OFFICE OF ENVIRONMENT
PRINCIPALITY OF LIECHTENSTEIN

Liechtenstein's Greenhouse Gas Inventory 1990 - 2014

National Inventory Report 2016

Submission of 27 May 2016
under the United Nations Framework Convention on Climate Change
and under the Kyoto Protocol

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Glossary

ARR	Annual Inventory Review Report (UNFCCC)
AD	Activity Data
ART	Agroscope Reckenholz-Tänikon Research Station
AZV	Abwasserzweckverband der Gemeinden Liechtensteins (Liechtenstein's wastewater administration union)
BCEF, BEF	Biomass conversion and expansion factor, biomass expansion factor
CC	Combined Category for land-use/land-cover
CFC	Chlorofluorocarbon (organic compound: refrigerant, propellant)
CH_4	Methane
chp.	Chapter
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2, (CO_2 eq)	Carbon dioxide (equivalent)
CORINAIR	CORe INventory of AIR emissions (under the European Topic Centre on Air Emissions and under the European Environment Agency)
CRF	Common reporting format
DOC	Degradable Organic Carbon
EF	Emission Factor
EMEP	European Monitoring and Evaluation Programme (under the Convention on Long-range Transboundary Air Pollution)
EMIS	Swiss Emission Information System (database run by FOEN)
EMPA	Swiss Federal Laboratories for Material Testing and Research
ERT	Expert Review Team
FAL	Swiss Federal Research Station for Agroecology and Agriculture (since 2006: ART)
FCCC	Framework Convention on Climate Change
FMRL	Forest Management Reference Level
FOCA	Swiss Federal Office of Civil Aviation
FOD	First Order Decay Model
FOEN	Swiss Federal Office of the Environment (former name SAEFL)
g	Gramme
GHFL	Genossenschaft für Heizöllagerung im Fürstentum Liechtenstein (Cooperative society for the Storage of Gas Oil in the Principality of Liechtenstein)
GHG	Greenhouse gas

GJ	Giga Joule (10^9 Joule = 1’000 Mega Joule)
GRUDAF	Grundlagen für die Düngung im Acker – und Futterbau
GWP	Global Warming Potential
ha	Hectare (100 m x 100 m)
HFC	Hydrofluorocarbons (e.g. HFC-32 difluoromethane)
HWP	Harvested Wood Products
IDP	Inventory Development Plan
IEF	Implied Emission Factor
IPCC	Intergovernmental Panel on Climate Change
IR	Initial Report (UNFCCC)
KC, KCA	Key Category, Key Category Analysis
KP	Kyoto Protocol
kg	Kilogramme (1’000 g)
kha	Kilo hectare (1’000 ha)
kt	Kilo tonne (1’000 tons)
LFO	Light fuel oil (Gas oil)
LGV	Liechtensteinische Gasversorgung (Liechtenstein’s gas utility)
LKW	Liechtensteinische Kraftwerke (Liechtenstein’s electric power company)
LPG	Liquefied Petroleum Gas (Propane/Butane)
LTO	Landing-Take-off-Cycle (Aviation)
LULUCF	Land-Use, Land-Use Change and Forestry
LWI	Landeswaldinventar (Liechtenstein's National Forest Inventory)
MJ	Mega Joule (10^6 Joule = 1’000'000 Joule)
MSW	Municipal solid waste
MCF	Methane Conversion Factor
MWh	Mega Watt hour (1 MWh = 3.6 MJ)
MWWTP	Municipal Waste Water Treatment Plant
NCV	Net Calorific Value
NFI	National Forest Inventory (see also LWI)
NF_3	Nitrogen trifluoride 2006 IPCC GWP: 17’200 (UNFCCC 2014, Annex III)
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
OA	Office for Agriculture, former name of today's Division of Agriculture within the Office of Environment, since 2012
OCI	Office of Construction and Infrastructure
ODS	Ozone-depleting substances (CFCs, halons etc.)
OE	Office of Environment
OEA	Office of Economic Affairs
OEP	Office of Environmental Protection, former name of today's Office of Environment (OE) since 2012
OFIVA	Office of Food Inspection and Veterinary Affairs
OS	Office of Statistics
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 of the Environment FOEN)
SF_6	Sulphur hexafluoride, 2006 IPCC GWP: 22800 (UNFCCC 2014, Annex III)
SFOE	Swiss Federal Office of Energy
SFSO	Swiss Federal Statistical Office
SO_2	Sulphur dioxide
TJ	Tera Joule (10^{12} Joule = 1'000'000 Mega Joule)
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile organic compounds

