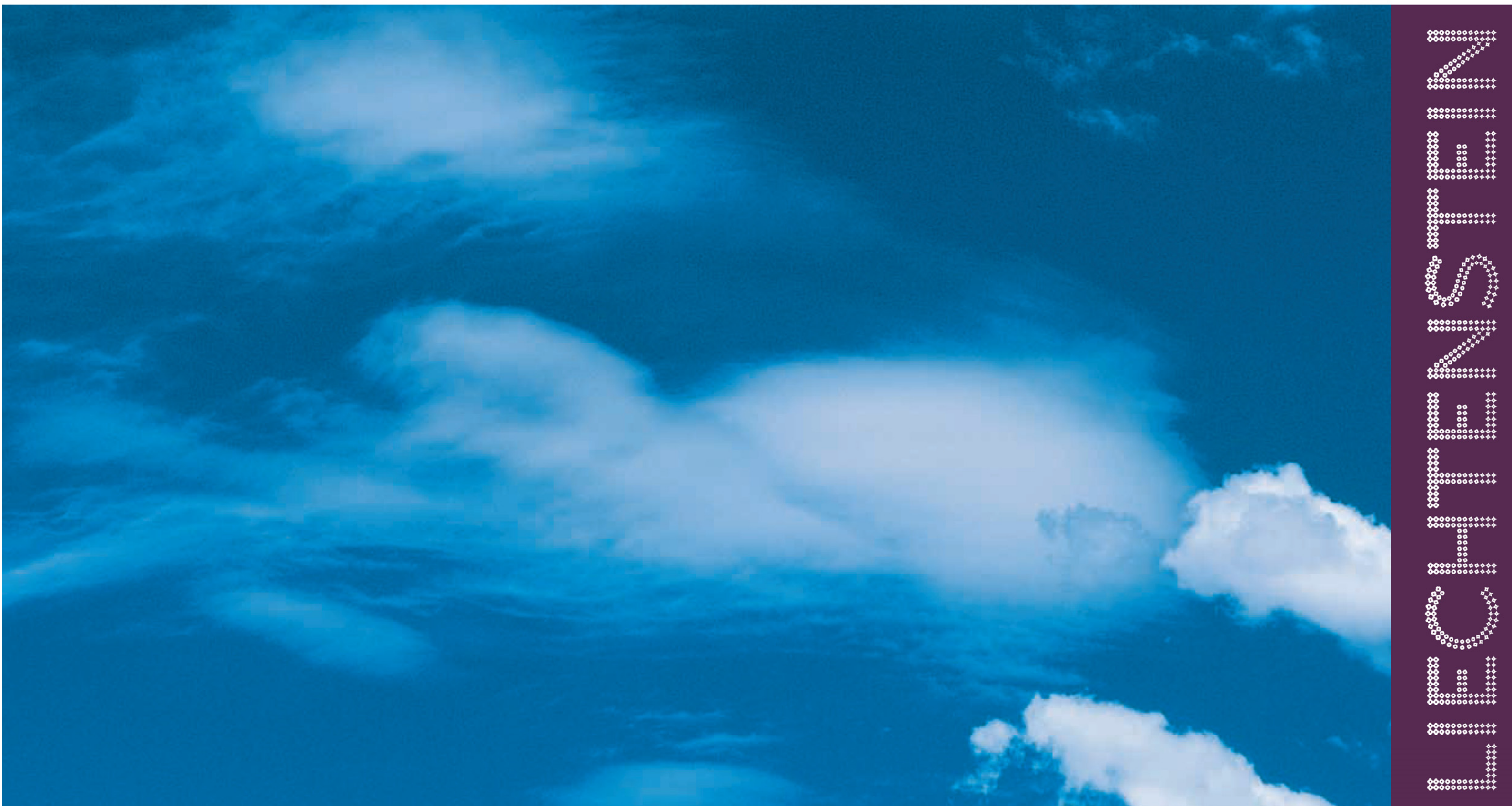
OFFICE OF ENVIRONMENTAL PROTECTION (OEP)
PRINCIPALITY OF LIECHTENSTEIN

Liechtenstein‘s Greenhouse Gas Inventory 1990 - 2006

National Inventory Report 2008

Submission of 29 February 2008
to the United Nations Framework Convention on Climate Change



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Principality of Liechtenstein

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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
kilotonnes	1000 tonnes
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)
MJ	Mega Joule (10^6 Joule = 1'00'000 Joule)
MSW	Municipal solid waste
NFR	Nomenclature for reporting (IPCC code of categories)
NIC	National Inventory Compiler
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)
QA/QC	Quality assurance/quality control: QA includes a system of review procedures conducted by persons not directly involved in the inventory development process. QC is a system of routine technical activities to control the quality of the inventory.
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
TJ	Tera Joule (10^{12} Joule = 1’00'000 Mega Joule)
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Introduction

In 1995, the Principality of Liechtenstein ratified the United Nations Framework Convention on Climate Change (UNFCCC). Furthermore 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 been implemented.

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 including the national greenhouse gas inventory for 1990 and 2004 as well as the National Inventory Report. The second submission on 22 December contained the national greenhouse gas inventory for the whole time period 1990–2004, National Inventory Report and the Initial Report under Article 7, paragraph 4 of the Kyoto Protocol (OEP 2006, 2006a). In May 2007 the GHG inventory 1990–2005 was submitted together with the National Inventory Report (2007).

From 11 to 15 June 2007 an individual review (In-Country Review) took place in Vaduz: The submission documents, the Initial Report and the GHG inventory 1990-2004 including CRF tables and National Inventory Report were objects of the review. Following the recommendations of the expert review team, some minor corrections were carried out in the emission modelling leading to recalculations and some methodological changes (revision of the definition of forests). Due to the recalculation, the time series of the national total of emissions slightly changes and therefore, Liechtenstein’s assigned amount will be adjusted by -0.407%. After this correction, Liechtenstein’s assigned amount is 1055.623 Gg CO_2 equivalents.

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.

For the interpretation of the Liechtenstein’s emissions and removals it is important to recognise that Liechtenstein is a small central European State in the Alpine region with a population of 35’168 inhabitants (as of 31 December 2006) 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.

The **National Inventory Report (NIR)** follows in its structure the default chapters of the UNFCCC Guidelines on Reporting of Greenhouse Gas Inventories (UNFCCC 2002):

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. For 2006, 16 categories were identified as key categories in level and trend analysis for Liechtenstein, covering 96.1% of total greenhouse gas (GHG) emissions (CO_2 equivalent). 37.1% of total GHG emissions resulted from the two most important key categories: CO_2 from source category 1A3b Fuel Combustion – Transport/gasoline (20.3%) and CO_2 from source category 1A4a Fuel Combustion – Other Sectors; Commercial, Institutional/ liquid fuels (16.8%). Besides the energy sector, other key categories are found in source category 2 Industrial Processes, 3 Solvent and Other Product Use and 4 Agriculture. In a further Key Category Analysis the LULUCF sector is included, too. Five additional key categories are identified, where 5A1 Forest Land remaining Forest Land is the predominant LULUCF category. Finally, the same analyses were also carried out for the base year 1990.

An uncertainty analysis (Tier 1) is carried out and presented in Chapter 1. It estimates the level uncertainty of 11.1% and the trend uncertainty of 18.1% of total CO_2 equivalent emissions in 2006.

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 1990–2006.

Chapter 9 After the In-Country Review in June 2007 some methodological and numerical corrections have been realised. A recalculation is the direct consequence of these modifications. The results are discussed in Chapter 9.

Trend Summary: National GHG Emissions and Removals

In 2006, Liechtenstein emitted 273.0 Gg (kilotonnes) CO_2 equivalent, or 7.76 tonnes CO_2 equivalent per capita (CO_2 only: 6.87 tonnes per capita) to the atmosphere not including emissions and removals from Land Use, Land-Use Change and Forestry (LULUCF).

Figure 1 and Table 1 show Liechtenstein’s annual GHG emissions by individual GHG for 1990 (base year) till 2006. Over this period, total annual GHG emissions increased by 19.0% (total excluding emissions and removals from LULUCF).

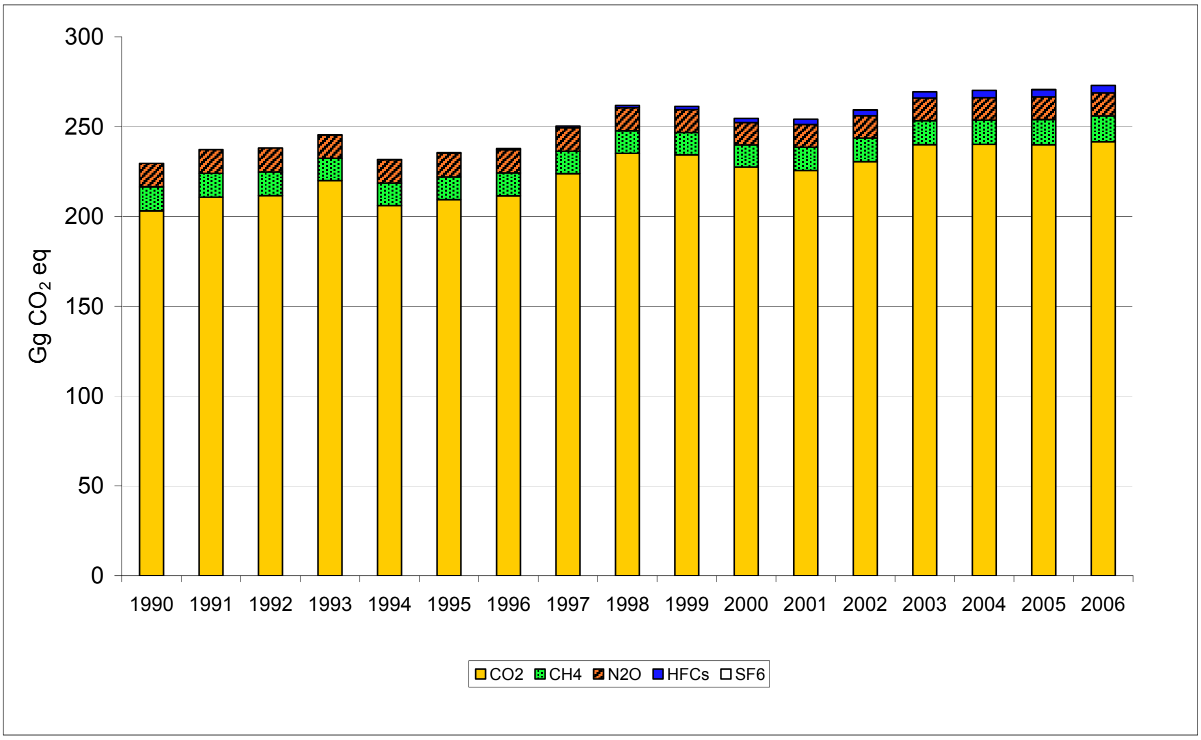

Figure 1 Trend of Liechtenstein's greenhouse gas emissions by gases1990–2006. CO_2, CH_4 and N_2O correspond to the respective total emissions excluding LULUCF.

Greenhouse Gas Emissions	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	CO_2 equivalent (Gg)									
CO_2 emissions including net CO_2 from LULUCF	194.7	202.4	203.3	211.6	197.6	200.9	203.0	218.9	230.2	229.4
CO_2 emissions excluding net CO_2 from LULUCF	203.1	210.8	211.7	220.0	206.1	209.4	211.6	223.8	235.1	234.3
CH_4 emissions including CH_4 from LULUCF	13.4	13.2	13.1	12.4	12.6	12.6	12.7	12.5	12.6	12.5
CH_4 emissions excluding CH_4 from LULUCF	13.4	13.2	13.1	12.4	12.6	12.6	12.7	12.5	12.6	12.5
N_2O emissions including N_2O from LULUCF	13.1	13.3	13.4	13.0	13.0	13.2	13.0	13.0	12.8	12.8
N_2O emissions excluding N_2O from LULUCF	13.1	13.3	13.4	13.0	13.0	13.1	12.9	13.0	12.7	12.7
HFCs	0.0	0.0	0.0	0.1	0.1	0.4	0.7	1.0	1.4	1.8
PFCs	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
SF_6	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	0.0	0.0	0.0	0.0
Total (including LULUCF)	**221.2**	**228.9**	**229.8**	**237.0**	**223.3**	**227.1**	**229.4**	**245.5**	**257.0**	**256.4**
Total (excluding LULUCF)	**229.5**	**237.3**	**238.2**	**245.4**	**231.7**	**235.5**	**237.9**	**250.4**	**261.9**	**261.3**

Greenhouse Gas Emissions	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	***1990-2006***
	CO_2 equivalent (Gg)							%
CO_2 emissions including net CO_2 from LULUCF	222.6	220.7	225.6	233.5	233.7	233.4	235.1	*20.7*
CO_2 emissions excluding net CO_2 from LULUCF	227.5	225.6	230.5	240.0	240.2	240.0	241.6	*19.0*
CH_4 emissions including CH_4 from LULUCF	12.3	13.0	13.1	13.3	13.5	14.0	14.4	*7.4*
CH_4 emissions excluding CH_4 from LULUCF	12.3	13.0	13.1	13.3	13.5	14.0	14.4	*7.4*
N_2O emissions including N_2O from LULUCF	12.5	12.6	12.5	12.5	12.5	12.6	12.9	*-1.7*
N_2O emissions excluding N_2O from LULUCF	12.5	12.6	12.5	12.5	12.5	12.6	12.9	*-1.7*
HFCs	2.3	3.0	3.2	3.6	4.0	4.1	4.1	---
PFCs	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	---
SF_6	0.0	0.0	0.1	0.1	0.1	0.1	0.1	---
Total (including LULUCF)	**249.7**	**249.3**	**254.5**	**263.0**	**263.8**	**264.2**	**266.5**	***20.5***
Total (excluding LULUCF)	**254.6**	**254.2**	**259.4**	**269.5**	**270.3**	**270.7**	**273.0**	***19.0***

Table 1 Summary of Liechtenstein's GHG emissions in CO_2 equivalent (Gg) by gas, 1990–2006. The column on the far right (digits in italics) shows the percent change in emissions in 2006 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 2006. The share of CH_4 decreased slightly from 5.8% (1990) to 5.3% (2006). Simultaneously, the share of N_2O decreased from 5.7% to 4.7%. The share of synthetic gases increased from 0.0% (1990) to 1.5% (2006). Figure 2 shows the share of 2006 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.

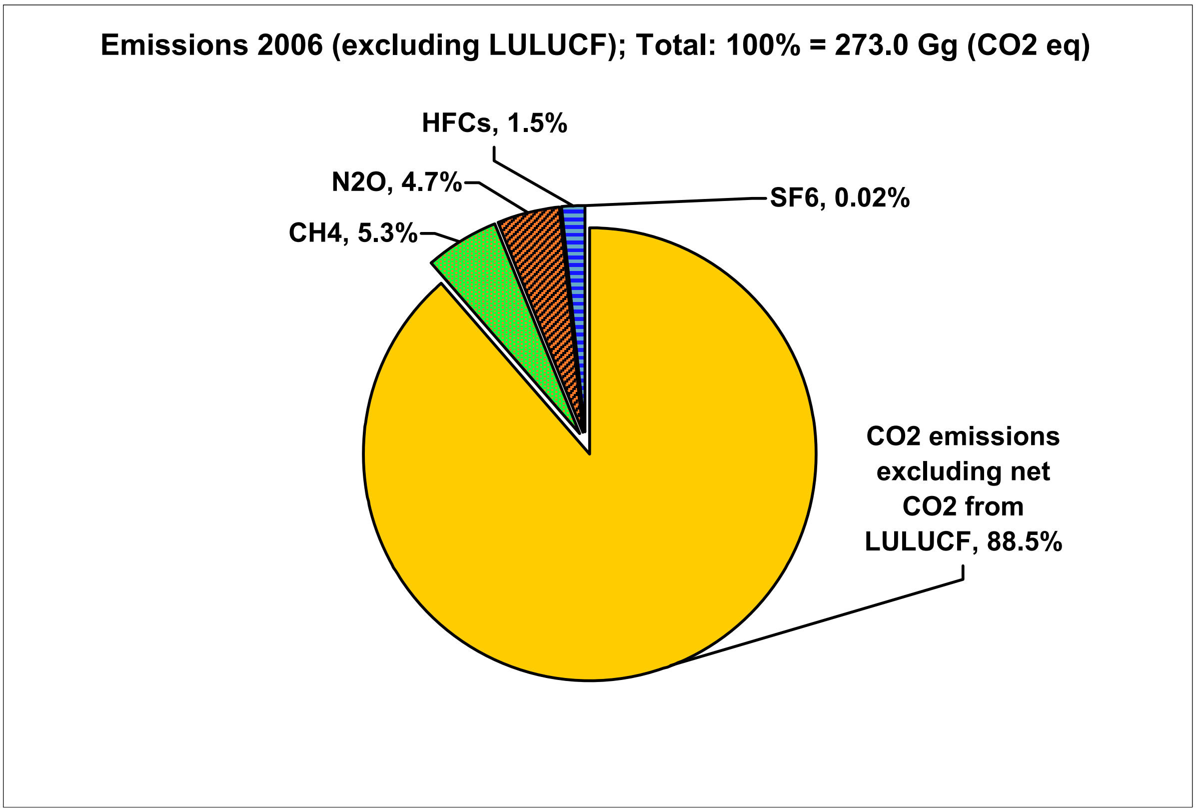

Figure 2 Liechtenstein's GHG emissions by gas (excluding LULUCF), 2006.

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 89.2% of the emissions. An increase of 19.7% is found for the energy sector for the period 1990–2006. The emissions from industrial processes exclusively consist of synthetic gases, which have also increased, whereas emissions from Solvent and other Product Use have strongly decreased, more than 44%. The emissions from agriculture showed a slight decrease from 1990–2000 followed by a slight increase. In 2006, the emissions were 0.9% below the 1990’s level. Emission and removals in the LULUCF sector form a net sink with net removals in the range between -4.9 (1997) to -8.5 Gg CO_2 eq (1996).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, municipal solid waste is exported to a Swiss incineration plant).

Source and Sink Categories	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	***1990/2006***
	CO$_2$ equivalent (Gg)																	***%***
1 Energy	**203.5**	**211.5**	**212.6**	**221.1**	**207.2**	**210.7**	**212.9**	**225.4**	**236.8**	**236.0**	**229.5**	**227.4**	**232.3**	**241.9**	**242.1**	**241.9**	**243.6**	***19.7***
1A1 Energy Industries	0.2	0.8	1.9	1.9	1.8	2.0	2.5	2.5	2.9	2.9	2.7	2.9	2.5	2.8	2.9	3.1	2.8	*1499*
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	35.7	38.3	37.4	36.2	37.4	*6.0*
1A3 Transport	76.4	89.7	89.1	87.0	79.6	81.7	82.9	86.6	86.2	91.9	95.9	92.2	87.7	87.3	86.0	85.5	82.5	*8.0*
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	102.9	109.2	111.9	112.6	116.2	*30.7*
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	2.8	3.4	3.1	3.5	3.7	*53.3*
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	0.8	0.9	0.9	1.0	1.1	*232*
2 Industrial Processes	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.4**	**0.7**	**1.0**	**1.4**	**1.8**	**2.4**	**3.0**	**3.2**	**3.6**	**4.1**	**4.1**	**4.2**	***---***
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**	**1.1**	**1.1**	***-44.2***
4 Agriculture	**22.5**	**22.5**	**22.3**	**21.1**	**21.1**	**21.3**	**21.2**	**21.0**	**20.8**	**20.5**	**19.8**	**21.0**	**20.9**	**21.1**	**21.2**	**21.6**	**22.3**	***-0.9***
6 Waste	**1.6**	**1.5**	**1.5**	**1.5**	**1.6**	**1.5**	**1.6**	**1.5**	**1.6**	**1.6**	**1.7**	**1.6**	**1.8**	**1.8**	**1.8**	**1.9**	**1.8**	***14.3***
Total (excluding LULUCF)	**229.5**	**237.3**	**238.2**	**245.4**	**231.7**	**235.5**	**237.9**	**250.4**	**261.9**	**261.3**	**254.6**	**254.2**	**259.4**	**269.5**	**270.3**	**270.7**	**273.0**	***19.0***
5 Land Use, Land-Use Change and Forestry	-8.3	-8.4	-8.4	-8.4	-8.5	-8.5	-8.5	-4.9	-4.9	-4.9	-4.9	-4.9	-4.9	-6.5	-6.5	-6.5	-6.5	*-21.3*
Total (including LULUCF)	221.2	228.9	229.8	237.0	223.3	227.1	229.4	245.5	257.0	256.4	249.7	249.3	254.5	263.0	263.8	264.2	266.5	*20.5*

Table 2 Summary of Liechtenstein's GHG emissions by source and sink categories in CO$_2$ equivalent (Gg), 1990–2006. The column on the far right (digits in italics) shows the percent change in emissions in 2006 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 GHG Inventory Core Group at the Swiss Federal Office for Environment (FOEN). The free use of methods and tools developed by the FOEN has been essential during the development of the completely revised Liechtenstein GHG inventory and the NIR.

The OEP also gratefully acknowledges the support of the Agroscope Reckenholz-Tänikon Research Station (ART). The use of the worksheet developed by ART facilitated very much the modelling of the agricultural emissions and its uncertainties. 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 in due time.

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 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 including the national greenhouse gas inventory for 1990 and 2004 as well as the National Inventory Report. The second submission on 22 December contained the national greenhouse gas inventory for the whole time period 1990–2004, National Inventory Report and the Initial Report under Article 7, paragraph 4 of the Kyoto Protocol (OEP 2006, 2006a). In May 2007 the GHG inventory 1990–2005 was submitted together with the National Inventory Report (2007).

From 11 to 15 June 2007 an individual review (In-Country Review) took place in Vaduz: The submission documents, the Initial Report and the GHG inventory 1990-2004 including CRF tables and National Inventory Report were objects of the review. Following the recommendations of the expert review team (UNFCCC ERT 2007), some minor corrections were carried out in the emission modelling leading to recalculations and some methodological changes (revision of the definition of forests). The consequences are documented in the reports of the review of the initial report of Liechtenstein (UNFCCC IRR 2007) and of the individual review of the greenhouse gas inventory of Liechtenstein submitted in 2006 (UNFCCC ARR 2007). Due to the recalculation, the time series of the national total of emissions slightly changes and therefore, Liechtenstein's assigned amount will be adjusted by -0.407%. The modifications are documented in a corrigendum to the Initial Report (OEP 2007a, 2007b)

The current submission includes the complete national greenhouse gas inventory for the time period 1990–2006 and the National Inventory Report on hand.

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 with a population of 35'168 inhabitants (as of 31 December 2006) 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 QA/QC 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.

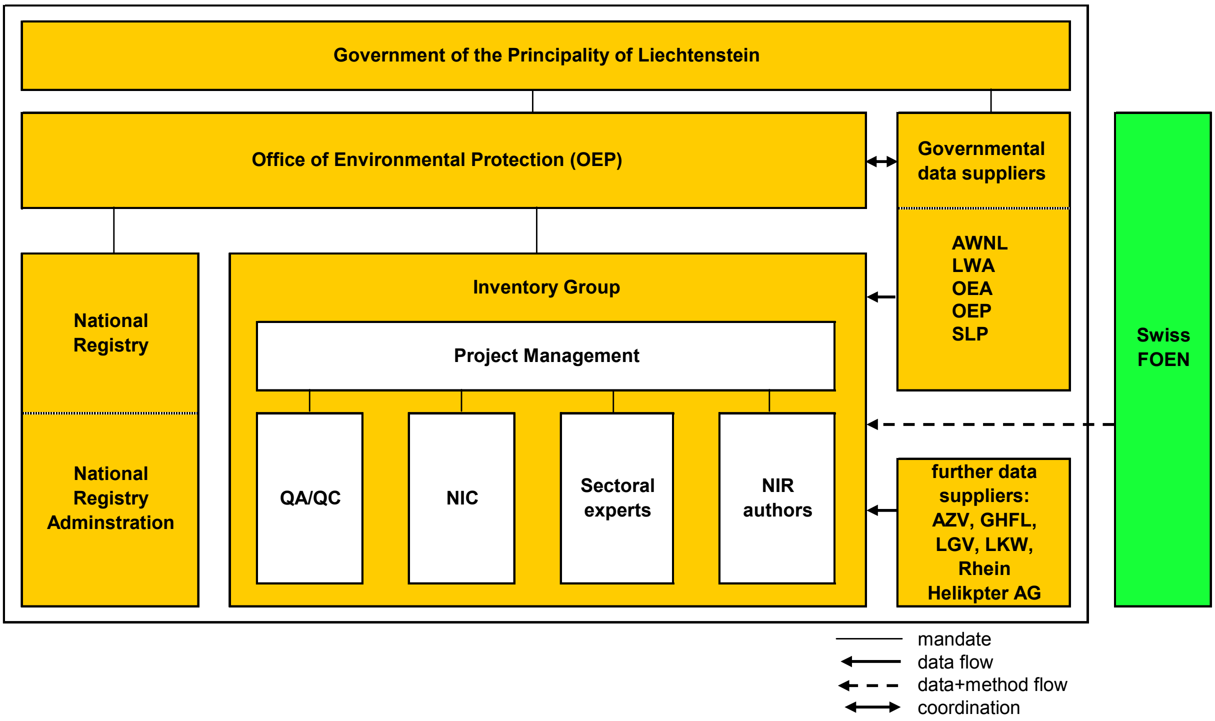

Figure 3 National Inventory System: Institutional setting.

The **Government of the Principality of Liechtenstein** bears the overall responsibility for the NIS. By Liechtenstein's Emission Trading Act (Emissionshandelsgesetz), 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

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

group and the National Registry Administrator. He also coordinates in cooperation with the responsible head of the unit 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), represented by the head of the OEP and his replacement. 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)
- 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 Federal Office for the Environment (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. The FOEN and Liechtenstein's 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, synthetic gases, solvents). Liechtenstein has benefited to a large extend from the methodological support by the inventory core group within the 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.

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[2] Schweizerische Gesamtenergiestatistik 2005. Statistique globale Suisse de l'énergie 2005. Swiss Federal Office of Energy (SFOE 2006).

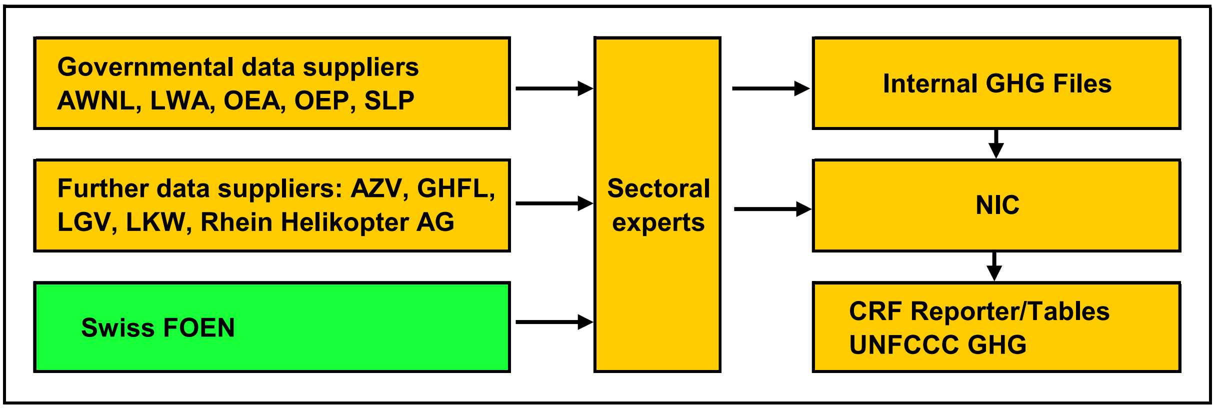

Figure 4 Data suppliers and data collection for setting up the UNFCCC GHG Inventory (see Glossary for abbreviations).

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 (see Section 1.2). 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. In the following paragraph, a short summary of the methods used is given for every sector.

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: Country specific and IPCC default values are applied.
- Emissions from 1B Fugitive Emissions from Fuels: A Tier 3 method is applied, activity data is taken from the Liechtenstein's gas utility (LGV). Emission factors: 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, corresponding to a Tier 2 approach.

- 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 rough estimate of Liechtenstein's emissions.
- 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 by country specific methods and emission factors: Swiss emissions are transformed using the number of Liechtenstein’s inhabitants as a proxy for the rough estimate of Liechtenstein's emissions.

4 Agriculture

- Emissions are reported for 4A Enteric Fermentation, 4B Manure Management and 4D Agricultural Soils: Tier 1b, Tier 2 and country specific methods are applied. Country specific activity data and country specific or default emission factors are applied.

5 LULUCF

- Emissions and removals are reported for 5A to 5F. The methods are adopted from Switzerland and correspond to Tier 2. Country specific activity data and country specific emission (carbon) factors are used.

6 Waste

- Emissions from 6B Waste Water Handling 6C Waste Incineration and 6D Other are reported. Tier 2, country specific or default methods are applied. Country specific activity data and Swiss or IPCC default emission factors are used.

1.4.2. Specific Assumptions for the Year 2006

For the modelling of its emission, Liechtenstein uses several emission factors stemming from the Swiss GHG inventory. Important examples are the implied emission factors for 1A3b Road Transportation. Currently, the emissions 2006 of the Swiss inventory are not yet available in their final version, therefore the implied emission factors 2006 are not available too. For the time being, implied emission factors 2005 are used as a preliminary estimate for the implied emission factors 2006. The following sectors are concerned

- Energy: 1A3b, 1A4c, 1A5b
- Ind. Process: 2A5, 2A6, 2F1, 2F4
- Solvent and other Product Use: 3A, 3B, 3C, 3D
- Agriculture: 4A, 4B, 4D

For the subsequent submission in April 2009, the emissions 2006 will be recalculated using the final Swiss emission factors 2006.

1.4.3. Reference Approach for the Energy Sector

Liechtenstein has carried out for the first time the Reference Approach to estimate energy consumption and CO_2 emissions for the energy sector. The results are shown in Section 3.6.

1.5. Key Categories

The key category analysis (KCA) 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%. The analysis is performed four times for the base year 1990 and the latest year 2006, both years with and without LULUCF categories.

1.5.1. KCA without LULUCF categories

For 2006, among a total of 121 categories, 16 have been identified as key categories with an aggregated contribution of 96.1% 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 out of the energy sector, contributing 87.6% to total CO_2 equivalent emissions in 2006. The other key categories are from sectors Industrial Processes (1.5%), Solvent and Other Product Use (0.3%) and Agriculture (6.7%). There are two major key sources:

- 1A3b Energy, Fuel Combustion, Road Transportation, gasoline, CO_2, level contribution 20.3%,
- 1A4a Energy, Fuel Combustion, Other Sectors, Commercial/Institutional, liquid fuels, CO_2, level contribution 16.8%.

The complete Key Category Analysis is provided in Annex 1.

Table 3 List of Liechtenstein's 16 key categories 2006. Upper part sorted by NFR code (by category code), lower part sorted by contribution in level.

Key Category Analysis 2006 (without LULUCF) IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year 2006 Estimate	Level Assessment	Trend Assessment	% Contribution in Trend	Result level assessment	Result trend assessment
Sorted by NFR code						Gg CO2 eq	Gg CO2 eq					
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	0.12	2.69	0.99%	0.007855	2.1%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	22.20	8.13%	0.007992	2.2%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	15.13	5.54%	0.022059	6.0%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	24.01	8.79%	0.019826	5.4%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CO2	0.00	2.00	0.73%	0.006157	1.7%	-	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	55.56	20.35%	0.050623	13.8%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	29.34	10.75%	0.058461	15.9%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	45.75	16.76%	0.068254	18.6%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	23.72	8.69%	0.063824	17.3%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	15.13	5.54%	0.022059	6.0%	KC level	KC trend
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	3.62	1.33%	0.002499	0.7%	KC level	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			HFC	0.00	4.15	1.52%	0.012769	3.5%	KC level	KC trend
3	3. Solvent and Other Product Use				CO2	1.53	0.88	0.32%	0.002887	0.8%	-	KC trend
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	10.24	3.75%	0.004367	1.2%	KC level	KC trend
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	5.62	2.06%	0.003779	1.0%	KC level	KC trend
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.49	0.91%	0.002347	0.6%	KC level	-
Sorted by contribution in level												
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	55.56	20.35%	0.050623	13.8%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	45.75	16.76%	0.068254	18.6%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	29.34	10.75%	0.058461	15.9%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	24.01	8.79%	0.019826	5.4%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	23.72	8.69%	0.063824	17.3%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	22.20	8.13%	0.007992	2.2%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	15.13	5.54%	0.022059	6.0%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	15.13	5.54%	0.022059	6.0%	KC level	KC trend
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	10.24	3.75%	0.004367	1.2%	KC level	KC trend
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	5.62	2.06%	0.003779	1.0%	KC level	KC trend
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			HFC	0.00	4.15	1.52%	0.012769	3.5%	KC level	KC trend
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	3.62	1.33%	0.002499	0.7%	KC level	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	0.12	2.69	0.99%	0.007855	2.1%	KC level	KC trend
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.49	0.91%	0.002347	0.6%	KC level	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CO2	0.00	2.00	0.73%	0.006157	1.7%	-	KC trend
3	3. Solvent and Other Product Use				CO2	1.53	0.88	0.32%	0.002887	0.8%	-	KC trend

For the base year 1990, the level analysis is given in Table 4. There are 12 level key categories, which are also key categories in 2006. Gaseous fuels in 1A1, 1A3b, consumption of halocarbons in 2F and Solvent and other product use sector 3, which are all key categories with respect to level or trend 2006, are no level key categories in 1990.

Key Category Analysis 1990 (without LULUCF) IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Level Assessment	Cumulative Total Column E-L	Result level assessment
Sorted by NFR code						Gg CO2 eq			
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	7.18%	74.76%	KC level
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	8.17%	59.41%	KC level
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	6.43%	81.19%	KC level
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	26.37%	26.37%	KC level
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	3.79%	89.26%	KC level
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	24.88%	51.25%	KC level
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	1.09%	94.05%	KC level
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	8.17%	67.58%	KC level
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	1.03%	95.08%	KC level
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	4.27%	85.46%	KC level
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	2.51%	91.76%	KC level
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	1.19%	92.95%	KC level
Sorted by contribution in level									
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	7.18%	74.76%	KC level
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	8.17%	59.41%	KC level
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	6.43%	81.19%	KC level
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	26.37%	26.37%	KC level
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	3.79%	89.26%	KC level
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	24.88%	51.25%	KC level
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	1.09%	94.05%	KC level
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	8.17%	67.58%	KC level
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	1.03%	95.08%	KC level
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	4.27%	85.46%	KC level
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	2.51%	91.76%	KC level
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	1.19%	92.95%	KC level

Table 4 List of Liechtenstein's 12 key categories in 1990. Upper part sorted by NFR code (by category code), lower part sorted by contribution in level.

