes and from the soils are relatively small (see Figure 20).

LULUCF	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Gg CO_2														
Increase of living biomass in forest	-68.2	-68.0	-68.7	-68.1	-67.8	-69.5	-68.4	-69.8	-69.4	-70.5	-69.8	-70.0	-69.9	-69.2	-68.9
Decrease of living biomass in forest	50.4	49.8	50.4	49.9	50.0	50.8	50.1	50.3	50.2	50.5	50.2	50.4	50.4	50.9	50.4
Land-use change and soil	10.5	9.2	11.1	11.1	10.3	9.3	10.3	15.7	14.3	15.5	13.9	15.5	14.0	12.5	12.1
Sector 5 LULUCF (total)	-7.3	-8.9	-7.3	-7.1	-7.5	-9.4	-7.9	-3.9	-4.9	-4.4	-5.6	-4.0	-5.5	-5.8	-6.4

Table 75 Liechtenstein’s CO_2 equivalent emissions/removals [Gg] of the source category 5 LULUCF 1990-2004. Positive values refer to emissions; negative values refer to removals from the atmosphere.

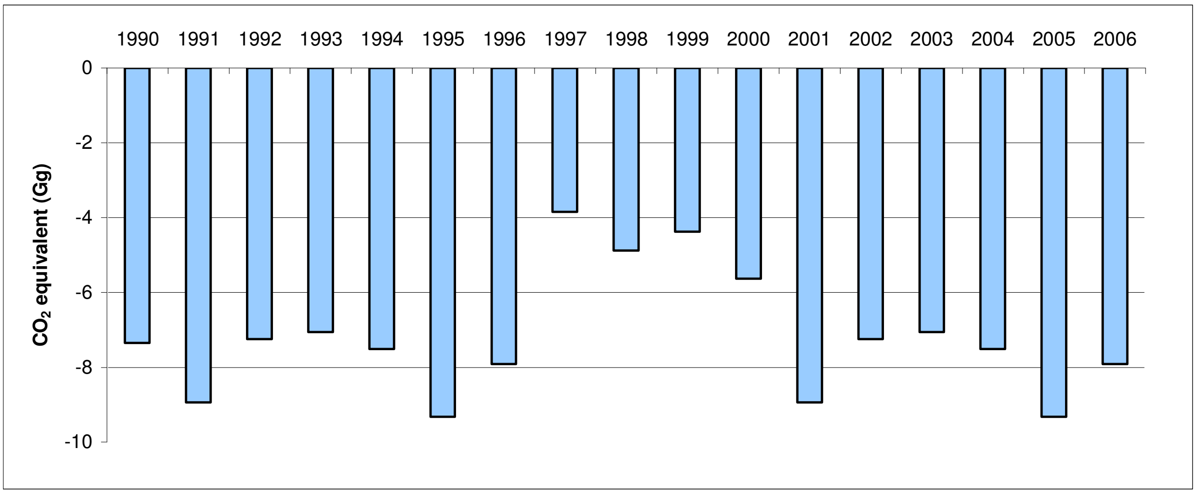


Figure 19 Liechtenstein's CO_2 emissions/removals of source category 5 LULUCF 1990–2004 in Gg CO_2 equivalent. Negative values refer to removals.

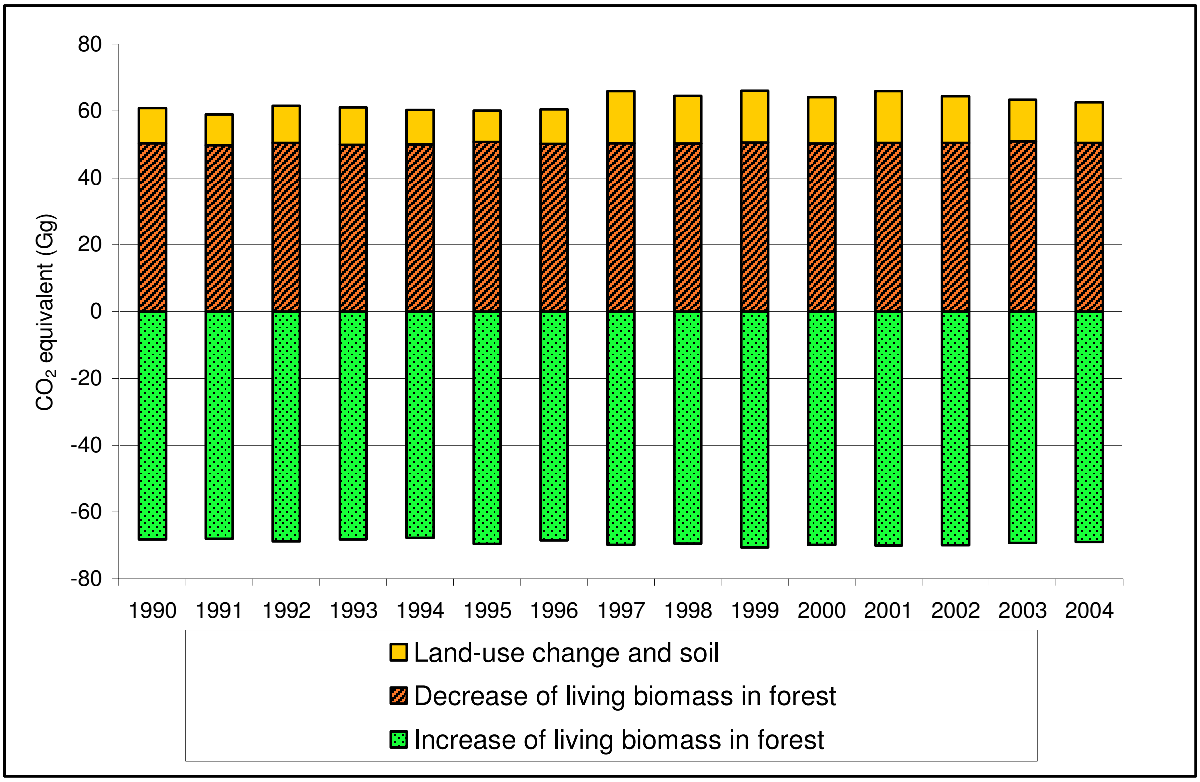


Figure 20 The CO_2 removals due to the increase (growth) of living biomass on forest land, the CO_2 emissions due to the decrease (harvest and mortality) of living biomass on forest land and the net CO_2 equivalent emissions due to land-use changes and from use of soils, 1990–2004.

The next chapter (7.2.) gives an overview of the methodical approach including the calculation of the activity data (land-use data) and carbon emissions. The following chapters (7.3-7.8) describe the details of the CO_2 equivalent removal/emission calculations for each main land-use category.

Non CO_2-emissions are very small (less than 0.0002 Gg N_2O). They arise from soil disturbances associated with land-conversion to cropland (CRF Table 5 III). The calculation method is based on IPCC default procedures (IPCC 2003, chapter 3) and summarized in chapter 7.4.2.

7.2. Methodical Approach and Activity Data

7.2.1. General Approach for Calculating Carbon Emissions/Removals

The selected procedure for calculating carbon emissions and removals in the LULUCF sector is done as for Switzerland. It corresponds to a Tier 2 approach as described in IPCC (2003; chapter 3) and can be summarised as follows:

- Land use categories and sub-divisions with respect to available land-use data (see Table 76) were defined. For this carbon emissions and removals estimations so-called combination categories (CC) were defined on the basis of the land-use and land-cover categories of the Swiss land-use statistics (FOEN 2006a; SFSO 2006a).
- Criteria for the spatial stratification of the land-use categories (altitude and soil type) were taken from Switzerland. Based on these criteria data for the spatial stratification of the land-use categories were collected in Liechtenstein.
- For carbon stocks and carbon stock changes for each spatial stratum of the land-use categories Swiss data based on measurements and estimations were taken.
- The land use and the land-use change matrix was calculated in each spatial stratum.
- Carbon stock changes in living biomass (deltaC_l), in dead organic matter (deltaC_d) and in soil (deltaC_s) were calculated for all cells of the land-use change matrix.
- Finally, aggregate the results by summarising the carbon stock changes over land-use categories and strata according to the level of disaggregation displayed in the CRF tables.

The procedure of calculating emissions and removals in LULUCF and the different institutions involved are displayed in Figure 21.

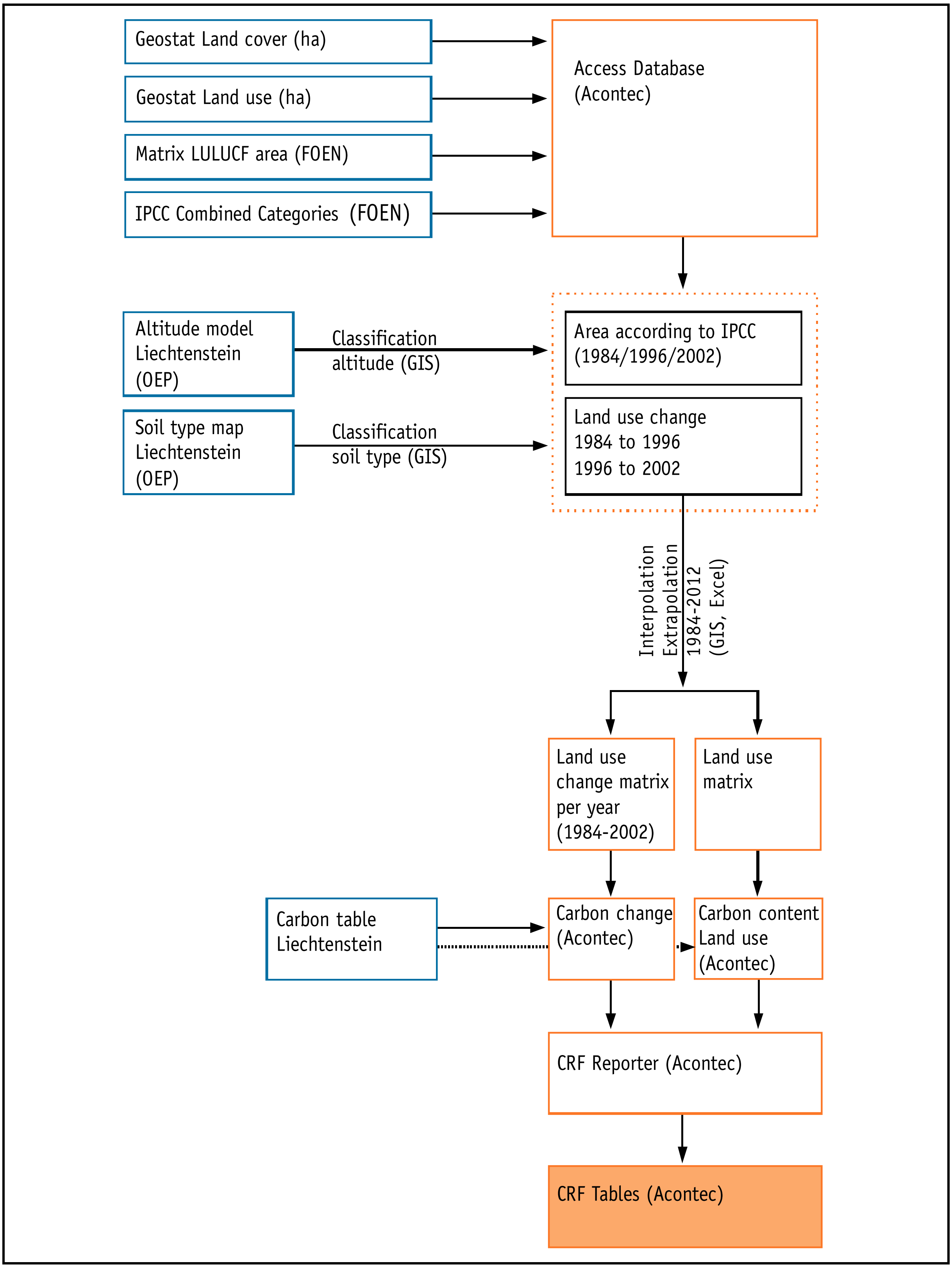


Figure 21 Procedure of calculating emissions and removals from LULUCF in Liechtenstein.

The following paragraph gives some further explanations about the Swiss calculation of carbon stock changes.

Swiss methodology (excerpt from NIR CH, chp 7.2.1, FOEN 2006):

For calculating carbon stock changes, the following input parameters (mean values per hectare) must be quantified for all land-use categories (CC) and spatial strata (i):

- $stockC_{l,i,CC}$: *carbon stock in living biomass*
- $stockC_{d,i,CC}$: *carbon stock in dead organic matter*
- $stockC_{s,i,CC}$: *carbon stock in soil*
- $increaseC_{l,i,CC}$: *annual increase (growth) of carbon in living biomass*
- $decreaseC_{l,i,CC}$: *annual decrease (harvesting) of carbon in living biomass*
- $changeC_{d,i,CC}$: *annual net carbon stock change in dead organic matter*
- $changeC_{s,i,CC}$: *annual net carbon stock change in soil*

CC Main category	***CC Sub-division***	***Remarks***	***Terminology in CRF tables***	***CC code***
A. Forest Land	*Afforestations*	*areas converted to forest by active measures, e.g. planting*	*affor*	*11*
	Managed Forest	*dense and open forest meeting the criteria of forest land*	*managed*	*12*
	Unproductive Forest	*brush forest and inaccessible forest meeting the criteria of forest land*	*unprod*	*13*
B. Cropland		*arable and tillage land (annual crops and leys in arable rotations)*		*21*
C. Grassland	*Permanent Grassland*	*meadows, pastures (low-land and alpine)*	*perm*	*31*
	Shrub Vegetation	*agricultural and unproductive areas predominantly covered by shrubs*	*woody, shrub*	*32*
	Vineyards, Low-Stem Orchards, Tree Nurseries	*perennial agricultural plants with woody biomass (no trees)*	*woody, vine*	*33*
	Copse	*agricultural and unproductive areas covered by perennial woody biomass including trees*	*woody, copse*	*34*
	Orchards	*permanent grassland with fruit trees*	*woody, orchard*	*35*
	Stony Grassland	*grass, herbs and shrubs on stony surfaces*	*unprod, stony*	*36*
	Unproductive Grassland	*unmanaged grass vegetation*	*unprod*	*37*
D. Wetlands	*Surface Waters*	*lakes and rivers*	*surface*	*41*
	Unproductive Wetland	*reed, unmanaged wetland*	*unprod*	*42*
E. Settlements	*Buildings and Constructions*	*areas without vegetation such as houses, roads, construction sites, dumps*	*build*	*51*
	Herbaceous Biomass in Settlements	*areas with low vegetation, e.g. lawns*	*herb*	*52*
	Shrubs in Settlements	*areas with perennial woody biomass (no trees)*	*shrub*	*53*
	Trees in Settlements	*areas with perennial woody biomass including trees*	*tree*	*54*
F. Other Land		*areas without soil and vegetation: rocks, sand, screes, glaciers*		*61*

Table 76 Land-use categories used in this report (so-called combination categories CC): 6 main land-use categories and the 18 sub-divisions. Additionally, descriptive remarks, abbreviations used in the CRF tables, and CC codes are given. For a detailed definition of the CC categories see FOEN (2006a) and SFSO (2006a).