EXECUTIVE SUMMARY

ES.1 Background information on climate change, greenhouse gas inventories and supplementary information required under Art. 7.1. KP

ES.1.1 Background information on climate change

According to research programs, significant negative effects of global climate warming in the Alpine region are to be expected. Changes in the permafrost layer and water drainages will play a central role in this regard.

Liechtenstein's annual mean temperature has risen by 0.7°C between the reference period 1961-1990 and 1981-2010. This increase is up to three times higher as the worldwide increase and has been observed in the other Alpine countries as well. The increase projected between 1990 and 2100 for the neighbouring northern Switzerland is 2.7 °C and 4.8 °C depending on the scenario considered. Further reductions between 18% and 28% in the summer precipitation amount are being predicted compared to the period 1980-2009, representing a substantial shift in the seasonal precipitation distribution. Glaciers in the Alps have lost 25% of their volume since 1970. Phenological observations show that the biological beginning of spring has been advancing by 1.5–2.5 days per decade.

The following effects are expected as a consequence of a further temperature rise: Heat waves with increased mortality will occur more frequently, also tropical diseases will surface in Central Europe and existing diseases will spread to higher elevations. Indirect consequences for health are to be expected from storm, floods, and landslides. The increasing weather instabilities may lead to floods in winter and droughts in summer time and composition of forest vegetation may change too. Global climate warming will therefore affect various economic sectors in Liechtenstein (e.g. Tourism, Agriculture, Forestry).

ES.1.2 Background information on greenhouse gas inventories

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. On 23 April 2015 Liechtenstein submitted its "Intended Nationally Determined Contribution (INDC)" to the UNFCCC, which aims at a reduction of greenhouse gases by 40% compared to 1990 by 2030.

In 1995, 2001, 2005, 2010 and 2014 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 May 31, including the national greenhouse gas inventory for 1990 and 2004, as well as the National Inventory Report (NIR). The second submission on 22 December 2006 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, 2007a). In May 2007 the GHG inventory 1990–2005 was submitted together with the National Inventory Report (OEP 2007). In February 2008, in April 2009, 2010, 2011, 2012, 2013, 2014 and in April 2016 the further GHG inventories 1990–2006, 1990-2007, 1990-2008, 1990-2009, 1990-2010, 1990-2011, 1990-2012 and 1990-2013 were submitted together with the National Inventory Report (OEP 2008, OEP 2009, OEP 2010, OEP 2011, OEP 2012b, OE 2013, OE 2014, OE 2016a). The present report is Liechtenstein's 11th National Inventory Report, NIR 2016, prepared under the UNFCCC and under the Kyoto Protocol. It includes, as a separate document, Liechtenstein's 1990–2014 Inventory in the CRF. Furthermore, the Standard Electronic Format application (SEF) is submitted along with the NIR 2016, providing an annual account of Kyoto units traded in the respective year.

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 did slightly change and therefore, Liechtenstein's assigned amount has been adjusted by -0.407%. After this correction, Liechtenstein's assigned amount corresponded to 1'055.623 Gg CO_2 equivalents.

In September 2008, 2009, 2010, 2011, 2012 and 2014 centralized reviews of Liechtenstein's GHG inventories and NIRs of 2007/2008, 2009, 2010, 2011, 2012 and 2014 took place in Bonn, Germany. Again, a number of recommendations were addressed to Liechtenstein, which was accounted for in the subsequent submissions (FCCC/ARR 2009, 2010, 2010a, 2011, 2012 and 2014).

Between 2 and 6 September 2013 a second individual (in-country) review took place in Vaduz. The submission documents, GHG inventory 1990-2011 including CRF tables and the National Inventory Report were scrutinized during the review. Following the recommendations of the Expert Review Team (ERT), numerous improvements were implemented in the 2014 submission. Amongst others, this included methodological changes, where data was delineated from the Swiss inventory (sectors Energy, Industrial Processes and Solvents) and complementation of the text in the NIR for transparency reasons. The recommendations by the ERT are documented in the report of the individual review of the greenhouse gas inventory of Liechtenstein submitted in 2013 (FCCC/ARR 2013).