1.5.2. Combined KCA without and with LULUCF categories

The key category analysis including LULUCF categories is also carried out for 1990 and 2006. The results are summarised in Table 5. According to IPCC Good Practice Guidance for LULUCF (IPCC 2003), Section 5.4.2, the set of key categories consists of all non-LULUCF key categories that result from the KCA without LULUCF combined with all LULUCF-key-categories that result from the KCA with LULUCF.

Key Category Analysis 2006 (combined with/without LULUCF) IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate (2006)	Result level assessment	Result trend assessment
						Gg CO2 eq	Gg CO2 eq		
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	0.12	2.69	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	22.20	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	15.13	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	24.01	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CO2	0.00	2.00	-	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	55.56	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	29.34	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	45.75	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	23.72	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	15.13	KC level	KC trend
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	3.62	KC level	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			HFC	0.00	4.15	KC level	KC trend
3	3. Solvent and Other Product Use				CO2	1.53	0.88	-	KC trend
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	10.24	KC level	KC trend
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	5.62	KC level	KC trend
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.49	KC level	-
5A1	5. LULUCF	A. Forest Land	1. Forest Land remaining Forest Land		CO2	18.64	19.02	KC level	KC trend
5B1	5. LULUCF	B. Cropland	1. Cropland remaining Cropland		CO2	4.33	4.45	KC level	-
5C1	5. LULUCF	C. Grassland	1. Grassland remaining Grassland		CO2	2.13	1.81	KC level	KC trend
5C2	5. LULUCF	C. Grassland	2. Land converted to Grassland		CO2	0.08	0.87	-	KC trend
5E2	5. LULUCF	E. Settlements	2. Land converted to Settlements		CO2	3.30	3.47	KC level	-

Key Category Analysis 1990 (combined with/without LULUCF) IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate (2006)	Result level assessment
						Gg CO2 eq	Gg CO2 eq	
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	16.48	KC level
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	18.74	KC level
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	14.77	KC level
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	60.53	KC level
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	8.70	KC level
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	57.10	KC level
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	2.51	KC level
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	18.74	KC level
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	2.36	KC level
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	9.80	KC level
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	5.75	KC level
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.73	KC level
5A1	5. LULUCF	A. Forest Land	1. Forest Land remaining Forest Land		CO2	18.64	18.64	KC level
5B1	5. LULUCF	B. Cropland	1. Cropland remaining Cropland		CO2	4.33	4.33	KC level
5C1	5. LULUCF	C. Grassland	1. Grassland remaining Grassland		CO2	2.13	2.13	KC level
5E2	5. LULUCF	E. Settlements	2. Land converted to Settlements		CO2	3.30	3.30	KC level

Table 5 Liechtenstein's key categories in 2006 and in 1990 including LULUCF categories.

In the KCA 2006 including LULUCF categories there are totally 135 categories. 21 of them are key categories. Five of the key categories are out of the LULUCF sector. The largest category is 5A1 Forest Land remaining Forest Land; the other LULUCF key categories are of minor importance. The other 16 key categories are identical to the categories in Table 3.

In 1990, 12 non-LULUCF categories appear as key categories identical to the KCA without the LULUCF sector. Among the LULUCF categories, 5C2 Land converted to Grassland drops from the list of key categories since its contribution is small. The other four LULUCF key categories already appear in 2006.

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

1.6.1. Terms and objectives

According to the IPCC Good Practice Guidance (IPCC 2000) the major elements of a QA/QC system are:

- an inventory agency responsible for coordinating QA/QC activities;
- a QA/QC plan;
- QC procedures;
- QA review procedures;
- reporting, documentation, and archiving procedures.

The state of implementation of these quality elements is described in the following chapters. One has to note that Liechtenstein's QA/QC system accounts for 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.

Objectives of the quality system

The quality management shall enable the party to principally fulfil the requirements of the articles 3, 5 and 7 of the Kyoto Protocol. Specifically, it shall ensure and improve the quality of GHG inventory that means a continuous improvement **of transparency, consistency, comparability, completeness and confidence**. In detail, it serves

- for providing checks to ensure data integrity, correctness and completeness;
- to identify errors and omissions,
- to reduce the uncertainties of the emission estimates,
- to document and archive inventory material.

1.6.2. Responsible agency for coordinating QA/QC activities

The QA/QC activities are coordinated by the project manager of the GHG Inventory Group. The responsible person is Mr. Andreas Gstoehl, head of the unit Air Pollution Control, Noise and Climate (e-mail: Andreas.Gstoehl@aus.llv.li, phone: +423 236 61 86) in the Office of Environmental Protection (OEP). The QA/QC activities are organised within the Inventory Group, see National System represented in Figure 3.

Operational tasks are delegated to the lead NIR author. He distributes the checklists to the NIC, to the sectoral experts, to the other NIR authors and to the project manager. They fill in the procedures that they carried out. The list is then sent back to the project manager, who confirms the performance of the QA/QC activities. The activities are documented in the NIR (see Annex 2).

1.6.3. QA/QC plan

Table 6 illustrates the annual cycle of inventory planning and preparation including the time-lines for the performance of QC activities. The current inventory preparation started two months in advance compared to the plan due to exceptional activities caused by the In-Country Review in June 2007. From 2008 on, the preparation will follow the schedule shown in the table.

Issue	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Mai
Meeting of Inventory Group		🟨				🟨				🟨			
Meeting of Group Environment/Spatial Planning					🟨					🟨			
Considerataion of UNFCCC Syn.&Ass. II	🟨												
Data Collection				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨		
Quality check of sectoral data							energy		other sectors				
Calculation of emissions/removals						🟨	🟨	🟨	🟨	🟨	🟨		
Generation of CRF tables									🟨	🟨	🟨		
Quality checks CRF tables										🟨	🟨		
Key Category Analysis incl. QC checks										🟨	🟨		
Uncertainty Analysis incl. QC checks											🟨		
Generation of NIR tables									🟨	🟨	🟨		
Compilation/Editing of NIR						🟨	🟨	🟨	🟨	🟨	🟨	🟨	
QC: Proofread of NIR (correctness, transparency etc.)											🟨	🟨	
QC: Fill in checklist									energy	other issues			
QA activities				external review CH inventory				LULUCF		int. rev. CH inv.			
Official consideration and approval												🟨	
Submission to the UNFCCC secretariat												🟨	
Publication of NIR/CRF													🟨
Arciving, storage of GHG inventory documents	🟨	🟨										🟨	🟨

Table 6 Schedule for inventory planning and preparation. “external/internal review CH inventory”: QA activities for the Swiss GHG inventory serve as QA activities for Liechtenstein’s GHG inventory (see section QA activities below).

1.6.4. QC procedures

Quality control (QC) is defined by: “System of routine technical activities to measure and control the quality of the inventory as it is being developed.” (IPCC 2000).

Overall Activities

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 spatial 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.
- The project manager, the sectoral experts, the national inventory compiler (NIC) 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.
- The NIC checks the integrity of the database files, the consistency of time series, the correct and complete inputs into the CRF Reporter.
- 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: 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.

It may be mentioned that the OEP enlarged its staff in the unit Climate Protection in the beginning of 2007 by two more collaborators. They are responsible for emission modelling, GHG inventory, implementation of the emission trading system, national registry, national allocation plan, Kyoto mechanisms (JI, CDM).

Documentation of the QC Activities

For the current submission 2008, the QC activities have been documented for the first time by means of a checklist. The list is shown in the Annex 2 Table 126. The classification of the QC activities follows the IPCC GPG table 8.1 (IPCC 2000). The following persons are involved in the QC activities:

- Sectoral experts for energy, industrial processes etc.
- NIC
- NIR authors
- Project manager

Special attention of the QC activities for emissions has been directed to the key categories.

1.6.5. QA review procedures

Quality assurance (QA): System of activities that include a “system of review procedures conducted by personnel not directly involved in the inventory compilation development process, to verify that data quality objectives were met, ensure that the inventory represents the best possible estimate of emissions and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the QC programme” (IPCC 2000).

Liechtenstein’s NIS quality management system follows a Plan-Do-Check-Act-Cycle (PDCA-cycle), which is a generally accepted model for pursuing a systematic quality performance according to international standards. This approach is in accordance with procedures described in decision 19/CMP.1 and in the IPCC Good Practice Guidance.

Liechtenstein carries out the following QA activities:

- The Swiss inventory management charges external experts for sectoral QA activities to review the Swiss GHG inventory. Since a number of Swiss methods and Swiss emission factors are used for the preparation of the Liechtenstein inventory, the results of the Swiss QA activities have to be checked and analysed by Liechtenstein's experts. Positive reviews may be interpreted as positive for Liechtenstein too, and problematic findings must not only be taken account for in Switzerland but also in Liechtenstein. Which sectors have already been reviewed for the Swiss GHG inventory?
    - In 2006, a consulting group (not involved in the GHG emission modelling) was mandated to review the two sectors Energy and Industrial Processes with respect to methods, activity data, emission factors, CRF tables, NIR chapter (Eicher and Pauli 2006). The results were documented in a review report and communicated to Liechtenstein's Inventory Group. The consequences for the main findings have been evaluated for Liechtenstein's GHG inventory and for the NIR for submission December 2006.
    - For the Swiss NIR, an internal review takes places annually shortly before the submission. Every chapter of the NIR is being proofread by specialists not involved in the emission modelling or in the NIR editing. The internal review is organised by the quality officer and the results are compiled by the same person that is also compiling Liechtenstein's NIR (lead author J. Heldstab, INFRAS). The results of the Swiss review are therefore communicated to Liechtenstein's Inventory Group. Where methods and results are concerned that are relevant for Liechtenstein too, the consequences were taken into account. This procedure has been performed in the three last and the current submissions (May and December 2006, May 2007, February 2008). It will also be repeated for future submissions.
- The NIR chapter 7. LULUCF (submission December 2006 and current submission) was reviewed by a specialist of the OEP (H. Eberle), who was not involved in the emission/removal modelling. This QA activity will also be repeated for future submissions.
- The applicability of Swiss methodologies and emission factors to Liechtenstein's GHG inventory is reviewed as well: Before Swiss methods are applied, they are discussed with the experts of Liechtenstein's administration. This process has taken place for the sectors Energy, Agriculture and Waste before the submission in December 2006. For the current submission the process went on for the LULUCF sector due to the revision of the definition of forests. It will be repeated in the future in every case when Switzerland changes methods or emission factors.

1.6.6. Archiving procedures

The electronic files of Liechtenstein's GHG inventory are all saved by the backup system of Liechtenstein's administration.

Every computer belonging to the administration, including the computers of the Office of Environmental Protection, are connected to the central network. The data of the server systems, file-clusters and database servers, are being saved in a tape-library. Due to safety reasons, the tape-library is not in the computing centre but in a building of the National police: In case of a total lost of the computing centre, the data are still available.

There are several backups

- daily incremental saved up to one month (4 weeks)
- Weekly full backup saved up to two months
- Monthly full backup saved up to one year

The backup files are being initialised via scheduler of the master server. The data are written via network onto one of the LTO 2 Drives (tape). The master server manages the handling of the tapes. Backups are checked daily via Activity Monitor. If a backup is not carried out, it may be caught up manually. Since daily restores of user data is carried out, there is a guarantee for keeping the data readable.

For archiving reasons, the backup tapes are being doubled four times a year. The duplicates are not being overwritten during five years.

In addition to the administrational archiving system, the external experts of Acontec, who are mandated with the emission modelling and CRF generation, save all CRF and background tables yearly on CD ROM /DVD ROM. The disks are stored in a bank safe of the Liechtensteinische Landesbank (Liechtenstein's National Bank).

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, uncertainty data from the Swiss NIR (FOEN 2007) and expert estimates.

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 the 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 summarised in Table 7.

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 11.1% for the level 2006. Trend uncertainty is 18.1%. It should be noted that this result is almost the same as in the previous submission (11.1% level, 18.0% trend uncertainty, see OEP 2007), although the uncertainties for the key categories of the agricultural sector have been revised. They have been reduced for 4A/CH_4 and have been increased for 4D3/N_2O. For 4D1 they remained nearly unchanged. The combined uncertainty of the three categories adds up to 3.9% of the national total (2006); in the previous submission this value was 3.4% (2005). That means that the revision did not change much on the aggregated level.

The overall uncertainty is still 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 specific uncertainties of the LULUCF sector are not considered. The activity data (areas) are supposed to be quite exact, whereas no information is available yet about the uncertainty of the carbon factors. As soon as Switzerland will provide information on its LULUCF categories, Liechtenstein will implement these numbers into its uncertainty analysis to have an idea of the implications.
- Errors due to methodological shortcomings,
- Errors due to non-key categories are only contained in an overall uncertainty estimate.

Table 7 Tier 1 Uncertainty calculation and reporting for sources in Liechtenstein, 2006 (IPCC 2000, Table 6.1).

IPCC GPG Table 6.1
Tier 1 Uncertainty Calculation and Reporting

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions 1990	Year 2006 emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	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
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%	%	%	%	%	%
1. CO2 emissions from Fuel Combustion												
1A 1. Energy A. Fuel Combustion Gaseous fuels	CO2	27.81	79.95	5.0	4.6	6.8	1.989	0.2039	0.3483	0.94	2.46	2.64
1A 1. Energy A. Fuel Combustion Liquid fuels	CO2	173.62	160.76	18.0	0.5	18.0	10.602	-0.1980	0.7004	-0.11	17.83	17.83
1A 1. Energy A. Fuel Combustion Solid fuels	CO2	0.09	0.01	20.0	5.0	20.6	0.001	-0.0004	0.0001	0.00	0.00	0.00
Total CO2 Emissions Fuel Combustion	CO2	201.53	240.73									

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	4.15		13.8	13.8	0.210	0.0181	0.0181	0.25	0.00	0.25
3 3. Solvent and Other Product Use	CO2	1.53	0.88		80.0	80.0	0.257	-0.0041	0.0038	-0.33	0.00	0.33
4A 4. Agriculture A. Enteric Fermentation	CH4	9.80	10.24	6.4	17.2	18.3	0.688	-0.0062	0.0446	-0.11	0.41	0.42
4D1 4. Agriculture D. Agricultural Soils; Direct Soil Emissions	N2O	5.75	5.62		76.5	76.5	1.574	-0.0053	0.0245	-0.41	0.00	0.41
4D3 4. Agriculture D. Agricultural Soils; Indirect Emissions	N2O	2.73	2.49		159.1	159.1	1.450	-0.0033	0.0108	-0.53	0.00	0.53
Rest of sources	all	8.19	8.95	20.0	34.6	40.0	1.311	-0.0035	0.0390	-0.12	1.10	1.11
Total other Key Sources and rest of sources		28.00	32.32									

A	B	C	D				H					M
		Gg CO2 equivalent	Gg CO2 equivalent									
3. Total (combined uncertainty of 1. and 2.)												
Total Emissions	all	229.53	273.05									
Total Uncertainties						Overall uncertainty in the year (%)	**11.10**				Trend uncertainty (%)	**18.08**

Table 6.1 (CONTINUED)
Tier 1 Uncertainty Calculation and Reporting

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	R		Section 6.5.3
	Rest of sources			All	R	R		Exp. est.

Table 8 Further information on the Tier 1 uncertainty calculation and reporting for sources in Liechtenstein, 2006 (IPCC 2000, Table 6.1 continued).

1.8. Completeness Assessment

Liechtenstein's current GHG inventory is complete 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 2 Industrial Processes and 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 1990–2006.

2.1. *Aggregated Greenhouse Gas Emissions 2006*

In 2006, Liechtenstein emitted 273.0 Gg (kilotonnes) CO_2 equivalent, or 7.76 tonnes CO_2 equivalent per capita (CO_2 only: 6.87 tonnes per capita) to the atmosphere not including emissions and removals from Land Use, Land-Use Change and Forestry (LULUCF). The largest contributor gas is CO_2, and the most important sources of emissions are fuel combustion activities in the Energy sector. Table 9 shows the emissions for individual gases and sectors in Liechtenstein for the year 2006. Fuel combustion within the Energy sector was by far the largest source of emissions of CO_2 in 2006. Emissions of CH_4 and N_2O originated mainly from Agriculture, and the synthetic gas emissions stemmed by definition from Industrial Processes.

Emissions 2006	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**Total**
	CO_2 equivalent (Gg)						
1 All Energy	240.7	1.8	1.1				**243.6**
2 Industrial Processes	NO	NO	NO	4.1	NA,NO	0.1	**4.2**
3 Solvent Use	0.9		0.2				**1.1**
4 Agriculture (1 year average)		12.0	10.4				**22.3**
6 Waste	0.0	0.7	1.1				**1.8**
Total (excluding LULUCF)	**241.6**	**14.4**	**12.9**	**4.1**	**0.0**	**0.1**	**273.0**
5 LULUCF	-6.5	NO	NO				**-6.5**
Total (including LULUCF)	235.1	14.4	12.9	4.1	0.0	0.1	**266.5**
International Bunkers	*0.8*	*0.0*	*0.0*				***0.8***

Table 9 Summary of Liechtenstein’s GHG emissions by gas and sector in CO_2 equivalent (Gg), 2006.

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.

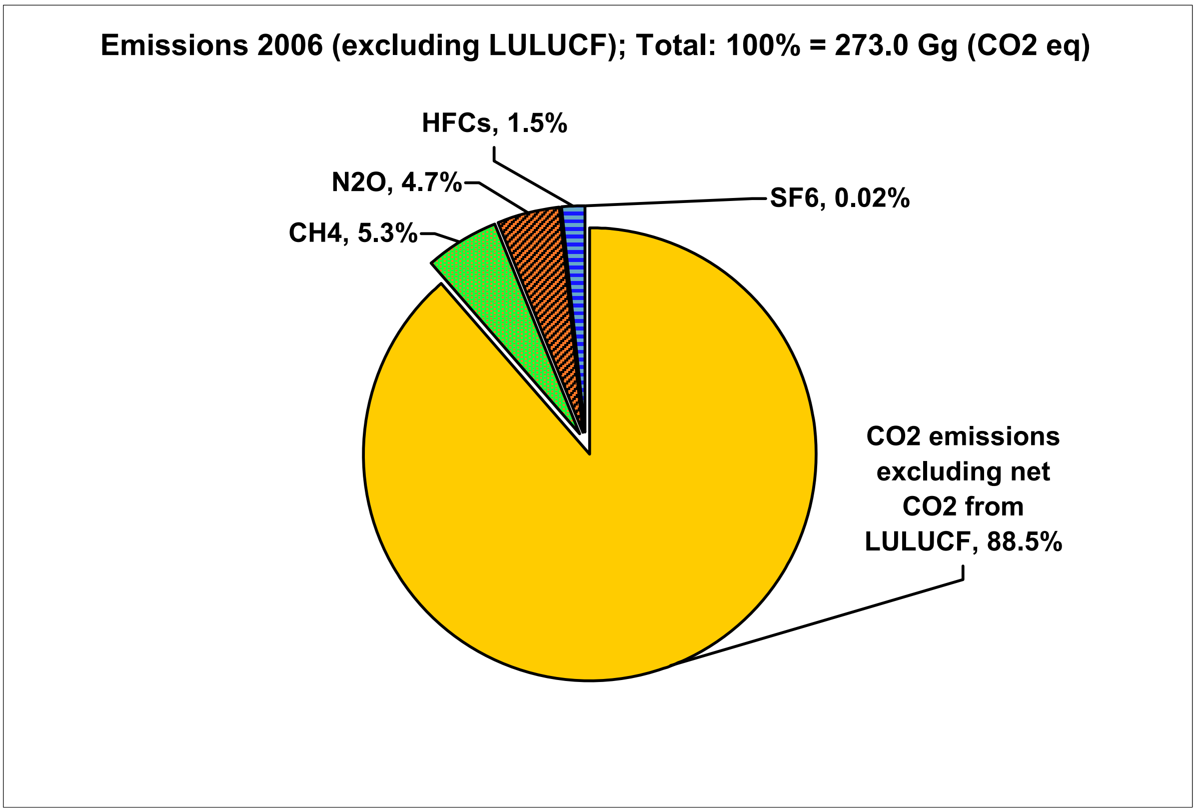

Figure 5 Liechtenstein's GHG emissions by gas (excluding LULUCF), 2006.

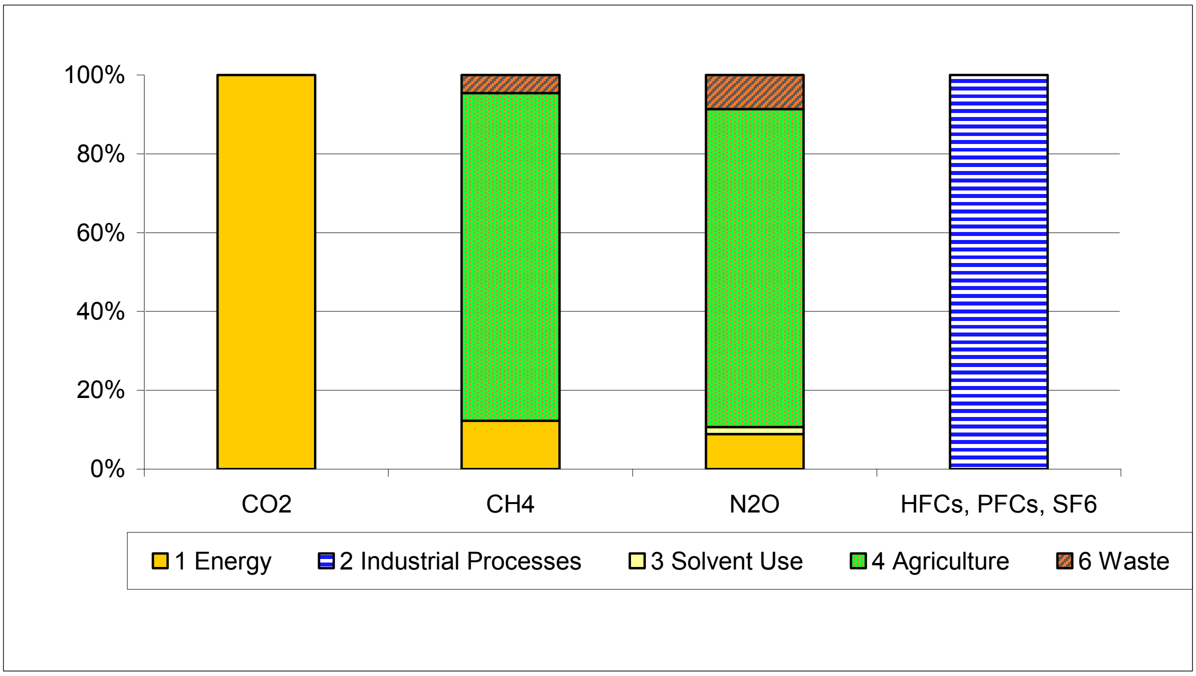

Figure 6 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions, 2006.

2.2. Emission Trends by Gas

Emission trends 1990–2006 by gas are summarised in the Table 10 and in Figure 7.

Greenhouse Gas Emissions	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	CO_2 equivalent (Gg)									
CO_2 emissions including net CO_2 from LULUCF	194.7	202.4	203.3	211.6	197.6	200.9	203.0	218.9	230.2	229.4
CO_2 emissions excluding net CO_2 from LULUCF	203.1	210.8	211.7	220.0	206.1	209.4	211.6	223.8	235.1	234.3
CH_4 emissions including CH_4 from LULUCF	13.4	13.2	13.1	12.4	12.6	12.6	12.7	12.5	12.6	12.5
CH_4 emissions excluding CH_4 from LULUCF	13.4	13.2	13.1	12.4	12.6	12.6	12.7	12.5	12.6	12.5
N_2O emissions including N_2O from LULUCF	13.1	13.3	13.4	13.0	13.0	13.2	13.0	13.0	12.8	12.8
N_2O emissions excluding N_2O from LULUCF	13.1	13.3	13.4	13.0	13.0	13.1	12.9	13.0	12.7	12.7
HFCs	0.0	0.0	0.0	0.1	0.1	0.4	0.7	1.0	1.4	1.8
PFCs	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
SF_6	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	0.0	0.0	0.0	0.0
Total (including LULUCF)	**221.2**	**228.9**	**229.8**	**237.0**	**223.3**	**227.1**	**229.4**	**245.5**	**257.0**	**256.4**
Total (excluding LULUCF)	**229.5**	**237.3**	**238.2**	**245.4**	**231.7**	**235.5**	**237.9**	**250.4**	**261.9**	**261.3**

Greenhouse Gas Emissions	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	***1990-2006***
	CO_2 equivalent (Gg)							%
CO_2 emissions including net CO_2 from LULUCF	222.6	220.7	225.6	233.5	233.7	233.4	235.1	*20.7*
CO_2 emissions excluding net CO_2 from LULUCF	227.5	225.6	230.5	240.0	240.2	240.0	241.6	*19.0*
CH_4 emissions including CH_4 from LULUCF	12.3	13.0	13.1	13.3	13.5	14.0	14.4	*7.4*
CH_4 emissions excluding CH_4 from LULUCF	12.3	13.0	13.1	13.3	13.5	14.0	14.4	*7.4*
N_2O emissions including N_2O from LULUCF	12.5	12.6	12.5	12.5	12.5	12.6	12.9	*-1.7*
N_2O emissions excluding N_2O from LULUCF	12.5	12.6	12.5	12.5	12.5	12.6	12.9	*-1.7*
HFCs	2.3	3.0	3.2	3.6	4.0	4.1	4.1	---
PFCs	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	---
SF_6	0.0	0.0	0.1	0.1	0.1	0.1	0.1	---
Total (including LULUCF)	**249.7**	**249.3**	**254.5**	**263.0**	**263.8**	**264.2**	**266.5**	***20.5***
Total (excluding LULUCF)	**254.6**	**254.2**	**259.4**	**269.5**	**270.3**	**270.7**	**273.0**	***19.0***

Table 10 Summary of Liechtenstein's GHG emissions in CO_2 equivalent (Gg) by gas, 1990–2006. The column on the far right (digits in italics) shows the percent change in emissions in 2006 as compared to the base year 1990.

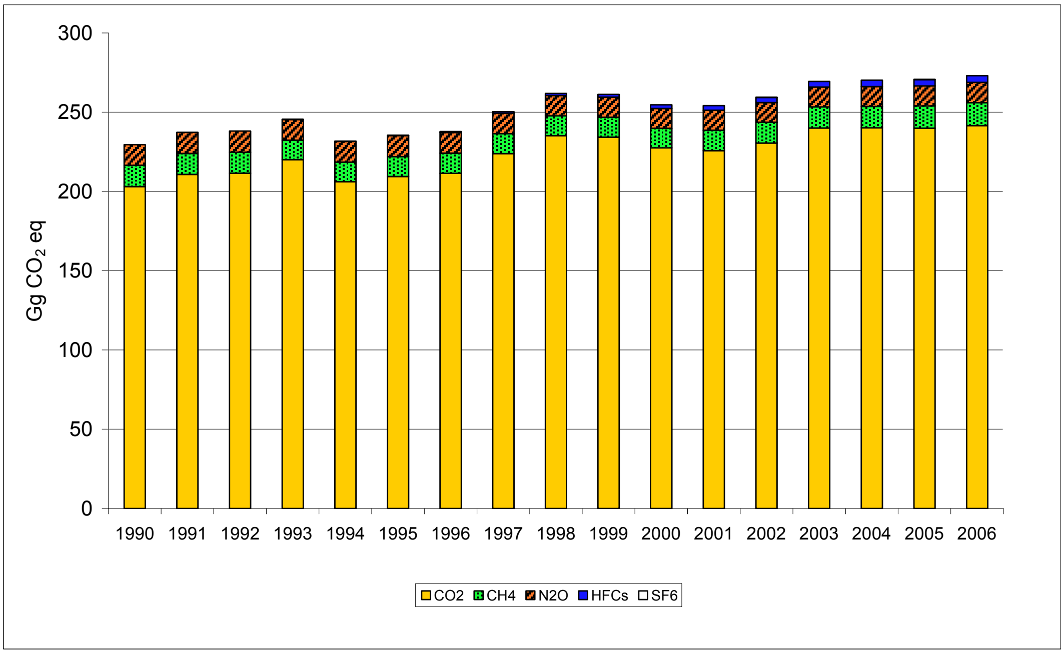

Figure 7 Trend of Liechtenstein's greenhouse gas emissions by gases1990–2006. CO_2, CH_4 and N_2O correspond to the respective total emissions excluding LULUCF.

The emission trends for the individual gases are as follows:

- Total emissions excluding LULUCF Removals/Emissions increased from 1990 to 2006 by 19.0%.
- Total emissions including net CO_2 from LULUCF increased more strongly by 20.5%.
- The CO_2 emissions excluding net CO_2 emissions from LULUCF increased from 1990 to 2006 by 19.0%. It contributes the largest share of emissions, accounting for about 88.5% of the total emissions in 2006. This share fluctuated between 88.5% and 89.8% in the period 1990–2006.
- CH_4 emissions excluding CH_4 from LULUCF showed an increase of 7.4%, which is the result of an increase in the sectors energy and waste. Its contribution to the total national emissions is 5.3% in 2006, which is slightly lower than in 1990, where the number was 5.8%.
- N_2O emissions excluding N_2O from LULUCF have decreased by 1.7% due to reduced input of mineral fertilizers and due to a reduction of organic soils. Its contribution to the total national emissions decreased from 5.7% in 1990 to 4.7% in 2006.
- 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. The share of synthetic gases increased from 0.0% (1990) to 1.5% (2006).

2.3. Emission Trends by Sources and Sinks

Table 11 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**
	CO_2 equivalent (Gg)									
1 Energy	**203.5**	**211.5**	**212.6**	**221.1**	**207.2**	**210.7**	**212.9**	**225.4**	**236.8**	**236.0**
1A1 Energy Industries	0.2	0.8	1.9	1.9	1.8	2.0	2.5	2.5	2.9	2.9
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
1A3 Transport	76.4	89.7	89.1	87.0	79.6	81.7	82.9	86.6	86.2	91.9
1A4 Other Sectors	88.9	83.4	84.2	93.3	88.8	89.9	90.3	97.3	105.9	99.8
1A5 Other (Offroad)	2.4	2.9	2.9	2.4	2.3	2.2	2.3	2.5	3.0	3.1
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
2 Industrial Processes	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.4**	**0.7**	**1.0**	**1.4**	**1.8**
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**
4 Agriculture	**22.5**	**22.5**	**22.3**	**21.1**	**21.1**	**21.3**	**21.2**	**21.0**	**20.8**	**20.5**
6 Waste	**1.6**	**1.5**	**1.5**	**1.5**	**1.6**	**1.5**	**1.6**	**1.5**	**1.6**	**1.6**
Total (excluding LULUCF)	**229.5**	**237.3**	**238.2**	**245.4**	**231.7**	**235.5**	**237.9**	**250.4**	**261.9**	**261.3**
5 Land Use, Land-Use Change and Forestry	-8.3	-8.4	-8.4	-8.4	-8.5	-8.5	-8.5	-4.9	-4.9	-4.9
Total (including LULUCF)	221.2	228.9	229.8	237.0	223.3	227.1	229.4	245.5	257.0	256.4

Source and Sink Categories	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	***1990/2006***
	CO_2 equivalent (Gg)							***%***
1 Energy	**229.5**	**227.4**	**232.3**	**241.9**	**242.1**	**241.9**	**243.6**	***19.7***
1A1 Energy Industries	2.7	2.9	2.5	2.8	2.9	3.1	2.8	*1499*
1A2 Manufacturing Industries and Construction	34.3	34.6	35.7	38.3	37.4	36.2	37.4	*6.0*
1A3 Transport	95.9	92.2	87.7	87.3	86.0	85.5	82.5	*8.0*
1A4 Other Sectors	92.8	94.4	102.9	109.2	111.9	112.6	116.2	*30.7*
1A5 Other (Offroad)	3.0	2.6	2.8	3.4	3.1	3.5	3.7	*53.3*
1B Fugitive emissions from oil and natural gas	0.7	0.8	0.8	0.9	0.9	1.0	1.1	*232*
2 Industrial Processes	**2.4**	**3.0**	**3.2**	**3.6**	**4.1**	**4.1**	**4.2**	**---**
3 Solvent and Other Product Use	**1.3**	**1.2**	**1.2**	**1.2**	**1.1**	**1.1**	**1.1**	***-44.2***
4 Agriculture	**19.8**	**21.0**	**20.9**	**21.1**	**21.2**	**21.6**	**22.3**	***-0.9***
6 Waste	**1.7**	**1.6**	**1.8**	**1.8**	**1.8**	**1.9**	**1.8**	***14.3***
Total (excluding LULUCF)	**254.6**	**254.2**	**259.4**	**269.5**	**270.3**	**270.7**	**273.0**	***19.0***
5 Land Use, Land-Use Change and Forestry	-4.9	-4.9	-4.9	-6.5	-6.5	-6.5	-6.5	*-21.3*
Total (including LULUCF)	249.7	249.3	254.5	263.0	263.8	264.2	266.5	*20.5*

Table 11 Summary of Liechtenstein's GHG emissions by source and sink categories in CO_2 equivalent (Gg), 1990–2006. The column on the far right (digits in italics) shows the percent change in emissions in 2006 as compared to the base year 1990.

Figure 8 is a graphical representation of Table 11 data. For the development of the sub-sectors of source 1 Energy see Chapter 3.