On this basis, the carbon stock changes in living biomass ($deltaC_l$), in dead organic matter ($deltaC_d$) and in soil ($deltaC_s$) are calculated for all cells of the land-use change matrix. Each cell is characterized by a land-use category before the conversion (b), a land-use category after the conversion (a) and the area of converted land within the spatial stratum (i). Equations 7.2.1.-7.2.3 show the general approach of calculating C-removals/emissions taking into account the net carbon stock changes in living biomass, dead organic matter and soils as well as the stock changes due to conversion of land use (difference of the stocks before and after the conversion):

$$deltaC_{l,i,ba} = [increaseC_{l,i,a} - decreaseC_{l,i,a} + W_l * (stockC_{l,i,a} - stockC_{l,i,b})] * A_{i,ba} \quad (7.2.1)$$

$$deltaC_{d,i,ba} = [changeC_{d,i,a} + W_d * (stockC_{d,i,a} - stockC_{d,i,b})] * A_{i,ba} \quad (7.2.2)$$

$$deltaC_{s,i,ba} = [changeC_{s,i,a} + W_s * (stockC_{s,i,a} - stockC_{s,i,b})] * A_{i,ba} \quad (7.2.3)$$

where:

a: land-use category after conversion (CC = a)
b: land-use category before conversion (CC = b)
ba: land use conversion from b to a
$A_{i,ba}$: area of land converted from b to a in the spatial stratum i (activity data from the land-use change matrix)
W_l, W_d, W_s: weighting factors for living biomass, dead organic matter and soil, respectively.

The following values for W were chosen:

$W_l = W_d = W_s = 0$	*if land use after the conversion is 'Forest Land' (a = {11,12,13})*
$W_s = 0.5$	*if a or b is 'Buildings and Constructions' (a = 51 or b = 51)*
$W_l = W_d = W_s = 1$	*otherwise.*

The difference of the stocks before and after the conversion are weighted with a factor (W_l, W_d, W_s) accounting for the effectiveness of the land-use change in some special cases. For example, the succession from grassland to forest land is quite frequent in mountainous regions [in Switzerland]. Immediately after the conversion young forests have lower carbon stocks than the mean carbon stock values determined for 'managed forest'. Therefore, the weighting factors for the conversion 'to forest land' was set to zero in order to avoid an overestimation of C-sinks. In the case of land-use changes involving 'buildings and constructions' it is assumed that only 50% of the soil carbon is emitted as the humus layer is re-used on construction sites.

For all land-use categories applies: If a equals b, there is no change in land use and the difference in carbon stocks becomes zero.

For calculating annual carbon stock changes in soils due to land-use conversion, IPCC (2003) suggested a default delay time (inventory period) of 20 years. In this study, the inventory period of land-use changes is predetermined by the inter-survey period of the Swiss land-use statistics and averages approximately 12 years.

In the CRF tables 5.A to 5.F, land-use categories (CC) and associated spatial strata are partially shown at an aggregated level for optimal documentation and overview. The values of deltaC are accordingly summarised. Positive values of $deltaC_{l,i,ba}$ are inserted in the column "Increase" and negative values in column "Decrease", respectively (besides $increaseC_{l,i,CC}$ and $decreaseC_{l,i,CC}$ if land-use does not change).

7.2.2. General Approach for Compiling Land-use Data

a) Land-Use Statistics (AREA)

Land-use data from Liechtenstein are collected according to the same method as in Switzerland. Every hectare of the territory was assigned to one of 46 land-use categories and to one of 27 land-cover categories by means of stereographic interpretation of areal photos (SLP 2006).

For the reconstruction of the land use conditions in Liechtenstein for the period 1990-2004 three data sets are used:

- Land-Use Statistics 1984

- Land-Use Statistics 1996
- Land-Use Statistics 2002

Land-use statistics from the years 1984 and 1996 were originally evaluated according to a set of different land-use categories. For this purposes they were now being re-evaluated according to the newly designed land-use and land-cover categories (SFSO 2006a). For the interpretation of the 2002 data the new land-use and land-cover categories were used directly. Therefore, the whole territory of Liechtenstein can be interpreted coherently for the whole time series.

b) Combination Categories (CC) as derived from Land-Use Statistics

The 46 land-use categories and 27 land-cover categories of the land-use statistics were aggregated to 18 combination categories (CC, FOEN 2006a) implementing the main categories proposed by IPCC as well as by Swiss country-specific sub-divisions (see Table 76). The sub-divisions were defined with respect to optimal distinction of biomass densities, carbon turnover, and soil carbon contents.

The first digit of the CC-code represents the main category, whereas the second digit stands for the respective sub-division.

Table 77 Relation between the different land-use and land-cover categories and the combined categories (CC). FOEN 2006a

Land Use according to AREA

18 Kyoto Combined categories

Land Cover according to AREA	Settlements	Building area								Traffic infrastructure					Other settlement area							Recreational areas and parks					
		101 Industrie- und Gewerbeareal > 1 ha	102 Industrie- und Gewerbeareal < 1 ha	103 Ein- und Zweifamilienhausareal	104 Reihen- und Terrassenhausareal	105 Mehrfamilienhausareal	106 Öffentliches Gebäudeareal	107 Landwirtschaftliches Gebäudeareal	108 Nicht spezifiziertes Gebäudeareal	121 Autobahnareal	122 Strassenareal	123 Parkplatzareal	124 Bahnareal	125 Flugplatzareal	141 Energieversorgungsanlagen	142 Abwasserreinigungsanlagen	143 Übrige Ver- und Entsorgungsanlagen	144 Deponien	145 Abbau	146 Baustellen	147 Bau- und Siedlungsbrachen	161 Öffentliche Parkanlagen	162 Sportanlagen	163 Golfplätze	164 Campingplätze	165 Schrebergärten	166 Friedhöfe
10 Artificial surfaces																											
11 Befestigte Flächen		51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
12 Gebäude		51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
13 Treibhäuser		52	52	52	52	52	52	52	52			52	52	52						52	52	52	52	52	52	52	52
14 Beetstrukturen		52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
15 Rasen		52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
16 Bäume auf künstlich angelegten Flächen		54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54			54	54	54	54	54	54	54	54
17 Gemischte Kleinstrukturen		52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
20 Herbaceaous vegetation																											
21 Gras-, Krautvegetation		52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
30 Shrub vegetation																											
31 Gebüsch		53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
32 Verbuschte Flächen		53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
33 Niederstammobst		53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53
34 Reben		53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53
35 Gärtnerische Dauerkulturen		52	52	52	52	52	52	52	52	52	52	52	52								52	52				52	52
40 Trees																											
41 Geschlossene Baumbestände		54	54	54	54	54	54	54	54	54		54									54	54	54		54	54	54
42 Waldecken		54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54	54	54	54	54
43 Waldstreifen		54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54
44 Aufgelöste Baumbestände		54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54
45 Gebüschwaldbestände																						53			53		
46 Lineare Baumbestände		54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
47 Baumgruppen		54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
50 Surfaces without vegetation																											
51 Anstehender Fels		51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
52 Lockergestein		51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
53 Versteinte Flächen		52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
60 Water and wetlands																											
61 Wasser		41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
62 Gletscher, Firn																											
63 Nassstandorte		42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
64 Schilfbestände		42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42

Land Cover according to AREA	Agriculture	Orchard, vine-yards, garden			Agricultu-re and gropland			Pasture		
		201 Obstbau	202 Rebbau	203 Gartenbau	221 Ackerland i.w.S.	222 Naturwiesen i.w.S.	223 Heimweiden i.w.S.	241 Alpwiesen i.w.S.	242 Alp- und Juraweiden i.w.S.	243 Schafalpen i.w.S.
10 Artificial surfaces										
11 Befestigte Flächen			51	51						
12 Gebäude										
13 Treibhäuser				21						
14 Beetstrukturen			21	21	21	21		21		
15 Rasen			31	31						
16 Bäume auf künstlich angelegten Flächen										
17 Gemischte Kleinstrukturen			21	21						
20 Herbaceaous vegetation										
21 Gras-, Krautvegetation		31	31	31	21	31	31	31	31	31
30 Shrub vegetation										
31 Gebüsch			32	32						
32 Verbuschte Flächen			32	32		32	32	32	32	
33 Niederstammobst		33		33						
34 Reben			33	33						
35 Gärtnerische Dauerkulturen				33						
40 Trees										
41 Geschlossene Baumbestände		35								
42 Waldecken		35								
43 Waldstreifen		35								
44 Aufgelöste Baumbestände		35				12	12	12	12	13
45 Gebüschwaldbestände										
46 Lineare Baumbestände		34	34	34	34	34	34	34	34	34
47 Baumgruppen		34	34	34	34	34	34	34	34	34
50 Surfaces without vegetation										
51 Anstehender Fels										
52 Lockergestein			61	61						
53 Versteinte Flächen			36	36			36	36	36	
60 Water and wetlands										
61 Wasser										
62 Gletscher, Firn										
63 Nassstandorte						42	42	42	42	42
64 Schilfbestände					21	42	42	42	42	42

Land Cover according to AREA	Forest Land	Forest (non-agricultural use)				Unproductive	Lakes and rivers			Unproduc-tive land			
		301 Waldbestände	302 Aufforstungen	303 Holzschläge	304 Waldschadenflächen		401 Seen	402 Flüsse, Bäche	403 Hochwasserverbauungen	421 Keine Nutzung	422 Lawinen- und Steinschlagverbauungen	423 Alpine Sportinfrastruktur	424 Landschaftseingriffe
10 Artificial surfaces													
11 Befestigte Flächen							51	51	51		51	51	51
12 Gebäude													
13 Treibhäuser													
14 Beetstrukturen		12											
15 Rasen													
16 Bäume auf künstlich angelegten Flächen													
17 Gemischte Kleinstrukturen													
20 Herbaceaous vegetation													
21 Gras-, Krautvegetation			11	12	12		37	37	37	37	37	37	31
30 Shrub vegetation													
31 Gebüsch			11	12	12		32	32	32	32	32	32	32
32 Verbuschte Flächen			11	12	12		32	32	32	32	32	32	32
33 Niederstammobst													
34 Reben													
35 Gärtnerische Dauerkulturen		12											
40 Trees													
41 Geschlossene Baumbestände		12	11						12		12		
42 Waldecken		12	11	12	12				12		12		
43 Waldstreifen		12	11						12		12		
44 Aufgelöste Baumbestände		12	11	12	12				12		12	12	12
45 Gebüschwaldbestände		13							13		13		
46 Lineare Baumbestände			11	12	12		34	34	34	34	34	34	34
47 Baumgruppen			11	12	12		34	34	34	34	34	34	34
50 Surfaces without vegetation													
51 Anstehender Fels				13	13		61	61	61	61	61	61	61
52 Lockergestein				12	12		61	61	61	61	61	61	61
53 Versteinte Flächen			11	13	13		36	36	36	36	36	36	36
60 Water and wetlands													
61 Wasser							41	41	41				41
62 Gletscher, Firn										61			
63 Nassstandorte				12	13		42	42	42	42	42	42	42
64 Schilfbestände							42	42	42	42			

Kyoto combined categories:

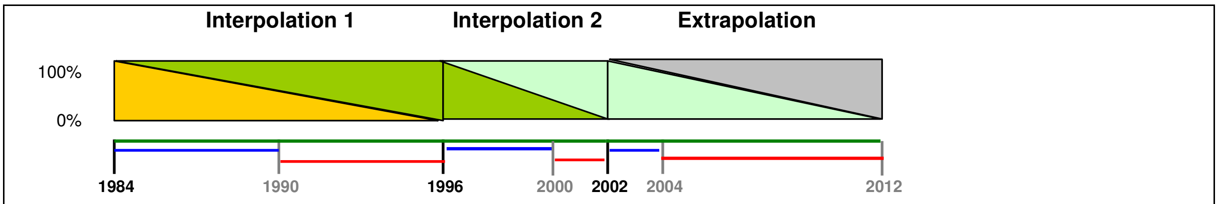
- 11 Afforestations
- 12 Managed forest
- 13 Unproductive forest
- 21 Cropland
- 31 Permanent grassland
- 32 Shrub vegetation
- 33 Vineyards, Niederstammobst, Tree nurseries
- 34 Copse
- 35 Orchards
- 36 Stony grassland
- 37 Unproductive grassland
- 41 Surface waters
- 42 Unproductive wetland
- 51 Buildings and construction (sites)
- 52 Herbaceous biomass in settlements
- 53 Shrubs in settlements
- 54 Trees in settlements
- 61 Other land

c) Interpolation and extrapolation of the status for each year

The exact dates of aerial photo shootings are known for each hectare (in Liechtenstein data available for the years 1984, 1996 and 2002). However, the exact year of the land-use change on a specific hectare is unknown. The actual change can have taken place in any year between the two land-use surveys. It is assumed that the probability of a land-use change from 1984 and 1996 and from 1996 to the 2002 survey is uniformly distributed over the respective interim period between two surveys. Therefore, the land-use change of each hectare has to be equally distributed over its specific interim period. However, a minimal unit of one hectare for reporting land-use changes was defined. This means that a change of for example one hectare within two years is assigned to only one of the two years. In the other year it is assumed that land-use change is zero.

Thus, the land-use status for the years between two data collection dates can be calculated by linear interpolation. Dates of aerial photo and the land-use categories of 1984 and 1996 for every hectare are used for these calculations. The status after 2002 was estimated by extrapolation

Example (Figure 22): A hectare has been assigned to the land-use category “Cropland” (CC 21) in 1984. A land-use change to “Shrubs in Settlements” (CC 53) has been discovered in 1996. And another change to “Herbaceous biomass in settlement was discovered in 2002.