The latest recommendations concerning the submission 2014 are published in the Report on the individual review of the annual submission of Liechtenstein submitted in 2014 (FCCC/ARR 2014). Although the report was published before the final submission 2015 not all recommendations were incorporated in the current inventory development plan due to focus on the implementation of Liechtenstein's emissions into the new CRF reporter as well as on the implementation of the requirements related to the new reporting guidelines (IPCC 2006) in the NIR. Nevertheless, the most important recommendations of the latest review have been taken into account in the current IDP (see also Annex 8.3).

The Office of Environment (OE) is in charge of compiling the emission data and bears the overall responsibility for Liechtenstein's national greenhouse gas inventory. 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. In addition to the OE, the Office of Economic Affairs (OEA), the Office of Statistics (OS) and the Office of Construction and Infrastructure (OCI) participate directly in the compilation of the inventory. Several other administrative and private institutions are involved in the inventory preparation.

The emissions are calculated based on the standard methods and procedures of the Revised 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC2006) adopted by the UNFCCC as well as of the revised supplementary methods and good practice guidance arising from the Kyoto Protocol (IPCC 2014). 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 finally implemented in the CRF Reporter that generates the **reporting tables**.

The **National Inventory Report** follows in its structure the default chapters of the "UNFCCC reporting guidelines on annual greenhouse gas inventories" (UNFCCC 2014).

For the interpretation of 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 37'366 inhabitants(2014) 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 European Economic Area. The Customs Union Treaty with Switzerland impacts greatly on environmental and fiscal strategies. Many Swiss levies 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.

ES.1.3 Background information on supplementary information required under Article 7.1. of the Kyoto Protocol (KP)

Chapter 11 of this NIR and Liechtenstein's Second Initial Report under the Kyoto Protocol (Government 2016) provide information on KP-LULUCF.

Liechtenstein only accounts for the mandatory activity Forest Management under Article 3, paragraph 4 of the Kyoto Protocol. In accordance with Annex I to Decision 2/CMP.7 (Annex I, Para 13), credits from Forest Management are capped in the second commitment period. Thus for Liechtenstein the cap amounts to 3.5% of the 1990 emissions (excluding LULUCF).

Liechtenstein will choose to account over the entire commitment period for emissions and removals from activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol. In addition to the mandatory submission of the inventory years 2013 and 2014, data for the years 2008-2012 are available and shown in Liechtenstein's NIR.

ES.2 Summary of national emission and removal-related trends as well as emissions and removals from KP-LULUCF activities

ES.2.1 GHG inventory

National total emissions

Liechtenstein's greenhouse gas emissions in the year 2014 amount to 205.1 kt CO_2 equivalent excluding LULUCF. This refers to 0.0055 kt CO_2 equivalent per capita. Total emissions declined by 10.5% compared to 1990 and by 12.6% compared to 2013 when excluding LULUCF categories. This decrease is less pronounced when including LULUCF (1990-2014: 7.3%).

Uncertainties

- An uncertainty analysis approach 1 is carried out and presented in Chapter 1.6.1.3. In 2014, it estimates a level uncertainty of total CO_2 equivalent emissions excluding the LULUCF sector of 5.46% (level uncertainty) and the trend uncertainty 1990-2014 of 5.49%.
- Including the LULUCF categories, the level uncertainty is 5.38%, trend uncertainty 5.43%.

Recalculations

Some emissions have been recalculated due to updates in respective sectors. The results are discussed in Chapter 10. For the base year 1990, recalculations lead to a decrease of 0.2% in the national total emissions in both cases, when excluding and when including LULUCF. Also the national total emissions of the year 2013 show a decrease of 0.8% in both cases, excluding and including LULUCF activities.

ES.2.2 KP-LULUCF activities

Liechtenstein reports LULUCF activities Afforestation and reforestation, deforestation, forest management including the forest management reference level (FMRL) and harvested wood products (HWP) from forest management. ES Table 1-1 shows the result for the KP-LULUCF Inventory year 2014. The total net CO_2eq removals add up to -2.03 kt. In total net emissions of 7.49 kt occurred in 2014. The level uncertainty (Approach 1) is estimate as 52.8%.