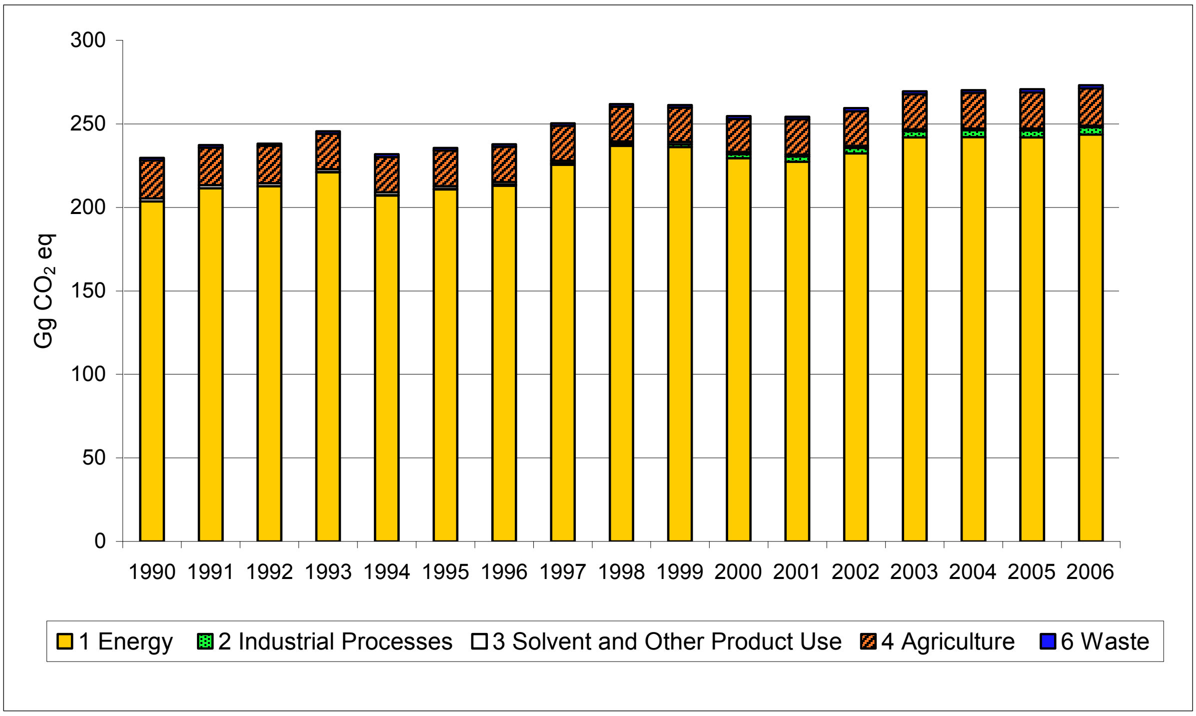

Figure 8 Trend of Liechtenstein's greenhouse gas emissions by main source categories in CO_2 equivalent (Gg), 1990–2006 (excl. net CO_2 from LULUCF).

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 sub-sector, the emissions have increased between 1990 and 2006.
  - 1A1: The consumption of natural gas in co-generation plants has enormously increased (1499%).
  - 1A2: The consumption of natural gas by industries has increased whereas gas oil has decreased. In the total there results a net increase of 6.0%.
  - 1A3: In line with a general increase of the road-vehicle kilometres of all vehicle categories, the fuel consumption and the emissions are increasing (8.0%).
  - 1A4: Inhabitants have increased by 20% whereas employment has increased by 40% in the period 1990-2006, which is reflected in a similar increase of energy consumption and GHG emissions (30.7%).
  - 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 (53.3%).
  - 1B: In parallel with the built-up of Liechtenstein's gas supply network since 1990, the fugitive emissions have strongly increased over the period 1990-2006 (232%).
- 2 Industrial Processes: Due to the lack of heavy 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 strongly decreased due to reduction measures for NMVOCs resulting from legal restrictions and the introduction of the VOC levy (-44.2%).

- 4 Agriculture: CH_4 emissions are almost constant, whereas N_2O emissions from agricultural soils show a decrease (-5.7%).
- 5 LULUCF: Figure 9 shows the net removals (negative emissions) by sources and sinks from LULUCF categories in Liechtenstein. Increase and decrease of living biomass in forests are the dominant categories. The conversion rates of forest land, which are derived from aerial photographs in three years (1984, 1996, 2002), differ significantly. They result in a time series similar to a step function. Other categories of land-use changes and soils have a much smaller influence on the net removals.

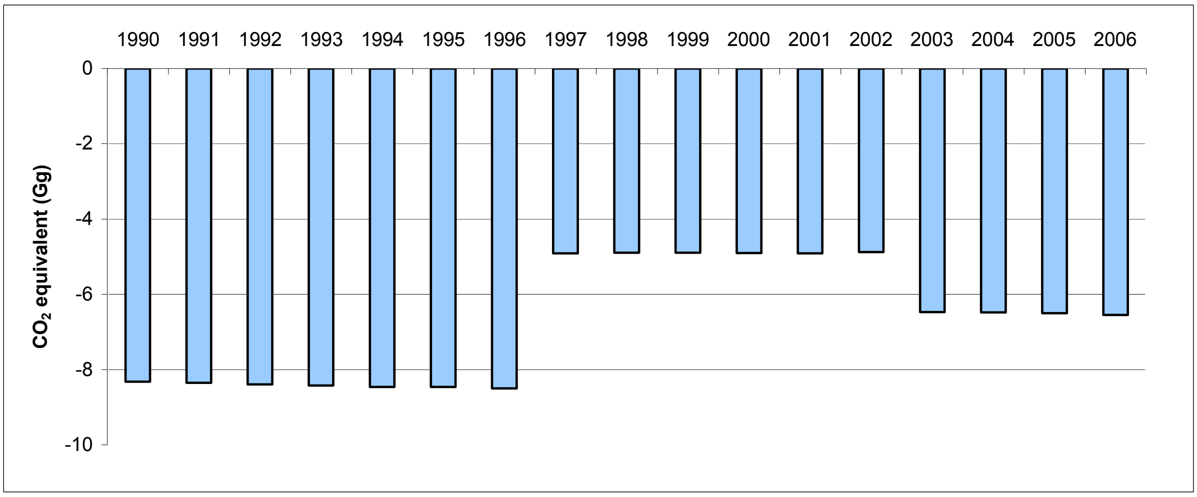

Figure 9 Net removals of CO_2 from LULUCF for 1990–2006.

- 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 2006, it emitted 243.6 Gg CO_2 equivalents which correspond to 89.2% of total emissions (273.0 Gg, without LULUCF). The emissions of the time period 1990–2006 are depicted in Figure 10.

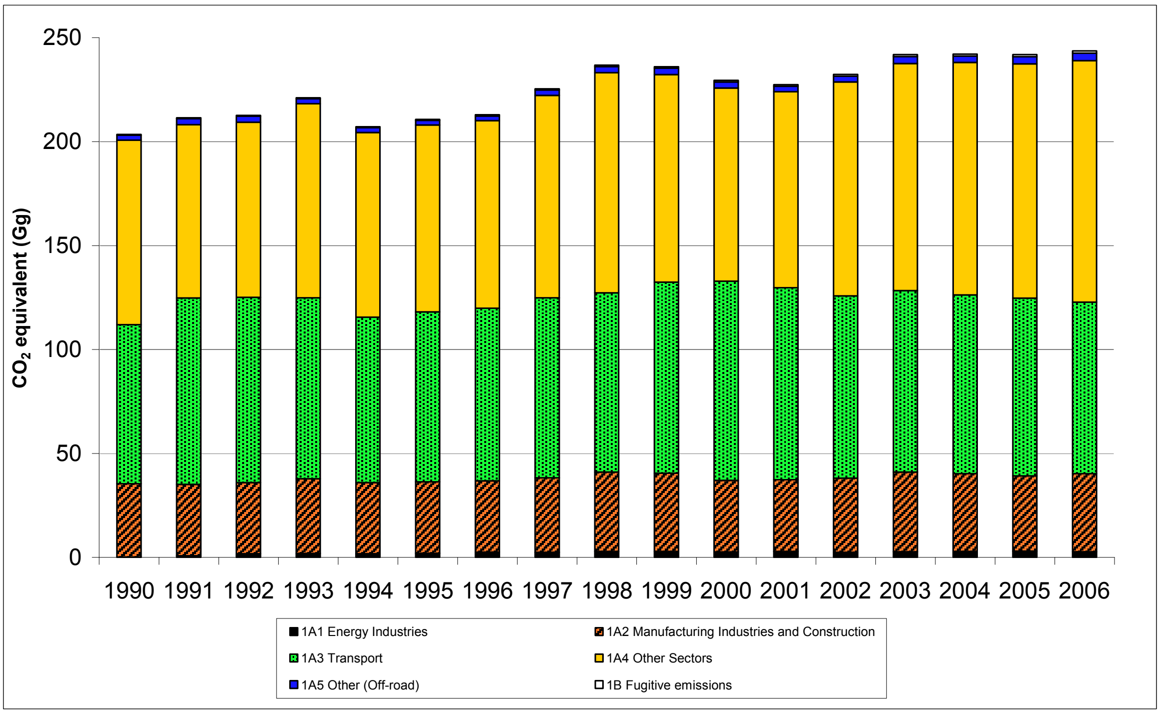

Figure 10 Liechtenstein's GHG emissions of the energy sector 1990–2006.

The following Table 12 summarises the emissions of the individual gases 1990–2006

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (Gg)									
CO_2	201.5	209.3	210.3	218.7	204.8	208.1	210.4	222.7	234.1	233.3
CH_4	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.3
N_2O	0.9	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.5
Sum	**203.5**	**211.5**	**212.6**	**221.1**	**207.2**	**210.7**	**212.9**	**225.4**	**236.8**	**236.0**

Gas	2000	2001	2002	2003	2004	2005	2006	*1990 →2006*
	CO2 equivalent (Gg)							%
CO_2	226.5	224.6	229.6	239.1	239.3	239.1	240.7	*19.5*
CH_4	1.4	1.3	1.4	1.5	1.6	1.7	1.8	*67.4*
N_2O	1.6	1.4	1.3	1.3	1.2	1.2	1.1	*29.0*
Sum	**229.5**	**227.4**	**232.3**	**241.9**	**242.1**	**241.9**	**243.6**	***19.7***

Table 12 GHG emissions of source category "1 Energy" in Liechtenstein by gas in CO_2 equivalent (Gg), 1990–2006 and the relative increase 1990–2006 (last column).

Table 13 shows more details of the emissions of source category 1 Energy in 2006. The table includes emissions from international bunkers (aviation) as well as biomass which are both not accounted for in the Kyoto Protocol.

Emissions 2006	**CO_2**	**CH_4**	**N_2O**	**Total**	
Sources	**CO_2 equivalent (Gg)**				**%**
1 Energy	**240.7**	**1.76**	**1.14**	**243.6**	***100.0***
1A Fuel Combustion	**240.7**	**0.70**	**1.14**	**242.6**	***99.6***
1A1 Energy Industries	2.7	0.03	0.08	**2.8**	***1.1***
1A2 Manufacturing Industries and Construction	37.3	0.06	0.05	**37.4**	***15.4***
1A3 Transport	81.7	0.15	0.66	**82.5**	***33.9***
1A4 Other Sectors	115.4	0.47	0.32	**116.2**	***47.7***
1A5 Other	3.6	0.00	0.03	**3.7**	***1.5***
1B Fugitive Emissions from Fuels	**NA,NO**	**1.07**	**NA,NO**	**1.1**	***0.4***
International Bunkers	0.8	0.0	0.0	**0.0**	***NE,NO***
CO_2 Emissions from Biomass	12.1	0.0	0.0	**12.1**	***---***

Table 13 Summary of source category “1 Energy”, emissions in 2006 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 19.7% may be observed between 1990 and 2006. 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 96.9% of its emissions:
  - 1A2 Manufacturing Industries and Construction contribute 15.4% of the emissions.
  - 1A3 Transport is responsible for 33.9% of the emissions.
  - 1A4 Other Sectors (commercial/institutional, residential) is the largest source with 47.7% of the emissions.
  - 1A1 Energy Industries, 1A5 Other (Off-road) and 1B Fugitive Emissions only play a minor role. In 2006, they cover 1.1%, 1.5% 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 0.77 Gg CO_2 eq.
- CO_2 emissions from biomass add up to 12.1 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 99.0% of the category in 1990 and for 98.8% in 2006.
- In 2006, CH_4 emissions contributed 0.70% 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 0.44% (1990) and 0.48% (2006) 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).

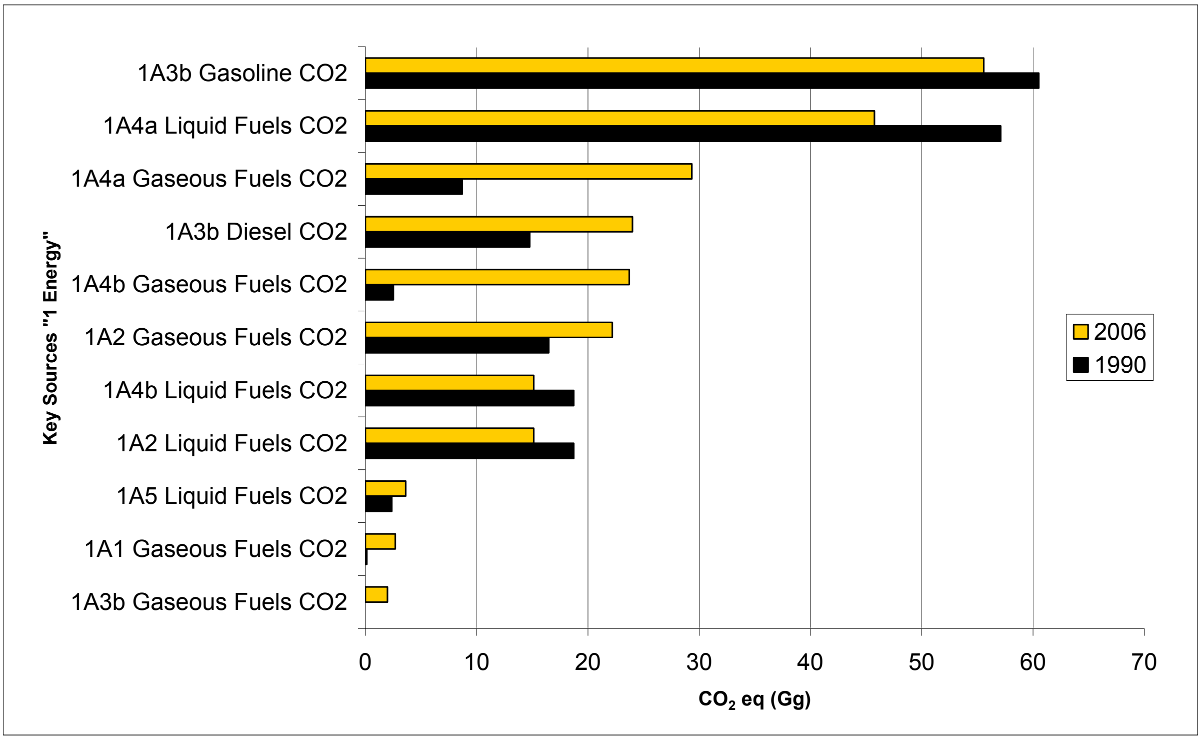

Figure 11 Key sources in the Liechtenstein GHG inventory pertaining to the energy sector.

3.1.2. CO_2 Emission Factors and Net Calorific Values

The CO_2 emission factors and the net calorific values (NCV) used for the calculation of the emissions of 1 Energy are shown in Table 14.

Fuel	**CO_2 Emission Factor**			**Net calorific value (NCV)**	
	t CO_2 / TJ	t CO_2 / t	t CO_2 / volume	GJ / t	GJ / volume
Hard Coal	94.0	2.47	---	26.3	---
Gas Oil	73.7	3.14	2.65t / 1000 liter	42.6	36.0 / 1000 l
Residual Fuel Oil	77.0	3.17	3.01t / 1000 liter	41.2	39.1 / 1000 l
Natural Gas	55.0	2.56	2.00t / 1000 Nm^3	46.5	36.3 / 1000 Nm^3
Gasoline	73.9	3.14	2.34t / 1000 liter	42.5	31.7 / 1000 l
Diesel Oil	73.6	3.15	2.61t / 1000 liter	42.8	35.5 / 1000 l
Propane/Butane (LPG)	65.5	---	---	46.0	---
Jet Kerosene	73.2	3.15	2.52t / 1000 liter	43.0	34.4 / 1000 l
Lignite	104.0	2.09	---	20.1	---

Table 14 CO_2 emission factors and Net Calorific Values for fuels. The values are assumed to be constant over the period 1990-2006. 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 2007). 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 15.

Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	TJ									
Gasoline	819	916	957	947	878	903	909	954	896	940
Diesel	250	339	288	261	230	230	242	252	311	347
Gas Oil	1'272	1'116	1'077	1'189	1'095	1'065	988	1'125	1'208	1'060
Natural Gas	506	614	688	742	754	824	943	914	1'008	1'084
LPG	13.3	8.1	15.5	12.1	9.5	8.1	9.8	7.0	7.2	5.8
Hard Coal	0.97	0.92	1.10	1.00	0.71	0.68	0.50	0.53	0.55	0.29
Kerosene (domestic)	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.05	1.06	1.07
Sum	**2'862**	**2'995**	**3'027**	**3'154**	**2'969**	**3'032**	**3'093**	**3'253**	**3'431**	**3'438**
1990=100%	100%	105%	106%	110%	104%	106%	108%	114%	120%	120%
Kerosene (bunker)	5.84	5.84	5.84	5.84	5.84	5.84	6.00	6.16	6.33	6.49
Biomass										
Wood	44.7	30.9	44.6	40.5	51.1	37.7	35.0	42.5	47.5	52.2
Sewage gas	15.6	16.3	17.3	17.3	18.7	17.0	18.1	18.4	20.0	21.5
Sum biomass	60.2	47.2	61.8	57.7	69.8	54.7	53.1	60.9	67.5	73.7

Fuel	2000	2001	2002	2003	2004	2005	2006
	TJ						
Gasoline	1'040	1'007	920	879	851	823	752
Diesel	298	267	284	330	339	364	395
Gas Oil	931	885	1'001	1'061	1'030	986	1'026
Natural Gas	1'067	1'181	1'210	1'294	1'368	1'427	1'454
LPG	5.5	3.9	4.2	4.6	4.1	3.7	5.5
Hard Coal	0.63	0.34	0.32	0.34	0.26	0.24	0.16
Kerosene (domestic)	1.08	1.09	1.14	1.19	0.85	1.15	1.85
Sum	**3'342**	**3'345**	**3'420**	**3'571**	**3'593**	**3'605**	**3'634**
1990=100%	117%	117%	120%	125%	126%	126%	127%
Kerosene (bunker)	6.66	6.82	6.12	6.74	4.82	6.52	10.47
Biomass							
Wood	91.5	56.0	58.6	77.4	84.7	93.8	107.1
Sewage gas	21.7	20.9	20.0	20.7	21.6	20.8	22.5
Sum biomass	113.2	76.9	78.6	98.2	106.3	114.6	129.6

Table 15 Time series of Liechtenstein's fuel consumption due to the sales principle, including bunker fuel consumption (kerosene only) and biomass. Data sources: AVW (2007), OEP (2006b, 2006c, 2007c), Rhein Heli (2006, 2007).

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 2007). 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 16).

	Total supply	Supplied to stoc	Consumption 1	Assumed densit	Consumption	Actual density	Consumption 2	Consumption
Source	Energy Statistics	GHFL 2006	Calculated	OEA-LIE	Calculated	FOEN 2006	Calculated	Calculated
Year	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
2005	23'100	98	23'002	0.840	27'383	0.845	23'139	986
2006	24'231	278	23'953	0.840	28'516	0.845	24'096	1'026

Table 16 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 2007) Therefore, the *Consumption 1* is corrected accordingly, resulting in *Consumption 2*, as is shown in Table 16. Using a net calorific value of 42.6 GJ/t (FOEN 2007), the actual consumption in energy units results as used in Liechtenstein's GHG inventory. See also Table 127.

Natural gas: Natural gas consumption as published in the energy statistics (AVW 2007) 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"[3]), but it covers only the years 2000-2006. 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.

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[3] 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.

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

Table 17 Values used for the entire period 1990-2006 (OEP 2006c, FOEN 2007). See also Table 127 in Annex 2.

For gasoline consumption, 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 2006, the values of the second census are used. The result of this modification is shown in Table 15 in row gasoline (OEP 2007c).

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 (OEP 2006c).
- Finally, the agriculture part is known by another way:
  - Until 2005: 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. For simplification reasons, Switzerland has given up the refunding system.
  - Since 2005: The OEP collects the consumption data directly at the 171 farmers by questionnaire. For the first time this was carried out in winter 2007 to collect the consumption data 2005, which was also available from the former method practised by the General Directorate of Swiss Customs. This allowed a quality control check. Since the difference was only 1%[4] (OEP 2006c), both methods may be characterised as of equal and very high quality. The census is now being repeated annually.
- 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.

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 2006, 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 15 in line “diesel” (OEP 2006c).

Kerosene: The fuel sales at the single helicopter base have been reported in detail (domestic, international/bunker) for 2001, 2002, 2005, 2006 and less detailed for 1995

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[4] Consumption due to General Directorate of Swiss Customs 514'759 litres of diesel oil, due to questionnaire: 520'618 litres. Difference 5859 litres (1.1%). Data source OEP 2007a.

(Rhein Heli 2007, 2007). For the other years in the reporting period, adequate assumptions were made (see Section 3.2.2.c)

Bunker (kerosene, civil aviation): See Section 3.4.

Biomass: See Section 3.5.

b) Energy Statistics and Contribution to the IPCC Source Categories

b1) Gas oil

No data on the specific contribution of Source Categories 1A2, 1A4a 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 2006:

Source category		**Share in consumption (1990-2006)**
1A2	Manufaturing Industries and Contruction	20%
1A4a	Other Sectors - Commercial/Institutional	60%
1A4b	Other Sectors - Residential	20%
Total 1A		100%

Table 18 Estimated share of source categories in total consumption of gas oil in 1A Fuel Combustion Activities.

b2) Natural gas

The data on total consumption of natural gas in Liechtenstein is provided by the gas utility (LGV 2007) and published in the national energy statistics (refers to the net import).

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 19 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 above).

Shares of diesel sales Data source	**1A3b Road Transportation**	**1A4c Other Sect./Agriculture**	**1A5b Other/Mobile**	**Sum**
Questioning gasoline stations	100%	0%	0%	100%
Diesel "tanks"	70%	0%	30%	100%
"Oberzolldirektion"	0%	100%	0%	100%

Table 20 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 2007). 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 or biogas[5] fuelled public co-generation units.	AD: Energy Statistics 2006 (AVW 2007) EF: SAEFL 2005
1A1 b	Petroleum Refining	Not occurring	-
1A1 c	Manufacture of Solid Fuels and Other Energy Industries	Not occurring	-

Table 21 Specification of source category 1A1 “Energy Industries” (AD: activity data; EF: emission factors)

In Liechtenstein, over 80% of electricity consumption is imported and less than 20% is produced domestically (see Table 22).

	(MWh)	
Total consumption Liechtenstein 2006	369'497	100%
Power generation in Liechtenstein 2006	67'135	18%
Hydro power	62'846	
Natural gas co-generation	3'092	
Bio gas co-generation	996	
Photovoltaic	201	
Imports	302'362	82%

Table 22 Electricity consumption, generation and imports in Liechtenstein in 2006. Data source Energy Statistics 2006 (AVW 2007).

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.

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[5] Biogas from sewage sludge in waste water treatment.

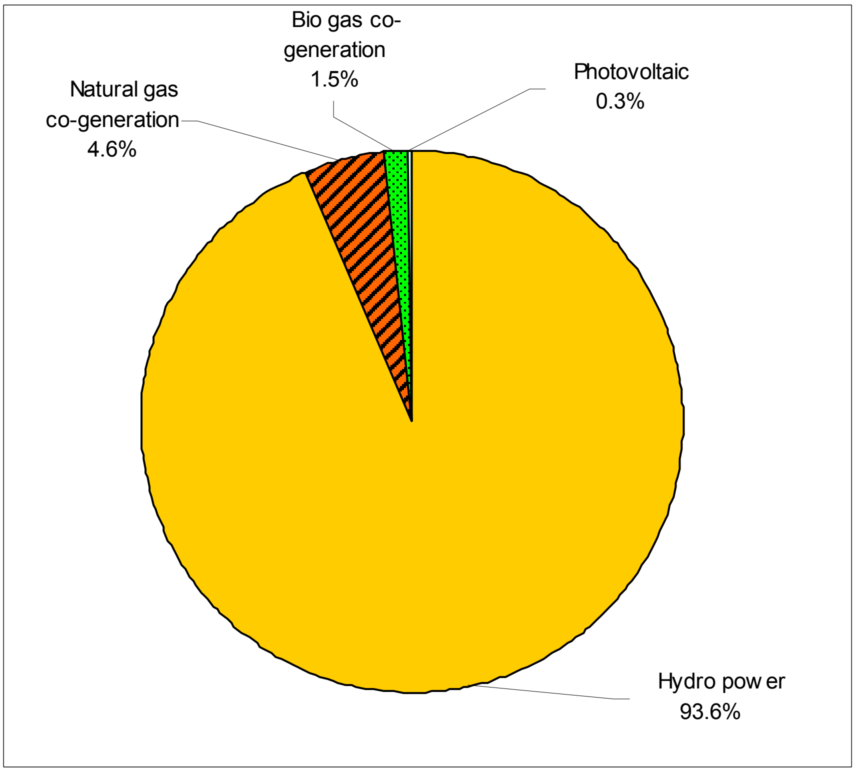

Figure 12 Structure of power generation in Liechtenstein 2006. Data source: Energy Statistics (AVW 2007).

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 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 (AVW 2007) EF: EMIS, SAEFL 2000a

Table 23 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, 2007 Acontec 2006 EF: FOEN 2007, IPCC 1997c
1A3b	Road Transportation	Light and heavy motor vehicles, coaches, two-wheelers	AD: AVW 2007, OEP 2006c, EF: NIR CH (FOEN 2007), IPCC 1997c
1A3c	Railways	Fully electrified system, no electricity infeed, no diesel locomotives, shunting yards	---
1A3d-e	Navigation, military aviation	Not occurring	---

Table 24 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 (AVW 2007) EF: EMIS, SAEFL 2000a; SFOE 2001
1A4 b	Residential	Emissions from fuel combustion in households	AD: Energy Statistics (AVW 2007) EF: EMIS, SAEFL 2000a; SFOE 2001
1A4 c	Agriculture/ Forestry/ Fishing	Comprises fuel combustion for agricultural machinery.	AD: Energy Statistics (AVW 2007) EF: EMIS, SAEFL 2000a; SFOE 2001; SAEFL 2005a

Table 25 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: OEP 2007c
	Industry	Industrial off-road vehicles and machinery	

Table 26 Specification of Liechtenstein's source category 1A5b “Other, Mobile” (off-road).

3.2.2. Methodological Issues

General Issues

National and Reference Approach

The Reference Approach uses Tier 1 methods for the different source categories of the energy sector.

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 0.015 Gg CO_2 in 2006).

As the consumption of liquid fuels slightly decreased (1990 to 2006: -7.2% to 2179 TJ) and gaseous fuels strongly increased (1990 to 2006: +187% to 1454 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 and biogas 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 GHG are calculated by multiplying fuel consumption (in TJ) by emission factors.

Emission Factors

The emission factors for CO_2 and CH_4 for co-generation are country specific and representative for engines used in Switzerland and Liechtenstein (lean fuel-air-ratio). They

have been taken from Switzerland (SAEFL 2005). For the N_2O emissions the default emission factors from IPCC 1997c have been used.
Biomass: Country specific emission factors for biogas from wastewater treatment plants are taken from 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**
1A1a Public Electricity/Heat				
Natural gas	55.00	NO	25	0.1
Biomass (biogas from WWTP)	NO	55	6	11

Table 27 Emission Factors for 1A1a Public Electricity and Heat Production in Energy Industries for all years 1990 - 2006 (public co-generation).

Activity Data

Activity data on natural gas consumption (in 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**	**2005**	**2006**
1A1a Public Electricity/Heat Fuel Consumption								
Natural gas	TJ	47.52	50.40	43.20	48.60	50.76	54.00	48.96

Table 28 Activity data for natural gas consumption in 1A1a Public Electricity/Heat Production.

The table above documents the increase of Gaseous Fuel consumption by a factor of over 22 from 1990 to 2006. This increase is the reason for category 1A1 Gaseous Fuels being a key category regarding trend.

Activity data on biogas consumption (TJ) from waste water treatment plants are provided by plant operators (for data see section 8.3.1).

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 GHG 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 country specific and 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).

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). For the N_2O emissions the default emission factors from IPCC 1997c have been used.

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
1A2 f Other				
Gas oil	73.7	1.0	0.6	NE
Gas	55.0	6.0	0.1	NE

Table 29 Emission factors for sources in 1A2f for all years 1990 - 2006.

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 2006 is provided in Table 30.

Source	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
1A2f Other	TJ	554	545	546	572	546	550	555	574	611	610
Gas oil	TJ	254	223	215	238	219	213	198	225	242	212
Natural gas	TJ	300	322	331	334	327	338	358	349	369	398

Source	**Unit**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
1A2f Other	TJ	559	566	578	622	608	589	609
Gas oil	TJ	186	177	200	212	206	197	205
Natural gas	TJ	373	389	378	410	402	392	404

Table 30 Activity data fuel consumption in 1A2f Manufacturing Industries and Construction 1990 to 2006.

Table 30 documents the increase of Natural Gas consumption for manufacturing industries by 35% from 1990 to 2006 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 2007	IPCC 1996	IPCC 1996

Table 31 Emission factors used for estimating emissions of helicopters. The values are used for the entire time series 1990-2006.

Activity Data

The two operating companies of the helicopter base provided the fuel consumption for 1995, 2001–2006 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, 2007). The fleet consists of

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, 2003–2006. 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
	TJ									
1A3a Civ. Aviation (domestic)	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.05	1.06	1.07

Kerosene	2000	2001	2002	2003	2004	2005	2006
	TJ						
1A3a Civ. Aviation (domestic)	1.08	1.09	1.14	1.19	0.85	1.15	1.85

Table 32 Activity data for civil aviation: Kerosene consumption 1990-2006 in TJ (only domestic consumption without bunker).

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 14). 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 since 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 14. They are the same over the whole time period 1990–2006.
- 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 for the period 1990–2005. For 2006, the Swiss values 2005 have been used according to the assumptions of Chp. 1.4.2. 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 (INFRAS 2004, 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.

- For 2006, the implied emission factors of Switzerland are not yet available. For the provisional emission modelling, the factors 2006 are set equal to the factors of 2005. The emissions 2006 will therefore be recalculated for the submission 2009.
- 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	2005	2006
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	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	6.6	6.6
N_2O	kg/TJ	1.86	2.26	2.66	2.96	3.24	3.74	3.63	3.64	3.59	3.49	3.34	3.15	2.91	2.67	2.46	2.25	2.25
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	73.6	73.6
CH_4	kg/TJ	1.99	1.95	1.86	1.75	1.65	1.58	1.49	1.41	1.34	1.26	1.17	1.03	0.92	0.87	0.76	0.73	0.73
N_2O	kg/TJ	0.75	0.75	0.74	0.71	0.71	0.71	0.72	0.80	0.87	0.94	1.04	1.12	1.18	1.25	1.30	1.36	1.36
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	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	50.0	50.0
N_2O	kg/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.10	0.10	0.10	0.10	0.10	0.10

Table 33 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, NIR CH, FOEN 2007). For gaseous fuels, IPCC default values are used (IPCC 1997c). Swiss factors for 2006 are not available yet. For the emission modelling, they are provisionally set equal to the factors 2005.

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 2007):

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, INFRAS et al. 2004c (in German),*
- *Emission Factors for Passenger Cars and Light Duty Vehicles Switzerland, Germany, Austria, INFRAS 2004a (in English),*
- *Update of the Emission Factors for Heavy Duty Vehicles, Hausberger et al. 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", INFRAS 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 2007.

The CO_2 factors are constant over the whole period 1990–2005 (2006)*. 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 (Gense and Vermeulen 2002, Gense and Vermeulen 2000a, Riemersma et al. 2003).*

It may be added that

- CO_2 emission factors 2006 is the same as for 1990–2005
- 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 15 line "gasoline". For diesel, around 80% of the value for “diesel” in the national statistics of Table 15 is consumed in 1A3b Road Transportation, the remaining amount in 1A5b (construction) and 1A4c Other Sectors, agricultural machinery (see also Table 34 and Table 39). For gaseous fuels, the amount reported by gasoline stations is used.

Fuel	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	TJ									
Gasoline	819	916	957	947	878	903	909	954	896	940
Diesel	201	282	231	211	182	184	195	199	253	287
Natural Gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sum	1'020	1'198	1'188	1'159	1'060	1'087	1'104	1'152	1'149	1'226
	100%	118%	116%	114%	104%	107%	108%	113%	113%	120%

Fuel	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
	TJ						
Gasoline	1'040	1'007	920	879	851	823	752
Diesel	240	214	229	264	277	298	326
Natural Gas	NO	14	31	32	31	32	36
Sum	1'279	1'235	1'179	1'175	1'159	1'153	1'114
	125%	121%	116%	115%	114%	113%	109%

Table 34 Activity data for 1A3b Road Transportation.

The share of gasoline has decreased from 80% in 1990 to 67% in 2006. In the same period, the consumption of diesel has increased from 20% to 29%.

In the study OEP (2002) the territorial fuel consumption was estimated based on kilometres travelled. This approach is substantiated by a model which uses input data from transport statistics and traffic counting. The CO_2 emissions are more than 40% lower in the base year and 30% lower in 2004 than the emissions reported in the GHG inventory. The differences between this result and the statistics of fuel sales are explained by fuelling of Austrian cars due to lower gasoline prices in Liechtenstein. (Moreover, the differences show the importance of collecting sales numbers as activity data and not using data derived from the territorial principle.)

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 GHG 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 country specific and 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 2007), where similar conditions prevail.

Emission factors for CH_4 are country specific and 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. For the N_2O emissions the default emission factors from IPCC 1997c have been used.

The country specific emission factor for CH_4 emissions from Liquefied Petroleum Gas (LPG) is from UBA 2004.

All emission factors for biomass are country specific and 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 35 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**
1A4 a+b Other Sectors: Commercial/Institutional and Residential				
Gas oil	73.7		1	0.6
LPG	65.5		2.5	0.1
Coal	94.0		300	1.6
Natural gas	55.00		6	0.1
Biomass (1A4a)		92	8	1.6
Biomass (1A4b)[6]		92	350	1.6

Table 35 Emission Factors for 1A4a and 1A4b: Commercial/Institutional and Residential in “Other Sectors” for all years 1990 - 2006.

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 1990–2006 is provided in Table 36.

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[6] The CH_4 emission factor of 350 kg/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).