Interpolation 1	Calculation formulas:	State 1990:
y diff = 1996-1984	Percentage "shrubs in settlements 1990" = (ybefore 1990/ydiff) * 100 [%]	50.00%
ybefore 1990 = 1990-1984		
yafter 1990 = 1996-1990	Percentage "Cropland 1990 " = (yafter 1990/ydiff)*100 [%]	50.00%
Interpolation 2		**State 2000:**
ydiff = 2002-1996	Percentage "herbaceous biomass in settlement 2000" = (ybefore 2000 /ydiff) * 100 [%]	66.66%
ybefore 2000 = 2000-1996		
yafter 2000 = 2002-2000	Percentage "shrubs in settlements 2000" = (yafter 2000/ydiff) * 100 [%]	33.33%
Extrapolation		**State 2004:**
ydiff = 2012-2002	Percentage "buildings and construction 2004" = (ybefore 2004/ydiff) * 100 [%]	20%
ybefore 2004 = 2004-2002		
yafter 2004 = 2012-2004	Percentage "herbaceous biomass in settlement 2004" = (yafter 2004/ydiff) * 100 [%]	80%

Figure 22 Hypothetical linear development of land-use changes between AREA1 and AREA2 and 2002 data considering as example a hectare changing from “cropland” to “shrubs in settlements” and then from "shrubs in settlements" to "herbaceous biomass in settlement” and finally to “buildings and constructions".

The ‘status 1990’ is determined by calculating the fractions of the two land-use categories for the year 1990. A linear development from “cropland” to “shrubs in settlements” during the whole interim period is assumed. Thus, in 1990 the hectare is split up in two fractions: 50.00% is “shrubs in settlements” and 50.00% is “cropland”. The same procedure can be applied for two survey dates between 1996 and 2002 (see Figure 22: example ‘status 2000’). Extrapolation to 2012 is done accordingly. The ‘status’ for each individual year in the period 1990-2004 for the whole territory of Liechtenstein results from the summation of the fractions of all hectares per combined category CC (considering the spatial strata where appropriate) (see Table 78).

7.2.3. Spatial Stratification

In order to quantify carbon stocks and increases/decreases, a further spatial stratification of the territory turned out to be useful. For forests and grassland three different altitudinal belts were differentiated. The whole territory of Liechtenstein is considered to be part of the pre-alpine region (Thürig et al. 2004).

Altitude data were available on a hectare-grid from the Office of Environmental Protection (2006c) and classified in belts <600 m a.s.l. (meters above sea level), 601-1200 m a.s.l., and >1200 m a.s.l. (Figure 23).

For cropland and grassland, two differentiate soil types (organic and mineral soils) were additionally differentiated.

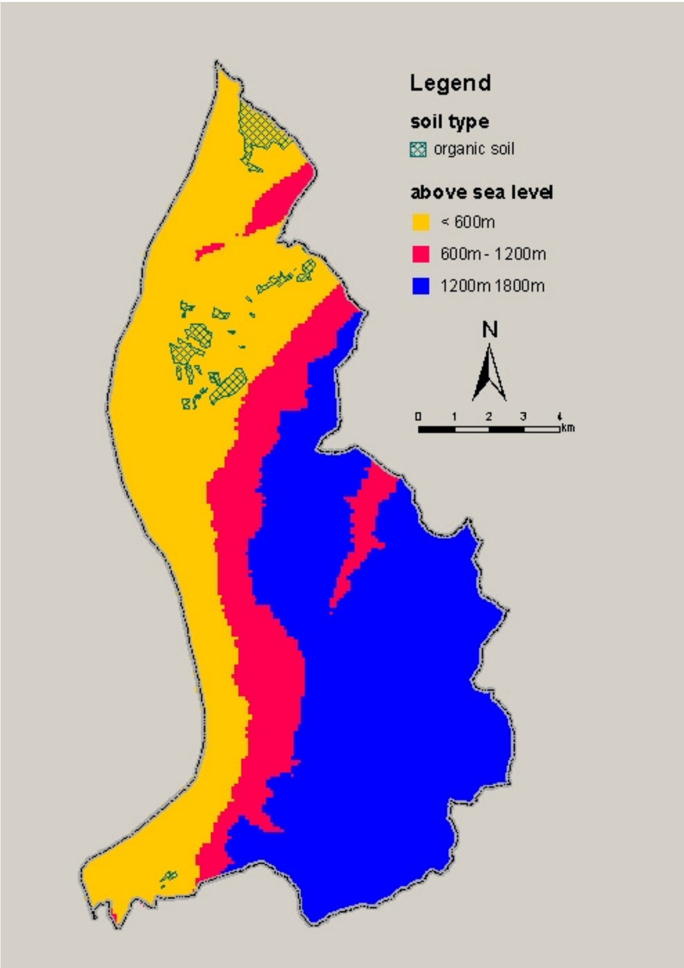


Figure 23 Map of Liechtenstein showing the altitude classes and soil types. Reference: Office of Environmental Protection 2006c.

7.2.4. The Land-use Tables and Change Matrices (activity data)

Table 78 shows the overall trends of land-use changes between 1990 and 2004. The data is resulting from interpolation and extrapolation in time and from spatial stratification (altitude classes and soil types). For example, the area of afforestations (combined category 11) decreases in all altitude classes between 43 and 57%, while the area of managed forests increases by 3% in an altitude over 1200 m.

CC-code	altitude	soil type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Change 1990-2004 (ha)	Change 1990-2004 (%)
11	< 600	n.s.	7	9	9	10	11	11	12	10	8	7	6	5	4	5	4	-3	-43%
	600-1200	n.s.	7	6	5	4	3	2	1	2	3	3	3	3	3	3	3	-4	-57%
	> 1200	n.s.	30	30	33	32	34	34	32	30	28	26	22	19	18	17	17	-13	-43%
12	< 600	n.s.	992	992	993	992	992	993	996	995	994	994	994	996	996	994	995	3	0%
	600-1200	n.s.	1955	1957	1957	1958	1959	1961	1960	1959	1959	1959	1959	1959	1958	1959	1957	2	0%
	> 1200	n.s.	2157	2164	2168	2175	2182	2190	2197	2199	2202	2203	2206	2207	2212	2218	2224	67	3%
13	< 600	n.s.	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0%
	600-1200	n.s.	3	3	3	3	3	4	4	3	3	2	2	1	1	1	1	-2	-67%
	> 1200	n.s.	614	619	623	625	629	630	635	635	635	637	638	638	638	640	642	28	5%
21	n.s.	mineral	1822	1817	1813	1809	1804	1798	1794	1791	1788	1782	1777	1774	1769	1766	1764	-58	-3%
	n.s.	organic	132	131	131	130	129	129	129	130	128	129	130	130	131	131	131	-1	-1%
31	< 600	mineral	1134	1126	1117	1109	1100	1094	1088	1083	1077	1072	1067	1064	1059	1051	1045	-89	-8%
	< 600	organic	61	62	61	61	61	61	60	59	60	59	57	57	56	56	55	-6	-10%
	600-1200	mineral	362	361	359	357	357	355	353	353	353	352	350	350	348	345	342	-20	-6%
	600-1200	organic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
	> 1200	mineral	1665	1661	1660	1657	1652	1649	1646	1646	1647	1648	1648	1651	1650	1646	1646	-19	-1%
	> 1200	organic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
32	< 600	n.s.	18	20	21	21	22	21	21	20	18	19	19	18	19	20	21	3	17%
	600-1200	n.s.	10	9	10	9	9	8	8	6	7	7	7	6	6	5	4	-6	-60%
	> 1200	n.s.	564	559	550	543	536	530	521	519	518	514	512	510	507	503	497	-67	-12%
33	n.s.	mineral	32	31	31	32	33	32	32	34	33	33	33	33	32	32	31	-1	-3%
	n.s.	organic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
34	< 600	n.s.	380	380	380	378	376	376	373	366	358	352	347	340	333	330	327	-53	-14%
	600-1200	n.s.	85	83	83	83	83	81	82	81	80	77	76	75	75	74	75	-10	-12%
	> 1200	n.s.	517	518	519	522	523	524	526	525	522	522	520	519	518	518	516	-1	0%
35	n.s.	mineral	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0%
	n.s.	organic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
36	n.s.	n.s.	345	344	343	343	343	342	340	341	346	347	347	350	351	349	348	3	1%
37	n.s.	n.s.	402	399	396	395	391	389	387	387	385	383	381	379	379	378	377	-25	-6%
41	n.s.	n.s.	217	217	216	216	215	216	215	215	215	216	215	216	215	213	213	-4	-2%
42	n.s.	n.s.	160	160	160	159	160	160	161	163	164	165	166	165	165	167	168	8	5%
51	n.s.	n.s.	905	918	929	942	954	967	982	997	1017	1033	1050	1067	1084	1100	1108	203	22%
52	n.s.	n.s.	305	305	307	308	311	315	316	319	323	329	335	337	342	346	350	45	15%
53	n.s.	n.s.	16	15	17	15	14	13	11	12	11	13	14	16	14	12	13	-3	-19%
54	n.s.	n.s.	142	146	149	154	156	159	161	159	156	153	150	145	145	146	147	5	4%
61	n.s.	n.s.	1009	1007	1006	1007	1007	1005	1006	1010	1011	1014	1019	1020	1022	1024	1028	19	2%
Sum			16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	0	0%

Table 78 Statistics of land use (CC) for the whole period 1990-2004 (in ha) and change (absolute and relative) between 1990 and 2004. The table displays the data for the land-use categories remaining the same land-use category (excluding land converted to a specific category).

The mean annual rates of change in the whole country (change-matrix) are achieved by adding up the mean annual change rates of all hectares per combined category (CC). Table 79 shows an overview of the mean annual changes of all CC in 1990 as an example. The totals of the columns are equal to the total increase of one specific category. The totals of the rows are equal to the total decrease of one specific category. The absolute values of increases and decreases are identical.

For calculating the carbon stock changes, fully stratified land-use change matrices are used for each year. In principle, those matrices consists of various matrices like the one shown in Table 79, one for each spatial stratum (see section 7.2.3.).

	Combined category code	To																		
		11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Decrease
From	11		3																	3
	12			1									1		2					4
	13																			0
	21					3		1							3	1				8
	31	1	1		3		2	1	5						6	3			1	23
	32		4	4		2			2											12
	33														1					1
	34	1	4			3									1	1				10
	35																			0
	36					1														1
	37						1		1											2
	41																		1	1
	42		1																	1
	51															1				1
	52														3			2		5
	53																			0
	54														1	1				2
	61						1						1							2
	Increase	2	13	5	3	9	4	2	8	0	0	0	2	0	17	7	0	2	2	76

Table 79 Mean annual rates of land-use change in 1990 (change matrix). Units: ha/year

7.2.5. Carbon Emission Factors and Stocks at a Glance

Table 80 lists all values of carbon stocks, increases, decreases and net changes of carbon specified for land-use category (CC) and associated spatial strata for the year 1990. These values remain constant during the period 1990-2004 (exception of carbon stock of afforestations and of managed forests, which are increasing every year due to annual net growth).

CC-code	altitude zone z	soil type	carbon stock in living biomass (stockCl,i) 1990	carbon stock in dead organic matter (stockCd,i)	carbon stock in soil (stockCs,i)	growth of living biomass (increaseCl,i)	harvesting of living biomass (decreaseCl,i)	net change in dead organic matter (changeCd,i)	net change in soil (changeCs,i)
	Strata		**Stocks (t C ha-1)**			**Changes (t C ha-1 yr-1)**			
11	1	n.s.	12.35	0	75.30	2.56	0	0	0
	2	n.s.	6.70	0	75.30	1.70	0	0	0
	3	n.s.	2.41	0	75.30	0.85	0	0	0
12	1	n.s.	156.80	4.45	92.70	4.49	-3.05	0	0
	2	n.s.	152.16	4.01	92.70	4.18	-3.11	0	0
	3	n.s.	116.23	3.98	92.70	2.52	-2.06	0	0
13	1	n.s.	41.41	0	92.70	0	0	0	0
	2	n.s.	43.01	0	92.70	0	0	0	0
	3	n.s.	26.23	0	92.70	0	0	0	0
21	n.s.	0	5.66	0	53.40	0	0	0	0
	n.s.	1	5.66	0	240.00	0	0	0	-9.52
31	1	0	7.45	0	62.02	0	0	0	0
	1	1	7.45	0	240.00	0	0	0	-9.52
	2	0	6.26	0	67.50	0	0	0	0
	2	1	6.26	0	240.00	0	0	0	-9.52
	3	0	4.45	0	75.18	0	0	0	0
	3	1	4.45	0	240.00	0	0	0	-9.52
32	1	n.s.	11.60	0	68.23	0	0	0	0
	2	n.s.	11.60	0	68.23	0	0	0	0
	3	n.s.	11.60	0	68.23	0	0	0	0
33	n.s.	0	3.74	0	53.40	0	0	0	0
	n.s.	1	3.74	0	240.00	0	0	0	-9.52
34	1	n.s.	11.60	0	68.23	0	0	0	0
	2	n.s.	11.60	0	68.23	0	0	0	0
	3	n.s.	11.60	0	68.23	0	0	0	0
35	n.s.	0	24.63	0	64.76	0	0	0	0
	n.s.	1	24.63	0	240.00	0	0	0	-9.52
36	n.s.	n.s.	4.06	0	26.31	0	0	0	0
37	n.s.	n.s.	6.05	0	68.23	0	0	0	0
41	n.s.	n.s.	0	0	0	0	0	0	0
42	n.s.	n.s.	7.96	0	154.00	0	0	0	0
51	n.s.	n.s.	0	0	0	0	0	0	0
52	n.s.	n.s.	5.80	0	53.40	0	0	0	0
53	n.s.	n.s.	4.80	0	53.40	0	0	0	0
54	n.s.	n.s.	4.80	0	53.40	0	0	0	0
61	n.s.	n.s.	0	0	0	0	0	0	0

Legend

altitude zones:		*soil type:*		n.s. = no stratification
1	< 600 m	0	mineral soil	
2	601 - 1200 m	1	organic soil	
3	> 1200 m			

Table 80 Carbon stocks and changes in biomass, dead organic matter and soils for the combination categories (CC), disaggregated for altitude and soil type. These values are valid for the whole period 1990-2004 (no annual changes).