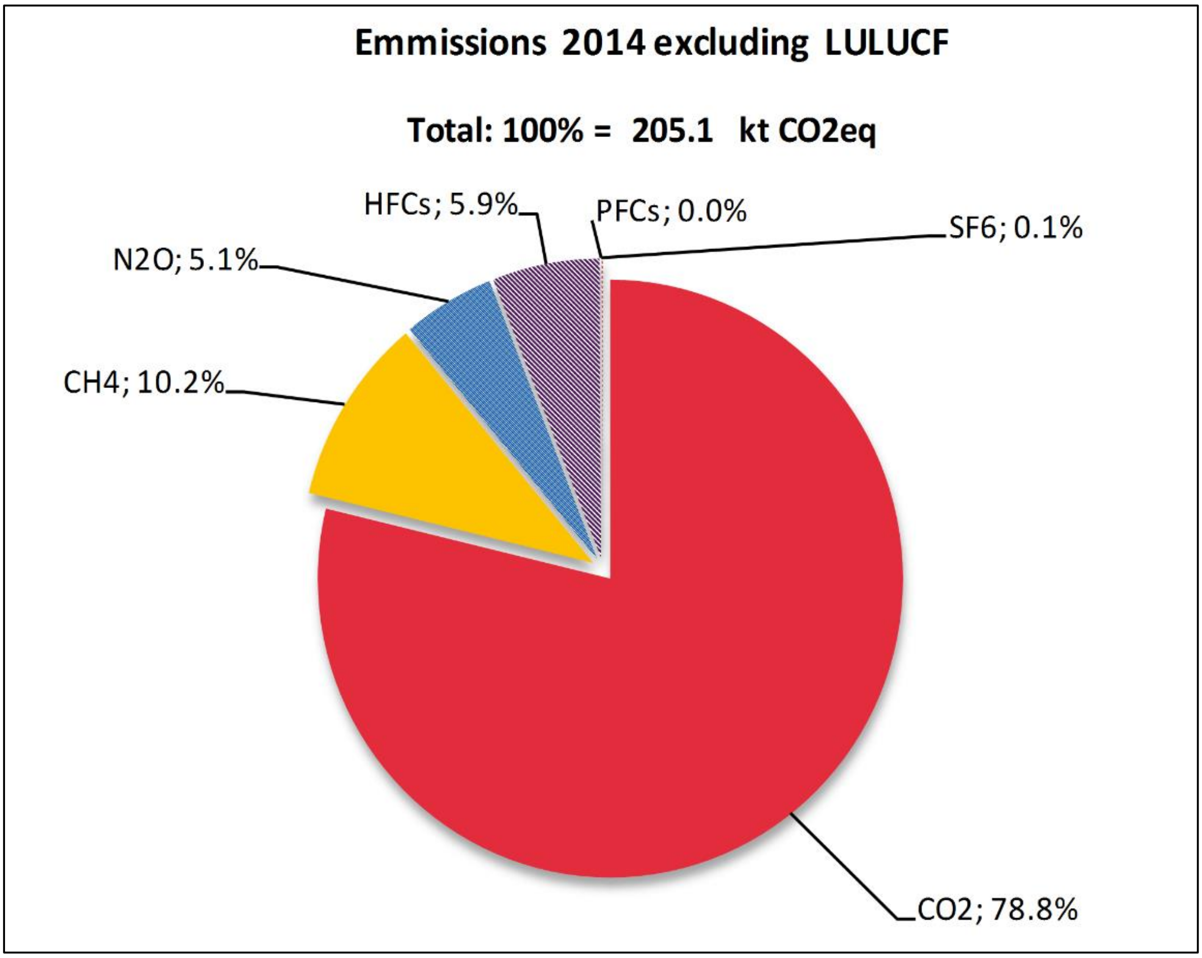
ES Table 1-1: Summary table afforestation and reforestation, deforestation, forest management and HWP.