Source/Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1A4a Commercial/Institutional	TJ	961	892	893	979	943	933	942	1'005	1'100	1'020	976	963	1'057	1'123	1'151	1'168	1'219
Gas oil	TJ	763	669	646	713	657	639	593	675	725	636	558	531	601	637	618	591	616
LPG	TJ	13	8.1	15	12	9.5	8.1	9.8	7.0	7.2	5.8	5.5	3.9	4.2	4.6	4.1	3.7	5.5
Natural gas	TJ	158	196	204	229	246	264	319	298	340	347	357	394	417	435	478	516	533
Coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	27	19	27	24	31	23	21	25	29	31	55	34	35	46	51	56	64
1A4b Residential	TJ	319	319	354	401	390	416	434	466	510	522	513	533	565	612	647	667	679
Gas oil	TJ	254	223	215	238	219	213	198	225	242	212	186	177	200	212	206	197	205
Natural gas	TJ	46	82	120	146	150	188	222	224	248	289	290	334	341	369	407	432	431
Coal	TJ	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	0.2	0.2
Biomass	TJ	18	12	18	16	20	15	14	17	19	21	37	22	23	31	34	38	43

Table 36 Activity data in 1A4a Commercial/Institutional and 1A4b Residential.

The table above documents the increase of natural gas consumption by a factor of over three (1A4a) and by a factor of over nine (1A4b) from 1990 to 2006 with the built-up of Liechtenstein's gas supply network. Gas oil consumption decreased by -19% in both categories 1A4a and 1A4b over the same period. 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 until 2005) and by OEP census, data 2005 (OEP 2007c). For details, see above in Section 3.1.3 a), paragraph Gasoline/Diesel oil.

Emission Factors

Emission factors for the use of diesel in off-road machinery are country specific and are taken from SAEFL 2005a (diesel engines).

Activity Data

Off-road machinery: Activity data (diesel consumption) is shown in Table 37.

Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	TJ									
Diesel	17.7	18.1	17.8	17.2	17.3	16.8	16.5	18.5	17.4	18.8

Fuel	2000	2001	2002	2003	2004	2005	2006
	TJ						
Diesel	17.7	18.4	18.5	19.9	20.5	18.5	19.2

Table 37 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 20, among private diesel tanks non-agriculture, the amount of 30% 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 country specific and 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
liquid fuels											
CO2	t/TJ	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6
CH4	kg/TJ	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
N2O	kg/TJ	2.15	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.17	2.17

Gas	unit	2000	2001	2002	2003	2004	2005	2006
liquid fuels								
CO2	t/TJ	73.6	73.6	73.6	73.6	73.6	73.6	73.6
CH4	kg/TJ	0.45	0.45	0.45	0.46	0.46	0.46	0.46
N2O	kg/TJ	2.17	2.17	2.17	2.17	2.17	2.16	2.16

Table 38 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 and Section 3.1.3 a), paragraph Gasoline/Diesel oil.

Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	TJ									
Diesel	32.1	38.8	39.6	32.7	30.7	29.7	30.4	34.3	39.8	42.1

Fuel	2000	2001	2002	2003	2004	2005	2006
	TJ						
Diesel	40.3	34.4	37.2	46.3	41.1	47.5	49.2

Table 39 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). Finally, the Rule A approximation is used to obtain 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 2007).

Table 40 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 2006 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	79.95	5.0	4.6	6.8	2.257	0.2316	0.3967	1.07	2.81	3.00
1A Liquid fuels	CO2	173.62	160.76	18.0	0.55	18.01	12.026	-0.2294	0.7977	-0.13	20.31	20.31
1A Solid fuels	CO2	0.09	0.01	20.0	5.0	20.6	0.001	-0.0005	0.0001	0.00	0.00	0.00
1A Other fuels	CO2	NA,NO	NA,NO									
Total CO2 Emissions Fuel		201.53	240.73									
		Overall uncertainty CO2 combustion emissions in the year (%):					12.24	CO2 combustion emissions trend uncertainty (%):				20.53

Table 40 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 12.24% for the year 2006 and in a trend uncertainty for the period 1990 to 2006 of 20.53%.

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 is the same for the years 1990 to 2006; time series are consistent

Completeness:
The emissions for the full time series 1990–2006 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

QC activities have been performed due to Section 1.6. They are documented in the checklist in Annex 2. Special attention has been focused on the update of the activity data i.e. on the energy sales data. They were checked independently by two NIR authors and by the OEP specialist.

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 2006 EF: FOEN 2007
1B2 c	Venting / Flaring	Not occurring	-

Table 41 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 2007). 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 42; sources cited in FOEN 2007: 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**	**1- 5 bar**	**> 5 bar**
Steel cath.	-	-	0.0284
HDPE (Polyethylene)	0.0080	0.0024 (0.00062)	-

Table 42 CH_4-Emission Factors for 1B2 “Fugitive Emissions from Oil and Natural Gas” in 2006 (Battelle 1994, Xinmin 2004). For HDPE (Polyethylene) 1-5 bar, the first value shows the assumption for 1993 and previous years while the second value (in brackets) shows the value for 2003 and following years. Data between 1993 and 2003 are linearly interpolated between the two values.

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 2006).

Source/Fuel			**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
1B2 Fugitive Emissions from Oil and Natural Gas																				
Steel cath. > 5 bar			km	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.6	26.6	26.6	26.6	26.6
HDPE (Polyethylene) < 100 mbar			km	67.0	84.3	96.5	109.0	122.4	135.9	147.6	162.7	179.3	192.0	206.0	218.7	238.5	252.0	264.9	276.3	289.1
HDPE (Polyethylene) 1-5 bar			km	28.5	28.5	28.3	28.5	29.2	29.5	29.8	30.0	34.1	35.8	37.3	37.4	36.0	38.9	45.3	45.6	49.3
Connections			No.	479	698	890	1'060	1'221	1'398	1'584	1'782	1'984	2'195	2'460	2'657	2'863	3'067	3'271	3'464	3'659

Table 43 Activity Data for 1B2 “Fugitive Emissions from Oil and Natural Gas”: length of pipes and number of connections to customers

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

The current 1B2 methane emission calculation is based on data on natural gas quality from Switzerland (FEON 2007). For future submissions, the use of more country specific data from Liechtenstein's natural gas utility will be considered.

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. Marine bunker emissions are not occurring.

Kerosene	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	TJ									
international (bunker)	5.84	5.84	5.84	5.84	5.84	5.84	6.00	6.16	6.33	6.49
domestic (1A3a)	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.05	1.06	1.07
total	6.87	6.87	6.87	6.87	6.87	6.87	7.04	7.21	7.39	7.56

domestic (1A3a)

Kerosene	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
	TJ						
international (bunker)	6.66	6.82	6.12	6.74	4.82	6.52	10.47
domestic (1A3a)	1.08	1.09	1.14	1.19	0.85	1.15	1.85
total	7.74	7.91	7.26	7.93	5.68	7.67	12.32

Table 44 Kerosene (civil aviation) due to sales principle: International flights (bunker, memo item), domestic flights (reported under 1A3a) and total. Data source: Rhein Heli (2006, 2007).

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 3.2.2(d) (Energy) and 0 (Waste).

3.6. Comparison of Sectoral Approach with Reference Approach

The apparent consumption, the net carbon emissions and the effective CO_2 emissions are calculated for the Reference Approach as prescribed in the CRF tables 1A(b)–1A(d). Data is taken from the energy statistics as described in 3.1.3. The Reference approach covers the CO_2 emissions of all imported fuels.

The following table and the figure show the differences between the Reference and the Sectoral (National) Approaches 1990–2006. Energy consumption and CO_2 emissions agree very well for all years. The largest difference occurs in 1998 with 0.48% and 0.33% respectively. On an average, the energy consumption in the Reference Approach is 5 TJ higher than in the Sectoral Approach. The CO_2 emissions in the Reference Approach exceed those of the Sectoral Approach by 0.1 Gg on an average.

Difference between Reference and Sectoral Approach										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	percent (%)									
Energy Consumption	0.17	0.24	0.42	0.14	0.04	0.05	0.08	0.05	0.48	0.08
CO_2 Emissions	0.06	0.12	0.27	0.04	-0.03	-0.02	0.01	-0.02	0.33	0.01

	2000	2001	2002	2003	2004	2005	2006
	percent (%)						
Energy Consumption	0.04	0.06	0.05	0.21	0.12	0.10	0.21
CO_2 Emissions	-0.02	0.00	-0.02	0.12	0.05	0.03	0.12

Table 45 Differences in energy consumption and CO_2 emissions between the Reference and the Sectoral (National) Approach. The difference is calculated according to [(RA-SA)/SA] 100% with RA = Reference Approach, SA = Sectoral (National) Approach.

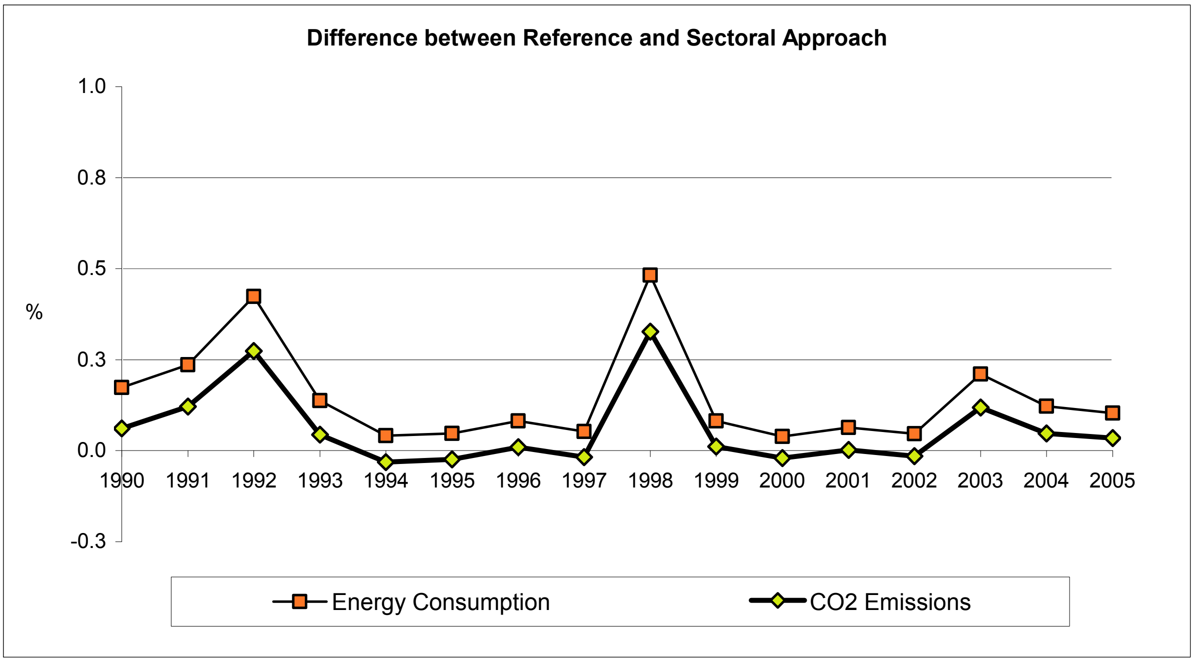

Figure 13 Time series for the differences between Reference and Sectoral Approach. Numbers are taken from the table above.

The oxidations factor is consequently set to 1.0 due to the following reason: combustion installations in Liechtenstein have very good combustion properties; combined emissions of CO and unburnt VOC lie in the range of only 0.1 to 0.3 percent of CO_2 emissions for oil and gas combustion. Also for coal an oxidation factor of 1.0 was used for conservative reasons and due to the negligible quantity consumed, which results in an emission of 0.015 Gg CO_2.

Conversion factors (TJ/unit) and carbon emission factors (t C /TJ) in CRF table1.A(b) have been taken from Table 14 and are therefore identical to the ones used for the Sectoral Approach.

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. Emissions are reported from categories 2A Mineral Products and 2F Consumption of Halocarbons and SF_6. HFC emissions are estimated from refrigeration and air conditioning equipment as well as some SF_6 emissions from electrical equipment. The emissions have increased from 1990 to 2006, as shown in Table 46. PFC emissions are not occurring in Liechtenstein.

Gas	**Category**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
	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	0.013	0.013
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	0.014	0.014
	2F Consumption of Halocarbons and SF6	**Gg CO_2 eq**																
HFC	2F1, 2F4	8.E-06	1.E-03	0.01	0.05	0.14	0.38	0.66	1.04	1.39	1.82	2.33	2.97	3.18	3.58	4.03	4.07	4.15
PFC		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF6	2F8	NO	NO	NO	NO	NO	NO	0.00	1.0E-08	1.0E-08	4.1E-08	7.8E-07	1.5E-06	2.2E-06	2.2E-06	2.4E-06	2.4E-06	2.2E-06
Sum	**2F**	**8.E-06**	**1.E-03**	**0.01**	**0.05**	**0.14**	**0.38**	**0.66**	**1.04**	**1.39**	**1.82**	**2.33**	**2.97**	**3.18**	**3.58**	**4.03**	**4.07**	**4.15**

Table 46 GHG emissions of source category 2 “Industrial Processes” 1990–2006 by gases in CO_2 equivalent (Gg).

The most obvious features of the emissions from industrial processes may be characterised as follows: The most relevant emissions in source category 2 are those of HFCs. HFC use started to be relevant from 1992 when they were introduced as substitutes for CFCs. In 1992 HFC contributed 17% to the total emissions from industrial processes. Since then HFC use experienced a very steep growth (44’200% between 1992 and 2006). With this HFC emissions are today by far dominant in source category 2 Industrial Processes. In 2006 they contributed 99.4% of the total emissions in source category 2. In the recent years the growth trend almost came to a halt with only 16% increase since 2003 and 3% increase since 2004. This is mainly on account of the declining use of HFC in commercial refrigeration.

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 2006 EF: FOEN 2007
2A6	Road Paving with Asphalt		AD: AVW 2006 EF: FOEN 2007
2A7	Other	Not occurring in Liechtenstein.	-

Table 47 Specification of source category 2A "Mineral Products"

4.2.2. Methodological Issues

a) 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 availability in Liechtenstein is very limited.

In order to establish rough estimates of emissions for Liechtenstein, the specific emissions per inhabitant in Switzerland[7] (from FOEN 2007) 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.

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[7] The emission estimates for 2A5 Asphalt Roofing in the *Swiss* national inventory (FOEN 2007) are based on emission factors of 42g (1998-2006) NMVOC per square meter of roofing fabric. A total of 15 mio. Square meters of roofing fabric is estimated to have been used in Switzerland in 2005 (source EMIS).
The emission estimates for 2A6 Road Paving with Asphalt in the *Swiss* national inventory (FOEN 2007) are based on emission factors of 100g NMVOC per ton of "Mischgut" (bitumous material) used for preparatory works of road surface ("Voranstrich") and 360 g NMVOC per ton of "Mischgut" (bitumous material) used for the implementation of new asphalt cover on streets ("Belagsarbeiten"). A total of 5 mio. tons of "Mischgut" (bitumous material) have been used in Switzerland in 2005 (source EMIS).

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 2007) by the number of inhabitants in Switzerland, as given below. [8]

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**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Liechtenstein	**29'032**	**29'386**	**29'868**	**30'310**	**30'629**	**30'923**	**31'143**	**31'320**	**32'015**	**32'426**	**32'863**	**33'525**	**33'863**	**34'294**	**34'600**	**34'905**	**35'168**
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	7'209'000	7'209'000	7'209'000	7'209'000	7'209'000	7'459'128	
Liechtenstein/Switzerland	0.427%	0.427%	0.430%	0.434%	0.435%	0.437%	0.438%	0.440%	0.449%	0.452%	0.456%	0.465%	0.470%	0.476%	0.480%	0.468%	

Table 48 Inhabitants in Liechtenstein 1990 – 2006 (AVW 2007) and inhabitants in Switzerland (SFSO 2006).[9]

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

No recalculations have been carried out.

4.2.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

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[8] This approach is used for all years but the latest (2006). Here, for Liechtenstein the specific emissions of Switzerland of the previous year (2005) are used, because the Swiss National Inventory is published only after the drafting of Liechtensteins NIR. For the next submission, the emission factors used for Liechtenstein will be updated according to the latest Swiss NIR.

[9] Please note that the number of inhabitants in Switzerland 2006 is not used, because the provisional value for the specific emissions for the latest year (2006) is based on the Swiss value of the year before (2005). See also footnote [8].

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 49 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 50 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 source category 2F "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 2007, Carbotech 2007)
2F7	Electrical Equipment	Emissions from use in electrical equipment	AD: Industry data EF: Industry data

Table 51 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 developing 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 2007) and Carbotech 2007.

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 52 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 2007) are applicable.

The data reported in Table 53 is taken from FOEN 2007 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	94	190 **)
Commercial and Industrial Refrigeration	12	NR	1	10 (5)	100	10
Transport Refrigeration / Trucks	8	1.8 … 7.8	1	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	1	10 (3) / 6 (4)	100	28 / 19
Mobile Air Conditioning / Cars	15	4.7 …7.5 till 1999 Going down to 2.8 …4.5 in 2010	1	0.65	100	10
Mobile Air Conditioning / Trucks	12	0.78	NO	8.5 (3)	60	100 (30)
Mobile Air Conditioning / Railway	10	1.1	NO	10 (8.5)	35	100 (30)

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

**) takes into account R134a content in foams, based on information from the Swiss national recycling organisation SENS.

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

Table 53 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 2007, Carbotech 2007.

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		2006	
Number of households				
Liechtenstein	10’556	Source: National census 1990	15’022	Source: National census 2000 with trend extrapolation
Switzerland	2’859’766	Source: National census 1990	3’347’480	Source: National census 2000 with trend extrapolation [1]
Conversion Factor CH→LIE	0.0036912		0.0044876	
Number of employees in industrial and service sector				
Liechtenstein	19’554	Source: National census of enterprises 1990	30’676	Source: National census of enterprises 2004
Switzerland	3’664’214	Source: National census of enterprises 1985 and 1991, interpolated	3’839’712	Source: National census of enterprises 1998 and 2001, extrapolated [1]
Conversion Factor CH→LIE	0.0053364		0.0079891	
Number of registered cars				
Liechtenstein	16’891	Source: National motor car statistic for Liechtenstein	24’293	Source: National motor car statistic for Liechtenstein
Switzerland	2’985’399	Source: www.statweb.admin.ch	3’863’807	Source: www.statweb.admin.ch [1]
Conversion Factor CH→LIE	0.0056578		0.0062873	

[1] Due to unavailability of statistical data for Switzerland in 2006 at time of writing this report, 2005 data is being used here as a proxy. The actual data for Switzerland in 2006 will be included in the next submission. If any vales are changing, they will be recalculated (see also section 1.4.2)

Table 54 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 2F Consumption of halocarbons and SF6 no specific uncertainties have been determined. For the Swiss GHG inventory, the uncertainties of the emissions of source category 2F were at approx. 14% (Monte Carlo simulation based on 2005 data). 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 1990–2006 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 source-specific recalculations have been carried out.

4.7.6. Source-Specific Planned Improvements

Under the Swiss GHG inventory gradual improvement of the data quality in co-operation with industry is ongoing. Methodologies and emission models will be updated during the yearly process of F-gas inquiry. The focus will be on improvements of HFC-emission calculations from refrigeration and air-conditioning equipment. As the GHG emissions for Liechtenstein under source category 2F are methodologically based on the Swiss GHG inventory data this will also benefit the GHG inventory for Liechtenstein.

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. Also included are indirect CO_2 emissions from the atmospheric decomposition of NMVOC.

Furthermore, evaporative emissions of N_2O are included arising from other types of product use and from medical use. 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.

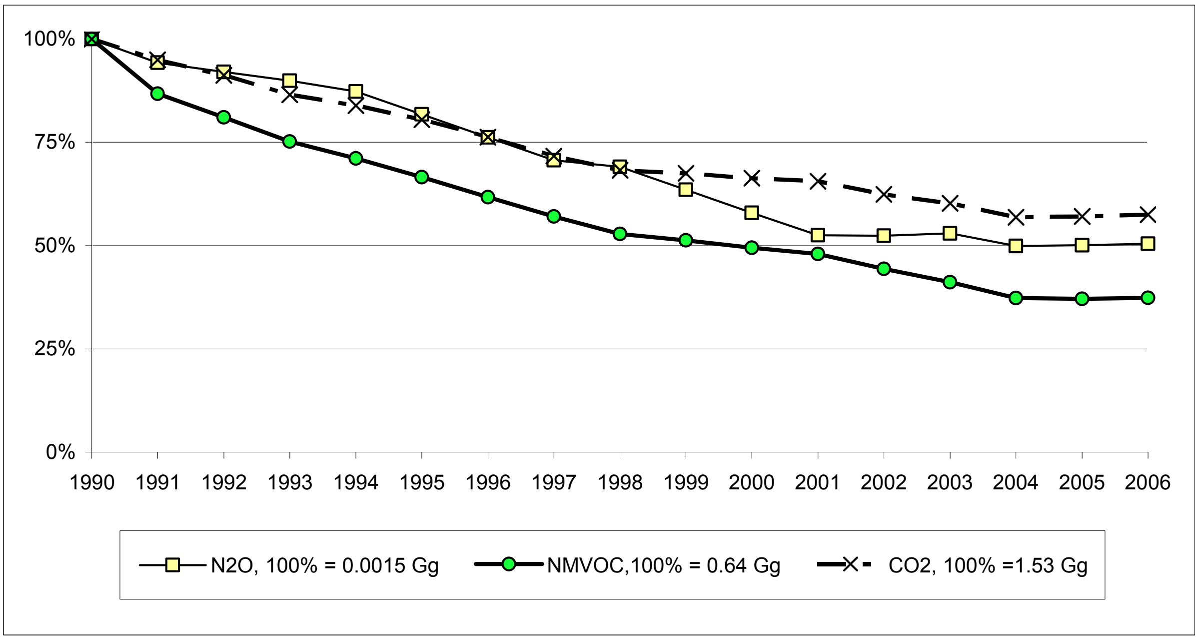

Figure 14 Overview of emissions in category 3 Solvent and Other Product Use in Liechtenstein 1990–2006.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Gg									
CO_2	1.53	1.45	1.39	1.32	1.28	1.23	1.16	1.09	1.04	1.03
N_2O	0.0015	0.0014	0.0014	0.0013	0.0013	0.0012	0.0011	0.0011	0.0010	0.0010
NMVOC	0.64	0.56	0.52	0.48	0.46	0.43	0.40	0.37	0.34	0.33

Gas	2000	2001	2002	2003	2004	2005	2006
	Gg						
CO_2	1.01	1.00	0.95	0.92	0.87	0.87	0.88
N_2O	0.0009	0.0008	0.0008	0.0008	0.0007	0.0007	0.0008
NMVOC	0.32	0.31	0.28	0.26	0.24	0.24	0.24

Table 55 Emissions of source category 3 Solvent and Other Product Use.

The emissions of NMVOC, CO_2 and N_2O are all calculated by a country specific method 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 2006 EF: FOEN 2007

Table 56 Specification of source category 3A "Paint Application".

5.2.2. Methodological Issues

a) Methodology

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*.[10]

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[10] This approach is used for all years but the latest (2006). Here, for Liechtenstein the specific emissions of Switzerland of the previous year (2005) are used, because the Swiss National Inventory is published only after the drafting of Liechtenstein's NIR. For the next submission, the emission factors used for Liechtenstein will be updated according to the latest Swiss NIR.

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.

b) 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	2005	2006
3A. Paint Application								
CO_2	g/inhabitant	8'444	8'021	6'816	5'592	4'190	4'149	4'149
NMVOC	g/inhabitant	3'404	3'225	2'724	2'201	1'615	1'598	1'598

Table 57 Emission factors - specific emissions per inhabitant, 1990 to 2006 (Source: Swiss emissions from FOEN 2007; 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.].

c) 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 and uncertainty of simple approach).

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

No recalculations have been carried out.

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 2006 EF: FOEN 2007

Table 58 Specification of source category 3B “Degreasing and Dry Cleaning”.

5.3.2. Methodological Issues

a) Methodology

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*. [11]

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.

b) Emission Factors

Source	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	1'488	1'380	1'323	1'278	1'228	1'189	1'189
NMVOC	g/inhabitant	1'833	1'664	1'509	1'366	1'229	1'099	980	867	759	710	660	612	586	566	545	527	527

Table 59 Emission factors - specific emissions per inhabitant, 1990 to 2006 (Source: Swiss emissions from FOEN 2007; 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[12]: p. 5-2ff.].

c) Activity Data

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

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[11] This approach is used for all years but the latest (2006). Here, for Liechtenstein the specific emissions of Switzerland of the previous year (2005) are used, because the Swiss National Inventory is published only after the drafting of Liechtensteins NIR. For the next submission, the emission factors used for Liechtenstein will be updated according to the latest Swiss NIR.

[12] 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.

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 and uncertainty of simple approach).

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

No recalculations have been carried out.

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 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 2006 EF: FOEN 2007

Table 60 Specification of source category 3C "Chemical Products, Manufacture and Processing".

5.4.2. Methodological Issues

a) Methodology

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*.[13]

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.

b) 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	2005	2006
3C. Chemical Products, Manufacture and Processing								
CO_2	g/inhabitant	4'707	4'559	4'680	4'769	4'892	4'986	4'986
NMVOC	g/inhabitant	803	731	706	690	661	652	652

Table 61 Emission factors - specific emissions per inhabitant, 1990 to 2006 (Source: Swiss emissions from FOEN 2007; 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.].

c) 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 and uncertainty of simple approach).

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

No recalculations have been carried out.

5.4.6. Source-Specific Planned Improvements

There are no source-specific planned improvements.

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[13] This approach is used for all years but the latest (2006). Here, for Liechtenstein the specific emissions of Switzerland of the previous year (2005) are used, because the Swiss National Inventory is published only after the drafting of Liechtensteins NIR. For the next submission, the emission factors used for Liechtenstein will be updated according to the latest Swiss NIR.

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 2006 EF: FOEN 2007

Table 62 Specification of source category 3D “Other”.

5.5.2. Methodological Issues

a) Methodology

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*.[14]

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.

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[14] This approach is used for all years but the latest (2006). Here, for Liechtenstein the specific emissions of Switzerland of the previous year (2005) are used, because the Swiss National Inventory is published only after the drafting of Liechtensteins NIR. For the next submission, the emission factors used for Liechtenstein will be updated according to the latest Swiss NIR.

b) 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	2005	2006
3D1. Other. Use of N_2O for Anaesthesia								
N_2O	g/inhabitant	17	14	14	14	12	12	12
3D3. Other. N_2O from Aerosol Cans								
N_2O	g/inhabitant	10	10	10	10	9	9	9
3D. Other. Other. Spray cans, cosmetic institutions, etc.								
CO_2	g/inhabitant	16'124	15'869	15'278	15'132	14'762	14'597	14'597
NMVOC	g/inhabitant	4'795	4'621	4'399	4'248	4'103	4'046	4'046

Table 63 Emission factors - specific emissions per inhabitant, 1990 to 2006 (Source: Swiss emissions from FOEN 2007; 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.].

c) 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 and uncertainty of simple approach).

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

No recalculations have been carried out.

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 2006 were 22.3 Gg CO_2 equivalents in total, which is a contribution of 8.2% to the total of Liechtenstein's greenhouse gas emissions (excluding LULUCF). Main agricultural sources of greenhouse gases in 2006 were enteric fermentation emitting 10.2 Gg CO_2 equivalents, followed by agricultural soils with 8.8 Gg CO_2 equivalents. In general, emissions decreased until 2000 and are since then increasing again. However, they are still lower than in 1990.

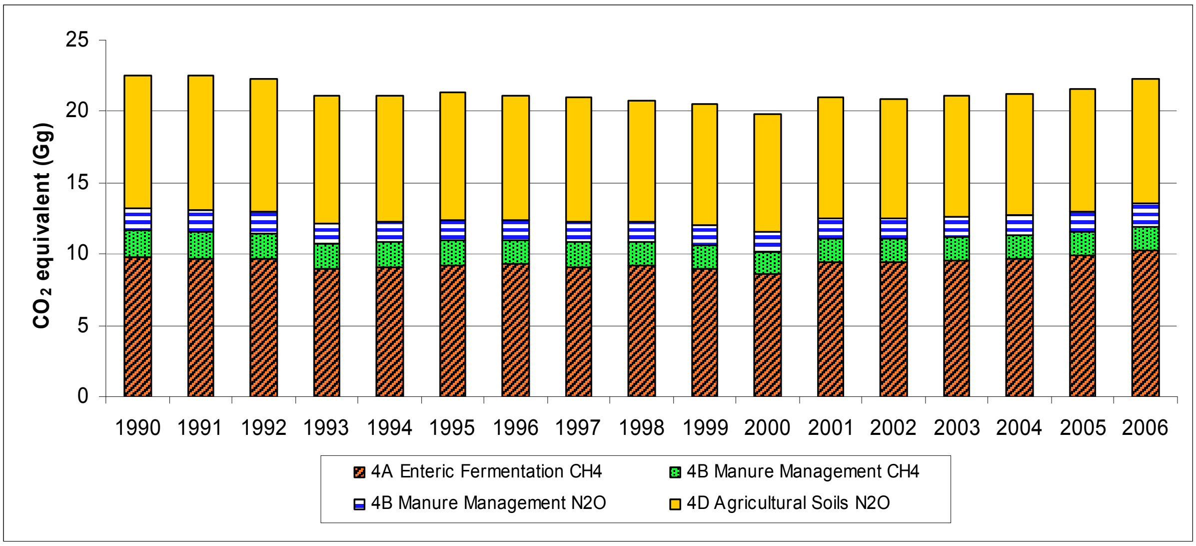

Figure 15 Greenhouse gas emissions in Gg CO_2 equivalents of agriculture 1990-2006.

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**
	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
N_2O	10.8	10.9	10.8	10.4	10.3	10.4	10.2	10.1	9.9	9.9
Sum	**22.5**	**22.5**	**22.3**	**21.1**	**21.1**	**21.3**	**21.2**	**21.0**	**20.8**	**20.5**

Gas	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	***1990/2006***
	CO2 equivalent (Gg)							*%*
CH_4	10.2	11.1	11.0	11.2	11.3	11.5	12.0	*2.3*
N_2O	9.6	9.9	9.8	9.9	10.0	10.1	10.4	*-4.2*
Sum	**19.8**	**21.0**	**20.9**	**21.1**	**21.2**	**21.6**	**22.3**	***-0.9***

Table 64 Greenhouse gas emissions in Gg CO_2 equivalents of agriculture 1990-2006.

CH_4 emissions increased since 2000 and are now 4.5% higher than in 1990 due to higher emission factors for dairy cattle and an increase of the number of some animal populations (e.g. dairy cattle). N_2O emissions decreased mainly due to a reduced input of mineral fertilizers.

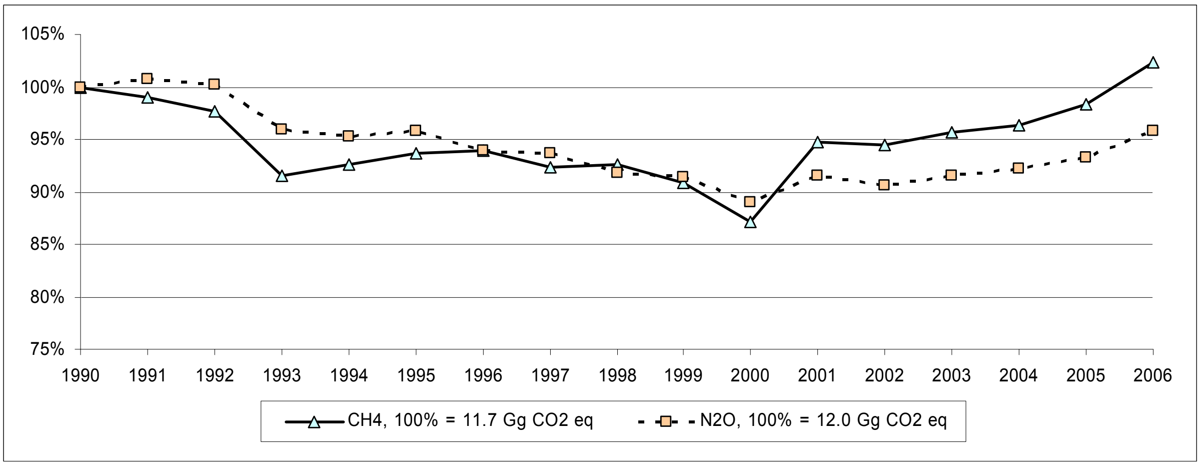

Figure 16 Trend of greenhouse gases of the agricultural sector 1990-2006. The base year 1990 represents 100%.

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.

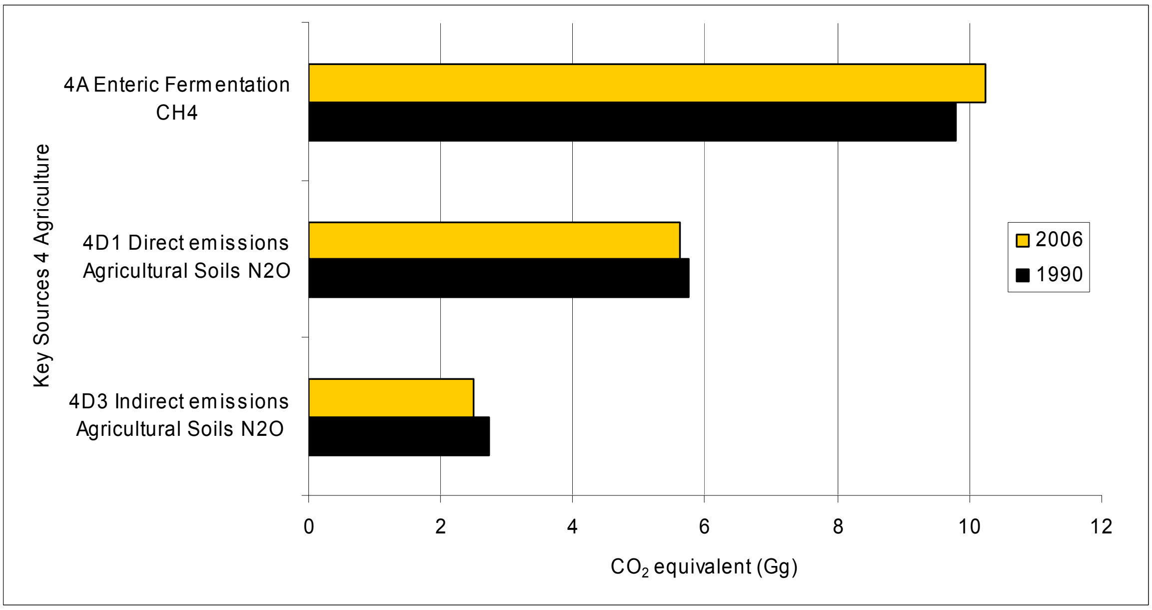

Figure 17 Key sources in Agriculture (emissions in CO_2 equivalents per source category).

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 increasing since 1990 due to different reasons. One reason is an increase in the dairy cattle population and also a higher emission factor for the dairy cattle category. Another reason is the increase of the animal population of fattening cattle. Emissions from cattle contribute to approximately 89% of the emissions from enteric fermentation.