On organic soils, a value of 240 t C ha^{-1} for stock C_s was assumed for all land-use categories, even where this is not explicitly indicated in Table 80, i.e. where no stratification according to soil type is indicated (e.g. in CC 12). Thus, when calculating carbon changes in soils as a consequence of land-use changes, the difference of carbon stocks in organic soils is always zero.

Carbon data for forests are derived from monitoring data of the Swiss National Forest Inventory NFI I and NFI II. The data for agriculture, grassland and settlements are based on experiments, field studies, literature and expert estimates. For wetlands and other land, expert estimates or default values are available. The deduction of the individual values is explained in detail in the following chapters.

7.3. Source Category 5A – Forest Land

7.3.1. Source Category Description

Only temperate forests are occurring in Liechtenstein. The definition of forest land is based on the Swiss definition. According to the Swiss land use statistics (SFSO 2005, and 2006a) and the Swiss National Forest Inventory (NFI; EAFV/BFL 1988; Brassel and Brändli 1999), forest land is defined by the following criteria:

- Normal dense forest: tree crown cover > 60%, width > 25m, height > 3m.
- Open forest: tree crown cover 20-60%, width > 50m, height > 3m.
- Other forest land: afforestations, brush forest, young or temporarily unstocked stands.

For reporting in the CRF tables, forest land was subdivided into afforestations (CC 11), managed forest (CC 12) and unproductive forest (CC 13) based on the land use and land cover categories (see Table 76; FOEN 2006a; SFSO 2006a).

7.3.2. Methodological Issues

a) Swiss National Forest Inventories (NFI)

Data for growing stock, gross growth, cut (harvesting), and mortality was derived from the first and the second Swiss National Forest Inventory (see Table 81). The NFI I was conducted between 1983 and 1985 (EAFV/BFL 1988), the NFI II was conducted between 1993 and 1995 (Brassel and Brändli 1999).

	NFI I	NFI II	NFI III
Inventory cycle	1983-1985	1993-1995	2004-2006
Grid size	1 x 1 km	1.4 x 1.4 km	1.4 x 1.4 km
Terrestrial sample plots	~12’000	~6’000	~6’000
Measured single trees	~130’000	~70’000	~70’000

Table 81 Characteristics of the Swiss National Forest Inventories I, II and III.

b) Stratification, Spatial strata

As in Switzerland, forests in Liechtenstein reveal a high heterogeneity in terms of elevation, growth conditions, and tree species composition. To find explanatory variables that significantly reduce the variance of gross growth and biomass expansion factors (BEFs) an analysis of variance was done in Switzerland (Thürig et al. 2005a). The explanatory variables considered are (see also 7.2.3):

- altitude (<601 m, 601-1200 m, >1200 m)
- tree species (coniferous and deciduous species).

In Liechtenstein, most forests are mixed stands. It was assumed that the mix between coniferous and deciduous species in different altitudes is identical as in the prealpine region of Switzerland (no national data considered).

In Switzerland, the forest area derived by the land use statistics does not allow separating coniferous and deciduous sites. If species specific measures for growing stock, gross growth, harvesting and BEFs are to be applied, the total forest area has to be divided according to the species mixture. It was assumed that the space asserted by a single tree is highly correlated with its basal area. The required ratio of coniferous forest area (R_c) per spatial stratum (Table 82) was calculated by dividing the sum of the basal area of the conifers (BA_c) over the sum of the basal area of all trees (BA).

$R_{ci} = BA_{ci} / BA_i$ i = spatial strata

As both species add up to 1 (or 100%) the rate of deciduous forest area (R_d) is:

$R_{di} = 1 - R_{ci}$ i = spatial strata

The following Swiss ratio of coniferous and deciduous species per altitude class was implied:

Altitude [m]	Coniferous	Deciduous
<601	0.395	0.605
601-1200	0.713	0.287
>1200	0.925	0.075

Table 82 Ratio of coniferous and deciduous species (source: NFI II; Brassel and Brändli 1999).

c) Biomass Expansion Factors (BEF)

The Swiss Biomass Expansion Factors were applied in Liechtenstein (FOEN 2006).

In the Swiss National Forest Inventory, growing stock, gross growth, cut (harvesting) and mortality is expressed as round wood over bark. Round wood over bark was expanded to total biomass as done in Thürig et al. (2005) by applying allometric single-tree functions to all trees measured at the NFI II. BEFs were then calculated for each spatial stratum as the ratio between round wood over bark (m^3 ha^{-1}) and the total above- and belowground biomass (t ha^{-1}). Table 83 shows the BEFs for coniferous and deciduous species stratified for altitude.

Altitude [m]	Conifers		Deciduous species	
	Number of trees measured	BEFs	Number of trees measured	BEFs
< 600	129	1.48	239	1.49
601-1200	4220	1.48	1980	1.49
> 1200	2909	1.59	241	1.56

Table 83 Biomass expansion factors (BEFs) to convert round-wood over bark (m^3 C ha^{-1}) to total biomass (t C ha^{-1}) for conifers and deciduous species, respectively.

d) Wood Densities

To convert round wood over bark ($m^3\ ha^{-1}$) into $t\ ha^{-1}$ it was multiplied by a species-specific density. Table 84 shows the applied densities.

	Wood density [$t\ m^{-3}$]
Coniferous trees	0.4
Deciduous trees	0.55

Table 84 Wood densities for coniferous and deciduous trees (Vorreiter 1949).

e) Carbon Content

The IPCC default carbon content of solid wood of 50% was applied (IPCC 2003; p. 3.25).

f) Growing Stock, Gross Growth and Cut & Mortality in Managed Forests (CC 12)

The Swiss values for growing stock, gross growth, cut and mortality were applied in Liechtenstein (FOEN 2006).

Growing stock, gross growth, cut and mortality for managed forests were derived from those 5'425 sample plots measured at both Swiss National Forest Inventories NFI I and NFI II (Kaufmann 2001). All values derived from the NFI I and II are related to round wood over bark (with stock, without branches) and are given in $m^3\ ha^{-1}$ per spatial stratum (Table 85 and Table 86).

Coniferous trees				
Altitude [m]	**Growing stock 1985 [$m^3\ ha^{-1}$]**	**Growing stock 1995 [$m^3\ ha^{-1}$]**	**Gross growth [$m^3\ ha^{-1}\ 10.1yr^{-1}$]**	**Cut and mortality [$m^3\ ha^{-1}\ 10.1yr^{-1}$]**
<601	473.58	506.79	132.36	99.14
601-1200	482.43	515.95	132.71	98.85
>1200	356.09	372.59	76.12	59.58

Note: 10.1 years correspond to the average inter-survey period between NFI I and NFI II; see below.

Table 85 Growing stock, gross growth, cut and mortality for coniferous trees (related to coniferous forest area).

Deciduous trees				
Altitude [m]	**Growing stock 1985 [$m^3\ ha^{-1}$]**	**Growing stock 1995 [$m^3\ ha^{-1}$]**	**Gross growth [$m^3\ ha^{-1}10.1yr^{-1}$]**	**Cut and mortality [$m^3\ ha^{-1}\ 10.1yr^{-1}$]**
<601	379.93	427.12	115.75	68.56
601-1200	374.75	427.88	113.4	60.82
>1200	257.27	311.7	72.32	17.88

Note: 10.1 years correspond to the average inter-survey period between NFI I and NFI II; see below.

Table 86 Growing stock, gross growth, cut and mortality for deciduous trees (related to deciduous forest area).

Conversion of NFI data to annual estimates of gross growth and cut & mortality

The average inter-survey period between the Swiss NFI I and NFI II is not exactly 10 years, but 10.1 years. With regard to the individual spatial strata, the variance is even larger (Table 87).

Altitude [m]		
< 601	**601-1200**	**> 1200**
10.4	10.1	10.0

Table 87 Average inter-survey period [in years] between NFI I and NFI II for all spatial strata.

To convert gross growth and cut & mortality measured between NFI I and II into average annual gross growth and average annual cut & mortality, those data had to be divided by the time periods shown in Table 87.

[annual gross growth $_i$ = [gross growth between NFI I and II] $_i$ / time period $_i$

[annual cut & mortality] $_i$ = [cut & mortality between NFI I and II] $_i$ / time period $_i$

where i indicates the different altitudes.

Annual cut and mortality

In order to simplify the estimation of annual cut and mortality, it is assumed that the annual cut and mortality is constant over the whole time period. This is in difference to the Swiss calculation, where different annual cut and mortality amounts are estimated. Liechtenstein implies the Swiss values for the year 1990 for all years between 1990 and 2004.

To calculate the annual cut and mortality (CMy) for the year 1990, the total amount of cut and mortality was distributed among the ten years between 1986 and 1995 and weighted by the percentage of the annual harvesting amounts taken from the forest statistic (SFSO 2006b, SAEFL 2005b).

The annual cut and mortality for coniferous and deciduous trees is as follows:

Coniferous trees		
Altitude [m]	**Annual cut and mortality [m^3 ha^{-1}]**	**Annual cut and mortality [t C ha^{-1}]**
<601	11.34	3.36
601-1200	11.3	3.35
>1200	6.81	2.17

Table 88 Annual cut and mortality for coniferous trees in m^3 ha^{-1} and t C ha^{-1} (value for 1990, applied for all years).

Deciduous trees		
Altitude [m]	**Annual cut and mortality [m^3 ha^{-1}]**	**Annual cut and mortality [t C ha^{-1}]**
<601	6.95	2.85
601-1200	6.16	2.53
>1200	1.81	0.78

Table 89 Annual cut and mortality for deciduous trees in m^3 ha^{-1} and t C ha^{-1} (value for 1990, applied for all years).

Gross growth

It is assumed that the growth rate of living biomass is constant over the whole time period. Liechtenstein applies the Swiss annual growth values for the year 1990 for all the years between 1990 and 2004. These values are displayed in Table 90.

Growing stock of managed forests (CC 12) 1990-2004																	
	carbon stock in living biomass (stockCl,i)															annual growth of living biomass (increase)	annual harvesting of living biomass (decrease)
Altitude	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**		
< 601 m	156.80	158.24	159.68	161.13	162.57	164.01	165.46	166.90	168.34	169.78	171.23	172.67	174.11	175.55	177.00	4.49	-3.05
601-1200 m	152.16	153.23	154.30	155.37	156.44	157.51	158.59	159.66	160.73	161.80	162.87	163.94	165.01	166.08	167.15	4.18	-3.11
> 1200 m	116.23	116.69	117.15	117.61	118.07	118.53	118.99	119.45	119.92	120.38	120.84	121.30	121.76	122.22	122.68	2.52	-2.06

Table 90 Growing stock of managed forests (CC12) 1990-2004 in t C ha^{-1}.

g) Growing Stock in Unproductive Forests (CC 13)

The unproductive forest in Liechtenstein mainly consists of brush forest and inaccessible forest. The same carbon stock per hectare as in Switzerland is assumed.

Brush forest

No data from the Swiss National Forest Inventory (NFI) are available to derive their growing stock. Therefore, following estimations were made:

Average growing stock: 40 m^3 ha^{-1}

Wood density for coniferous trees: 0.4 t m^{-3} (Vorreiter 1949)

BEF: 1.45 (Burschel et al. 1993)

Carbon content: 50% (IPCC default carbon content)

Carbon stock : 40 m^3 ha^{-1} * 0.4t m^{-3} * 1.45 * 0.5 = 11.6 t C ha^{-1}

Inaccessible forest

Inaccessible forest in Liechtenstein is mainly located in higher altitudes (above 1200 m). No data from the Swiss National Forest Inventory (NFI) are available to derive the stock growth. Therefore, the following assumptions were made:

Average growing stock: 150 m^3 ha^{-1}

Wood density for coniferous trees: 0.4 t m^{-3} (Vorreiter 1949)

BEF: 1.45 (Burschel et al. 1993)

Carbon content: 50% (IPCC default carbon content)

Carbon stock : 150 m^3 ha^{-1} * 0.4t m^{-3} * 1.45 * 0.5 = 43.5 t C ha^{-1}

Carbon content of unproductive forests (CC 13): Weighted means

The carbon content of unproductive forest was calculated as a weighted average of brush forest and inaccessible forest per spatial stratum:

$[\text{weighted C content}]_i = RS_i * CS + (1- RS_i) * CI$

where RS_i is the rate of the brush forest per spatial stratum i,

CS is the carbon content of brush forest (11.6 t C ha^{-1}),

CI is the carbon content of inaccessible forest (43.5 t C ha^{-1}).

Table 91 shows the carbon content per altitude class in t C ha^{-1}.

Altitude [m]	Rate of brush forest	Rate of inaccessible forest	Weighted C content [t C ha^{-1}]
<601	0.0656	0.9344	41.41
601-1200	0.0154	0.9846	43.01
>1200	0.541	0.459	26.23

* Derived from the NFI II (Brassel and Brändli 1999)

Table 91 Rate of brush forest and inaccessible forest and the resulting weighted carbon content in t C ha-1 of Swiss unproductive forests (CC 13) specified for all spatial strata.

h) Dead Wood in managed forests (CC 12)

The Swiss carbon stock amounts per hectare are applied in Liechtenstein.

In the second Swiss NFI, all dead trees (standing and lying) larger than 12 cm were measured. Thus, an estimate of the dead-wood pool in Swiss managed forests (CC 12) can be done.

	Dead wood [m^3 ha^{-1}]
Lying trees	3.7
Standing trees	8.4
Total	12.2

Table 92 Dead wood in Swiss managed forests (CC12) (Brassel and Brändli 1999).

Applying the same wood densities, BEFs and carbon content as for the living growing stock, dead wood per spatial stratum can be estimated (Table 93).

Altitude [m]	Carbon in dead biomass [t C ha^{-1}]
<601	4.45
601-1200	4.01
>1200	3.98

Table 93 Dead wood in managed forests (CC12) per altitude class in t C ha-1.

i) Carbon Stock of Afforestations (CC 11)

Growing stock and growth

The Swiss growing stock and growth rates are applied in Liechtenstein. The following paragraph gives some further explanations about the Swiss calculation of carbon stock changes.