4A	Source	Specification	Data Source
4A1	Cattle	Mature dairy cattle	AD: Livestock data from LWA 2007 (since 2002), AVW 2006 (before 2002) Net energy and metabolisable energy (calves) from RAP 1999 EF: Soliva 2006a
		Mature non-dairy cattle	
		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)	
4A3 4A4	Sheep Goats		AD: Livestock data from LWA 2007 (since 2002), AVW 2006 (before 2002) Data on net energy and feed intake losses from SBV 2006 EF: Soliva 2006a
4A6 4A8	Horses Swine		AD: Livestock data from LWA 2007 (since 2002), AVW 2006 (before 2002) Data on digestible energy and feed intake losses from SBV 2006 EF: Soliva 2006a
4A7	Mules and asses		AD: Livestock data from LWA 2007 (since 2002), AVW 2006 (before 2002) Data on digestible energy and feed intake losses from SBV 2006 EF: Soliva 2006a
4A9	Poultry		AD: Livestock data from LWA 2007 (since 2002), AVW 2006 (before 2002) Data on metabolisable energy and feed intake losses from SBV 2006 EF: Soliva 2006a; Hadorn and Wenk 1996.

Table 65 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 2007):

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 2006 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.

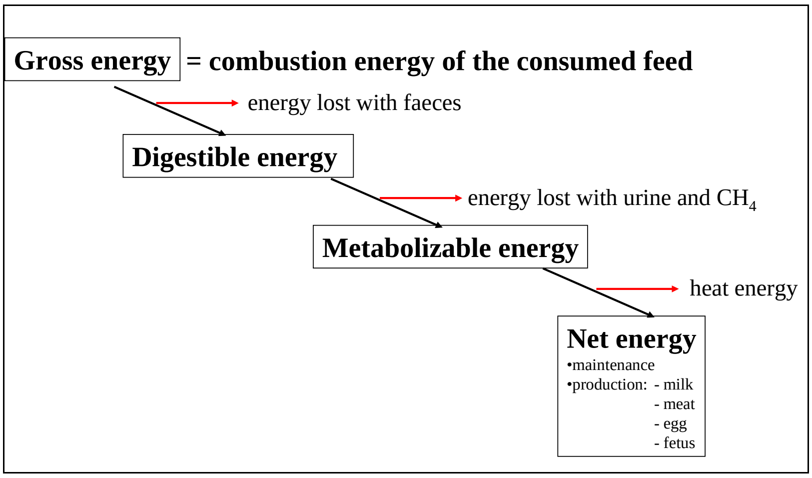

Figure 18 Levels of feed energy conversion. Reference: Soliva 2006a.

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 66 *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 from the year 2005 (except emission factor for dairy cattle, which is based on country specific data on milk production). Emission factors from the year 2006 are not yet available. 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**
	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
Mature non-dairy cattle	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
Milk-fed calf	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
Breeding calf	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
Fattening calf	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
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
Sheep	20.8	21.4	21.7	21.1	23.2	24.3	21.4	21.8	21.6	22.8
Goats	31.7	32.0	32.3	32.3	33.2	34.8	32.4	29.3	29.2	28.9
Horses	145.3	135.1	133.4	125.2	153.3	176.8	131.9	133.9	134.1	134.1
Ponies, Mules and Asses	162.0	158.1	159.7	152.9	161.0	156.1	118.3	115.0	110.3	101.7
Swine	35.2	36.0	36.2	36.1	36.8	40.4	43.0	37.0	36.5	37.4
Poultry	1.8	1.9	1.9	1.7	1.7	1.8	1.7	1.8	1.7	1.6

Gross Energy Intake	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
	MJ/head/day						
Cattle							
Mature dairy cattle	296.4	303.6	305.5	306.3	311.4	308.9	307.9
Mature non-dairy cattle	205.1	205.1	205.1	205.1	205.1	205.1	205.1
Young cattle (average)	41.9	46.4	52.0	50.4	53.0	53.7	52.1
Milk-fed calf	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
Breeding calf	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
Fattening calf	55.6	55.6	55.6	55.6	55.6	55.6	55.6
Fattening cattle	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
Sheep	22.1	22.8	22.6	22.5	23.0	22.7	22.7
Goats	31.9	31.9	30.9	31.4	30.9	31.7	31.7
Horses	134.1	139.4	139.2	139.6	139.7	140.3	140.3
Ponies, Mules and Asses	100.9	98.9	95.3	92.0	89.2	87.0	87.0
Swine	36.4	35.2	34.9	34.9	35.1	34.6	34.6
Poultry	1.7	1.7	1.7	1.7	1.6	1.7	1.7

Table 67 Gross energy intake of different livestock groups. Calculation is based on the above mentioned parameters net energy, digestible energy, metabolisable energy according to the method described in Soliva 2006a. Input data on net energy, digestible energy and metabolisable energy is taken from SBV 2006 and RAP 1999. All sub-categories displayed in italic.

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 mature dairy cattle increased which is mainly a result of higher milk production (Milk production was 5’792 kg per head and year in 1990 and 6’744 kg per year in 2006). The gross energy intake for mature non-dairy cattle is significantly higher than IPCC default values, since this category only comprehends mature cows to produce offspring for meat. The gross energy intake of young cattle was calculated separately for all sub-categories displayed in Table 67 (in italic) and subsequently averaged. The values for all sub-categories summarized under young cattle are constant over time. Since the composition of the young cattle category is changing over time, the average gross energy intake for young cattle is also changing over time. 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 2007, for all years since 2002) and from the Office of Economic Affairs (AVW 2006, for the years before 2002).

Data for the livestock categories mature dairy cattle, breeding cattle, sheep, goats and swine are available annually for the whole time series. For the other livestock categories data from the year 1990 was interpolated for all the years between 1991 and 2001. Since 2002 data for all livestock categories is available on an annual basis. Livestock data is collected each year in March.

Population Size	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	head									
Cattle	6'117	5'950	5'947	5'545	5'675	5'814	5'748	5'657	5'546	5'461
Mature dairy cattle	2'850	2'843	2'747	2'601	2'677	2'643	2'652	2'622	2'614	2'589
Mature non-dairy cattle	20	25	31	36	42	47	52	58	63	69
Young cattle	1'713	1'647	1'683	1'642	1'780	1'850	1'830	1'890	1'840	1'931
Milk-fed calf	40	47	54	62	69	76	83	90	98	105
Suckler cow calf	25	24	22	21	19	18	17	15	14	12
Breeding calf	280	302	323	345	366	388	410	431	453	474
Breeding cattle (4-12 months)	856	725	697	590	664	669	584	580	464	491
Fattening calf	205	225	244	264	284	304	323	343	363	382
Fattening cattle	307	325	342	360	378	396	413	431	449	466
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
Sheep	2'781	2'689	2'878	2'641	2'627	2'632	3'352	3'234	3'608	3'264
Goats	171	213	277	181	136	145	275	269	287	313
Horses	156	178	183	202	190	204	220	218	227	231
Ponies, Mules and Asses	50	58	66	75	83	91	99	107	115	124
Swine	3'251	3'543	2'902	3'236	2'787	2'429	2'392	2'128	2'056	2'122
Poultry	4'386	4'049	3'712	3'375	3'037	2'700	3'592	4'484	5'376	6'268

(cont'd next page)

Population Size	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
	head						
Cattle	5'229	5'270	5'235	5'539	5'768	5'587	5'822
Mature dairy cattle	2'440	2'639	2'560	2'543	2'460	2'489	2'589
Mature non-dairy cattle	74	112	149	199	279	362	405
Young cattle	1'804	1'652	1'529	1'781	2'084	1'776	1'829
Milk-fed calf	112	92	71	89	87	83	63
Suckler cow calf	11	56	101	141	252	266	283
Breeding calf	496	386	276	262	219	209	299
Breeding cattle (4-12 months)	299	360	451	493	663	392	418
Fattening calf	402	283	164	290	287	250	212
Fattening cattle	484	475	466	506	576	576	554
Breeding cattle (more than one year)	911	868	997	1'016	945	960	999
Sheep	3'319	3'319	3'201	3'070	3'149	3'603	3'687
Goats	239	210	205	241	286	324	362
Horses	153	284	196	220	255	266	286
Ponies, Mules and Asses	132	140	148	127	159	143	140
Swine	2'013	2'248	2'101	1'979	990	1'703	1'723
Poultry	7'159	8'772	10'384	10'408	11'130	10'453	11'742

Table 68 Activity for calculating methane emissions from enteric fermentation. (LWA 2007, AVW 2006)

The number of swine was declining during the last 16 years whereas the number of sheep, goats, horses and poultry were increasing. The massive increase in the poultry population is a result of two new poultry farms that were established in Liechtenstein. The drastic decrease of the swine population between 2003 and 2004 was caused by a disease.

6.2.3. Uncertainties and Time-Series Consistency

For the uncertainty analysis the following input data from the Swiss Agroscope Reckenholz-Tänikon Research Station ART was used (ART 2007):

Input data for uncertainty analysis 4A	**Lower bound (2.5 Percentile)**	**Upper bound (97.5 Percentile)**	**Mean uncertainty**
Activity data (head)	-6.4%	+6.4%	±6.4%
Emission factor (kg CH_4 /head/yr)	-14.7%	+19.6%	±17.2%

Table 69 Input data for the uncertainty analysis of the source category 4A "Enteric Fermentation" (ART 2007).

It is assumed that uncertainty estimations from Switzerland are also applicable for Liechtenstein. Liechtenstein applies the same methods and emission factors and has since 2002 a sophisticated livestock data collection system with low inaccuracies.

To apply for the Tier 1 uncertainty analysis, the arithmetic mean of lower and upper bound is used for activity data and for emission factors. For further results see Section 1.7.

Time series between 1990 and 2006 is consistent.

6.2.4. Source-Specific QA/QC and Verification

Documentation about the calculation method of Switzerland assures transparency and traceability of the calculation methods (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.

The agriculture expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 2).

Source-specific activities have not been carried out.

6.2.5. Source-Specific Recalculations

No recalculations have been carried out.

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 in 2006 are lower than the emissions in 1990, which is mainly a result of the reduction of the dairy cattle and swine population. N_2O emissions from manure management slightly increased due to an increase of the poultry population.

4B	Source	Specification	Data Source
4B1	Cattle	Mature dairy cattle	AD: LWA 2007 (since 2002), AVW 2006 (before 2002) EF: IPCC 2000; IPCC 1997c; FAL/RAC 2001; Menzi et al. 1997; Soliva 2006a.
		Mature non-dairy cattle	
		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)	
4B3 4B4 4B6 4B8	Sheep Goats Horses Swine		AD: LWA 2007 (since 2002), AVW 2006 (before 2002) EF: IPCC 2000; IPCC 1997c; FAL/RAC 2001; Menzi et al. 1997; Soliva 2006a.
4B7	Mules and Asses		AD: LWA 2007 (since 2002), AVW 2006 (before 2002) EF: IPCC 2000; IPCC 1997c; FAL/RAC 2001; Menzi et al. 1997; Soliva 2006a.
4B9	Poultry		AD: LWA 2007 (since 2002), AVW 2006 (before 2002) EF: IPCC 2000; IPCC 1997c; FAL/RAC 2001; Menzi et al. 1997; Soliva 2006a.

Table 70 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 2007 (since 2002), AVW 2006 (before 2002); FAL/RAC 2001; Menzi et al. 1997; Soliva 2006a EF: IPCC 2000; IPCC 1997c

Table 71 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-categories are used. The livestock categories reported in the CRF tables are the same, but the respective sub-categories as a basis for the calculation are slightly different. 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 2007):

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, swine and goats as provided by FAL/RAC (2001) do not correspond to the categories of the Swiss Farmers Union (SBV 2006). 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[15].*

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 and IPCC 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 2007):

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).

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[15] 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.

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 1997 (1997c: 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 1997c: Reference Manual: p. 4.47). The digestible energy of the feed for cattle is assumed to be 60% on average, except for calves with 65% (IPCC 1997c: Reference Manual: p. 4.39). The calculation of gross energy intake per head is described in detail in chapter 6.2.2.*

For the Methane Producing Potential ($\boldsymbol{B_o}$*) default values are used (IPCC 1997c: Reference Manual: p. 4.39 to 4.47).*

*For the Methane Conversion Factor (****MCF****) IPCC default values are used (IPCC 2000, p. 4.36 and IPCC 1997c: 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 72 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.*	*3.9%*
Poultry system	*Manure is excreted on the floor with or without bedding.*	*1.5%*

*According to the Swiss methodology, 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 2007) and the Office of Economic Affairs (AVW 2006). For details 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 2007):

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 1997c: Reference Manual: p. 4.104).

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

Table 73 Emission factors for calculating N_2O emissions from manure management (IPCC 1997c: p. 4.104).

Activity data

Input data on all livestock groups are taken from LWA 2007 and AVW 2006. Data are converted into the following livestock categories.

Population Size	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	head									
Cattle	6'117	5'950	5'947	5'545	5'675	5'814	5'748	5'657	5'546	5'461
Mature dairy cattle	2'850	2'843	2'747	2'601	2'677	2'643	2'652	2'622	2'614	2'589
Mature non-dairy cattle	20	25	31	36	42	47	52	58	63	69
Young cattle	1'713	1'647	1'683	1'642	1'780	1'850	1'830	1'890	1'840	1'931
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
Fattening calf	205	225	244	264	284	304	323	343	363	382
Fattening cattle	307	325	342	360	378	396	413	431	449	466
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
Sheep (Sheep places)	1'391	1'345	1'439	1'321	1'314	1'316	1'676	1'617	1'804	1'632
Goats (Goat places)	94	117	152	100	75	80	151	148	158	172
Horses	156	178	183	202	190	204	220	218	227	231
Foals (< 1 year)	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.
Foals (1-2 years)	16	16	17	17	18	18	18	19	19	20
Other horses	140	161	166	184	173	186	202	199	207	211
Ponies, Mules and Asses	50	58	66	75	83	91	99	107	115	124
Swine										
Fattening pig places	1'983	2'097	1'717	2'003	1'720	1'449	1'488	1'169	1'200	1'208
Breeding pig places	273	394	324	228	204	253	158	373	254	308
Poultry	4'386	4'049	3'712	3'375	3'037	2'700	3'592	4'484	5'376	6'268
Laying hens	4'118	3'802	3'486	3'170	2'854	2'538	3'403	4'268	5'133	5'998
Young hens	105	96	88	79	70	61	53	44	35	26
Broilers	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	36	71	107	143
Other poultry	163	151	138	126	113	101	101	101	101	100

Population Size	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
	head						
Cattle	5'229	5'270	5'235	5'539	5'768	5'587	5'822
Mature dairy cattle	2'440	2'639	2'560	2'543	2'460	2'489	2'589
Mature non-dairy cattle	74	112	149	199	279	362	405
Young cattle	1'804	1'652	1'529	1'781	2'084	1'776	1'829
Milk fed calf, suckler cow calf, breeding calf and breeding cattle less than one year	918	894	899	985	1'221	950	1'063
Fattening calf	402	283	164	290	287	250	212
Fattening cattle	484	475	466	506	576	576	554
Breeding cattle (more than one year)	911	868	997	1'016	945	960	999
Sheep (Sheep places)	1'660	1'660	1'601	1'535	1'575	1'802	1'844
Goats (Goat places)	131	116	113	133	157	178	199
Horses	153	284	196	219	249	258	279
Foals (< 1 year)	i.e.	i.e.	i.e.	1	5	6	5
Foals (1-2 years)	20	12	4	10	18	20	25
Other horses	133	272	192	209	231	238	254
Ponies, Mules and Asses	132	140	148	127	159	143	140
Swine							
Fattening pig places	1'221	1'306	1'329	1'240	654	1'056	1'076
Breeding pig places	180	287	106	117	8	117	108
Poultry	7'159	8'772	10'384	10'408	11'130	10'453	11'742
Laying hens	6'863	8'449	10'034	10'113	10'549	10'112	11'398
Young hens	18	9	0	11	9	0	9
Broilers	179	214	250	250	520	250	300
Other poultry	100	100	100	34	52	91	35

Table 74 Activity data for calculating N_2O emissions from manure management (LWA 2007, AVW 2006). For calculation of sheep places, goat places, fattening pig places and breeding pig places, 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), Walther et al. (1994) and Schmid et al. (2000) (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

For the uncertainty analysis the following input data from the Swiss Agroscope Reckenholz-Tänikon Research Station ART was used (ART 2007):

Input data for uncertainty analysis 4B	**Lower bound (2.5 Percentile**	**Upper bound (97.5 Percentile)**	**Mean uncertainty**
Activity data CH_4 (head)	-6.4%	+6.4%	±6.4%
Activity data N_2O (liquid systems and solid storage, kg N)	-29.9%	+29.2%	±29.5%
Emission factor CH_4 (kg CH_4 /head/yr)	-54.7%	+53.6%	±54.1%
Emission factor N_2O (liquid systems, kg N_2O-N / kg N)	-100%	+0%	±50%
Emission factor N_2O (solid storage, kg N_2O-N / kg N)	-75%	+50%	±62.5%

Table 75 Input data for the uncertainty analysis of the source category 4B “Manure Management”. (ART 2007).

It is assumed that uncertainty estimations from Switzerland are also applicable for Liechtenstein. Liechtenstein applies the same methods and emission factors and has since 2002 a sophisticated and livestock data collection system with low inaccuracies.

To apply for the Tier 1 uncertainty analysis, the arithmetic mean of lower and upper bound is used for activity data and for emission factors. For further results see Section 1.7.

For further results see Section 1.7. The time series 1990-2006 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 of the calculation methods (Soliva 2006a). Additionally a document in German lists all the methodological differences between the former calculations and the current methodology (Soliva 2006b). For N_2O 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.

The agriculture expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 2).

6.3.5. Source-Specific Recalculations

No recalculations 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.

In general, direct and indirect N_2O emissions are slightly decreasing since 1990, mainly due to a reduced input of mineral fertilizer. Within the source category direct emissions a slight increase of emissions from fixation can be noted, which is a result of the growing areas of pasture range and paddock.

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 2007a, FAL/RAC 2001, Leifeld et al. 2003, Menzi et al. 1997, Schmid et al. 2000, Walther et al. 1994 EF: IPCC 1997c (N_2O); IPCC 2000
4D2	Pasture, range and paddock manure		AD: LWA 2007, LWA 2007a, AVW 2006, FAL/RAC 2001, Menzi et al. 1997, Schmid et al. 2000, Walther et al. 1994 EF: IPCC 1997c
4D3	Indirect emissions	Leaching and run-off, N deposition air to soil	AD: LWA 2007a, FAL/RAC 2001, Prasuhn and Braun 1994, Braun et al. 1994, Schmid et al. 2000, Walther et al. 1994. EF: IPCC 2000

Table 76 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 2007):

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 Schmid et al. (2000) IULIA is better adapted to the conditions of Swiss agriculture, compared to the IPCC method. 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 on grasslands are considered. This is explained by the fact that the emissions from plant residues returned to soils on cropland 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 2000 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 2006). The amount of nitrogen in sewage sludge is taken from the Office of Agriculture (LWA 2007a). From the amount of nitrogen in fertilizer losses to the atmosphere in form of NH3 are subtracted and the rest is multiplied with the corresponding emission factor. NOx emissions are not subtracted since they occur mainly after the fertilizer application. According to the Swiss method IULIA losses to the atmosphere are set to 6% (NH3) 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. 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). NOx emissions are not subtracted since they occur after the application of animal wastes. For details regarding the volatized N refer to Table 78.
- 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) the calculation of nitrogen in crop residues is based on data reported on crop yields (LWA 2007a), the standard values for arable crop yields for Switzerland (FAL/RAC 2001 and Walther et al. 1994) and standard amounts of nitrogen in crop residues returned to soils for Switzerland (FAL/RAC 2001 and Walther et al. 1994). 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/ha)

  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 2007a).
- 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). This is in line with IPCC, assuming that biological nitrogen fixation supplies 50-60 per cent of the nitrogen in grain legumes (IPCC 1997c, p. 4.89). 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 a nitrogen concentration of 3.5% in the dry matter from which 80% derives from biological nitrogen fixation. For the dry matter production of clover on pastures and meadows statistical data were used (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 77 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 2007a) and the IPCC default emission factor for N_2O emissions from cultivated organic soils (IPCC 1997b). The estimation of the area of cultivated organic soils was revised due to an inconsistency with the area reported in the LULUCF sector.

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, refer to chapter 6.3.2.

Only emissions of Pasture range and Paddock are to be reported under Agricultural Soils. 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; Schmid et al. 2000; Walther et al. 1994 (nitrogen excretion in kg N/head/yr) and Menzi et al. 1997 (fraction of animal waste management system)).

Indirect emissions (4D3)

Calculation of the indirect emissions is based on IPCC 2000 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 2005a). 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) and Schmid et al. (2000). 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 and 1.5 kg NH_3 - N/ha agricultural soil is produced during decomposition of organic material. 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 2006	**Losses NH3 (%)**	**Emissions NH3 (t N) 2006**	**Losses NOx (%)**	**Emissions NOx (t N) 2006**	**Volatized N total (NH3, NOx in t) 2006**
Cattle						
Mature dairy cattle and non-dairy cattle	341.6	32%	109.3	0.7%	2.4	111.7
Young cattle	41.1	22-37%	11.9	0.7%	0.3	12.1
Milk fed calf, suckler cow calf, breeding calf and breeding cattle less than one year	*22.4*	*22%*	*4.9*	*0.7%*	*0.2*	*5.1*
Fattening calf	*0.4*	*37%*	*0.2*	*0.7%*	*0.0*	*0.2*
Fattening cattle	*18.3*	*37%*	*6.8*	*0.7%*	*0.1*	*6.9*
Breeding cattle (more than one year)	45.5	22%	10.0	0.7%	0.3	10.3
Sheep (Sheep places)	**22.1**	**14%**	**3.1**	**0.7%**	**0.2**	**3.3**
Goats (Goats places)	**3.2**	**29%**	**0.9**	**0.7%**	**0.0**	**0.9**
Horses	**12.3**	**32%**	**3.9**	**0.7%**	**0.1**	**4.0**
Foals (< 1 year)	*0.1*	*32%*	*0.0*	*0.7%*	*0.0*	*0.0*
Foals (1-2 years)	*1.1*	*32%*	*0.3*	*0.7%*	*0.0*	*0.3*
Other horses	*11.2*	*32%*	*3.6*	*0.7%*	*0.1*	*3.7*
Ponies, Mules and Asses	**3.6**	**32%**	**1.2**	**0.7%**	**0.0**	**1.2**
Swine	**17.8**	**46%**	**8.2**	**0.7%**	**0.1**	**8.3**
Fattening pig places	*14.0*	*46%*	*6.4*	*0.7%*	*0.1*	*6.5*
Breeding pig places	*3.8*	*46%*	*1.7*	*0.7%*	*0.0*	*1.8*
Poultry	**8.2**	**48-54%**	**4.4**	**0.7%**	**0.1**	**4.5**
Laying hens	*8.1*	*54%*	*4.4*	*0.7%*	*0.1*	*4.4*
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)	*0.0*	*48%*	*0.0*	*0.7%*	*0.0*	*0.0*
Total animals	**495**		**152.9**	**0.7%**	**3.5**	**156.3**
Mineral fertilizer, compost and sewage sludge (t N)	172.7	6%	10.4	0.7%	1.2	11.6
NH3 emissions from cropland (ha)	5'476	1.5 kg/ha	8.2			8.2
Total			**171.5**		**4.7**	**176.1**

Table 78 Overview of the volatized N (NH_3 and NO_X) from animal wastes and fertilizer for 2006. 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
Animal production	
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 79 Emission factors for calculating N_2O emissions from agricultural soils (IPCC 1997c, tables 4.18 (direct emissions), 4.22 (pasture, range and paddock) and 4.23 (indirect emissions); IPCC 2000: table 4.17 (organic soils)).

Activity data

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

- the Office of Agriculture (LWA 2007a): Use of synthetic fertilizer[16], crops produced, area of pasture range and paddock, area of cultivated organic soils[17]
- and by FAL/RAC (2001 p. 48/49), Schmid et al. (2000), Walther et al. (1994): Nitrogen excretion.

Relevant activity data for calculating N_2O emissions from soils is displayed in the following table.

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[16] 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. Since 2006 data is not yet available, data from 2005 was implied for 2006. The amount of nitrogen in sewage sludge is taken from the Office of Agriculture (LWA 2006)

[17] The area of cultivated organic soils was revised for this submission. It is estimated to be constant for all the years between 1990 and 2006.

Emission type	Related activity data	unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
			Value									
Direct emissions												
Fertilizer	Sum	t N/yr	233	236	236	221	211	204	186	188	166	172
	Mineral fertilizer	t N/yr	202	192	199	180	173	172	164	164	145	156
	Sewage sludge	t N/yr	30	44	37	41	38	31	21	24	21	16
	Compost	t N/yr	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.4
Animal manure	Nitrogen input from manure applied to soils	t N/yr	281	283	276	262	261	262	263	263	262	260
N-fixing crops	Peas, dry beans, soybeans and leguminous vegetables produced	t N/yr	146	150	153	156	162	167	161	162	164	165
Crop residue	Dry production of other crops	t N/yr	197	204	205	206	209	213	203	202	200	198
Organic soils	Area of cultivated organic soils	ha	159	159	159	159	159	159	159	159	159	159
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
	N fixation pasture range and paddock	t N/yr	1.7	1.8	1.8	1.9	1.9	1.9	2.0	2.0	2.0	2.0
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
	N from residues pasture range and paddock	t N/yr	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1
Indirect emissions												
Leaching and run-off	N excretion of all animals	t N/yr	519	519	509	480	477	481	482	480	478	470
	Fertilizer	t N/yr	233	236	236	221	211	204	186	188	166	172
	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
Deposition	Emissions NH3 from fertilizers, animal wastes and cropland	t N/yr	180	182	177	169	167	167	166	166	164	164
	Emissions NOx from fertilizers and animal wastes	t N/yr	5	5	5	5	5	5	5	5	5	4
	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
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

Emission type	Related activity data	unit	2000	2001	2002	2003	2004	2005	2006
			Value						
Direct emissions									
Fertilizer	Sum	t N/yr	173	187	182	175	176	173	173
	Mineral fertilizer	t N/yr	162	180	176	169	176	172	172
	Sewage sludge	t N/yr	11	6	5	6	0	0	0
	Compost	t N/yr	0.4	0.3	0.5	0.5	0.4	0.5	0.4
Animal manure	Nitrogen input from manure applied to soils	t N/yr	248	257	251	256	255	265	277
N-fixing crops	Peas, dry beans, soybeans and leguminous vegetables produced	t N/yr	167	169	171	177	180	181	180
Crop residue	Dry production of other crops	t N/yr	197	197	198	202	205	201	201
Organic soils	Area of cultivated organic soils	ha	159	159	159	159	159	159	159
N-fixing pasture range and paddock	Area of pasture range and paddock	ha	4'336	4'368	4'400	4'543	4'670	4'570	4'546
	N fixation pasture range and paddock	t N/yr	2.1	2.1	2.1	2.2	2.2	2.2	2.2
Residues pasture range and paddock	Area of pasture range and paddock	ha	4'336	4'368	4'400	4'543	4'670	4'570	4'546
	N from residues pasture range and paddock	t N/yr	2.1	2.1	2.1	2.1	2.2	2.1	2.1
Indirect emissions									
Leaching and run-off	N excretion of all animals	t N/yr	448	459	451	459	457	473	495
	Fertilizer	t N/yr	173	187	182	175	176	173	173
	N from fertilizers and animal wastes that is lost through leaching and run off	t N/yr	124	129	127	127	127	129	134
Deposition	Emissions NH3 from fertilizers, animal wastes and cropland	t N/yr	157	163	159	161	159	165	172
	Emissions NOx from fertilizers and animal wastes	t N/yr	4	5	4	4	4	5	5
	Sum of volatized N (NH3 and NOx) from fertilizers, animal wastes and cropland	t N/yr	161	167	164	165	163	170	177
Pasture, range and paddock manure									
Pasture, range and paddock	N excretion on pasture range and paddock	t N/yr	65	62	64	64	65	65	68

Table 80 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

For the uncertainty analysis the following input data from the Swiss Agroscope Reckenholz-Tänikon Research Station ART was used (ART 2007):

Input data for uncertainty analysis 4D	**Lower bound (2.5 Percentile**	**Upper bound (97.5 Percentile)**	**mean uncertainty**
Activity data 4D1 (fertilizer, kg N)	-12.4%	+10.3%	±11.3%
Activity data 4D1 (organic soils, hectares)	-29.4%	+29.4%	±29.4%
Activity data 4D2 (kg N)	-54.2%	+60.5%	±57.3%
Activity data 4D3 (deposition, kg N)	-34.6%	+48.3%	±41.4%
Activity data 4D3 (leaching and run-off, kg N)	-22.2%	+22.0%	±22.1%
Emission factor 4D1 (fertilizer, kg N_2O-N / kg N)	-80%	+80%	±80%
Emission factor 4D1 (organic soils, kg N_2O-N / kg N)	-75%	+87.5%	±81.3%
Emission factor 4D2 (kg N_2O-N / kg N)	-75%	+50%	±62.5%
Emission factor 4D3 (deposition, kg N_2O-N / kg N)	-80%	+100%	±90%
Emission factor 4D3 (leaching and run-off, kg N_2O-N / kg N)	-92%	+380%	±236%

Table 81 Input data for the uncertainty analysis of the source category 4D “Agricultural Soils”. (ART 2007).

It is assumed that uncertainty estimations from Switzerland are also applicable for Liechtenstein, since Liechtenstein applies the same methods and emission factors. Also for activity data country specific uncertainty estimations are not available. Therefore, Swiss estimations are used as a first guess.

To apply for the Tier 1 uncertainty analysis, the arithmetic mean of lower and upper bound is used for activity data uncertainty and for emission factor uncertainty. For further results see Section 1.7.

Time series between 1990 and 2006 is consistent.

6.5.4. 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. 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

The area of cultivated organic soils was revised due to an inconsistency between the areas reported in the agriculture and the LULUCF sector. It is now estimated to be constant over the whole time period. Therefore, a recalculation of the whole time-series has 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 2006 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, 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 from Switzerland 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 84). 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 82 and Figure 20 summarize the CO_2 equivalent emissions and removals in consequence of carbon losses and gains for the years 1990-2006. The total net removals/emissions of CO_2 equivalent vary between -4.9 Gg (1997) and -8.5 Gg (1996) from 1990 to 2006. 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
	Gg CO2									
Increase of living biomass in forest	-68.73	-68.82	-68.90	-68.98	-69.07	-69.15	-69.23	-70.26	-70.26	-70.26
Decrease of living biomass in forest	50.32	50.38	50.45	50.52	50.58	50.65	50.70	50.96	50.97	50.99
Land-use change and soil	10.10	10.08	10.06	10.04	10.03	10.01	9.99	14.36	14.35	14.34
Sector 5 LULUCF	-8.32	-8.35	-8.39	-8.43	-8.46	-8.50	-8.53	-4.95	-4.94	-4.93

LULUCF	2000	2001	2002	2003	2004	2005	2006
	Gg CO2						
Increase of living biomass in forest	-70.26	-70.26	-70.26	-69.56	-69.62	-69.67	-69.73
Decrease of living biomass in forest	51.00	51.02	51.03	50.84	50.89	50.93	50.98
Land-use change and soil	14.34	14.33	14.33	12.24	12.23	12.21	12.20
Sector 5 LULUCF	-4.92	-4.91	-4.90	-6.49	-6.51	-6.53	-6.55

Table 82 Liechtenstein's CO_2 equivalent emissions/removals [Gg] of the source category 5 LULUCF 1990-2006. Positive values refer to emissions; negative values refer to removals from the atmosphere.

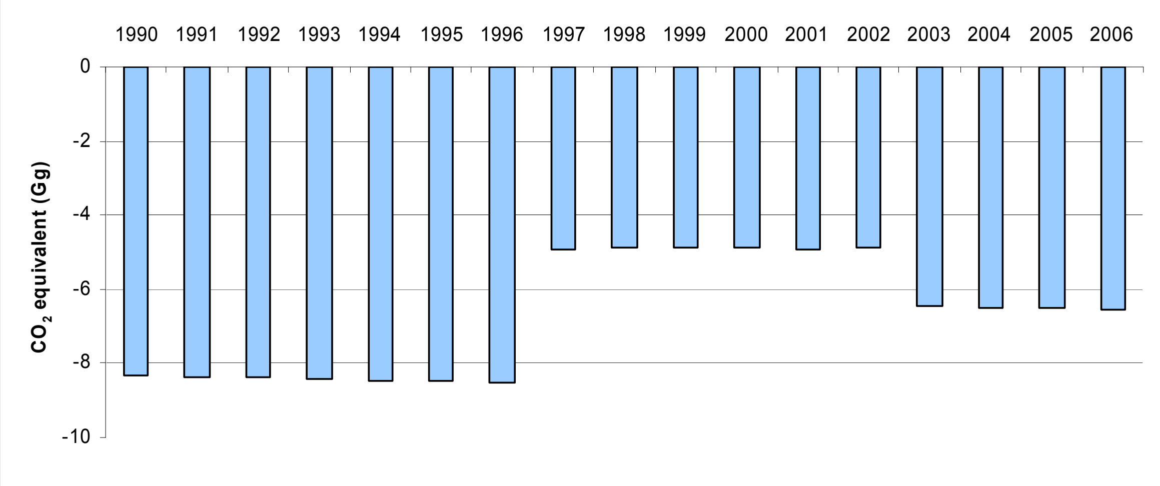

Figure 19 Liechtenstein's CO_2 emissions/removals of source category 5 LULUCF 1990–2006 in Gg CO_2 equivalent. Negative values refer to removals.

Increase and decrease of living biomass in forests are the dominant categories when looking at the CO_2 emissions and removals (refer to Table 82 and Figure 20). Emissions and removals from forest land are quite stable over time. The dominant category when looking at the changes in net CO_2 removals is grassland (refer to Table 83). It can be observed that land-use conversions from and to grassland differ significantly between the three time periods 1990 to 1996, 1997 to 2002 and 2003 to 2006. In the period 1997 to 2002 the conversion from grassland to forest land exceeded the conversion from forest land to grassland, which leads to lower net CO_2 removals from 1997 to 2002.