Swiss methodology (excerpt from NIR CH, chp 7.3.2, FOEN 2006):

As the results from the NFI III were not yet available, the average growing stock and growth of afforestations were empirically assessed with NFI I and II, specifically with those stands that were approximately 10 years old in the first NFI and 20 years old in the second NFI. The average growing stock of those 20 year old stands was derived from NFI II. The NFI data were therefore stratified for site quality It was assumed that forest areas below 600 m show a *good site quality, areas between 600 and 1200 m a moderate site quality, and forest areas above 1200 m show a poor site quality. The growing stock of forest stands on good sites was 90 m^3 ha^{-1}. The growing stock on moderate sites was assumed to be one-third smaller than on good sites (60 m^3 ha^{-1}), and two-third smaller on bad sites (30 m^3 ha^{-1}). As trees below 12 cm DBH were not measured in the NFI, the growing stock of 10 year old stands on good sites was assumed to be 2 m^3 ha^{-1}. Within the first few years of stand age, the growing stock was assumed to develop exponentially. The development of the growing stock on good sites between 10 and 20 years was therefore simulated by calibrating an exponential growth function. To simulate the development of growing stock on intermediate and poor sites, growing stock was assumed to develop one-third slower on intermediate, and two-third slower on poor sites. The annual growth was calculated as the difference between growing stocks of two following years. These assumptions are not valid for single stands, but can be applied as a rough simplification. Table 94 shows the simulated growing stock and growth for all three site qualities.*

Stand age [yr]	**< 601 m altitude**		**601 - 1200 m altitude**		**> 1200 m altitude**	
	Growing stock [$m^3 ha^{-1}$]	**Growth** [m^3 ha^{-1} $year^{-1}$]	**Growing stock** [$m^3 ha^{-1}$]	**Growth** [m^3 ha^{-1} $year^{-1}$]	**Growing stock** [$m^3 ha^{-1}$]	**Growth** [m^3 ha^{-1} $year^{-1}$]
0-9	0	0	0	0	0	0
10	**2**	2	0	0	0	0
11	7	5	0	0	0	0
12	13	6	1	1	0	0
13	19	6	5	4	0	0
14	27	8	10	5	0	0
15	35	8	16	6	1	1
16	44	9	23	7	5	4
17	54	10	31	8	10	5
18	66	12	40	9	16	6
19	78	12	50	10	23	7
20	**90**	12	**60**	10	**30**	7

Table 94 Estimated average growing stock and annual growth of forest stands in stemwood (defined in Table 24) up to 20 years (CC11) specified for altitude zone.

To convert the estimated growing stock and growth into carbon, the following equations were applied:

*C stock in living biomass = Average growing stock * density * BEF * C-content*

*Growth of living biomass = Average growth * density * BEF * C-content*

In Table 95, abbreviations and units are explained. Table 96 shows the parameters and the converted values.

Name	*Description*	*Value*	*Unit*
Average growing stock	*Average growing stock of stemwood over bark, without branches*	*See Table 96*	*$m^3\ ha^{-1}$*
Average growth	*Average growth per ha and year*	*Table 96*	*$m^3\ ha^{-1}\ year^{-1}$*
Density	*Tree density averaged for coniferous and deciduous trees*	*0.47*	*$t\ m^{-3}$*
BEF	*Biomass expansion factor to convert stemwood over bark into total tree biomass (Burschel et al. 1993); averaged value for coniferous and deciduous trees.*	*1.45*	*-*
C-content	*Carbon to total biomass ratio (IPCC default)*	*0.5*	*-*
C stock in living biomass	*Carbon content in total above- and belowground biomass*	*See Table 96*	*$t\ C\ ha^{-1}$*
Growth of living biomass	*Growth of carbon in t C per ha and year*	*See Table 96*	*$t\ C\ ha^{-1}\ year^{-1}$*

Table 95 Conversion of growing stock and growth to total carbon in biomass.

Altitude [m]	*Average growing stock [$m^3\ ha^{-1}$]*	*Average growth [$m^3\ ha^{-1} year^{-1}$]*	*Density [$t\ m^{-3}$]*	*BEF*	*Carbon content*	*Carbon stock in living biomass [$t\ C\ ha^{-1}$]*	*Growth of living biomass [$t\ C\ ha^{-1}\ year^{-1}$]*
0-600	*36.25*	*7.5*	*0.47*	*1.45*	*0.5*	*12.35*	*2.56*
601-1200	*19.67*	*5*	*0.47*	*1.45*	*0.5*	*6.70*	*1.70*
>1200	*7.08*	*2.5*	*0.47*	*1.45*	*0.5*	*2.41*	*0.85*

Table 96 Carbon stock in living biomass and growth of living biomass in afforestations (CC11) specified for altitude zone.

k) Soil carbon in Managed Forests (CC12), Unproductive Forests (CC13) and Afforestations (CC11)

According to a study of Perruchoud et al (2000), a carbon stock of mineral forest soils of 75.3 t C ha $^{-1}$ in 0-30 cm topsoil is assumed for the pre-alpine region (which also covers the area of Liechtenstein).

The soil horizons L (litter), F (fermentation) and H (humus) were not included in the soil samples analyzed by Perruchoud et al. (2000). However, especially in forests, those horizons may contain substantial amounts of carbon and should be included in the estimation of forest soil carbon. In a study done by Moeri (2006) soil carbon of organic soil horizons on mineral soils were estimated. According to this study, the soil carbon in these soil horizons in the pre-alpine region, which is relevant for Liechtenstein, is 17.4 t C ha $^{-1}$. Further details are displayed in Table 97.

	L Horizon	F Horizon	H Horizon	Total
Soil carbon (in t C ha^{-1})	4.4 (± 3.2)	6.4 (± 9.4)	6.6 (± 19.8)	17.4 (± 28.5)

Table 97 Soil organic carbon of mineral forest soils (CC12, CC13) in organic soil horizons in t C ha^{-1} in the pre-alpine region. The average values ± standard deviation are given.

Unlike stated in the GPG LULUCF (IPCC 2003), soil carbon of mineral forest soils in organic soil horizons was added to the soil carbon of the mineral layer for Swiss managed and unproductive forests (CC 12 and CC 13). According to IPCC (2003; Table 3.1.2) soil carbon of the organic soil horizons should be accounted as dead organic matter, together with dead wood.

For afforestations (CC 11), the amount of soil carbon in the soil organic horizons was assumed to be zero. Total soil carbon was defined as soil carbon contained in the 0-30 cm mineral topsoil.

Due to following reasons it is assumed that in the years 1990 to 2004 forest soils in Switzerland as well as in Liechtenstein were no source of carbon:

- Within the last decades, no drastic changes of management practices in forests have been taken place due to restrictive forest laws.
- Fertilization of forests is prohibited in Liechtenstein. Drainage of forests is not common practice in Liechtenstein.
- As growing stock has increased since many years, soil carbon is assumed to increase due to increasing litter production.
- As shown in the study by Thürig et al. (2005), wind-throw may have a slightly increasing effect on soil carbon. However, this study neglected the effect of soil disturbances which could equalize those effects.

l) Specifications for Calculating Carbon Fluxes in Case of Land-use Change Comprising Forest Land

According to the land use statistic, certain areas switch from a non-forest land use category to forest. These are mainly areas that used to be populated with grassland or woody biomass (see Table 79, combined category 32) not fulfilling the definition of minimal forest density and area. According to the stock change approach, the growing stock of e.g. shrub vegetation (CC 32) (living biomass and soil carbon) should be subtracted and the average growing stock of forests should be added. However, these forests are supposed to have a growing stock smaller than the growing stock of an average forest and adding the average growing stock of forest areas would possibly overestimate the carbon increase. In terms of IPCC good practice a conservative assumption was met (see also Chapter 7.2.1): The amount of living biomass (carbon stock in living biomass) on land changing from non-forest to forest was not increased but left unchanged. The annual increase of biomass (carbon flux) on these areas was approximated by the annual gross growth rate of the respective forest type (CC 11, 12 or 13). The change of soil carbon was not considered and was set to zero.

Cut and mortality was inferred from the Swiss land-use statistics NFI I and NFI II, applying the stock change approach on forest areas remaining forest. Thus, the total harvesting amount was already considered. To avoid double-counting of the harvesting amount on areas changing from non-forested to forested areas, no additional loss in terms of cut and mortality was accounted for, but the converted areas were only multiplied with the average annual gross growth of the respective spatial stratum.

The annual area of forest changing to other land use categories was also derived by land use statistics. To account for the “decrease of carbon”, above- and belowground biomass, the amount of dead-wood and the amount of soil carbon of forest areas changing into other land use categories were subtracted. To account for the “increase of carbon”, the carbon stock in biomass and soil of the new land use category was added.

m) N_2O Emissions from N Fertilization and Drainage of Soils

Fertilization of forests is prohibited by law in Liechtenstein. Therefore, no emissions are reported in CRF Table 5(I).

Drainage of forests is not common practice in Liechtenstein. As a first guess drainage activity was set to zero, and no emissions are reported for forest land in CRF Table 5(II).

n) Emissions from Wildfires

Controlled burning of forests is not allowed in Liechtenstein. Some information on wildfires affecting forest land is available. It is however not taken into account since the area affected by wildfires in some years is always much below one hectare. Emissions from wildfires are insignificant and are therefore set to zero. No emissions are reported for forest land in CRF Table 5 (V).

7.3.3. Uncertainties and Time-Series Consistency

No uncertainty assessments have been carried out in Liechtenstein. According to the Swiss National Inventory Report (FOEN 2006), the uncertainty of gross growth, cut and mortality is assessed as low. In case of BEFs, the uncertainty is assessed as medium. In case of soil carbon pool, the uncertainty is assessed as medium.

Time series are consistent.

7.3.4. Source-Specific QA/QC and Verification

No source-specific QA/QC activities have been carried out.

7.3.5. Source-Specific Recalculations

For the first time, emissions and removals have been estimated for the whole time-series and according to the new Swiss methodology. Therefore, no recalculations have been carried out.

7.3.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

7.4. Source Category 5B – Crop Land

7.4.1. Source Category Description

Croplands in Liechtenstein belong to the cold temperate wet climatic zone. Carbon stocks in aboveground living biomass and carbon stocks in mineral and organic soils are considered. Croplands (CC 21) include annual crops and leys in arable rotations.

7.4.2. Methodological Issues

a) Carbon in Living Biomass

The Swiss mean biomass stock for cropland of 5.66 t C ha^{-1} was implied in Liechtenstein. The value is based on area-weighted means of standing stocks at harvest for the seven most important annual crops (wheat, barley, maize, silage maize, sugar beet, fodder beet, potatoes) (FOEN 2006).

b) Carbon in Soils

The Swiss mean soil organic carbon stocks for cropland (53.40 ± 5 t C ha^{-1}) and for cultivated organic soils (240 ± 48 t C ha^{-1}) were implied in Liechtenstein. Both are based on studies from FAL (2003a) and Leifeld et al. (2005).

c) Changes in Carbon Stocks

Changes in carbon stocks in mineral soil are assumed to be zero for cropland remaining cropland. Carbon stock changes in soil for cropland remaining cropland occur only in the case of shifts from mineral to organic soils or vice versa. These carbon stock changes are not estimated in Liechtenstein since data on mineral and organic soils is only available for one year. Changes can therefore not be estimated.

d) N_2O Emissions from Land Use Conversion to Cropland

N_2O emissions as a result of the disturbance associated with land-use conversion to cropland are reported in CRF Table 5 (III). The emissions are calculated with default values proposed by IPCC (2003, following Equations 3.3.14 and 3.3.15, and Chapter 3.3.2.3.1.2):

Emission(N_2O) = deltaC_s * 1 / (C : N) * EF1 * 44 / 28 [Gg N_2O]

where:

deltaC_s: soil carbon loss in soils induced by land-use conversion to cropland [Gg C]

C:N: IPCC default C:N ratio = 15 in forest or grassland soils

EF1: IPCC default emission factor = 0.0125 kg N_2O-N (kg $N)^{-1}$

Where negative emissions would occur (when the deltaC_s is negative), they are set to zero.

e) Carbon Emissions from Agricultural Lime Application

Emissions from lime application are not occurring in Liechtenstein.

7.4.3. Uncertainties and Time-Series Consistency

No uncertainty assessments have been carried out in Liechtenstein. Some assessments have been carried out in Switzerland. Where available, uncertainties for soil carbon stocks are given together with the mean value in the text. The relative uncertainty in yield determination has been estimated at 13% for biomass carbon from agricultural land (Leifeld and Fuhrer 2005). Data on biomass yields for different elevations and management intensities as published by FAL/RAC (2001) are based on many agricultural field experiments and have a high reliability.

Time-series is consistent.

7.4.4. Source-Specific QA/QC and Verification

No source-specific QA/QC has been carried out.

7.4.5. Source-Specific Recalculations

For the current submission all emissions have been calculated for the first time, based to the Swiss methodology with the new combined categories. Therefore, no recalculation has been carried out.

7.4.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

7.5. Source Category 5C – Grassland

7.5.1. Source Category Description

Liechtenstein's grasslands belong to the cold temperate wet climatic zone.

Carbon stocks in living biomass and carbon stocks in soils are considered. Grasslands include permanent grassland (CC 31), shrub vegetation (CC 32), vineyards, low-stem orchards ('Niederstammobst') and tree nurseries (CC 33), copse (CC 34), orchards ('Hochstammobst'; CC 35), stony grassland (CC 36), and unproductive grassland (CC 37).

7.5.2. Methodological Issues

a) Carbon in Living Biomass

Permanent Grassland (CC 31)

Permanent grasslands range in altitude from < 300 m to 3000 m above sea level. Because both biomass productivity and soil carbon rely on the prevailing climatic and pedogenic conditions, grassland stocks were calculated separately for three altitude zones (corresponding to those used in source category 5A - Forest Land).

Swiss values for carbon stock in living biomass of permanent grassland are implied (FOEN 2006). The estimation of carbon stocks is based on annual cumulative yield of differentially managed grasslands (FAL/RAC 2001) and on root biomass-C (Ammann et al.). The values for the different altitude zones including roots are displayed in Table 98.

Altitude [m]	C_l [t C ha^{-1}]
<601	7.45
601-1200	6.26
>1200	4.45

Table 98 Living biomass Cl of permanent grassland (CC 31).

Shrub Vegetation (CC 32) and Copse (CC 34)

Swiss values for living biomass in shrub vegetation and copse were implied (FOEN 2006). Due to a lack of more precise data, the living biomass of shrub vegetation and copse was assumed to correspond with brush forest described in section 7.3.2. g. Brush forest is assumed to contain 11.6 t C ha^{-1}.