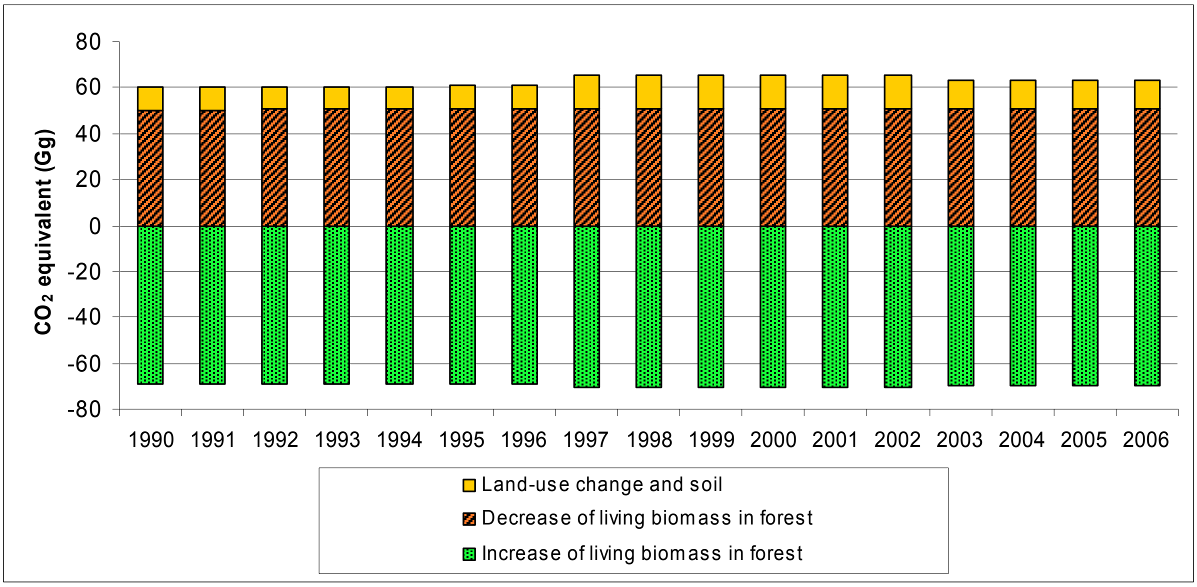

Figure 20 The CO_2 removals due to the increase (growth) of living biomass on forest land, the CO_2 emissions due to the decrease (harvest and mortality) of living biomass on forest land and the net CO_2 equivalent emissions due to land-use changes and from use of soils, 1990–2006.

Net CO2 emissions/removals	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Total Land-Use Categories	**-8.32**	**-8.35**	**-8.39**	**-8.43**	**-8.46**	**-8.50**	**-8.53**	**-4.95**	**-4.94**	**-4.93**
A. Forest Land	**-18.74**	**-18.76**	**-18.78**	**-18.79**	**-18.81**	**-18.83**	**-18.85**	**-19.78**	**-19.77**	**-19.75**
1. Forest Land remaining Forest Land	-18.64	-18.65	-18.67	-18.69	-18.71	-18.72	-18.74	-19.71	-19.70	-19.68
2. Land converted to Forest Land	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.07	-0.07	-0.07
B. Cropland	**4.44**	**4.44**	**4.43**	**4.42**	**4.42**	**4.41**	**4.41**	**4.56**	**4.58**	**4.61**
1. Cropland remaining Cropland	4.33	4.32	4.32	4.31	4.31	4.30	4.29	4.32	4.34	4.36
2. Land converted to Cropland	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.24	0.24	0.24
C. Grassland	**2.05**	**2.04**	**2.03**	**2.02**	**2.00**	**1.99**	**1.98**	**4.27**	**4.24**	**4.21**
1. Grassland remaining Grassland	2.13	2.12	2.11	2.09	2.08	2.07	2.06	2.13	2.10	2.07
2. Land converted to Grassland	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	2.14	2.14	2.14
D. Wetlands	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.46**	**0.46**	**0.46**
1. Wetlands remaining Wetlands	NO	NO	NO	NO	NO	NO	NO	0.00	0.00	0.00
2. Land converted to Wetlands	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.47	0.47	0.47
E. Settlements	**3.35**	**3.35**	**3.35**	**3.35**	**3.35**	**3.35**	**3.35**	**3.89**	**3.89**	**3.89**
1. Settlements remaining Settlements	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.07	0.07
2. Land converted to Settlements	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.82	3.82	3.82
F. Other Land	**0.47**	**0.47**	**0.47**	**0.47**	**0.47**	**0.47**	**0.47**	**1.66**	**1.66**	**1.66**
1. Other Land remaining Other Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Land converted to Other Land	0.47	0.47	0.47	0.47	0.47	0.47	0.47	1.66	1.66	1.66

Net CO2- emissions/removals	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Total Land-Use Categories	**-4.92**	**-4.91**	**-4.90**	**-6.49**	**-6.51**	**-6.53**	**-6.55**
A. Forest Land	**-19.74**	**-19.72**	**-19.71**	**-19.10**	**-19.11**	**-19.12**	**-19.12**
1. Forest Land remaining Forest Land	-19.67	-19.65	-19.64	-19.00	-19.01	-19.01	-19.02
2. Land converted to Forest Land	-0.07	-0.07	-0.07	-0.10	-0.10	-0.10	-0.10
B. Cropland	**4.63**	**4.65**	**4.68**	**4.55**	**4.55**	**4.56**	**4.56**
1. Cropland remaining Cropland	4.39	4.41	4.43	4.44	4.44	4.44	4.45
2. Land converted to Cropland	0.24	0.24	0.24	0.11	0.11	0.11	0.11
C. Grassland	**4.18**	**4.15**	**4.12**	**2.74**	**2.72**	**2.70**	**2.68**
1. Grassland remaining Grassland	2.04	2.01	1.98	1.87	1.85	1.83	1.81
2. Land converted to Grassland	2.14	2.14	2.14	0.87	0.87	0.87	0.87
D. Wetlands	**0.46**	**0.46**	**0.46**	**0.76**	**0.76**	**0.76**	**0.76**
1. Wetlands remaining Wetlands	0.00	0.00	0.00	NO	NO	NO	NO
2. Land converted to Wetlands	0.47	0.47	0.47	0.76	0.76	0.76	0.76
E. Settlements	**3.89**	**3.89**	**3.89**	**3.53**	**3.53**	**3.53**	**3.53**
1. Settlements remaining Settlements	0.07	0.07	0.07	0.06	0.06	0.06	0.06
2. Land converted to Settlements	3.82	3.82	3.82	3.47	3.47	3.47	3.47
F. Other Land	**1.66**	**1.66**	**1.66**	**1.04**	**1.04**	**1.04**	**1.04**
1. Other Land remaining Other Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Land converted to Other Land	1.66	1.66	1.66	1.04	1.04	1.04	1.04

Table 83 Net CO_2 removals and emissions per land-use category, 1990-2006.

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 or even zero (zero in 2006). 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 84) were defined. For these 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 2006; SFSO 2006a). These combined categories were slightly revised for the current submission.
- 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 were 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, the results were aggregated 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.

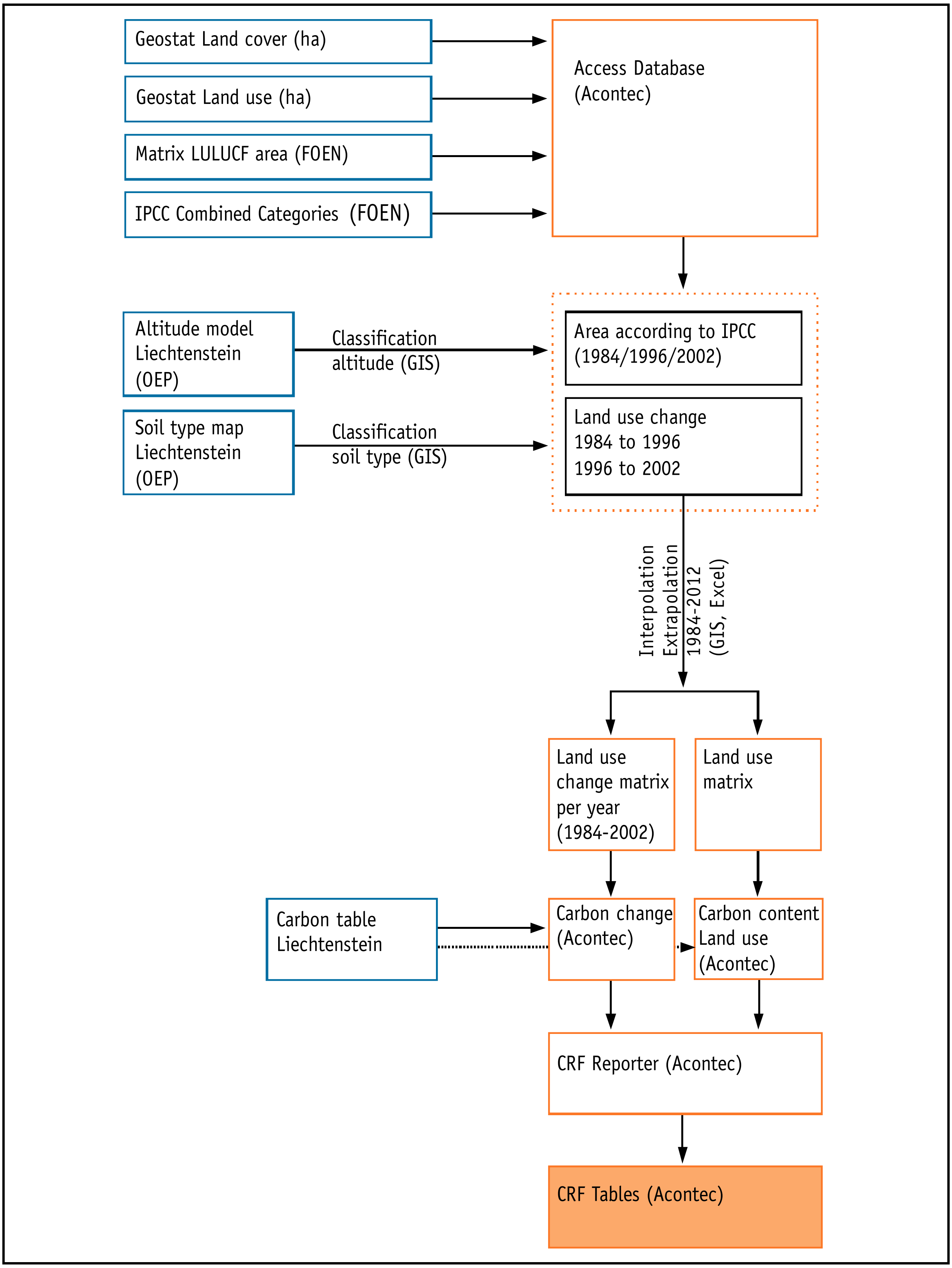

Figure 21 Procedure of calculating emissions and removals from LULUCF in Liechtenstein.

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 2007):

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**	**Managed or unmanaged**	***CC*** ***code***
A. Forest Land	*Afforestations*	*areas converted to forest by active measures, e.g. planting*[18]	managed	*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*	managed	*13*
B. Cropland		*arable and tillage land (annual crops and leys in arable rotations)*	managed	*21*
C. Grassland	*Permanent Grassland*	*meadows, pastures (low-land and alpine)*	managed	*31*
	Shrub Vegetation	*agricultural and unproductive areas predominantly covered by shrubs*	managed	*32*
	Vineyards, Low-Stem Orchards, Tree Nurseries	*perennial agricultural plants with woody biomass (no trees)*	managed	*33*
	Copse	*agricultural and unproductive areas covered by perennial woody biomass including trees*	managed	*34*
	Orchards	*permanent grassland with fruit trees*	managed	*35*
	Stony Grassland	*grass, herbs and shrubs on stony surfaces*	unmanaged	*36*
	Unproductive Grassland	*unmanaged grass vegetation*	unmanaged	*37*
D. Wetlands	*Surface Waters*	*lakes and rivers*	unmanaged	*41*
	Unproductive Wetland	*reed, unmanaged wetland*	unmanaged	*42*
E. Settlements	*Buildings and Constructions*	*areas without vegetation such as houses, roads, construction sites, dumps*	managed	*51*
	Herbaceous Biomass in Settlements	*areas with low vegetation, e.g. lawns*	managed	*52*
	Shrubs in Settlements	*areas with perennial woody biomass (no trees)*	managed	*53*
	Trees in Settlements	*areas with perennial woody biomass including trees*	managed	*54*
F. Other Land		*areas without soil and vegetation: rocks, sand, screes, glaciers*	unmanaged	*61*

Table 84 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 (2006) and SFSO (2006a). The column “Managed or unmanaged” was not included in the Swiss Inventory Report (FOEN 2007), but added for this submission for better clarification.

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):

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

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

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

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[18] Reforestation does not occur in Liechtenstein. For more than 100 years, the area of forest has not decreased anymore. Any reforestation would have required a deforestation within the last 50 years, but deforestation is prohibited by law (OEP 2007b).

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 $\mathrm{deltaC}_{l,i,ba}$ are inserted in the column "Increase" and negative values in column "Decrease", respectively (besides $\mathrm{increaseC}_{l,i,CC}$ and $\mathrm{decreaseC}_{l,i,CC}$ 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 aerial photos (SLP 2006).

For the reconstruction of the land use conditions in Liechtenstein for the period 1990-2006 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 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 2006) implementing the main categories proposed by IPCC as well as by Swiss country specific sub-divisions (see Table 84). 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. In the current submission the combination categories were slightly revised due to an improved forest definition. Groups of trees on meadows in higher altitudes are now allocated to the combination category “Unproductive forest” instead of the combination category “Copse” (under grassland).

Table 85 Relation between the different land-use and land-cover categories and the combination categories (CC). FOEN 2006 (revised)

18 Kyoto Combination Categories		Land Use according to AREA																																																
		Gebäudeareal								Verkehrsflächen					Besondere Siedlungsflächen							Erholungs- und Grünanlagen							Obstbau, Rebbau, Gartenbau			Acker- und Futterbau			Alp-wirtschaft				Wald (ohne landwirtschaftliche Nutzung)					Seen und Flüsse			Unproduktives Land			
Land Cover according to AREA	Settlements	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	Agricultural land	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.	Forest land	301 Waldbestände	302 Aufforstungen	303 Holzschläge	304 Waldschadenflächen	Unproductive	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	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	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				21																			
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			21	21	21	21		21				12											
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			31	31																			
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			21	21																			
20 Herbaceous 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		31	31	31	21	31	31	31	31	31			11	12	12		37	37	37	37	37	37	31
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	32									11	12	12		32	32	32	32	32	32	32
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			32	32		32	32	32	32				11	12	12		32	32	32	32	32	32	32
33 Niederstammobst		53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53		33		33																			
34 Reben		53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53			33	33																			
35 Gärtnerische Dauerkulturen		52	52	52	52	52	52	52	52	52	52	52	52								52	52				52	52				33								12											
40 Trees																																																		
41 Geschlossene Baumbestände		54	54	54	54	54	54	54	54	54		54									54	54	54		54	54	54		35										12	11						12		12		
42 Waldecken		54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54	54	54	54	54		35										12	11	12	12				12		12		
43 Waldstreifen		54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54		35										12	11						12		12		
44 Aufgelöste Baumbestände		54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54		35				12	12	12	12	13		12	11	12	12				12		12	12	12
45 Gebüschwaldbestände																						53			53														13							13		13		
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		34	34	34	34	34	34	34	34	34			11	12	12		34	34	34	34	34	34	34
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		34	34	34	34	34	34	34	13	34			11	12	12		34	34	34	34	34	34	34
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														13	13		61	61	61	61	61	61	61
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			61	61										12	12		61	61	61	61	61	61	61
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			36	36			36	36	36				11	13	13		36	36	36	36	36	36	36
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																	41	41	41				41
62 Gletscher, Firn																																														61			
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						42	42	42	42	42				12	13		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					21	42	42	42	42	42							42	42	42	42			

Kyoto Combination Categories

11	Afforestations
12	Managed forest
13	Unproductive forest
21	Cropland
31	Permanent grassland
32	Shrub vegetation
33	Vineyards, Low-stem Orchards, Tree nurseries
34	Copse
35	Orchards
36	Stony grassland
37	Unproductive grassland
41	Surface waters
42	Unproductive wetland
51	Buildings and construction
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 (e.g. when a specific area increased by three hectares between 1996 and 2002, it was assumed that the annual increase was 0.5 hectares).

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, assuming that the average trend observed between 1984 and 2002 would go on.

Example (Figure 22): A certain area has been assigned to the land-use category “Cropland” (CC 21) in 1984. A partial land-use change to “Shrubs in Settlements” (CC 53) has been discovered in 1996. And another partial change to “Buildings and construction” (CC 51) was discovered in 2002.

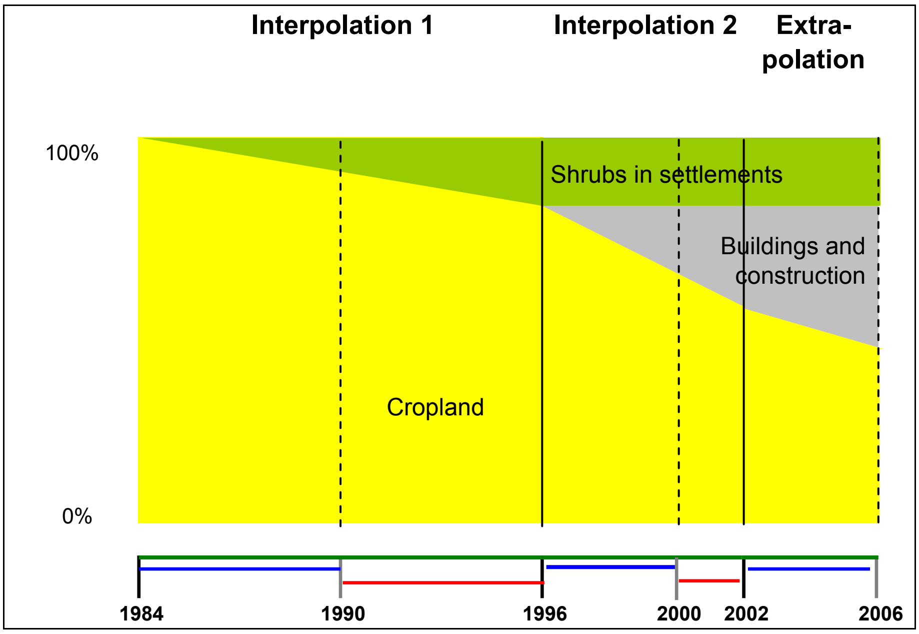

Figure 22 Hypothetical linear development of land-use changes between AREA1 and AREA2 and 2002 data considering as example a hectare changing from “cropland” to “shrubs in settlements” and then from "shrubs in settlements" to “buildings and constructions".

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. The same procedure can be applied for two survey dates between 1996 and 2002 (see Figure 22: example ‘status 2000’). Extrapolation to 2006 is done by taking the average trend of the whole time period 1984 to 2002. The ‘status’ for each individual year in the period 1990-2006 for the whole territory of Liechtenstein results from the summation of the fractions of all hectares per combination category CC (considering the spatial strata where appropriate) (see Table 87).

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 (2006d) and classified in belts <600 m a.s.l. (metres 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.

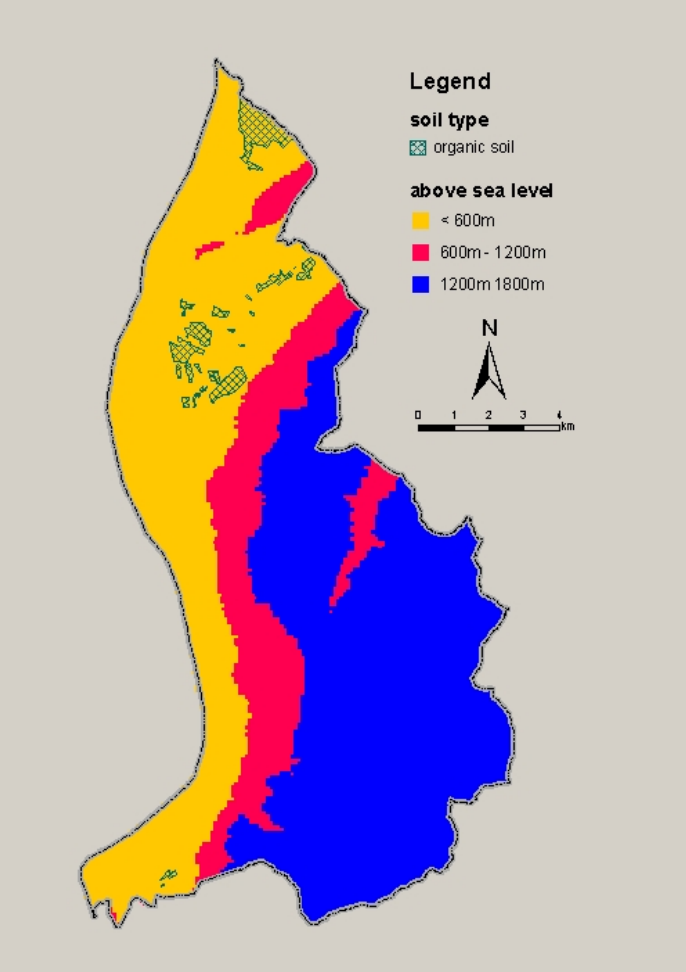

Figure 23 Map of Liechtenstein showing the altitude classes and soil types. Reference: OEP 2006d.

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

Table 86 shows the overall trends of land-use changes between 1990 and 2006 for the source and sink categories according to the CRF.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Change 1990-2006 (ha)	Change 1990-2006 (%)
Forest land	6036	6050	6063	6076	6089	6102	6113	6111	6109	6107	6104	6102	6100	6108	6116	6124	6132	95.088	1.6%
Cropland	1953	1948	1943	1938	1933	1928	1923	1919	1915	1912	1908	1904	1900	1895	1891	1886	1882	-70.737	-3.6%
Grassland	5312	5287	5262	5237	5212	5187	5162	5146	5130	5114	5097	5081	5063	5041	5019	4997	4975	-336.74	-6.3%
Wetlands	376	376	376	376	376	376	376	376	377	377	377	378	378	378	378	378	378	2.45	0.7%
Settlements	1366	1384	1401	1418	1435	1453	1470	1489	1508	1527	1547	1566	1585	1603	1621	1639	1657	290.071	21.2%
Other Land	1008	1008	1007	1007	1007	1006	1006	1009	1012	1015	1018	1021	1024	1025	1026	1026	1027	19.101	1.9%
Sum	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	0	0.0%

Table 86 Statistics of land use for the whole period 1990-2006 (in ha) and change (absolute and relative) between 1990 and 2006. The table displays the data for the land-use categories remaining the same land-use category (excluding land converted to a specific category).

The most significant land-use changes in absolute terms can be observed in the categories grassland (decrease by more than 6%) and settlements (increase by more than 21%).

Table 87 shows the same trends at the level of the more disaggregated land-use categories. 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 (combination category 11) decreases in all altitude classes between 44 and 89%, while the area of managed forests increases by 3.5% 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	2005	2006	Change 1990-2006 (ha)	Change 1990-2006 (%)
11	< 600	n.s.	8.5	9.1	9.7	10.2	10.8	11.4	12.0	10.7	9.3	8.0	6.7	5.3	4.0	3.9	3.9	3.8	3.8	-4.7	-55.5%
	600-1200	n.s.	7.0	6.0	5.0	4.0	3.0	2.0	1.0	1.3	1.7	2.0	2.3	2.7	3.0	2.4	1.9	1.3	0.8	-6.2	-88.9%
	> 1200	n.s.	29.0	29.5	30.0	30.5	31.0	31.5	32.0	29.7	27.3	25.0	22.7	20.3	18.0	17.6	17.1	16.7	16.2	-12.8	-44.0%
12	< 600	n.s.	993.5	993.9	994.3	994.7	995.2	995.6	996.0	996.0	996.0	996.0	996.0	996.0	996.0	996.3	996.6	996.8	997.1	3.6	0.4%
	600-1200	n.s.	1954.5	1955.4	1956.3	1957.3	1958.2	1959.1	1960.0	1959.7	1959.3	1959.0	1958.7	1958.3	1958.0	1958.5	1959.0	1959.5	1960.0	5.5	0.3%
	> 1200	n.s.	2158.0	2164.7	2171.3	2178.0	2184.7	2191.3	2197.0	2199.5	2202.0	2204.5	2207.0	2209.5	2212.0	2217.2	2222.4	2227.7	2232.9	74.9	3.5%
13	< 600	n.s.	0.5	0.6	0.7	0.7	0.8	0.9	1.0	0.8	0.7	0.5	0.3	0.2	0.0	0.0	0.0	0.0	0.0	-0.5	
	600-1200	n.s.	9.0	9.2	9.3	9.5	9.7	9.8	9.0	8.5	8.0	7.5	7.0	6.5	6.0	5.9	5.8	5.7	5.6	-3.4	-38.2%
	> 1200	n.s.	876.5	881.3	886.0	890.8	895.5	900.3	905.0	904.7	904.3	904.0	903.7	903.3	903.0	906.1	909.1	912.2	915.2	38.7	4.4%
21	n.s.	mineral	1828.5	1823.8	1819.0	1814.3	1809.5	1804.8	1800.0	1795.5	1791.0	1786.5	1782.0	1777.5	1773.0	1768.3	1763.7	1759.0	1754.3	-74.2	-4.1%
	n.s.	organic	124.0	123.8	123.7	123.5	123.3	123.2	123.0	123.7	124.3	125.0	125.7	126.3	127.0	127.1	127.2	127.3	127.4	3.4	2.8%
31	< 600	mineral	1132.0	1124.5	1117.0	1109.5	1102.0	1094.5	1087.0	1082.3	1077.7	1073.0	1068.3	1063.7	1059.0	1052.4	1045.9	1039.3	1032.8	-99.2	-8.8%
	< 600	organic	63.0	62.7	62.3	62.0	61.7	61.3	61.0	60.2	59.3	58.5	57.7	56.8	56.0	55.5	55.0	54.5	54.0	-9.0	-14.3%
	600-1200	mineral	364.5	362.6	360.7	358.8	356.9	354.9	353.0	352.2	351.3	350.5	349.7	348.8	348.0	346.4	344.9	343.3	341.8	-22.7	-6.2%
	600-1200	organic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
	> 1200	mineral	1666.5	1663.1	1659.7	1656.3	1652.8	1649.4	1646.0	1647.0	1648.0	1649.0	1650.0	1651.0	1650.0	1647.9	1645.9	1643.8	1641.8	-24.7	-1.5%
	> 1200	organic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
32	< 600	n.s.	20.0	20.2	20.3	20.5	20.7	20.8	21.0	20.7	20.3	20.0	19.7	19.3	19.0	19.0	19.0	19.0	19.0	-1.0	-5.0%
	600-1200	n.s.	9.5	9.3	9.0	8.8	8.5	8.3	8.0	7.7	7.3	7.0	6.7	6.3	6.0	5.7	5.4	5.2	4.9	-4.6	-48.5%
	> 1200	n.s.	563.0	556.0	549.0	542.0	535.0	528.0	521.0	518.7	516.3	514.0	511.7	509.3	507.0	501.6	496.1	490.7	485.2	-77.8	-13.8%
33	n.s.	mineral	30.5	30.7	31.0	31.2	31.5	31.7	32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.2	32.3	32.5	32.7	2.2	7.1%
	n.s.	organic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
34	< 600	n.s.	382.5	380.9	379.3	377.7	376.2	374.6	373.0	366.3	359.7	353.0	346.3	339.7	333.0	329.7	326.4	323.2	319.9	-62.6	-16.4%
	600-1200	n.s.	79.5	79.1	78.7	78.3	77.8	77.4	77.0	75.8	74.7	73.5	72.3	71.2	70.0	69.3	68.7	68.0	67.3	-12.2	-15.3%
	> 1200	n.s.	255.0	255.2	255.3	255.5	255.7	255.8	256.0	255.5	255.0	254.5	254.0	253.5	253.0	252.9	252.9	252.8	252.8	-2.2	-0.9%
35	n.s.	mineral	0.5	0.4	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	
	n.s.	organic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%
36	n.s.	n.s.	346.5	345.4	344.3	343.3	342.2	341.1	340.0	341.8	343.7	345.5	347.3	349.2	351.0	350.9	350.8	350.7	350.6	4.1	1.2%
37	n.s.	n.s.	398.5	396.6	394.7	392.8	390.9	388.9	387.0	385.7	384.3	383.0	381.7	380.3	379.0	377.3	375.6	373.8	372.1	-26.4	-6.6%
41	n.s.	n.s.	216.0	215.8	215.7	215.5	215.3	215.2	215.0	214.7	214.3	214.0	213.7	213.3	213.0	212.8	212.6	212.3	212.1	-3.9	-1.8%
42	n.s.	n.s.	160.0	160.2	160.3	160.5	160.7	160.8	161.0	161.7	162.3	163.0	163.7	164.3	165.0	165.3	165.7	166.0	166.3	6.3	4.0%
51	n.s.	n.s.	903.5	916.6	929.7	942.7	955.8	968.9	982.0	999.0	1016.0	1033.0	1050.0	1067.0	1084.0	1098.4	1112.8	1127.2	1141.6	238.1	26.3%
52	n.s.	n.s.	304.5	306.4	308.3	310.2	312.2	314.1	316.0	320.3	324.7	329.0	333.3	337.6	342.0	344.7	347.4	350.2	352.9	48.4	15.9%
53	n.s.	n.s.	15.0	14.3	13.7	13.0	12.3	11.7	11.0	11.5	12.0	12.5	13.0	13.5	14.0	13.7	13.4	13.2	12.9	-2.1	-14.1%
54	n.s.	n.s.	143.5	146.4	149.3	152.2	155.2	158.1	161.0	158.3	155.7	153.0	150.3	147.7	145.0	146.1	147.1	148.2	149.2	5.7	4.0%
61	n.s.	n.s.	1008.0	1007.7	1007.3	1007.0	1006.7	1006.3	1006.0	1009.0	1012.0	1015.0	1018.0	1021.0	1024.0	1024.8	1025.6	1026.3	1027.1	19.1	1.9%
Sum			16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	16050	0.0	0.0%

Table 87 Statistics of land use (CC) for the whole period 1990-2006 (in ha) and change (absolute and relative) between 1990 and 2006. 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 combination category (CC). Table 88 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 88, one for each spatial stratum (see section 7.2.3.).

	Combination category code	To																		
		11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Decrease
From	11		3.1																	3.1
	12			0.7		0.1	0.2		0.2		0.2	0.1	0.2	0.1	1.3	0.2	0.3	0.3	0.2	4.1
	13	0.5	1.4			0.4	0.1												0.2	2.6
	21					3.2		0.2	0.5						3.3	0.9	0.1	0.2		8.2
	31	0.9	0.2	1.8	3.1		1.9	0.4	3.7		0.1			0.4	5.7	3.6		0.3	0.4	22.5
	32	0.2	4.1	4.7		1.5			1.3			0.1				0.1				11.9
	33				0.2	0.3									0.1					0.5
	34	0.2	2.2	0.1	0.1	2.8	0.2				0.1				1.6	0.8		0.3		8.5
	35								0.1											0.1
	36	0.3	0.1	0.1		0.3	0.5	0.1	0.1			0.3							0.3	2.1
	37	0.2	0.2	0.2			1.2		0.6		0.1				0.1					2.4
	41						0.1								0.1				0.5	0.7
	42	0.2	0.3																	0.5
	51	0.6				0.4	0.2		0.2					0.1		0.8	0.1			2.2
	52					0.1									2.5		0.2	2.5		5.2
	53	0.1	0.2						0.1						0.3	0.1		0.5	0.1	1.3
	54														0.4	0.8				1.2
	61		0.2			0.2	0.5	0.1			0.6	0.1	0.3	0.1						2.1
	Increase	3.2	12.0	7.5	3.3	9.3	4.8	0.7	6.7	0.0	1.0	0.5	0.5	0.7	15.3	7.2	0.7	4.1	1.7	79.2

Table 88 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 89 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 1990-2006 (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 89 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 1990-2006 (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. Where no stratification according to soil type is indicated (e.g. in CC 12), all soils including organic soils are allocated to mineral soils.

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 from Switzerland. For wetlands and other land, expert estimates or default values are available. The deduction of the individual values is explained in the following chapters.

7.3. Source Category 5A – Forest Land

7.3.1. Source Category Description

Key source 5A1
CO_2 emissions and removals from 5A1 Forest Land remaining Forest land are a key source by level and trend. Source category 5A2 “Land converted to Forest Land” is not a key source.

38% of the total area of Liechtenstein is forest land. The annual net CO_2 removals range from 18.74 Gg CO_2 (1990) and 19.78 Gg CO_2 (1997). The sub-category 5A1 “Forest Land remaining Forest Land” is by far the most relevant sub-category accounting for 99.5% of net CO_2 removals from forest land.

All of the forest land is temperate forest. The definition of forest land is originally based on the Swiss definition and was revised after the In-Country Reviews carried out in Switzerland and Liechtenstein 2007. Forest land is now defined as follows (OEP 2007b):

- Minimum area of land: 0.0625 hectares with a minimum width of 25m)
- Minimum crown cover: 20%
- Minimum height of the dominant trees: 3m (dominant trees must have the potential to reach 3 m at maturity in situ)

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 84; FOEN 2006; SFSO 2006a).

7.3.2. Methodological Issues

a) Forest Land remaining Forest Land (5A1)

The activity data collection follows the methods described in chapter 7.2.2. Carbon stocks and carbon stock changes are taken from Switzerland. Details are described in the following paragraphs.

a1. 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 90). 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 90 Characteristics of the Swiss National Forest Inventories I, II and III.

a2. 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 and Schmid 2007). 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 91) 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 91 Ratio of coniferous and deciduous species (source: NFI II; Brassel and Brändli 1999).

a3. Biomass Expansion Factors (BEF)

The Swiss Biomass Expansion Factors were applied in Liechtenstein (FOEN 2007).

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 92 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 92 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.

a4. 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 93 shows the applied densities.

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

Table 93 Wood densities for coniferous and deciduous trees (Vorreiter 1949).

a5. Carbon Content

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

a6. 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 2007).

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 94 and Table 95).

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 94 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 95 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 96).

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

Table 96 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 96.

[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 2006.

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 97 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 98 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 2006. These values are displayed in Table 99.

Growing stock of managed forests (CC 12) 1990-2006																			
	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**	**2005**	**2006**		
< 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	178.44	179.88	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	168.22	169.29	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	123.14	123.61	2.52	-2.06

Table 99 Growing stock of managed forests (CC12) 1990-2006 in t C ha^{-1}.

a7. Growing Stock in Unproductive Forests (CC 13)

The unproductive forest in Liechtenstein mainly consists of brush forest and inaccessible forest. Although unproductive, this type of forest ist still categorized as managed 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 100 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 100 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.

a8. 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 101 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 102).

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

Table 102 Dead wood in managed forests (CC12) per altitude class in t C ha-1.

a9. 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 2007):

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 103 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^3ha^{-1}]	**Growth** [m^3 ha^{-1} $year^{-1}$]	**Growing stock** [m^3ha^{-1}]	**Growth** [m^3 ha^{-1} $year^{-1}$]	**Growing stock** [m^3ha^{-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 103 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 104, abbreviations and units are explained. Table 105 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 105*	*m^3 ha^{-1}*
Average growth	*Average growth per ha and year*	*Table 105*	*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 105*	*t C ha^{-1}*
Growth of living biomass	*Growth of carbon in t C per ha and year*	*See Table 105*	*t C ha^{-1} $year^{-1}$*

Table 104 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 105 Carbon stock in living biomass and growth of living biomass in afforestations (CC11) specified for altitude zone.

a10. 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 76 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 (2007) 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 106.

	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 106 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 2006 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.

a11. 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).

a12. 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).

b) Land converted to Forest Land (5A2)

Land conversion to forest land is of minor importance in terms of net CO_2 removals. In 2006 only 0.5% of net CO_2 removals from forest land result from a conversion to forest land. Between 1990 and 2006 approximately 242 ha or 1.5% of the total surface was converted to forest land. According to the land use statistic the areas switching to forest land are mainly areas that used to be populated with grassland or woody biomass (see Table 88, combined category 32) not fulfilling the definition of minimal forest density and area.

The carbon fluxes in case of land-use change comprising forest land are specified as follows:

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.

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 2007), 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

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 2). No additional source-specific QA/QC activities have been carried out.

7.3.5. Source-Specific Recalculations

A recalculation for the whole time series has been carried out due to the following reasons:

- New forest definition (Groups of trees on meadows in higher altitudes now allocated to the combination category “Unproductive forest”)
- More precise interpolation of areas between the years 1990 and 1996, between 1996 and 2002 and more precise extrapolation after 2002: In the former submission the minimal area allocated to one year was one hectare. Now no minimum size is defined.

7.3.6. Source-Specific Planned Improvements

As soon as uncertainty estimations for activity data and carbon factors are available from Switzerland, it will be assessed if Liechtenstein’s uncertainty analysis should be extended accordingly.

7.4. Source Category 5B – Cropland

7.4.1. Source Category Description

Key source 5B1
Emissions from 5B1 Cropland remaining Cropland are a key source by level. Source category 5B2 “Land converted to Cropland” is not a key source.

Approximately 12% of Liechtenstein's total surface is cropland. Land use changes to cropland or from cropland are not very common. The most important changes are from grassland to cropland on the one hand and from cropland to grassland and settlements on the other hand.

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) Cropland remaining Cropland (5B1)

The activity data collection follows the methods described in chapter 7.2.2. Carbon stocks and carbon stock changes are taken from Switzerland. Details are described in the following paragraphs.

a1. Carbon in Living Biomass

When cropland remains cropland, the carbon stocks of annual crops are not considered since they are harvested every year. Thus, there is no long term carbon storage.

a2. 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 Leifeld et al. (2003) and Leifeld et al. (2005).

a3. 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.

a4. Carbon Emissions from Agricultural Lime Application

Emissions from lime application are not occurring in Liechtenstein.

b) Land converted to Cropland (5B2)

The activity data collection follows the methods described in chapter 7.2.2. Carbon factors are displayed in the following paragraphs.

b1. Carbon in Living Biomass

When a conversion of a land to cropland occurs, carbon stocks of annual crops are taken into account. This is in line with the Good Practice Guidance LULUCF (IPCC 2003, p. 3.88, table 3.3.8).

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 2007).

b2. Carbon in Soils

As mentioned under the sub-category “Cropland remaining cropland” 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.

b3. 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.

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

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 2). No additional source-specific QA/QC activities have been carried out.

7.4.5. Source-Specific Recalculations

The area of organic soils was revised due to an inconsistency between the areas reported in the agriculture and the LULUCF sector. Therefore, a recalculation of the whole time-series has been carried out.

7.4.6. Source-Specific Planned Improvements

As soon as uncertainty estimations for activity data and carbon factors are available from Switzerland, it will be assessed if Liechtenstein's uncertainty analysis should be extended accordingly.

7.5. Source Category 5C – Grassland

7.5.1. Source Category Description

Key source 5C1 and 5C2
Emissions from 5C1 Grassland remaining Grassland are a key source by level and trend. Source category 5C2 "Land converted to Grassland" is a key source by trend.

31% of Liechteinstein's total surface is grassland, whereof 85.5% is managed and 14.5% is unmanaged grassland. Conversion to grassland occurs mainly from cropland to grassland and from forest to grassland. These changes are however less important than the reverse conversion from grassland to forest and from grassland to cropland. The total area of grassland decreased by 6.3% in 2006 compared to 1990.

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) Grassland remaining Grassland (5C1)

The activity data collection follows the methods described in chapter 7.2.2. Carbon stocks are taken from Switzerland. Details are described in the following paragraphs.

a1. 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 2007). 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. in press). The values for the different altitude zones including roots are displayed in Table 107.

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

Table 107 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 2007). 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. a7. 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 (CI) for CC 33 were implied (FOEN 2007). CI of vineyards is 3.61 t C ha^{-1}, CI 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 2007). 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)

Stony grassland is categorized as unmanaged grassland. Swiss values for carbon stock of stony grassland were implied (FOEN 2007). The carbon content is assumed to be 4.06 t C ha^{-1}.

Unproductive Grassland (CC 37)

Unproductive grassland is categorized as unmanaged grassland. The category 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. These areas are not used as grassland and are therefore categorised as unmanaged land.

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 2007).

a2. 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 2007). They are based on Leifeld et al. (2003) and Leifeld et al. (2005).

The mean carbon stock values for mineral soils are displayed in Table 108.

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 108 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 108, 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 2007). 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 2007).

a3. 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.

b) Land converted to Grassland (5C2)

The activity data collection follows the methods described in chapter 7.2.2.

The carbon stocks in living biomass and in soil are reported in detail under "Grassland remaining grassland" and are summarized as follows:

Combination category	**Carbon in living biomass**	**Carbon in soils**	
		Mineral soils	**Organic soils**
Permanent grassland (CC 31)	4.45-7.45 t C ha $^{-1}$	62.02-75.18 t C ha $^{-1}$	240 t C ha $^{-1}$
Shrub vegetation (CC 32)	11.6 t C ha $^{-1}$	68.23 t C ha $^{-1}$	
Vineyards, low-stem Orchards and Tree Nurseries (CC 33)	3.74 t C ha $^{-1}$	53.4 t C ha $^{-1}$	240 t C ha $^{-1}$
Copse (CC 34)	11.6 t C ha $^{-1}$	68.23 t C ha $^{-1}$	
Orchards (CC 35)	24.63 t C ha $^{-1}$	64.76 t C ha $^{-1}$	240 t C ha $^{-1}$
Stony Grassland (CC 36)	4.06 t C ha $^{-1}$	26.31 t C ha $^{-1}$	
Unproductive Grassland (CC 37)	6.05 t C ha $^{-1}$	68.23 t C ha $^{-1}$	

Table 109 Summary table of carbon stocks in grassland (CC 31 - 37).

By mistake, also land- use changes between two combination categories of unmanaged land (e.g. stony and unproductive grassland) were taken into account (refer to chapter 7.5.6). Land-use changes between two categories of unmanaged land are not human induced and should therefore not be considered.

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

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 2). No additional source-specific QA/QC activities have been carried out.

7.5.5. Source-Specific Recalculations

The area of organic soils was revised due to an inconsistency between the areas reported in the agriculture and the LULUCF sector. Therefore, a recalculation of the whole time-series has been carried out.

7.5.6. Source-Specific Planned Improvements

By mistake land-use changes from unmanaged grassland to another category of unmanaged land (and vice versa) are also taken into account. This will be corrected in the next submission by including a weighting factor zero when changes between two categories of unmanaged land occur (refer to chapter 7.2.1). The mistake occurs in case of a land-use change between the following combination categories: Stony grassland (CC 36), unproductive grassland (CC 37), surface waters (CC 41), unproductive wetland (CC 42) and other land (CC 61).

The correction would lead to the following differences in terms of emissions:

Between 1990 and 1996: +0.025 Gg CO_2 per year (compared to the current calculation)

Between 1997 and 2002: -0.116 Gg CO_2 per year (compared to the current calculation)

Between 2003 and 2006: +0.107 Gg CO_2 per year (compared to the current calculation).

As soon as uncertainty estimations for activity data and carbon factors are available from Switzerland, it will be assessed if Liechtenstein's uncertainty analysis should be extended accordingly.

7.6. Source Category 5D – Wetlands

7.6.1. Source Category Description

2.4% of the total surface of Liechtenstein are wetlands. Land-use changes from and to wetlands are not very common and occur mainly from forest land to wetlands (e.g. in case of rivers with flood water). Wetlands consist of surface waters (CC 41) and unproductive wet areas such as shore vegetation and fens (CC 42) (see Table 84). Both types of wetland are categorized as unmanaged.

7.6.2. Methodological Issues

Source category 5D1 "Wetlands remaining Wetlands" and source category 5D2 "Land converted to Wetlands" are not key sources.

a) Wetlands remaining Wetlands (5D1)

The activity data collection follows the methods described in chapter 7.2.2. Carbon stocks are taken from Switzerland. Details are described in the following paragraphs.

a1. Carbon in Living Biomass

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 2007). 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 leads to an average carbon stock of 7.96 t C ha^{-1}.

a2. Carbon in Soils

Land cover in CC 42 includes peatlands and reed. Swiss soil carbon stock values are implied (FOEN 2007). 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}.

a3. N2O emissions from drainage of soils

Drainage of intact wetlands is very unlikely. Therefore, no N_2O emissions are reported in CRF Table 5 (II).

b) Land converted to Wetlands (5D2)

The activity data collection follows the methods described in chapter 7.2.2. In the case of land-use change, the net changes in biomass and soil of both surface waters (CC 41) and unproductive wetland (CC 42) are calculated as described in chapter 7.2.1.

By mistake, also land-use changes between two combination categories of unmanaged land (e.g. between surface waters and unproductive wetland) were taken into account (refer to chapter 7.5.6). Land-use changes between two categories of unmanaged land are not human induced and should therefore not be considered.

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 2007), 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

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 2). No additional source-specific QA/QC activities have been carried out.

7.6.5. Source-Specific Recalculations

No recalculation has been carried out.

7.6.6. Source-Specific Planned Improvements

The mistake of considering changes between two unmanaged land categories will be corrected in the next submission. For details refer to chapter 7.5.6.

As soon as uncertainty estimations for activity data and carbon factors are available from Switzerland, it will be assessed if Liechtenstein's uncertainty analysis should be extended accordingly.

7.7. Source Category 5E – Settlements

7.7.1. Source Category Description

Key source 5E2
Source category 5E1 "Settlements remaining Settlements" is not a key source. Emissions from 5E2 "Land converted to Settlements" is a key source by level.

10.3% of Liechtenstein's total surface are settlements. Between 1990 and 2006 290 hectares were converted to settlements, which is an increase of more than 21%. 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 84.

7.7.2. Methodological Issues

a) Settlements remaining Settlements (5E1)

The activity data collection follows the methods described in chapter 7.2.2. Carbon stocks are taken from Switzerland. Details are described in the following paragraphs.

a1. Carbon in Living Biomass

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 2007). 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}).

a2. Carbon in Soils

Swiss values for soil carbon in settlements are implied (FOEN 2007).

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).

b) Land converted to Settlements (5E2)

The activity data collection follows the methods described in chapter 7.2.2. Carbon factors are reported a) "Settlements remaining Settlements".

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 2007), 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

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 2). No additional source-specific QA/QC activities have been carried out.

7.7.5. Source-Specific Recalculations

No source-specific recalculation has been carried out.

7.7.6. Source-Specific Planned Improvements

As soon as uncertainty estimations for activity data and carbon factors are available from Switzerland, it will be assessed if Liechtenstein's uncertainty analysis should be extended accordingly.

7.8. Source Category 5F – Other Land

7.8.1. Source Category Description

Source category 5F1 "Other Land remaining Other Land" and source category 5F2 "Land converted to Other Land" are not key sources.

As shown in Table 84, 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 2007) the uncertainty of activity data and carbon stock data is assessed as low.

7.8.4. Source-Specific QA/QC and Verification

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 2). No additional source-specific QA/QC activities have been carried out.

7.8.5. Source-Specific Recalculations

No source-specific recalculation has been carried out.

7.8.6. Source-Specific Planned Improvements

As soon as uncertainty estimations for activity data and carbon factors are available from Switzerland, it will be assessed if Liechtenstein's uncertainty analysis should be extended accordingly.

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”.

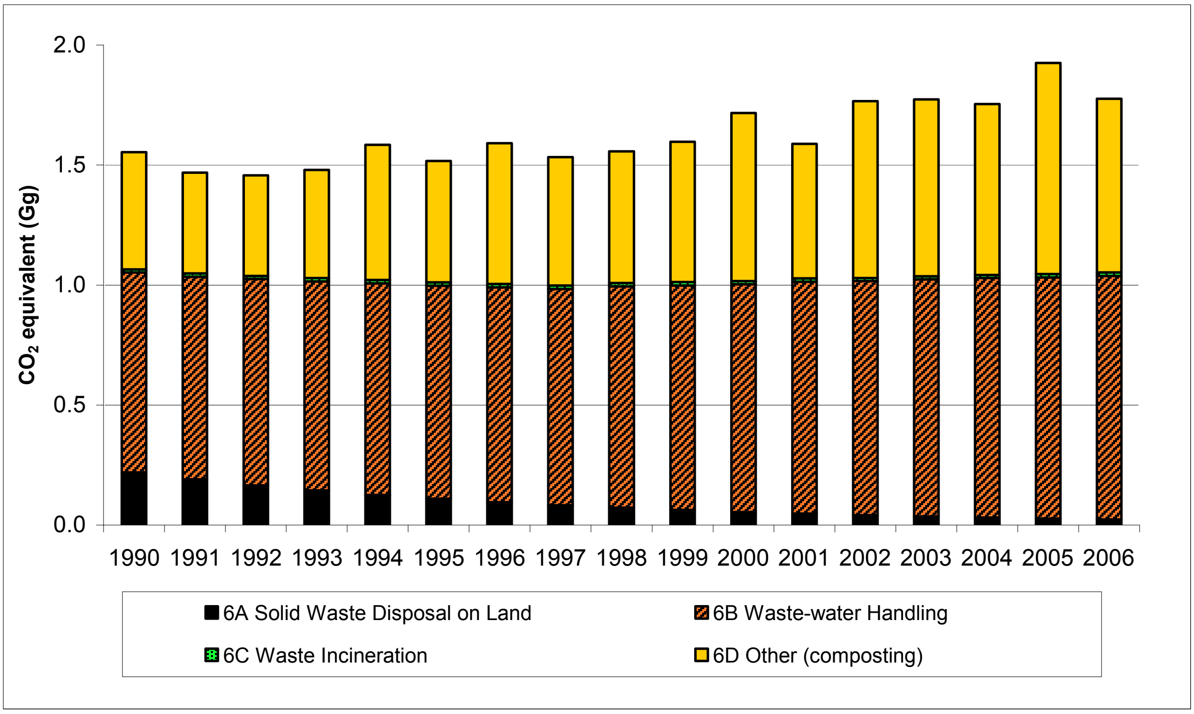

Figure 24 Liechtenstein’s greenhouse gas emissions in the waste sector 1990–2006.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (Gg)									
CO_2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CH_4	0.65	0.56	0.54	0.54	0.62	0.55	0.61	0.55	0.56	0.58
N_2O	0.90	0.90	0.91	0.93	0.96	0.95	0.97	0.97	0.99	1.01
Sum	**1.55**	**1.47**	**1.46**	**1.48**	**1.58**	**1.52**	**1.59**	**1.53**	**1.56**	**1.60**

Gas	2000	2001	2002	2003	2004	2005	2006	***1990→2006***
	CO2 equivalent (Gg)							*%*
CO_2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	*3.3*
CH_4	0.67	0.54	0.68	0.68	0.65	0.79	0.66	*1.4*
N_2O	1.04	1.04	1.08	1.09	1.09	1.13	1.11	*23.7*
Sum	**1.72**	**1.59**	**1.77**	**1.77**	**1.75**	**1.93**	**1.78**	*14.3*

Table 110 GHG emissions of source category 6 Waste by gas in CO_2 equivalent (Gg), 1990–2006.

In the waste sector a total of 1.78 Gg CO_2 equivalents of greenhouse gases were emitted in 2006. 1.3% of the total emissions stem from 6A “Solid Waste Disposal on Land”, 57.1% from 6B “Wastewater Treatment”, 0.8% from 6C “Waste Incineration” and 40.8% from the sub-category 6D “Others” (composting). In response to the recommendations made by the UNFCCC Expert Review Team during the In-Country Review in June 2007, CH_4 emissions from 6A “Solid Waste Disposal on Land” have been estimated for the subsequent revised Initial Report submission for the first time, though the last landfill in Liechtenstein has been closed in 1974.

The total greenhouse gas emissions show an increase from 1990 until 2005 by +14.3%. This is mostly due to the increase in composting activities in the country (+48%), 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.

Liechtenstein has historic unmanaged landfills. 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 in the country stopped land-filling.

The landfills in Liechtenstein were unmanaged (in the definition of IPCC GPG), because municipal solid waste (MSW) was disposed off on the landfills by users directly (only on 3 of over 30 landfill sites a temporary control by landfill staff was executed). No mechanical compacting or levelling of waste has been carried out. No collection or treatment of leachate took place which caused environmental pollution[19]. Landfills are all less than 5 m deep[20].

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[19] Source: E-mail Helmut Kindle/OEP of June 24, 2007.

No landfill gas was collected for flaring or energy recovery.

There are no *managed* waste disposal sites reported in Liechtenstein. Therefore emissions from the source category 6A1 “Managed Waste Disposal Sites” are not occurring.

6A1	Managed Waste Disposal on Land	Not occurring in Lichtenstein	-
6A2	Unmanaged Waste Disposal Sites	Emissions from handling of solid waste on unmanaged landfill sites	EF: OEP, FOEN 2007 AD: OEP
6A3	Others	Not occurring in Lichtenstein	-

Table 111 Specification of source category 6A “Solid Waste Disposal on Land”.

8.2.2. Methodological Issues

Solid Waste Disposal on Unmanaged Waste Disposal Sites (6A2)

Methodology

A Tier 2 approach is chosen. The rate of CH_4 generation over time is based on the First Order Decay model (FOD) according to IPCC (IPCC 1997a-c). The following equation is applied to calculate the CH_4 generation in the year t:

$$CH_4 \text{ generated in the year t [Gg/year]} = \sum_x [A \cdot k \cdot M(x) \cdot L_0(x) \cdot e^{-k(t-x)}] \cdot (1-OX)$$

where

t = current year
x = the year of waste input, $x \leq t$
A = (1-k)/k, norm factor (fraction)
k = methane generation rate [1/yr]
M(x) = the amount of waste disposed in year x
$L_0(x)$ = methane generation potential ($MCF(x) \cdot DOC(x) \cdot DOC_F \cdot F \cdot 16/12$) [Gg CH_4 / Gg waste]
MCF(x) = methane correction factor (fraction)
DOC(x) = degradable organic carbon [Gg C/ Gg waste]
DOC_F = fraction of DOC, that is converted to landfill gas (fraction)
F = fraction of CH_4 in landfill gas (fraction)
16/12 = factor to convert C to CH_4.
OX = oxidation factor (fraction)

The following general assumptions are made:

MCF(x) = 0.4 = constant for all years (default value according to IPCC for unmanaged solid waste disposal sites of less than 5 m depth)

OX = 0 (default value according to IPCC 1997a-c)

DOC_F = 0.6 (default value according to IPCC 2000)

F = 0.5 (default value according to IPCC 1997a-c)

The degradable organic carbon (DOC) is calculated based on the default values from IPCC 1997a-c and based on country specific data on waste composition for MSW in Switzerland

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[20] Source: Email Helmut Kindle/OEP of June 12, 2007, based on research in internal files on old landfills of OEP.

for 1993 (source EMIS). It is assumed that the Swiss MSW composition is roughly representative for the situation in Liechtenstein:

	SA 1993	DOC IPCC 1997c
Paper and Textile and Cardboard %	28%	0.4
Garden waste and non-food organic putrescible %	5%	0.17
Food waste %	22%	0.15
Wood and Straw %	0%	0.3
Other materials (glass, metals, plastic, minerals, etc. with no contribution to methane generation) %	45%	0
Resulting DOC		**0.154**

Table 112 Calculation of DOC for Liechtenstein (Source DOC: IPCC, source waste fractions: EMIS)

For the calculation of CH_4 generation from unmanaged landfilling of MSW the k factor is based on FOEN 2007 (Table 145). The Swiss NIR assumes a half-life of 5 years, for which k = 0.139 y^{-1} results.

Emission Factors

For parameters in FOD-model see above.

Activity data

Activity data for unmanaged MSW Disposal on Land (6A2) have been estimated by OEF. The estimates are based on internal (unpublished) research done at OEF from 1985 - 1990 that analysed the development of waste quantities in the last century for the elaboration of a national waste strategy.

Based on this work, the following MSW quantities[21] are assumed to have been landfilled from 1930 until the closure of the last landfill in 1974:

Year	**MSW/cap**	**Inhabitants**	**MSW**
	[kg/a]	(average)	[t/a]
1930-39	150	10500	1575
1940-49	100	12300	1230
1950-59	200	15200	3040
1960-69	300	18500	5550
1970-75	MSW declines linearly to 0		

Table 113 Amount of MSW landfilled in Liechtenstein (Source: OEP)

Because the transition from landfilling in the country to exporting MSW to Switzerland for incineration took place gradually, it is assumed that the amount of MSW landfilled declines linearly after 1970 to zero tons in 1975.

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[21] Source: Email by Helmut Kindle/OEP of July 2, 2007.

Emissions

The following Table 10 provides the results of the emission calculation based on the FOD-modelling as well as the waste quantities that have been annually disposed off:

Year	Annual Deposition Tons/Year	Emissions t CH4	Emissions t CO2 eq
1930	1575	5.0	105.4
1931	1575	9.4	197.2
1932	1575	13.2	277.0
1933	1575	16.5	346.5
1934	1575	19.4	406.9
1935	1575	21.9	459.5
1936	1575	24.1	505.3
1937	1575	26.0	545.1
1938	1575	27.6	579.8
1939	1575	29.0	610.0
1940	1230	29.2	613.2
1941	1230	29.3	615.9
1942	1230	29.4	618.3
1943	1230	29.5	620.4
1944	1230	29.6	622.2
1945	1230	29.7	623.8
1946	1230	29.8	625.2
1947	1230	29.8	626.4
1948	1230	29.9	627.4
1949	1230	29.9	628.3
1950	3040	35.7	750.2
1951	3040	40.8	856.4
1952	3040	45.2	948.7
1953	3040	49.0	1029.1
1954	3040	52.3	1099.0
1955	3040	55.2	1159.8
1956	3040	57.8	1212.8
1957	3040	59.9	1258.9
1958	3040	61.9	1299.0
1959	3040	63.5	1333.9
1960	5550	73.0	1532.2
1961	5550	81.2	1704.9
1962	5550	88.3	1855.1
1963	5550	94.6	1985.8
1964	5550	100.0	2099.6
1965	5550	104.7	2198.6
1966	5550	108.8	2284.7
1967	5550	112.4	2359.7
1968	5550	115.5	2425.0
1969	5550	118.2	2481.7
1970	5550	120.5	2531.1
1971	4440	119.0	2499.8
1972	3330	114.2	2398.3
1973	2220	106.5	2235.7
1974	1110	96.2	2019.8
1975	0	83.7	1757.7
1976	0	72.8	1529.6
1977	0	63.4	1331.1
1978	0	55.2	1158.4
1979	0	48.0	1008.0
1980	0	41.8	877.2
1981	0	36.4	763.4
1982	0	31.6	664.3
1983	0	27.5	578.1
1984	0	24.0	503.1
1985	0	20.8	437.8
1986	0	18.1	381.0
1987	0	15.8	331.5
1988	0	13.7	288.5
1989	0	12.0	251.1
1990	**0**	**10.4**	**218.5**
1991	0	9.1	190.1
1992	0	7.9	165.5
1993	0	6.9	144.0
1994	0	6.0	125.3
1995	0	5.2	109.0
1996	0	4.5	94.9
1997	0	3.9	82.6
1998	0	3.4	71.9
1999	0	3.0	62.5
2000	0	2.6	54.4
2001	0	2.3	47.4
2002	0	2.0	41.2
2003	0	1.7	35.9
2004	**0**	1.5	31.2
2005	0	1.3	27.2
2006	0	1.1	23.6
2007	0	1.0	20.6
2008	0	0.9	17.9
2009	0	0.7	15.6
2010	0	0.6	13.6
2011	0	0.6	11.8
2012	0	0.5	10.3

Table 114 CH_4 emissions from MSW landfilled in Liechtenstein 1930 – 2012 (Result of FOD model calculation)

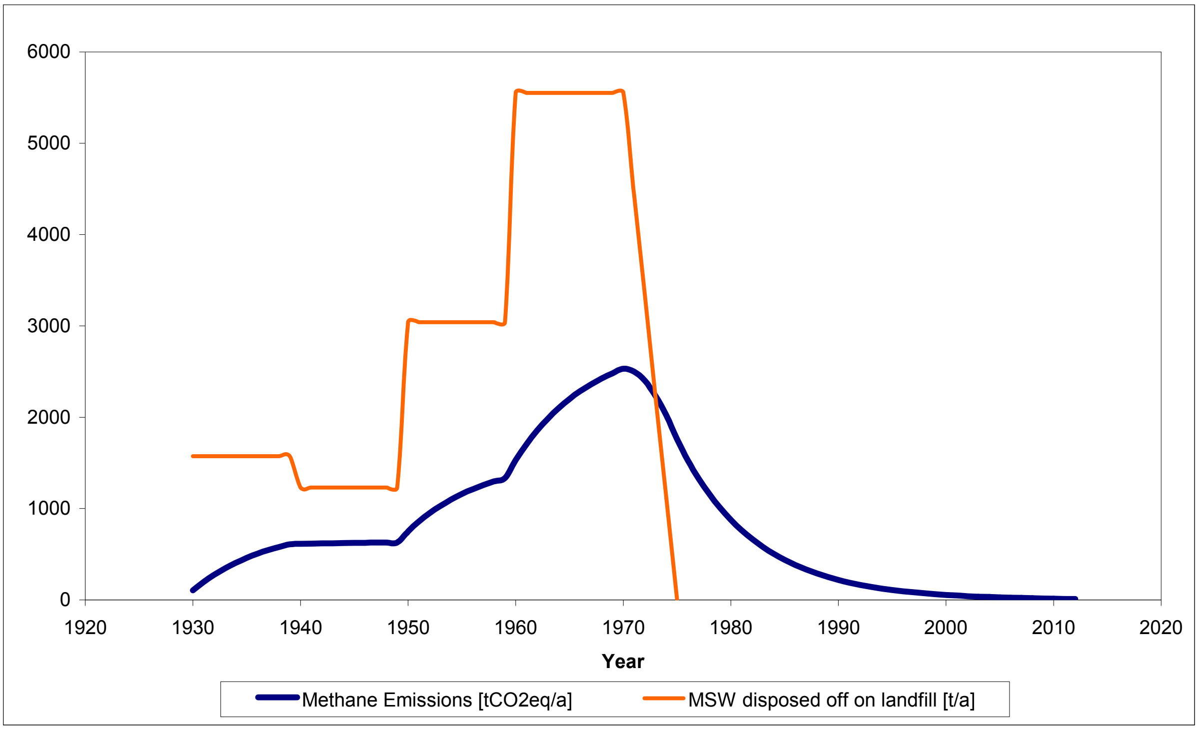

Figure 25 MMSW disposed off on landfill and corresponding emissions of CH_4 in Gg CO_2 equivalent.

8.2.3. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in low confidence in emission estimates.

Time series are consistent.

8.2.4. 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.

8.2.5. Source-Specific Recalculations

In response to the recommendations made by the UNFCCC Expert Review Team during the In-Country Review in June 2007, CH_4 emissions from 6A “Solid Waste Disposal on Land” have been estimated for the subsequent revised Initial Report submission for the first time.

8.2.6. 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 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: AVW 2006, OEP 2007d EF: FOEN 2007, IPCC 1997c
6B3	Others	Not occurring in Liechtenstein	-

Table 115 Specification of source category 6B “Wastewater Handling” (AD: activity data; EF: emission factors).

8.3.2. Methodological Issues

a) 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 2007). 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).

The emissions from the energy generation in the co-generation units itself are reported under 1A1 Energy Industries.

b) Emission Factors

For CH_4 it is assumed that 0.2% of the biogas (volume) is emitted as leakage (FOEN 2007). Based on actual meaurements in wastewater treatment plants in Switzerland, a methane content of the biogas by volume of 65% is assumed. With this 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 (taken from FEA 2004) and an N fraction of 0.16 kg N per kg protein (FracNPR; IPCC default), an emission factor of 90.5 g of N_2O per inhabitant results[22]. These assumptions are in line with the estimations in Switzerland, where similar conditions prevail (FOEN 2007).

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[22] Calculation: 36 * 0.16 * 0.01 * 44/28 = 0.0905 kg N_2O per inhabitant.

c) 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 in Bendern.

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**	**2005**	**2006**
Total gas production	m3	941'707	905'828	868'172	899'829	939'399	903'804	978'237
Balzers	m3	54'321	53'834	51'144	45'723	5'715	0	0
Vaduz	m3	0	0	0	0	0	0	0
Bendern	m3	887'386	851'994	817'028	854'106	933'684	903'804	978'237

Table 116 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 2007d).

Activity data for N_2O emissions from Domestic and Commercial Waste Water (6B2) are the number of inhabitants (total, i.e. connected and non-connected) in Liechtenstein (provided in Section 4.2.2).

8.3.3. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in low confidence in emission estimates.

Time series are consistent.

8.3.4. 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.

8.3.5. Source-Specific Recalculations

No recalculations have been carried out.

8.3.6. 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

a) 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 2007).

GHG emissions are calculated by multiplying the estimated amount of illegally incinerated waste by emission factors.

b) Emission Factors

Country specific emission factors for CO_2, and CH_4 are adopted from the Swiss NIR (FOEN 2007).

The country specific emission factor for N_2O is derived from the emission factor for biomass of 1.6 kg N_2O/TJ with a net calorific value of the waste of 12.7 GJ/t, taken from the Swiss NIR (FOEN 2007). 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** kg/t
Illegal waste incineration	0.508	6	0.02

Table 117 Emission Factors for 6C “Waste Incineration” in 2006. CO_2 emission factor relates to *fossil* carbon only. (Source FOEN 2007)

The main source of fossil CO_2 emissions is plastic. The assumption is taken, that the waste mix in illegal waste incineration is the same as the one for municipal solid waste incineration in Switzerland (FOEN 2007), i.e. 40% of the waste mix is of fossil origin.

c) 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[23] (OEP 2007b). Data for municipal solid waste has been interpolated.

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[23] This assumption is based on a Swiss study that showed that illegal incineration in private gardens and stoves are of the order of magnitude of 1% of total MSW generation. Assuming that no illegal incineration in gardens takes place in Liechtenstein, a value of 0.5% for illegal incineration in stoves is estimated.

		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	2005	2006
MSW generated	t/a	8'200	8'220	8'240	8'260	8'280	8'038	8'267
Fraction incinerated illegally		0.5%	0.5%	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	40.2	41.3

Table 118 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 source specific 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.

Emissions from the application of compost to agricultural land are reported under category 4 Agriculture.

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 2007b EF: FOEN 2007

Table 119 Specification of source category 6D “Other” (AD: activity data; EF: emission factors).

8.5.2. Methodological Issues

a) Methodology

For the CH_4 and N_2O emissions from composting a country specific method is used, based on the Swiss NIR (FOEN 2007). The GHG emissions are calculated by multiplying the quantity of wastes by the emission factors. For all years the same constant country specific 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.

b) Emission Factors

Emission factors for composting have been adopted from the Swiss NIR (FOEN 2007): 5 kg CH_4/t and 0.07 kg N_2O/t. They are based on measurements and expert estimates, documented in the Swiss EMIS database.

c) Activity data

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[24]: it is estimated to amount to 8% in 1990 and 5% in 2005 and following years compared to the 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	2005	2006
Composted centrally	t/a	5'210	4'181	5'501	5'508	5'345	6'614	5'442
Additionally in backyard		6.0%	5.8%	5.6%	5.4%	5.2%	5.0%	5.0%
Composted total	t/a	5'522	4'423	5'809	5'806	5'623	6'945	5'714

Table 120 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.

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[24] Source: Andreas Gstöhl, OEP, email to J. Beckbissinger, Acontec, of August 16th, 2006.

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.

9. Recalculations

9.1. Explanations and Justifications for Recalculations

In 2006, a fundamental effort has been accomplished to achieve the best possible data for Liechtenstein's GHG inventory 1990–2004. Best available data had been collected and methodologies fully in line with IPCC had been applied. Nevertheless, the In-Country Review in June 2007 detected some categories that had to be recalculated for the years 1990–2004. In particular, the definition of forest had to be modified with relevant changes in emissions and removals. Independently, some other and minor recalculations were carried for the submission in May 2007 concerning the data 1990–2005. Both recalculation steps are included in the recalculation that is presented in paragraphs above for the time series 1990–2006.

1 Energy

Due to a transcription error concerning fuel consumption in 1A3 Transport, the year 2005 had to be recalculated.

CH_4 and N_2O emissions from power generation based on biogas from sewage sludge have been included in category 1A1.

2 Industrial Processes

No recalculation was carried out.

3 Solvent and other Product Use

No recalculation was carried out.

4 Agriculture

4D Agricultural soils: The area of cultivated organic soils was revised, the whole time series was recalculated.

5 LULUCF

The whole sector was recalculated due to the new definition of forests. All sub-sectors are involved.

6 Waste

6A “Solid Waste Disposal on Land”: As recommended by the UNFCCC Expert Review Team during the In-Country Review in June 2007, the (very limited) CH_4 emissions from waste disposal on land have been been estimated for the subsequent revised Initial Report submission for the first time, though the last landfill in Liechtenstein has been closed in 1974.

9.2. *Implications for Emission Levels 1990 and 2005*

Table 121 shows the recalculation results for the base year 1990. The recalculation have very slight effect on the emissions in 1990: They decreased by 0.9 Gg CO_2 eq (without LULUCF), which corresponds to a decrease of 0.4% of the national total. **This decrease has already been identified in the In-Country Review in June 2007. It led to the adjustment documented in the corrigendum of the Initial Report** (OEP 2007a, 2007b).