Vineyards, Low-stem Orchards and Tree Nurseries (CC 33)

Swiss values for standing carbon stock of living biomass (Cl) for CC 33 were implied (FOEN 2006). Cl of vineyards is 3.61 t C ha^{-1}, Cl of low-stem orchards is 12.25 t C ha^{-1}. For tree nurseries no stand densities are available. The mean carbon stock for this combined category is 3.74 t C ha^{-1}.

Orchards (CC 35)

Orchards are loosely planted larger fruit trees (‘Hochstammobst’) with grass understory. Swiss values for the biomass stock of orchards were implied (FOEN 2006). The total biomass stock of this combined category (including the biomass of the grassland) is assumed to be 24.63 t C ha^{-1}.

Stony Grassland (CC 36)

Swiss values for carbon stock of stony grassland were implied (FOEN 2006). The carbon content is assumed to be 4.06 t C ha^{-1}.

Unproductive Grassland (CC 37)

The category CC 37 includes grass and herbaceous plants at watersides of lakes and rivers including dams and other flood protection structures, constructions to protect against avalanches and rock slides, and alpine infrastructure.

Swiss mean value of all grasslands of 6.05 t C ha^{-1} is implied, as for none of these land-use types, biomass data are currently available (FOEN 2006).

b) Carbon in Soils

Permanent Grassland (CC 31)

Carbon stocks in grassland soil refer to a depth of 0-30 cm.

Swiss values for carbon stocks in mineral and organic soils are implied (FOEN 2006). They are based on FAL (2003a) and Leifeld et al. (2005).

The mean carbon stock values for mineral soils are displayed in Table 99.

Altitude [m]	**C_S** [t C ha^{-1}, 0-30 cm]
<601	62.02 ± 13
601-1200	67.50 ± 12
>1200	75.18 ± 9

Table 99 Mean carbon stocks under permanent grassland on mineral soils.

The mean soil organic carbon stock (0-30 cm) for organic soils is 240 ± 48 t C ha^{-1}.

Shrub Vegetation (CC 32)

Due to lack of data, the mean value for permanent grassland (CC 31) of 68.23 t ha^{-1} was used as the soil carbon default for this category.

Vineyards, Low-stem Orchards and Tree Nurseries (CC 33)

Swiss soil carbon values for cropland were implied as it is supposed that these land-use types don't have grass undercover. These soil carbon values are 53.40 t C ha^{-1} for mineral soils and 240 t ha^{-1} for organic soils.

Copse (CC 34)

Due to lack of data, the mean value of Table 99, 68.23 t ha^{-1} was used as the soil carbon default for this category.

Orchards (CC 35)

Swiss soil carbon values for grassland from the two lower altitude zones were taken as no specific orchard values were available. These are 64.76 t C ha^{-1} for mineral soils and 240 t C ha^{-1} for organic soils.

Stony Grassland (CC 36)

Swiss values for soil organic carbon under stony grassland were implied (FOEN 2006). These grasslands are mainly located at altitudes > 1200m a.s.l. A carbon stock Cs of 26.31 t C ha^{-1} is assumed for this combined category.

Unproductive Grassland (CC 37)

The category CC 37 ‚unproductive grasslands' includes grass and herbaceous plants at watersides of lakes and rivers including dams and other flood protection structures, constructions to protect against avalanches and rock slides, and alpine infrastructure.

Swiss mean value of carbon stocks under permanent grassland on mineral soils of 68.23 t C ha^{-1} is implied, as for none of these land-use types, carbon soil data are currently available (FOEN 2006).

c) Changes in carbon stocks

Changes in carbon stock in mineral soils are assumed to be zero for grassland remaining grassland. Carbon stock changes in soil for grassland remaining grassland occur only in the case of shifts from mineral to organic soils or vice versa. These carbon stock changes are not estimated in Liechtenstein since data on mineral and organic soils is only available for one year. Changes can therefore not be estimated.

7.5.3. Uncertainties and Time-Series Consistency

No uncertainty assessments have been carried out in Liechtenstein.

Some assessments have been carried out in Switzerland. Where available, uncertainties for soil carbon stocks are given together with the mean value in the text. The relative uncertainty in yield determination has been estimated at 13% for biomass carbon from agricultural land (Leifeld and Fuhrer 2005). Data on biomass yields for different elevations and management intensities as published by FAL/RAC (2001) are based on many agricultural field experiments and have a high reliability.

Time-series is consistent.

7.5.4. Source-Specific QA/QC and Verification

No source-specific QA/QC has been carried out.

7.5.5. Source-Specific Recalculations

For the current submission all emissions have been calculated for the first time, based to the Swiss methodology with the new combined categories. Therefore, no recalculation has been carried out.

7.5.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

7.6. Source Category 5D – Wetlands

7.6.1. Source Category Description

Wetlands consist of surface waters (CC 41) and unproductive wet areas such as shore vegetation and fens (CC 42) (see Table 76).

7.6.2. Methodological Issues

Surface Waters (CC 41)

Surface waters have no carbon stocks by definition.

Unproductive Wetland (CC 42)

Swiss carbon contents for unproductive wetlands are implied (FOEN 2006). The combined category was stratified according to different tags (e.g. tree group on wetland, biotope, linear tree group on wetland, clear-cut on wetland) and each tag was assigned to a carbon content of a known combined category (e.g. tree group on wetland was assigned to the category unproductive forest). Using the percentages (according to occurrence) and the assigned carbon stock values, a weighted average for this combined category was calculated. This calculation lead to an average carbon stock of 7.96 t C ha^{-1}.

Soil

Land cover in CC 42 includes peatlands and reed.

Swiss soil carbon stock values are implied (FOEN 2006). Since only data on peatlands are available (240 t C ha^{-1} as for organic soils), it is suggested that the soil carbon stock of unproductive wetlands is the arithmetic mean of grassland on mineral soils (68.23 t C ha^{-1}) and organic soils (240 t C ha^{-1}), thus 154 t C ha^{-1}.

Changes in carbon stocks

In the case of land-use change, the net changes in biomass and soil of both CC 41 and CC 42 are calculated as described in chapter 7.2.1.

N_2O emissions from drainage of soils

Drainage of intact wetlands is very unlikely. Therefore, no N_2O emissions are reported in CRF Table 5 (II).

7.6.3. Uncertainties and Time-Series Consistency

No uncertainty assessments have been carried out in Liechtenstein. According to the Swiss National Inventory Report (FOEN 2006), the uncertainty of activity data is assessed as low. In case of carbon stocks, the uncertainty is assessed as high.

Time series are consistent.

7.6.4. Source-Specific QA/QC and Verification

No source-specific QA/QC activities have been carried out.

7.6.5. Source-Specific Recalculations

For the current submission all emissions have been calculated for the first time, based to the Swiss methodology with the new combined categories. Therefore, no recalculation has been carried out.

7.6.6. Source-Specific Planned Improvements

There are no planned improvements.

7.7. Source Category 5E – Settlements

7.7.1. Source Category Description

Settlements consist of buildings/constructions (CC 51), herbaceous biomass in settlements (CC 52), shrubs in settlements (CC 53) and trees in settlements (CC 54) as shown in Table 76.

7.7.2. Methodological Issues

Buildings and Constructions (CC 51)

Buildings/constructions contain no carbon by default.

Herbaceous Biomass, Shrubs and Trees in Settlements (CC 52, 53, 54)

Swiss values for carbon stocks of herbaceous biomass, shrubs and trees in settlements are implied (FOEN 2006). The calculation of carbon stock is based on the average crown cover area based annual growth rate (IPCC default value, IPCC 2003; p. 3.297), the percentage of vegetation coverage for the respective combined category (herbaceous biomass or shrubs in settlements) and the estimated average age of trees in settlements (20 years). The combined category "Herbaceous Biomass in Settlement" (CC 52) is estimated to contain an average carbon stock of 5.8 t C ha^{-1}, and the combined category "Shrubs in Settlements" (CC 53) a carbon stock of 4.8 t C ha^{-1}. Due to a lack of data, the carbon content of the combined category "Trees in Settlements" (CC 53) was also used for CC 54 (4.8 t C ha^{-1}).

Soils

Swiss values for soil carbon in settlements are implied (FOEN 2006).

The carbon stock in soil for the combined category "Buildings and Construction" (CC 51) was set to zero. However, a weighting factor of 0.5 was applied to soil carbon changes due to land-use changes involving CC 51 (see Chapter 7.2.1). The reason for this is that in general the soil organic matter on construction sites is stored temporarily and later used for replanting the surroundings or it is used to vegetate dumps for example. The oxidative carbon loss due to the disturbance of the soil structure may reach 50%.

The carbon stock in soil for CC 52, 53 and 54 is 53.40 t C ha^{-1} (0-30 cm, same value as for cropland).

7.7.3. Uncertainties and Time-Series Consistency

No uncertainty assessments have been carried out in Liechtenstein. According to the Swiss National Inventory Report (FOEN 2006), the uncertainty of activity data is assessed as low. In case of carbon stocks, the uncertainty is assessed as high.

7.7.4. Source-Specific QA/QC and Verification

No source-specific QA/QC activities have been carried out.

7.7.5. Source-Specific Recalculations

For the current submission emissions from settlements have been calculated for the first time, based to the Swiss methodology with the new combined categories. Therefore, no recalculation has been carried out.

7.7.6. Source-Specific Planned Improvements

There are no planned improvements.

7.8. Source Category 5F – Other Land

7.8.1. Source Category Description

As shown Table 76 other land (CC 61) covers non-vegetated areas such as glaciers, rocks and shores.

7.8.2. Methodological Issues

By definition, other land has no carbon stocks. In the case of land-use change, the net changes in biomass and soil are calculated as described in chapter 7.2.1.

7.8.3. Uncertainties and Time-Series Consistency

No uncertainty assessments have been carried out in Liechtenstein. According to the Swiss National Inventory Report (FOEN 2006) the uncertainty of activity data and carbon stock data is assessed as low.

7.8.4. Source-Specific QA/QC and Verification

No source-specific QA/QC activities have been carried out.

7.8.5. Source-Specific Recalculations

For the current submission all emissions from other lands have been calculated for the first time, based to the Swiss methodology with the new combined categories. Therefore, no recalculation has been carried out.

7.8.6. Source-Specific Planned Improvements

There are no planned improvements.

8. Waste

8.1. Overview GHG Emissions

Within the waste sector emissions from four source categories are considered:

- 6A "Solid Waste Disposal on Land",
- 6B "Wastewater Handling",
- 6C "Waste Incineration",
- 6D "Others".

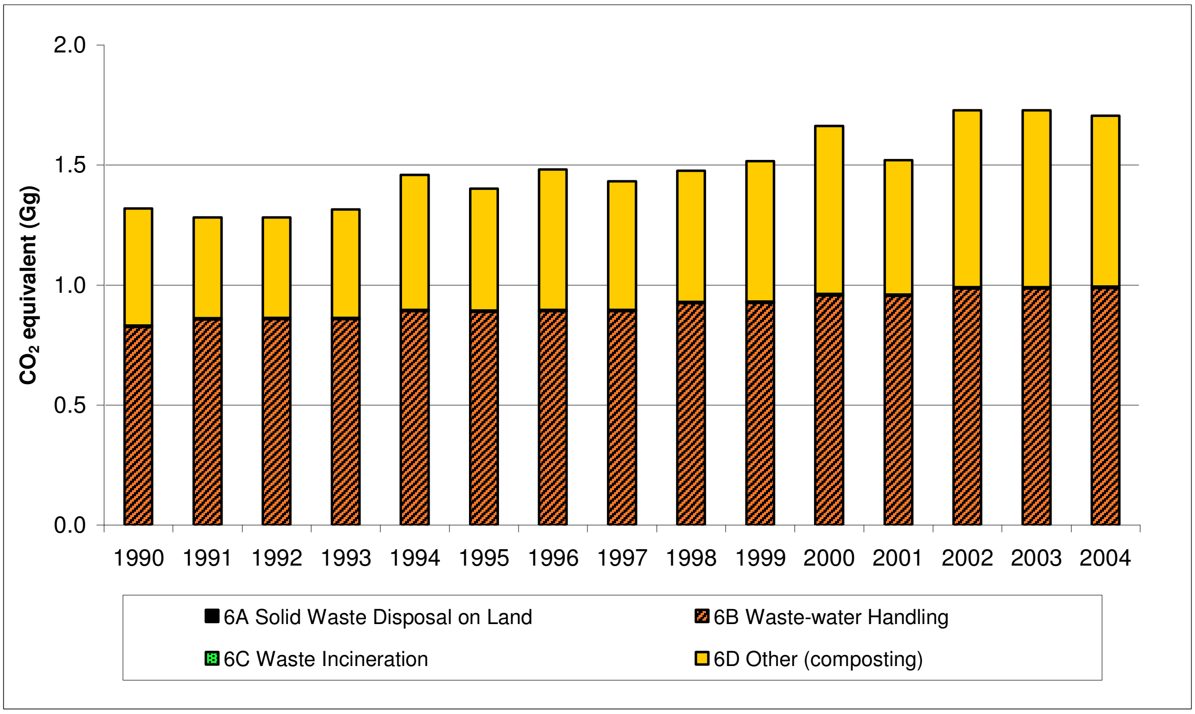


Figure 24 Liechtenstein's greenhouse gas emissions in the waste sector 1990–2004

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*1990→2004*
	CO_2 equivalent (Gg)															*%*
CO_2	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	---
CH_4	0.43	0.37	0.37	0.40	0.49	0.45	0.51	0.47	0.48	0.52	0.61	0.49	0.64	0.64	0.62	*45.0*
N_2O	0.89	0.91	0.91	0.91	0.96	0.96	0.97	0.96	0.99	1.00	1.05	1.03	1.09	1.09	1.08	*21.6*
Sum	**1.32**	**1.28**	**1.28**	**1.31**	**1.46**	**1.40**	**1.48**	**1.43**	**1.48**	**1.52**	**1.66**	**1.52**	**1.73**	**1.73**	**1.70**	***29.2***

Table 100 GHG emissions of source category 6 Waste by gas in CO_2 equivalent (Gg), 1990 and 2004.

In the waste sector a total of 1.7 Gg CO_2 equivalents of CH_4 and N_2O were emitted in the year 2004. 58.0% of the total emissions stem from 6B "Wastewater Treatment", 41.7% from the sub-category 6D "Others", and 0.3% from 6C "Waste Incineration". No emissions are from 6A "Solid Waste Disposal on Land".

The total greenhouse gas emissions show an increase from 1990 until 2004 by +29%. This is mostly due to the increase in composting activities in the country, reducing the amount of municipal solid waste exported for incineration to Switzerland.