Recalculation	**CO_2**			**CH_4**			**N_2O**			**Sum (CO_2, CH_4 and N_2O)**		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)									CO_2 equivalent (Gg)		
1 Energy	202	202	0.00	1.1	1.1	0.00	0.8	0.9	0.05	203.4	203.5	0.05
2 Ind. Processes (without syn. gases)	NO	NO		NO	NO		NO	NO				
3 Solvent and Other Product Use	2	2	0.00				0.5	0.5	0.00	2.0	2.0	0.00
4 Agriculture				11.7	11.7	0.00	12.0	10.8	-1.18	23.7	22.5	-1.18
5 LULUCF	-7	-8	-0.97	NO	NO		NO	NO		-7.3	-8.3	-0.97
6 Waste	0	0	0.00	0.4	0.6	0.22	0.9	0.9	0.01	1.3	1.6	0.23
Sum (without synthetic gases)	196	195	-0.97	13.2	13.4	0.22	14.2	13.1	-1.12	223.1	221.2	-1.87

Recalculation	**HFC**			**PFC**			**SF6**			**Sum (synthetic gases)**		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)									CO_2 equivalent (Gg)		
2 Ind. Processes (only syn. gases)	0.00	0.00	0.00	NA,NO	NA,NO		NA,NO	NA,NO		0.0	0.0	0.00

Recalculation		**Sum (all gases)**		
Emissions for 1990		Prev.	Latest	Differ.
Source and Sink Categories		CO_2 equivalent (Gg)		
Total CO_2 eq Em. with LULUCF		**223.08**	**221.21**	**-1.87**
		100.00%	99.16%	-0.84%
Total CO_2 eq Em. without LULUCF		**230.43**	**229.53**	**-0.90**
		100.00%	99.61%	-0.39%

Table 121 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submission in 2007 "Prev." (OEP 2007) and after the recalculation according to the present submission "Latest. The differences "Differ." are defined as latest minus previous submission.

For 2005, the recalculations result in a small increase of the total emissions in CO_2 equivalents (without emissions/removals from LULUCF) of 0.16 Gg CO_2 eq. This corresponds to an increase of the latest submission compared to the previous submission of -0.06% of the national total. If the LULUCF sector is included, the increase is even smaller: 0.16 Gg CO_2 eq or 0.02% of the national total.

Recalculation	**CO_2**			**CH_4**			**N_2O**			**Sum (CO_2, CH_4 and N_2O)**		
Emissions for 2005	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)									CO_2 equivalent (Gg)		
1 Energy	239	239	0.14	1.7	1.7	-0.01	1.1	1.2	0.07	241.7	241.9	0.20
2 Ind. Processes (without syn. gases)	NO	NO		NO	NO		NO	NO				
3 Solvent and Other Product Use	0.9	0.9	0.00				0.2	0.2	0.00	1.1	1.1	0.00
4 Agriculture				11.5	11.5	0.00	10.2	10.1	-0.07	21.7	21.6	-0.07
5 LULUCF	-6.4	-6.5	-0.14	NO	NO		NO	0.0	0.03	-6.4	-6.5	-0.11
6 Waste	0.0	0.0	0.00	0.8	0.8	0.03	1.1	1.1	0.00	1.9	1.9	0.03
Sum (without synthetic gases)	233	233	0.00	14.0	14.0	0.02	12.6	12.6	0.03	260.0	260.1	0.05

Recalculation	**HFC**			**PFC**			**SF6**			**Sum (synthetic gases)**		
Emissions for 2005	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)									CO_2 equivalent (Gg)		
2 Ind. Processes (only syn. gases)	4.07	4.07	0.00	NA,NO	NA,NO		0.1	0.1	0.00	4.1	4.1	0.00

Recalculation		**Sum (all gases)**		
Emissions for 2005		Prev.	Latest	Differ.
Source and Sink Categories		CO_2 equivalent (Gg)		
Total CO_2 eq Em. with LULUCF		**264.14**	**264.18**	**0.05**
		100.00%	100.02%	0.02%
Total CO_2 eq Em. without LULUCF		**270.52**	**270.68**	**0.16**
		100.00%	100.06%	0.06%

Table 122 Overview of implications of recalculations on 2005 data. Emissions are shown before the recalculation according to the previous submission in 2007 “Prev.” (OEP 2007) and after the recalculation according to the present submission “Latest”. The differences “Differ.” are defined as latest minus previous submission.

9.3. Implications for Emissions Trends, including Time Series Consistency

Due to recalculations, the emission trend 1990–2005 reported in the 2007 submission has changed. Compared to 1990, 2004 emissions (national total without emissions/removals from LULUCF) showed an increase of 17.40% before recalculation (previous submission). After recalculation, the increase turns out to be somewhat bigger: 17.93% (latest submission).

Recalculation	**1990**		**2005**		**change 1990/2005**	
submission	previous	latest	previous	latest	previous	latest
	CO_2 eq (Gg)				%	
Total excl. LULUCF	230.43	229.53	270.52	270.68	17.40%	17.93%

Table 123 Change of the emission trend 1990–2005 due to recalculations.

All time series in the present submission are consistent.

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Annexes

Annex 1: Key Category Analysis

A1.1 Complete KCA 2006 without LULUCF categories.

Key Category Analysis 2006 (without LULUCF) IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate (2006)	Level Assessment	Trend Assessment	% Contribution in Trend	Result level assessment	Result trend assessment
						[Gg CO2eq]	[Gg CO2eq]					
TOTAL					*All*	***229.53***	***273.05***	*100.00%*	*0.367912*	*100.0%*		
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	45.75	16.76%	0.068254	18.6%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	23.72	8.69%	0.063824	17.3%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	29.34	10.75%	0.058461	15.9%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	55.56	20.35%	0.050623	13.8%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	15.13	5.54%	0.022059	6.0%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	15.13	5.54%	0.022059	6.0%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	24.01	8.79%	0.019826	5.4%	KC level	KC trend
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			HFC	0.00	4.15	1.52%	0.012769	3.5%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	22.20	8.13%	0.007992	2.2%	KC level	KC trend
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	0.12	2.69	0.99%	0.007855	2.1%	KC level	KC trend
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	10.24	3.75%	0.004367	1.2%	KC level	KC trend
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	5.62	2.06%	0.003779	1.0%	KC level	KC trend
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	3.62	1.33%	0.002499	0.7%	KC level	-
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.49	0.91%	0.002347	0.6%	KC level	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CO2	0.00	2.00	0.73%	0.006157	1.7%	-	KC trend
3	3. Solvent and Other Product Use				CO2	1.53	0.88	0.32%	0.002887	0.8%	-	KC trend
1B2	1. Energy	B. Fugitive Emissions from Fuels	2. Oil and Natural Gas		CH4	0.32	1.07	0.39%	0.002103	0.6%	-	-
4B	4. Agriculture	B. Manure Management			CH4	1.90	1.72	0.63%	0.001644	0.4%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CH4	0.49	0.10	0.04%	0.001464	0.4%	-	-
3	3. Solvent and Other Product Use				N2O	0.46	0.23	0.09%	0.000978	0.3%	-	-
4D_o	4. Agriculture	D. Agricultural Soils without 4D1-N2O & 4D3-N2O			N2O	0.82	0.67	0.24%	0.000952	0.3%	-	-
6A	6. Waste	A. Solid Waste Disposal on Land			CH4	0.22	0.02	0.01%	0.000727	0.2%	-	-
4B	4. Agriculture	B. Manure Management			N2O	1.52	1.60	0.58%	0.000653	0.2%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Biomass	CH4	0.13	0.31	0.12%	0.000488	0.1%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CO2	1.30	1.42	0.52%	0.000412	0.1%	-	-
6D	6. Waste	D. Other			CH4	0.40	0.60	0.22%	0.000366	0.1%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Solid Fuels	CO2	0.09	0.01	0.01%	0.000289	0.1%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	N2O	0.05	0.14	0.05%	0.000253	0.1%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	N2O	0.01	0.08	0.03%	0.000216	0.1%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	N2O	0.14	0.11	0.04%	0.000167	0.0%	-	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			SF6	0.00	0.05	0.02%	0.000158	0.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CH4	0.01	0.05	0.02%	0.000146	0.0%	-	-
1A3a	1. Energy	A. Fuel Combustion	3. Transport; Civil Aviation		CO2	0.08	0.14	0.05%	0.000141	0.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CH4	0.02	0.07	0.02%	0.000134	0.0%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CH4	0.00	0.04	0.01%	0.000118	0.0%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	N2O	0.47	0.52	0.19%	0.000106	0.0%	-	-
6D	6. Waste	D. Other			N2O	0.08	0.12	0.05%	0.000076	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CH4	0.00	0.03	0.01%	0.000075	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	N2O	0.05	0.04	0.01%	0.000056	0.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	N2O	0.05	0.04	0.01%	0.000056	0.0%	-	-
6B	6. Waste	B. Wastewater Handling			N2O	0.81	0.99	0.36%	0.000055	0.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Biomass	N2O	0.01	0.03	0.01%	0.000049	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Biomass	N2O	0.05	0.08	0.03%	0.000042	0.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Biomass	N2O	0.01	0.02	0.01%	0.000033	0.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	N2O	0.00	0.02	0.01%	0.000033	0.0%	-	-
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	N2O	0.02	0.03	0.01%	0.000023	0.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Solid Fuels	CH4	0.01	0.00	0.00%	0.000019	0.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CH4	0.02	0.01	0.00%	0.000019	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CH4	0.04	0.05	0.02%	0.000018	0.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Biomass	CH4	0.00	0.01	0.00%	0.000017	0.0%	-	-

(Cont'd next page)

Table 124 Complete Key Category Analysis for 2006 without LULUCF categories.

Key Category Analysis 2006 (without LULUCF) IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate (2006)	Level Assessment	Trend Assessment	% Contribution in Trend	Result level assessment	Result trend assessment
6B	6. Waste	B. Wastewater Handling			CH4	0.02	0.03	0.01%	0.000015	0.0%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CH4	0.01	0.01	0.00%	0.000015	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CH4	0.01	0.00	0.00%	0.000006	0.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CH4	0.01	0.00	0.00%	0.000006	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	N2O	0.01	0.01	0.00%	0.000005	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	N2O	0.00	0.00	0.00%	0.000004	0.0%	-	-
6C	6. Waste	C. Waste Incineration			CO2	0.01	0.01	0.00%	0.000004	0.0%	-	-
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	N2O	0.00	0.00	0.00%	0.000003	0.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	N2O	0.01	0.01	0.00%	0.000003	0.0%	-	-
6C	6. Waste	C. Waste Incineration			CH4	0.01	0.01	0.00%	0.000002	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Biomass	CH4	0.00	0.00	0.00%	0.000002	0.0%	-	-
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Solid Fuels	N2O	0.00	0.00	0.00%	0.000002	0.0%	-	-
1A3a	1. Energy	A. Fuel Combustion	3. Transport; Civil Aviation		N2O	0.00	0.00	0.00%	0.000001	0.0%	-	-
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
6C	6. Waste	C. Waste Incineration			N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A3a	1. Energy	A. Fuel Combustion	3. Transport; Civil Aviation		CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Liquid Fuels	CO2	NO	NO	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Solid Fuels	CO2	NO	NO	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Other Fuels	CO2	NO	NO	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Liquid Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Solid Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Other Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Liquid Fuels	N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Solid Fuels	N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Other Fuels	N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Solid Fuels	CO2	NO	NO	0.00%	0.000000	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Other Fuels	CO2	NO	NO	0.00%	0.000000	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Solid Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Biomass	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Other Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Solid Fuels	N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Biomass	N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Other Fuels	N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A3e	1. Energy	A. Fuel Combustion	3. Transport; Other Transportation (military aviation)		CO2	NA	NA	0.00%	0.000000	0.0%	-	-
1A3e	1. Energy	A. Fuel Combustion	3. Transport; Other Transportation (military aviation)		CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A3e	1. Energy	A. Fuel Combustion	3. Transport; Other Transportation (military aviation)		N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Solid Fuels	CO2	NO	NO	0.00%	0.000000	0.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Solid Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Solid Fuels	N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	CO2	NO	NO	0.00%	0.000000	0.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	-	-
1A4c	1. Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	N2O	0.00	0.00	0.00%	0.000000	0.0%	-	-
1B2	1. Energy	B. Fugitive Emissions from Fuels	2. Oil and Natural Gas		CO2	NA,NO	NA,NO	0.00%	0.000000	0.0%	-	-
1B2	1. Energy	B. Fugitive Emissions from Fuels	2. Oil and Natural Gas		N2O	NA,NO	NA,NO	0.00%	0.000000	0.0%	-	-
2A	2. Industrial Proc.	A. Mineral Products			CO2	NO	NO	0.00%	0.000000	0.0%	-	-
2A	2. Industrial Proc.	A. Mineral Products			CH4	NO	NO	0.00%	0.000000	0.0%	-	-
2A	2. Industrial Proc.	A. Mineral Products			N2O	NO	NO	0.00%	0.000000	0.0%	-	-
2B	2. Industrial Proc.	B. Chemical Industry			CO2	NO	NO	0.00%	0.000000	0.0%	-	-
2B	2. Industrial Proc.	B. Chemical Industry			CH4	NO	NO	0.00%	0.000000	0.0%	-	-
2B	2. Industrial Proc.	B. Chemical Industry			N2O	NO	NO	0.00%	0.000000	0.0%	-	-
2C	2. Industrial Proc.	C. Metal Production			CO2	NO	NO	0.00%	0.000000	0.0%	-	-
2C	2. Industrial Proc.	C. Metal Production			CH4	NO	NO	0.00%	0.000000	0.0%	-	-
2C	2. Industrial Proc.	C. Metal Production			N2O	NO	NO	0.00%	0.000000	0.0%	-	-
2D	2. Industrial Proc.	D. Other Production			CO2	NO	NO	0.00%	0.000000	0.0%	-	-
2E	2. Industrial Proc.	E. Production of Halocarbons and SF6			CO2	0.00	0.00	0.00%	0.000000	0.0%	-	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			PFC	NO	NA,NO	0.00%	0.000000	0.0%	-	-
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			CO2	0.00	0.00	0.00%	0.000000	0.0%	-	-
2G	2. Industrial Proc.	G. Other			CO2	NO	NO	0.00%	0.000000	0.0%	-	-
2G	2. Industrial Proc.	G. Other			CH4	NO	NO	0.00%	0.000000	0.0%	-	-
2G	2. Industrial Proc.	G. Other			N2O	NO	NO	0.00%	0.000000	0.0%	-	-
4C	4. Agriculture	C. Rice Cultivation			CH4	NA,NO	NA,NO	0.00%	0.000000	0.0%	-	-
4D	4. Agriculture	D. Agricultural Soils			CH4	NA,NO	NA,NO	0.00%	0.000000	0.0%	-	-
4E	4. Agriculture	E. Prescribed Burning of Savannas			CH4	NA	NA	0.00%	0.000000	0.0%	-	-
4E	4. Agriculture	E. Prescribed Burning of Savannas			N2O	NA	NA	0.00%	0.000000	0.0%	-	-
4F	4. Agriculture	F. Field Burning of Agricultural Residues			CH4	NA,NO	NA,NO	0.00%	0.000000	0.0%	-	-
4F	4. Agriculture	F. Field Burning of Agricultural Residues			N2O	NA,NO	NA,NO	0.00%	0.000000	0.0%	-	-
4G	4. Agriculture	G. Other			CH4	NA	NA	0.00%	0.000000	0.0%	-	-
4G	4. Agriculture	G. Other			N2O	NA	NA	0.00%	0.000000	0.0%	-	-
6A	6. Waste	A. Solid Waste Disposal on Land			CO2	NE,NO	NE,NO	0.00%	0.000000	0.0%	-	-
6D	6. Waste	D. Other			CO2	NO	NO	0.00%	0.000000	0.0%	-	-

A1.2 KCA including LULUCF categories

Key Category Analysis 2006 (including LULUCF) IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Assessment	Trend Assessment	% Contribution in Trend	Result level assessment	Result trend assessment
Sorted by NFR code						Gg CO2 eq	Gg CO2 eq					
1A1	1. Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	0.12	2.69	0.88%	0.007115	2.1%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	22.20	7.29%	0.007799	2.2%	KC level	KC trend
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	15.13	4.96%	0.019330	5.6%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	24.01	7.88%	0.018453	5.3%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gaseous Fuels	CO2	0.00	2.00	0.66%	0.005574	1.6%	KC level	KC trend
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	55.56	18.23%	0.043760	12.6%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	29.34	9.63%	0.053223	15.3%	KC level	KC trend
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	45.75	15.01%	0.059839	17.3%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	23.72	7.78%	0.057866	16.7%	KC level	KC trend
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	15.13	4.96%	0.019330	5.6%	KC level	KC trend
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	3.62	1.19%	0.002343	0.7%	KC level	KC trend
2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6			HFC	0.00	4.15	1.36%	0.011560	3.3%	KC level	KC trend
3	3. Solvent and Other Product Use				CO2	1.53	0.88	0.29%	0.002562	0.7%	-	KC trend
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	10.24	3.36%	0.003618	1.0%	KC level	KC trend
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	5.62	1.84%	0.003225	0.9%	KC level	KC trend
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.49	0.82%	0.002032	0.6%	KC level	KC trend
5A1	5. LULUCF	A. Forest Land	1. Forest Land remaining Forest Land		CO2	18.64	19.02	6.24%	0.008135	2.3%	KC level	KC trend
5B1	5. LULUCF	B. Cropland	1. Cropland remaining Cropland		CO2	4.33	4.45	1.46%	0.001805	0.5%	KC level	-
5C1	5. LULUCF	C. Grassland	1. Grassland remaining Grassland		CO2	2.13	1.81	0.60%	0.001930	0.6%	KC level	KC trend
5C2	5. LULUCF	C. Grassland	2. Land converted to Grassland		CO2	0.08	0.87	0.29%	0.002170	0.6%	-	KC trend
5E2	5. LULUCF	E. Settlements	2. Land converted to Settlements		CO2	3.30	3.47	1.14%	0.001151	0.3%	KC level	-

Key Category Analysis 1990 (including LULUCF) IPCC Source Categories (and fuels if applicable)					Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Assessment	Cumulative Total Column E-L			
Sorted by NFR code						Gg CO2 eq	Gg CO2 eq					
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	16.48	16.48	6.37%	0.734917		KC level	
1A2	1. Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	18.74	18.74	7.24%	0.526837		KC level	
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	14.77	14.77	5.71%	0.791969		KC level	
1A3b	1. Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	60.53	60.53	23.38%	0.233849		KC level	
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	8.70	8.70	3.36%	0.863452		KC level	
1A4a	1. Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	57.10	57.10	22.06%	0.454431		KC level	
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	2.51	2.51	0.97%	0.935384		KC level	
1A4b	1. Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	18.74	18.74	7.24%	0.599243		KC level	
1A5	1. Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	2.36	2.36	0.91%	0.944518		KC level	
4A	4. Agriculture	A. Enteric Fermentation			CH4	9.80	9.80	3.79%	0.829833		KC level	
4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions			N2O	5.75	5.75	2.22%	0.885678		KC level	
4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions			N2O	2.73	2.73	1.06%	0.925692		KC level	
5A1	5. LULUCF	A. Forest Land	1. Forest Land remaining Forest Land		CO2	18.64	18.64	7.20%	0.671237		KC level	
5B1	5. LULUCF	B. Cropland	1. Cropland remaining Cropland		CO2	4.33	4.33	1.67%	0.902401		KC level	
5C1	5. LULUCF	C. Grassland	1. Grassland remaining Grassland		CO2	2.13	2.13	0.82%	0.952742		KC level	
5E2	5. LULUCF	E. Settlements	2. Land converted to Settlements		CO2	3.30	3.30	1.27%	0.915134		KC level	

Table 125 Liechtenstein's key categories in 2006 and in 1990 including LULUCF categories.

Inclusion of the LULUCF categories adds five LULUCF categories in 2006. Among a total of 135 categories there are 21 key categories adding up to 95.9% of the total. The LULUCF categories amount to 9.7%, where the largest category, 5A1 Forest Land remaining Forest

Land contributes with 6.2%. The other LULUCF key categories are of minor importance: 5B1 Cropland remaining Cropland (1.5%), 5C1 Grassland remaining Grassland (0.6%), 5C2. Land converted to Grassland (0.3%), 5E2. Land converted to Settlements (1.1%).

In 1990, twelve non-LULUCF categories appear as key categories identical to the KCA without the LULUCF sector. Among the LULUCF categories, 5C2 Land converted to Grassland drops from the list of key categories since its contribution is small. The other four LULUCF key categories already appear in 2006.

Please note that the KCA including LULUCF categories shown in the table above is not the same as the “combined KCA without and with LULUCF categories” provided in Table 5. The KCA including LULUCF is a full KCA that includes also LULUCF sources, whereas the “combined KCA with and without LULUCF categories” combines the result of two key category analyses:

- Key categories of all non-LULUCF key categories that result from the KCA without LULUCF plus
- all LULUCF-key-categories that result from the KCA with LULUCF.

Annex 2: QA/QC system

Checklist for QC activities

Quality control system for Climate Reporting Liechtenstein
Submission 29 February 2008

Checklist for NIC, saectoral experts, NIR Authors and project manager of GHG Inventory Group

Contact person:	Jürg Heldstab (INFRAS)
Telephone, e-mail:	044 205 95 11, juerg.heldstab@infras.ch

QC activity	**Procedure (description of checks that were carried out)**	**respon-sibles**	**date**	**visa**
General activities (table 8.1 IPCC GPG)	***General procedures***			
1. Check that assumptions and criteria for the selection of activity data and emission factors are documented	okay	SE/NIC	ongoing	JB
	okay	SE	02.11.07	HE
	EBP-internal checks, comparison with methods chosen	SE	20.11.07	FJ
	INFRAS-internal checks, comparison with methods chosen	SE	04.12.07	JH
2. Check for transcription errors in data input and reference	check Input-Data for Energy and Waste	SE	02.11.07	JB
	plausibility check of the basic input data from the LWA	SE	04.10.07	JB
	check input Data for Agriculture	SE	20.11.07	JB
	check stationary Energy, Ind. Proc., Solvents, Waste	SE	28.11.07	FJ
	check mobile Energy.xls: wrong attribution NCV	SE	02.11.07	JH
	re-check Energy.xls: NCV ok, time series ok	SE	05.11.07	JH
	Agriculture: Plausibility check of data in background tables Acontec	SE	12.11.07	MS
3. Check that emissions are calculated correctly.	Ongoing checks of the calculated emissions in all sectors	SE/NIC	Oct/Nov	JB
	reached the calculated Energie consumption	SE/NIC	15.11.07	JB
	Clarification of comprehension questions with HE and JB	PMA	23.10.07	AG
	EBP-internal control: Plausibility checks, "Delta-Analysis" combined with KCA, INFRAS-internal control of time series, comparison with April 07 submission.	SE	10.11.07	FJ
	INFRAS-internal checks during generationof tables/figure in Chapter. 2 Trends (independant control by second person)	SE	12.11.07	JH
4. Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used.	check energy-activity-data (input-data)	SE/NIC	12.11.07	JB
	check input data format in the sector waste	SE/NIC	29.09.07	JB
	check stationary Energy, Ind. Proc., Solvents, Waste	SE	20.11.07	FJ
	check mobile Energy, Agriculture	SE	21.11.07	JH
	check Agriculture	SE	26.11.07	MS
	check LULUCF	SE	29.11.07	MS
5. Check the integrity of database files.	integrity checked	NIC	25.02.08	JB
6. Check for consistency in data between source categories.	consistency checked	NIC	ongoing	JB
	check stationary Energy, Ind. Proc., Solvents, Waste	SE	20.11.07	FJ
	check mobile Energy, Agriculture,	SE	22.11.07	JH
	check Agriculture	SE	26.11.07	MS
	check LULUCF	SE	29.11.07	MS
7. Check that the movement of inventory data among processing steps is correct.	Processing checked	NIC	ongoing	JB
	Data transfer from the land-use statistics to the LULUCF tables	SE	23.10.07	HE
	check Agriculture	SE	26.11.07	MS
	check LULUCF	SE	27.11.07	MS
8. Check that uncertainties in emissions and removals are estimated or calculated	check stationary Energy, Ind. Proc., Solvents, Waste	SE	07.12.07	FJ
	check mobile Energy, Agriculture	SE	04.12.07	JH
9. Undertake review of internal documentation.	internal documentation checked	SE/NIC	14.01.08	JB
	OEP internal meeting: check on actual state of project, clarification of comprehensive questions	PM/NIC PMA	30.11.07	HK, AG
	proofread NIR	NA	20.12.07	FJ
	proofread NIR	NA	21.12.07	JH
10. Check methodological and data changes resulting in recalculations	okay	NIC	18.12.07	JB
11. Undertake completeness checks.	Completness check for Waste and Energy	SE/NIC	02.10.07	JB
	Completness check for all other sectors	SE/NIC	10.12.07	JB
12. Compare estimates to previous estimates.	check of KCA previous/latest key categories	NIC	18.12.07	JB
	plausibility checks of the CRF tables	PMA	02.11.07	AG
	check stationary Energy, Ind. Proc., Solvents, Waste	SE	20.11.07	FJ
	check mobile Energy, Agriculture,	SE	21.11.07	JH
	check Agriculture	SE	26.11.07	MS
	check LULUCF	SE	29.11.07	MS

continued next page

13. Archiving activities	Checked: Documents of submission April 2007 have been archived	PMA	31.01.08	AG
14. Further activities	see Inventory Development Plan, minutes of meetings Inventory Core Group and Review Reports UNFCCC			
Country-specific activities	***Specific procedures***			
20. Where LIE uses Swiss-specific methods: If a change in the Swiss inventory occurs, check whether the change has to be adopted for LIE or not	clarification of comprehensive questions	PMA	07.12.07	AG
	check: Energy (stationary), Solvents	SE	26.11.07	FJ
	check Energy (mobile)	SE	04.12.07	JH
	check Agriculture	SE	30.11.07	MS
21. Where LIE uses Swiss-specific EF: Where changes in the Swiss EFoccur, check whether the changes are also adequate for LIE or not	Clarify the changes of Emission factors in Agriculture	SE	02.11.07	JB
	check: Energy (stationary), Solvents	SE	28.11.07	FJ
	check Energy (mobile)	SE	08.12.07	JH
	check Agriculture	SE	30.11.07	MS
22. Check correctness of KCA, comparison with previous results	plausibility checks	PMA	26.11.07	AG
	EBP-internal plausibility control: caluculation and check of sub-totals, comparison with CRF, check of data transcription errors, comparison of changes CRF Apr 07 - Nov 06 (delta checks), independant plausibility checks by INFRAS	NA		FJ, JH
	cross-check within KCA with/without LULUCF 1990 and 2006: Emissions correct, thresholds correct. Comparison with KCA of Submission May 2007	NA		JH
23. Check correctness of uncertainty analysis, comparison with previous results	EBP-internal plausibility checks	NA		FJ
	INFRAS internal plausibility checks	NA		JH
24. Check of transcription errors CRF -> NIR (numbers, tables, figures)	EBP-internal control: Comparison of dataa in CRF tables with NIR	NA	09.12.07	FJ
	INFRAS-internal control. Comparison of data in CRF tables and NIR. For the transcription of emission data into chapters Exec. Summ., 2. Trends, X.1 Overview (in all sectors) a INFRAS collaborator generates figures and tables, copies them into NIR and adjusts the text correspondingly. These working steps are afterwards checked by another collaborator of INFRAS.	NA NIC	06.12.07 25.02.08	JH JB
25. Check for complete and correct references in NIR	EBP-internal checks	NA	16.12.07	FJ
	INFRAS-internal checks	NA	18.12.07	JH
26. Check for correctness, completeness, transparency and quality of NIR	proofread inventory/NIR	PM	07.01.07	HK
	proofread inventory/NIR	PMA	09.01.08	AG
	proofread inventory/NIR	SC	10.01.07	PI
	proofread inventory/NIR	SC	10.01.07	SB
	proofread inventory/NIR, section LULUCF	SE	10.01.08	HE
	OEP internal discussion of the inventory/NIR draft with AG, PI, SB, HE	PM	11.01.08	HK
	Feedback from the OEP internal discussion to the NIR authors	PMA	15.01.08	AG
	telefone conference between AG and JH: clarification of comprehensive questions	PMA	31.01.08	AG
	A number of failings/errors are being identified and communicated to the NIR authors. they correct the findings	NA	Dec. 07	FJ, JH
	clarification of comprehensive questions with JB	PMA	14.02.08	AG
	final proofread inventory/NIR, discussion with HK and feedback to JH	PMA	15.02.08	AG
	NIR-Authors are in contact with some data suppliers. If the documentation is sufficient or not will be decided by the Core Group in the draft version, later on by the UNFCCC review team. Their findings are being implemented in accordance with the project management.	NA	follow-up in-country review	JH
27. Check for completeness of submission documents	final check and submission	PM/ NIC	29.02.08	HK
28. Further activities	Archiving: INFRAS, EBP, Acontec save internally all data individually. NIR in MS-DOC and PDF format are sent to OEP. All tables in MS-EXCEL format are sent to OEP for separate archiving.	NA, NIC	20.01.08 28.02.08	JH, FJ, JB

Table 126 Checklist for QC activities (part in orange of previous page) and for follow-up activities if necessary (this page). The general activities are taken from IPCC GPG, table 8.1, the country specific activities are ad-hoc activities of Good Practice Guidance (IPCC 2006). Abbr.: NA NIR authors, NIC: national inventory compiler (HK is the NIC; note that preliminary feeding/running of the CRF Reporter is delegated to JB as NIC assistant), PM project manager, PMA project manager assistant, SC staff member climate unit, SE sectoral experts.
Member codes: AG Andreas Gstoehl, FJ Jürg Füssler, HE Hanspeter Eberle, HK Helmut Kindle, JB Jürgen Beckbissinger, JH Jürg Heldstab, MS Myriam Steinemann, PI Patrick Insinna, SB Sven Braden.

Annex 3: Energy

CO_2 Emission Factors, Net Calorific Values and densities of Fossil Fuels

All parameters of fossil fuels are assumed to be constant for the period 1990 to 2006.

Fuel	**CO_2 Emission Factor**			**Net calorific value (NCV)**		**Density**
	t CO_2 / TJ	t CO_2 / t	t CO_2 / volume	GJ / t	GJ / volume	**t / volume**
Hard Coal	94.0	2.47	---	26.3	---	---
Gas Oil	73.7	3.14	2.65t / 1000 liter	42.6	36.0 / 1000 l	0.845 t / 1000 l
Residual Fuel Oil	77.0	3.17	3.01t / 1000 liter	41.2	39.1 / 1000 l	0.950 t / 1000 l
Natural Gas	55.0	2.56	2.00t / 1000 Nm^3	46.5	36.3 / 1000 Nm^3	0.780 t / 1000 Nm^3
Gasoline	73.9	3.14	2.34t / 1000 liter	42.5	31.7 / 1000 l	0.745 t / 1000 l
Diesel Oil	73.6	3.15	2.61t / 1000 liter	42.8	35.5 / 1000 l	0.830 t / 1000 l
Propane/Butane (LPG)	65.5	---	---	46.0	---	---
Jet Kerosene	73.2	3.15	2.52t / 1000 liter	43.0	34.4 / 1000 l	0.800 t / 1000 l
Lignite	104.0	2.09	---	20.1	---	---

Table 127 Parameters of fossil fuels used for the modelling of Liechtenstein's GHG emissions. Data source: FOEN 2007.

Annex 3: Agriculture

A3.1 Livestock Population Data for N_2O Emission Calculation

Animals 2006		**Number of animals**	**kg N per head/year**
Cattle			
Mature dairy and non-dairy cattle		2'589	114.1
Mature non-dairy cattle		405	80.0
Young cattle			
	Milk fed calf, suckler cow calf, breeding calf and breeding cattle less than one year	1'063	13-25
	Fattening calf (places)	53	8
	Fattening cattle	554	33
Breeding cattle (more than one year)		999	40-55
Swine		**1'723**	
	Fattening pig places (2)	1'076	13
	Breeding pig places (3)	108	35
Sheep		**3'687**	
	Sheep places (4)	1'844	12
Goats		**362**	
	Goat places (5)	199	16
Horses		**284**	
	Foals < 1 year	5	17
	Foals 1 - 2 years	25	42
	Other horses	254	44
Ponies, Mules and Asses		**140**	26
Poultry		**11'483**	
	laying hens	11'398	0.7
	young hens < 18 weeks	5	0.3
	broilers	45	0.4
	turkeys	35	1.4
Total		**17'679**	

(1) N excretion calculated based on milk production according to Walther et al. 1997 and FAL/RAC 2001.

(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 NOx emissions of 0.7% of the excreted N.

Table 128 Livestock population data for N_2O emission calculation.

A3.2 Additional Data for N_2O Emission Calculation of Agricultural Soils (4D)

2006	**Total crop production Crop(O) and Crop(BF) (kg DM)**	**Nitrogen incorporated with crop residues F(CR) (t N)**	**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	507'858	3.8	0.1			
Barley	264'435	1.5	0.0			
Maize	301'104	2.5	0.0			
Oats	0	0.0	0.0			
Rye	0	0.0	0.0			
Other (please specify)						
Spelt	25'436	0.2	0.0			
Triticale	62'118	0.7	0.0			
Mix of fodder cereals	0	0.0	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	0.0	0.0	0.0330	0	0.0
Soybeans	34'659	1.4	0.0	0.0571	2'329	0.0
Other (please specify)						
Leguminous vegetables	33'480	3.4	0.1	0.0177	3'296	0.1
3. Tuber and Root						
Potatoes	612'612	2.7	0.1			
Other (please specify)						
Fodder beet	20'832	0.2	0.0			
Sugar beet	312'884	3.0	0.1			
5. Other (please specify)						
Silage corn	6'391'088	1.4	0.0			
Green corn	1'086'485	0.2	0.0			
Fruit	8'949	0.0	0.0			
Vine	17'600	0.1	0.0			
Non-leguminous vegetables	637'504	10.0	0.2			
Sunflowers	3'825	0.0	0.0			
Tobacco	0	0.0	0.0			
Rape	13'734	0.2	0.0			
Total Non-leguminous	10'266'464	26.5	0.5		0.0	0.0
Total Leguminous	68'139	4.9	0.1		5'625.6	0.1
Total	10'334'603	31.4	0.6		5'626	0.1

Table 129 Additional data for N_2O emission calculation of agricultural soils (4D).