8.2. Source Category 6A – Solid Waste Disposal on Land

8.2.1. Source Category Description

Source category 6A "Solid Waste Disposal on Land" is **not a key category.**

The source category 6A1 “Managed Waste Disposal on Land” comprises all emissions from handling of solid waste on managed landfill sites.

During the 1960ies, Liechtenstein stopped disposing of municipal solid waste on landfill sites and instead exported it for incineration to Switzerland. This transition was concluded in 1974, when the last municipality stopped landfilling.

It is assumed, that landfill gas production in the 16 years since the closure of the last landfill has decreased to a level that is negligible already in 1990. Therefore emissions from 6A1 Managed Waste Disposal on Land is reported as not occurring.

This is conservative, because the assumption tends to underestimate GHG emissions from waste disposal in 1990 compared to 2004.

There are also no *unmanaged* waste disposal sites reported in Liechtenstein. Therefore emissions from the source category 6A2 “Unmanaged Waste Disposal Sites” are not occurring.

6A	Source	Specification	Data Source
6A1	Managed Waste Disposal on Land	Not occurring in Liechtenstein	-
6A2	Unmanaged Waste Disposal Sites	Not occurring in Liechtenstein	-
6A3	Others	Not occurring in Liechtenstein	-

Table 101 Specification of source category 6A “Solid Waste Disposal on Land”.

8.2.2. Source-Specific Planned Improvements

No source-specific improvements are planned.

8.3. Source Category 6B – Wastewater Handling

8.3.1. Source Category Description

Source category 6B “Wastewater Handling” is **not a key source**.

The source category 6B1 “Industrial Waste Water” comprises all emissions from the handling of liquid wastes and sludge from industrial processes such as food processing, textiles, or pulp and paper production. Emissions from this source category 6B1 are included in source category 6B2 “Domestic and Commercial Waste Water”. This is motivated by the fact that industrial waste water is generally only pre-treated and not treated on-site, and is then processed in the municipal waste water treatment plants considered under 6B2.

The source category 6B2 “Domestic and Commercial Waste Water” comprises all emissions from handling of liquid wastes and sludge from housing and commercial sources (including gray water and night soil).

6B	Source	Specification	Data Source
6B1	Industrial Waste Water	Emissions from handling of liquid wastes and sludge from industrial processes. (included in 6B2)	-
6B2	Domestic and Commercial Waste Water	Emissions from handling of liquid wastes and sludge from housing and commercial sources	AD: SFSO 2004c, 2005 EF: FOEN 2006
6B3	Others	Not occurring in Liechtenstein	-

Table 102 Specification of source category 6B “Wastewater Handling” (AD: activity data; EF: emission factors).

Methodological Issues

a) Domestic and Commercial Waste Water (6B2)

Methodology

In Liechtenstein waste water treatment plants are equipped to collect sewage sludge. The sludge is processed in a digester to produce biogas. The biogas is used for co-generation of heat and power on-site.

For CH_4 emissions from domestic and commercial waste water treatment (6B2), a country-specific method is used, in line with the method used in the Swiss NIR (FOEN 2006). The CH_4 emissions are calculated by multiplying the amount of biogas produced in the digesters times the emission factor.

N_2O emissions are calculated based on the IPCC default method (IPCC 1997c).

Emission Factors

For CH_4 it is assumed that 0.2% of the biogas (volume) is emitted as leakage (FOEN 2006). Taking a methane content of the biogas by volume is 65%, an overall emission factor of 0.0013 m^3 CH_4 per m^3 of biogas results.

N_2O is derived based on the IPCC-default method. Assuming a protein consumption of 36 kg/person/yr and a N fraction of 0.16 kg N per kg protein, an emission factor of 90.5 g of N_2O per inhabitant results (FOEN 2006).

Activity data

Activity data for CH_4 emissions from Domestic and Commercial Waste Water (6B2) are the total amount of gas resulting from waste water treatment in Liechtenstein. In 1990 three waste water treatment plants had been operational. In 2004, two plants remained, and since 2005 all waste water of the principality is treated in one plant.

Gas production		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total gas production	m3	675'944	708'444	750'015	749'887	813'691	736'949	786'301	800'429	866'294	932'935
Balzers	m3	44'256	44'785	42'284	46'055	42'709	43'540	48'964	50'090	48'538	49'206
Vaduz	m3	66'024	55'745	58'464	64'464	64'436	57'713	47'703	0	0	0
Bendern	m3	565'664	607'914	649'267	639'368	706'546	635'696	689'634	750'339	817'756	883'729

Gas production		2000	2001	2002	2003	2004
Total gas production	m3	941'707	905'828	868'172	899'829	939'399
Balzers	m3	54'321	53'834	51'144	45'723	5'715
Vaduz	m3	0	0	0	0	0
Bendern	m3	887'386	851'994	817'028	854'106	933'684

Table 103 Activity data in 6B2 Domestic and Commercial Waste Water: Amount of waste water treatment gas produced by the three treatment plants in Liechtenstein (source: OEP; treatment plants).

Activity data for N_2O emissions from Domestic and Commercial Waste Water (6B2) are the number of inhabitants in Liechtenstein (provided in Section 4.2.2).

8.3.2. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in low confidence in emission estimates.

Time series are consistent.

8.3.3. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

8.3.4. Source-Specific Recalculations

No recalculations have been carried out.

8.3.5. Source-Specific Planned Improvements

There are no source-specific planned improvements.

8.4. Source Category 6C – Waste Incineration

8.4.1. Source Category Description

Source category 6C “Waste Incineration” is **not a key source**.

There are no waste incineration plants in Liechtenstein. Since the beginning of 1975 all municipal solid waste from Liechtenstein is exported to Switzerland for incineration.

Therefore, source category 6C includes only emissions from the illegal incineration of gardening and household wastes, and of wastes on construction sites (open burning).

8.4.2. Methodological Issues

Methodology

For the calculation of the greenhouse gas emissions from illegal incineration of wastes a country specific Tier 2 method is used, based on CORINAIR, adapted from the Swiss NIR (FOEN 2006).

GHG emissions are calculated by multiplying the estimated amount of illegally incinerated waste by emission factors.

Emission Factors

Emission factors for CO_2, and CH_4 are adapted from the Swiss NIR (FOEN 2006).

The emission factor for N_2O is derived from the emission factor for wood of 1.6 kgN_2O/TJ with a net calorific value of the waste of 12.7 GJ/t, taken from the Swiss NIR (FOEN 2006). This is based on the assumption that the waste that is incinerated illegally in gardens, households or on construction sites is composed of a high share of wood.

The following table presents the emission factors used in 6C:

6C Waste Incineration							
Source	**CO_2** t/t	**CH_4** kg/t	**N_2O** g/t	**NO_x** kg/t	**CO** kg/t	**NMVOC** kg/t	**SO_2** kg/t
Illegal waste incineration	0.51	6	0.02	NE	NE	NE	NE

Table 104 Emission Factors for 6C “Waste Incineration” in 2004.

Activity Data

The activity data for Waste Incineration (6C) are the quantities of waste incinerated illegally. This amount is calculated from the total amount of municipal solid waste generated in Liechtenstein by assuming that waste incinerated illegally represents 0.5% of waste generated (FOEN 2006). Data for municipal solid waste has been interpolated.

		1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
MSW generated	t/a	8'000	8'020	8'040	8'060	8'080	8'100	8'120	8'140	8'160	8'180
Fraction incinerated illegally		0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Waste incinerated illegally	t/a	40.0	40.1	40.2	40.3	40.4	40.5	40.6	40.7	40.8	40.9

		2000	**2001**	**2002**	**2003**	**2004**
MSW generated	t/a	8'200	8'220	8'240	8'260	8'280
Fraction incinerated illegally		0.5%	0.5%	0.5%	0.5%	0.5%
Waste incinerated illegally	t/a	41.0	41.1	41.2	41.3	41.4

Table 105 Activity data for the different emission sources within source category 6C “Waste Incineration”. Source of amount of municipal solid waste (MSW) generated: OEP.

8.4.3. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in low confidence in emissions estimates.

Time series are consistent.

8.4.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

8.4.5. Source-Specific Recalculations

No recalculations have been carried out.

8.4.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

8.5. Source Category 6D – Other

8.5.1. Source Category Description

Source category 6D "Other" is **not a key category.**

The source category 6D “Other” comprises the GHG emissions from composting of organic waste. Composting covers the GHG emissions from larger centralized composting plants as well as from backyard composting.

There are no shredding plants in Liechtenstein, therefore emissions from car shredding are not occurring.

6D	Source	Specification	Data Source
	Composting	Emissions from composting of organic waste	AD: OEP EF: FOEN 2006

Table 106 Specification of source category 6D “Other” (AD: activity data; EF: emission factors).

8.5.2. Methodological Issues

Methodology

For the CH_4 and N_2O emissions from composting a country specific method is used, based on the Swiss NIR (FOEN 2006). The GHG emissions are calculated by multiplying the quantity of wastes by the emission factors. For all years the same constant emission factors have been applied. N_2O emissions from the product of composting that arise after their application in agriculture are reported under source category 4D4.

Emission Factors

Emission factors for composting have been adopted from the Swiss NIR (FOEN 2006). They are based on measurements and expert estimates, documented in the Swiss EMIS database.

Activity data

The total amount of waste that is composted is calculated in Table 107. The office for Environmental Protection provides data on the amount of waste treated in centralized compost plants. In order to account for the numerous small compost sites in people's backyards, backyard composting has been estimated by an expert estimate[10]: it is estimated to contribute another 8% (1990) respectively 5% (2005) to the total amount of waste composted in centralized compost plants (in the years in between, the factor is linearly interpolated).

Waste composting		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Composted centrally	t/a	3'567	3'078	3'071	3'311	4'143	3'734	4'332	3'965	4'068	4'344
Additionally in backyard		8.0%	7.8%	7.6%	7.4%	7.2%	7.0%	6.8%	6.6%	6.4%	6.2%
Composted total	t/a	3'852	3'318	3'305	3'556	4'441	3'995	4'626	4'226	4'328	4'614

Waste composting		2000	2001	2002	2003	2004
Composted centrally	t/a	5'210	4'181	5'501	5'508	5'345
Additionally in backyard		6.0%	5.8%	5.6%	5.4%	5.2%
Composted total	t/a	5'522	4'423	5'809	5'806	5'623

Table 107 Activity data in 6D Other.

8.5.3. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in low confidence in emissions estimates.

Time series are consistent.

8.5.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the general QA/QC measures described in Section 1.6 have been carried out.

8.5.5. Source-Specific Recalculations

No recalculations have been carried out.

8.5.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

[10] Source: Andreas Gstöhl, OEP, email to J. Beckbissinger, Acontec, of August 16th, 2006.

9. Recalculations

As mentioned in Chapter 1.4.1, a fundamental effort has been accomplished to achieve the best possible data for the present GHG inventory. Actually, the inventory has been started from scratch, an incomplete, intermediate inventory having been presented in the submission 31 May 2006. Best available data has been collected and methodologies fully in line with IPCC have been applied. A number of previous results have now turned out to be rather different from the new results. The quality of the new results has much increased, the new data is now considered to be reliable. Also, the inventory is implemented using the CRF Reporter, which guarantees consistency and completeness within the implemented set of data. This situation is very different from before, where the previous results were based on preliminary data and on methodologies which were not fully in line with IPCC guidelines.

Table 108 summarises the latest result (current submission) with the data of the previous CRF submitted in May 2005.

Gas	1990		2003		1990→2003	1990→2004
	previous	latest	previous	latest	previous	latest
CO_2	227.3	203.1	239.9	240.0	5.5%	18.2%
CH_4	14.9	13.2	15.2	13.9	1.8%	5.6%
N_2O	8.2	14.2	8.6	12.8	5.5%	-9.5%
HFC, SF_6	0.0	0.0	0.1	3.5	---	---
Sum	250.4	230.4	263.7	270.3	5.3%	17.3%

Table 108 Comparison of GHG emission (without LULUCF) between the previous submission (2005) with the current submission (2006).

Comparison between previous and latest submission for 2003:

- The CO_2 emissions are very similar because they are both based on modified consumption figures from the national energy statistics and the OEP census on fuel sales. Also, the CH_4 emissions are quite similar, probably due to the same reason.
- There are larger differences for N_2O and synthetic gases. The emission factors for N_2O were generally underestimated, HFCs were not estimated at all in the previous submission.
- The national total 2003 in the previous submission underestimated the latest total by 2.4%. This small difference may be explained by the fact that the CO_2 emissions from the energy sector (reliable for both submissions) are dominant.

Comparison between previous and latest submission for 1990:

- Former 1990 emissions were obviously overestimated: CO_2: 11.9%, CH_4: 13.2%. This is mainly due to the fact that the activity data have been revised (elimination of inconsistencies in the national energy statistics).
- On the other hand, former N_2O emissions were underestimated by -42.5% because of too low emission factors for agricultural soils.
- The national total 1990 in the previous submission overestimated the latest total by 8.7%. This large difference may be explained by the fact that the CO_2 emissions from the energy sector (reliable for both submissions) are dominant.

Comparison between 1990→2003/previous and 1990→2004/latest:

- Based on the former results, an overall increase of 5.3% between 1990 and 2003 was estimated. The new results show that the increase is much stronger, 17.3%, which will significantly influence the national reduction strategy for the of GHG emissions in the near future.
- The recalculation has strong implications for the determination of Liechtenstein's Assigned Amount. The recalculation leads to a 8.7% reduction of the Assigned Amount.

It should be mentioned that the previous estimation seemed plausible in spite of the simplicity of the methods used at that time: Switzerland reported a zero growth in the period 1990–2003, whereas Liechtenstein expected a definitely stronger and positive growth; the resulting figure of 5.3%, calculated in May 2005 seemed to be reasonable. To improve the emission numbers for 1990, Liechtenstein has now made a special effort. Searching for he best consumption data, the most cautious (smallest) numbers have finally been taken to ensure that the growth will not be underestimated. With the latest and currently reported estimation and a resulting growth of 17.3%, this may certainly be guaranteed.

Notes

- Since up to May 2005, only emissions of 1990 and 2003 have been reported, there are only recalculation values for 1990 and 2003. for the other years, no recalculation is possible.
- The CRF tables LIE-2006-1990-v2.1.xls and LIE-2006-2003-v2.1.xls do not contain the complete values of the previous submission. Some data, e.g. for the source categories 1A1, 1A2, 1A5, have not been transferred to the CRF Reporter 2006. Therefore, the values used in Table 108 above, are not taken from the CRF tables but from the previous submission on 24 May 2005 (OEP 2005).

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Annexes

Annex 1: Key Category Analysis

IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Assessment	Trend Assessment	% Contribution in Trend	Cumulative Total Col. F	Result level assessment	Result trend assessment
						[Gg CO2eq]	[Gg CO2eq]						
TOTAL					*All*	*230.42*	*271.33*	*100%*	*0.31866*	100%			
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	45.82	16.89%	0.06703	21.0%	21.0%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	22.36	8.24%	0.06075	19.1%	40.1%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	26.27	9.68%	0.05015	15.7%	55.8%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	62.89	23.18%	0.02625	8.2%	64.1%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	15.18	5.60%	0.02156	6.8%	70.8%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Liquid Fuels	CO2	18.74	15.18	5.60%	0.02155	6.8%	77.6%	KC level	KC trend
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			HFC	0.00	3.95	1.45%	0.01235	3.9%	81.5%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	20.40	7.52%	0.00942	3.0%	84.4%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Gaseous Fuels	CO2	16.48	22.09	8.14%	0.00838	2.6%	87.1%	KC level	KC trend
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	0.12	2.79	1.03%	0.00830	2.6%	89.7%	KC level	KC trend
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	6.93	5.69	2.10%	0.00772	2.4%	92.1%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CO2	0.00	1.70	0.63%	0.00533	1.7%	93.8%	-	KC trend
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	10.40	3.83%	0.00359	1.1%	94.9%	KC level	KC trend
3	3. Solvent and Other Product Use				CO2	1.53	0.87	0.32%	0.00291	0.9%	95.8%	-	KC trend
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.46	0.91%	0.00236	0.7%	96.5%	KC level	-
1B2	1. Energy	B. Fugitive Emissions f	2. Oil and Natural Gas		CH4	0.32	0.93	0.34%	0.00172	0.5%	97.1%	-	-
4B	4. Agriculture	B. Manure Management			CH4	1.90	1.73	0.64%	0.00158	0.5%	97.6%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CH4	0.49	0.13	0.05%	0.00140	0.4%	98.0%	-	-
3	3. Solvent and Other Product Use				N2O	0.46	0.23	0.09%	0.00098	0.3%	98.3%	-	-
4D_o	4. Agriculture	D. Agricultural Soils without 4D1-N2O & 4D3-N2O			N2O	0.82	0.65	0.24%	0.00098	0.3%	98.6%	-	-
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	3.02	1.11%	0.00075	0.2%	98.9%	KC level	-
4B	4. Agriculture	B. Manure Management			N2O	1.52	1.58	0.58%	0.00065	0.2%	99.1%	-	-
6D	6. Waste	D. Other			CH4	0.41	0.59	0.22%	0.00035	0.1%	99.2%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Biomass	CH4	0.13	0.25	0.09%	0.00030	0.1%	99.3%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	N2O	0.47	0.65	0.24%	0.00029	0.1%	99.4%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Solid Fuels	CO2	0.09	0.02	0.01%	0.00026	0.1%	99.4%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	N2O	0.01	0.08	0.03%	0.00021	0.1%	99.5%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	N2O	0.05	0.11	0.04%	0.00018	0.1%	99.6%	-	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			SF6	0.00	0.06	0.02%	0.00018	0.1%	99.6%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	N2O	0.14	0.11	0.04%	0.00017	0.1%	99.7%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CH4	0.01	0.05	0.02%	0.00014	0.0%	99.7%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CH4	0.02	0.06	0.02%	0.00012	0.0%	99.8%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CH4	0.00	0.03	0.01%	0.00010	0.0%	99.8%	-	-
1A3a	1. Energy	A. Fuel Combustion	3. Transport; Civil Aviation		CO2	0.08	0.06	0.02%	0.00008	0.0%	99.8%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CO2	1.30	1.51	0.56%	0.00008	0.0%	99.8%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CH4	0.00	0.03	0.01%	0.00008	0.0%	99.9%	-	-
6D	6. Waste	D. Other			N2O	0.08	0.12	0.04%	0.00007	0.0%	99.9%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Liquid Fuels	N2O	0.05	0.04	0.01%	0.00005	0.0%	99.9%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	N2O	0.05	0.04	0.01%	0.00005	0.0%	99.9%	-	-
6B	6. Waste	B. Wastewater Handling			N2O	0.81	0.96	0.35%	0.00004	0.0%	99.9%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Biomass	N2O	0.01	0.03	0.01%	0.00003	0.0%	99.9%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	N2O	0.00	0.01	0.01%	0.00003	0.0%	100.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Biomass	N2O	0.01	0.02	0.01%	0.00002	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Gaseous Fuels	CH4	0.04	0.05	0.02%	0.00002	0.0%	100.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CH4	0.02	0.01	0.00%	0.00002	0.0%	100.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Solid Fuels	CH4	0.01	0.00	0.00%	0.00002	0.0%	100.0%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CH4	0.01	0.00	0.00%	0.00002	0.0%	100.0%	-	-
6B	6. Waste	B. Wastewater Handling			CH4	0.02	0.03	0.01%	0.00002	0.0%	100.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Biomass	CH4	0.00	0.01	0.00%	0.00001	0.0%	100.0%	-	-
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	N2O	0.02	0.03	0.01%	0.00001	0.0%	100.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CH4	0.01	0.00	0.00%	0.00001	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Liquid Fuels	CH4	0.01	0.00	0.00%	0.00001	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Gaseous Fuels	N2O	0.01	0.01	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
6C	6. Waste	C. Waste Incineration			CH4	0.01	0.01	0.00%	0.00000	0.0%	100.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Solid Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A3a	1. Energy	A. Fuel Combustion	3. Transport; Civil Aviation		N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	N2O	0.01	0.01	0.01%	0.00000	0.0%	100.0%	-	-
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-

(Cont'd next page)

IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Assessment	Trend Assessment	% Contribution in Trend	Cumulative Total Col. F	Result level assessment	Result trend assessment
						[Gg CO2eq]	[Gg CO2eq]						
6C	6. Waste	C. Waste Incineration			N2O	0.00	0.00	9.59709E-07	0.00	0.0%	100%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A3a	1. Energy	A. Fuel Combustion	3. Transport; Civil Aviation		CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Liquid Fuels	CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Solid Fuels	CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Other Fuels	CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Liquid Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Solid Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Biomass	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Other Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Liquid Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Solid Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Biomass	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Other Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Solid Fuels	CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Other Fuels	CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Solid Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Biomass	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Other Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Solid Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Biomass	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construct	Other Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A3e	1. Energy	A. Fuel Combustion	3. Transport; Other Transportation (military aviation)		CO2	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
1A3e	1. Energy	A. Fuel Combustion	3. Transport; Other Transportation (military aviation)		CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A3e	1. Energy	A. Fuel Combustion	3. Transport; Other Transportation (military aviation)		N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Solid Fuels	CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Solid Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Solid Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	CH4	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	N2O	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
1B2	1. Energy	B. Fugitive Emissions f	2. Oil and Natural Gas		CO2	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
1B2	1. Energy	B. Fugitive Emissions f	2. Oil and Natural Gas		N2O	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
2A	2. Industrial Proc.	A. Mineral Products			CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
2A	2. Industrial Proc.	A. Mineral Products			CH4	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
2A	2. Industrial Proc.	A. Mineral Products			N2O	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
2B	2. Industrial Proc.	B. Chemical Industry			CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
2B	2. Industrial Proc.	B. Chemical Industry			CH4	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
2B	2. Industrial Proc.	B. Chemical Industry			N2O	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
2C	2. Industrial Proc.	C. Metal Production			CO2	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
2C	2. Industrial Proc.	C. Metal Production			CH4	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
2C	2. Industrial Proc.	C. Metal Production			N2O	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
2D	2. Industrial Proc.	D. Other Production			CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-
2E	2. Industrial Proc.	E. Production of Halocarbons and SF6			CO2	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			PFC	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			CO2	0.00	0.00	0.00%	0.00000	0.0%	100.0%	-	-
2G	2. Industrial Proc.	G. Other			CO2	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
2G	2. Industrial Proc.	G. Other			CH4	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
2G	2. Industrial Proc.	G. Other			N2O	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
4C	4. Agriculture	C. Rice Cultivation			CH4	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
4D	4. Agriculture	D. Agricultural Soils			CH4	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
4E	4. Agriculture	E. Prescribed Burning of Savannas			CH4	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
4E	4. Agriculture	E. Prescribed Burning of Savannas			N2O	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
4F	4. Agriculture	F. Field Burning of Agricultural Residues			CH4	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
4F	4. Agriculture	F. Field Burning of Agricultural Residues			N2O	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
4G	4. Agriculture	G. Other			CH4	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
4G	4. Agriculture	G. Other			N2O	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
6A	6. Waste	A. Solid Waste Disposal on Land			CO2	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
6A	6. Waste	A. Solid Waste Disposal on Land			CH4	NA,NO	NA,NO	0.00%	0.00000	0.0%	100.0%	-	-
6C	6. Waste	C. Waste Incineration			CO2	NA	NA	0.00%	0.00000	0.0%	100.0%	-	-
6D	6. Waste	D. Other			CO2	NO	NO	0.00%	0.00000	0.0%	100.0%	-	-

Table 109 Complete Key Category Analysis.

Annex 2: Energy

Net Calorific Values of Fossil Fuels

The NCV of fossil fuels is assumed to be constant for the period 1990 to 2004. Therefore, the same values have been used for emission modelling in 1990 and in 2004.

Fuel	**Net calorific values (NCV)**		**Density**
	GJ / t	**GJ / volume**	**t / volume**
Hard Coal	26.3	---	---
Gas Oil	42.6	36.0 / 1000 l	0.845 t / 1000 l
Residual Fuel Oil	41.2	39.1 / 1000 l	0.950 t / 1000 l
Natural Gas	46.5	36.3 / 1000 Nm^3	0.780 t / 1000 Nm^3
Gasoline	42.5	31.7 / 1000 l	0.745 t / 1000 l
Diesel Oil	42.8	35.5 / 1000 l	0.830 t / 1000 l
Propane/Butane (LPG)	46.0	---	---
Jet Kerosene	43.0	34.4 / 1000 l	0.800 t / 1000 l

Table 110 Net calorific values (NCV) used for the modelling of Liechtenstein’s GHG emissions. Data source: FOEN 2006

Annex 3: Agriculture

A3.1 Livestock Population Data for N_2O Emission Calculation

Animals 2004		**Number of animals**	**kg N per head/year**	**FracGASM (6)**	**N volatilized (kg N)**
Cattle		**5'832**			
Mature dairy and non-dairy cattle		3'018	114.8	0.23	78637
Young cattle					
	Milk fed calf, suckler cow calf, breeding calf and breeding cattle less than one year	1'221	13-25	0-0.01	234
	Fattening calf (places)	72	8	0.00	0
	Fattening cattle	576	33	0.01	274
Breeding cattle (more than one year)		945	40-55	0.01	422
Swine		**990**			
	Fattening pig places (2)	654	13	0.01	68
	Breeding pig places (3)	8	35	0.00	0
Sheep		**3'149**			
	Sheep places (4)	1'575	12	0.01	102
Goats		**286**			
	Goat places (5)	157	16	0.00	4
Horses		**254**			
	Foals < 1 year	5	17	0.00	0
	Foals 1 - 2 years	18	42	0.00	0
	Other horses	231	44	0.01	68
Ponies, Mules and Asses		**159**	26	0.00	11
Poultry		**10'684**			
	laying hens	10'549	0.7	0.01	62
	young hens < 18 weeks	5	0.3	0.00	0
	broilers	78	0.4	0.00	0
	turkeys	52	1.4	0.00	0
Total		**21'353**		**0.31**	**79'882**

(1) N excretion calculated based on milk production: 105 kg N/head/year at a milk production of 5000 kg/head/year, increased by 10% for every 500 kg additional milk production. Milk production 2004: 6875 kg/head/year.
(2) One fattening pig place corresponds to one fattening pig over 25 kg, 1/6 fattening pig place to one young pig below 30 kg.
(3) One breeding pig place corresponds to one sow, 1/2 breeding pig place to one boar.
(4) One sheep place corresponds to one ewe over one year. Other sheep are not included.
(5) One goat place corresponds to one goat over 1.5 years. Goats younger than 1.5 years are not included.
(6) includes ammonia volatilization calculated for each species based on management practice and NO emissions of 1.5% of the excreted N.

Table 111 Livestock population data for N_2O emission calculation.

A3.2 Additional Data for N_2O Emission Calculation of Agricultural Soils (4D)

2004	Nitrogen incorporated with crop residues (t N)	Dry matter production (kg DM)	N2O emissions from crop residues (t N2O)	N fixed per kg crop (kg N/kg crop)	N fixed (kg N)	N2O emissions from N fixation (t N2O)
1. Cereals						
Wheat	3.6	480'471	0.1			
Barley	1.7	294'950	0.0			
Maize	4.1	486'200	0.1			
Oats	0.3	42'500	0.0			
Rye	0.0	0	0.0			
Other (please specify)						
Spelt	0.1	14'229	0.0			
Triticale	1.5	130'050	0.0			
Mix of fodder cereals	0.1	10'200	0.0			
Mix of bread cereals	0.0	0	0.0			
2. Pulse						
Dry bean	0.0	0	0.0	0.0443	0	0.0
Eiweisserbsen/peas	0.4	15'300	0.0	0.0330	594	0.0
Soybeans	1.8	42'500	0.0	0.0571	2'856	0.1
Other (please specify)						
Leguminous vegetables	0.0	0	0.0	0.0177	0	0.0
3. Tuber and Root						
Potatoes	2.7	610'236	0.1			
Other (please specify)						
Fodder beet	0.2	26'424	0.0			
Sugar beet	3.7	388'300	0.1			
5. Other (please specify)						
Silage corn	1.4	6'120'224	0.0			
Green corn	0.2	1'040'438	0.0			
Fruit	0.0	0	0.0			
Vine	0.1	24'000	0.0			
Non-leguminous vegetables	5.9	378'600	0.1			
Sunflowers	0.0	0	0.0			
Tobacco	0.0	0	0.0			
Rape	0.4	27'689	0.0			
Total	28.1	10'132'311	0.5	0.1521	3'450	0.1

Table 112 Additional data for N_2O emission calculation of agricultural soils (4D).