Activity, year 2014	**Area** kha	**Net CO_2 emission/removal** kt CO_2	**N_2O emission** kt N_2O	**Net CO_2 eq emission/removal** kt CO_2 eq
A.1 Afforestation	0.036	-0.27	NO	-0.27
A.2 Deforestation	0.174	4.32	0.00021	4.38
B.1 Forest managment (FM)	6.127	5.14	NO	5.14
B.1.1 minus FMRL	---	-0.36	NO	-0.36
4.C HWP from FM	---	-1.40	NO	-1.40
Total emission/removal		7.42	0.00021	7.49

ES.3. Overview of source and sink category emission estimates and trends including KP-LULUCF activities

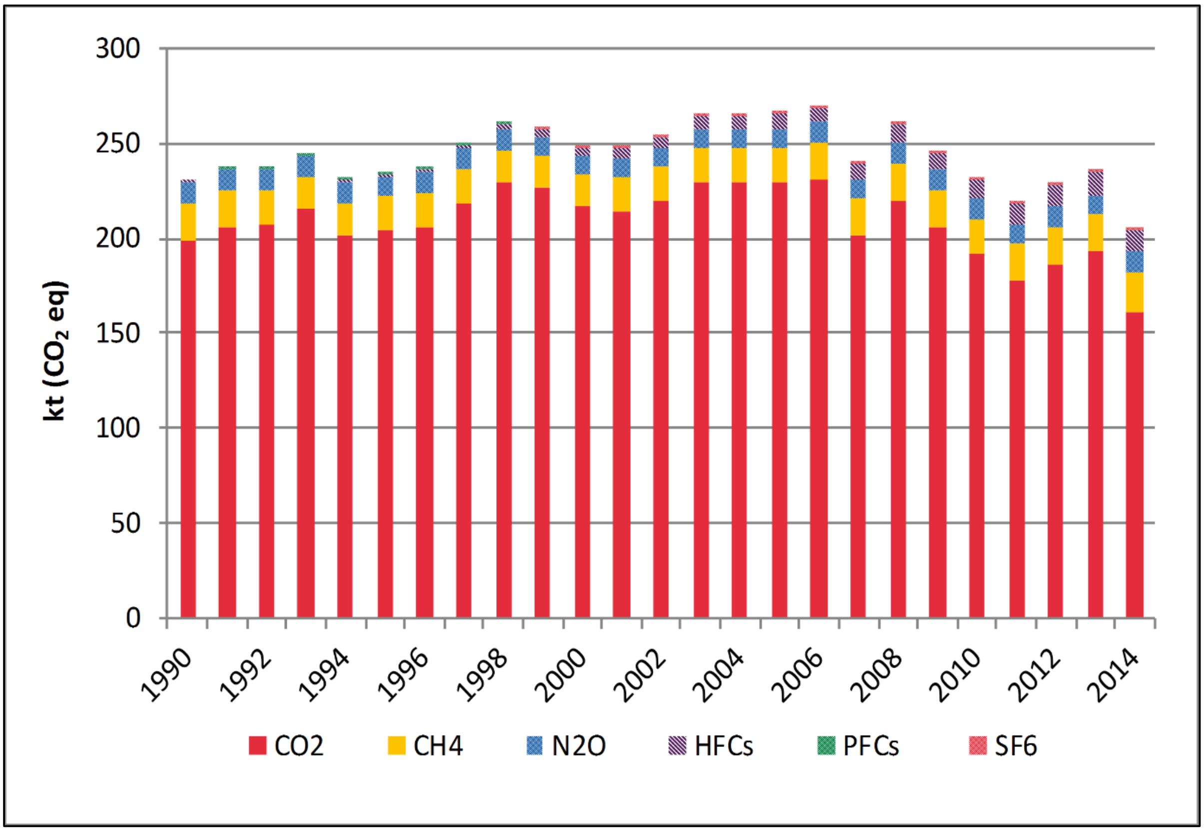
ES.3.1 GHG inventory

ES Figure 1-1 shows the emissions in 2014 by gases. The main GHG is CO_2 with a share of 78.8%. CH_4 and N_2O contribute with 10.2% and 5.1%, F-gases with 6.0%, respectively.



ES Figure 1-1 Liechtenstein's GHG emissions by gas (excluding LULUCF) in 2014.

ES Figure 1-2 illustrates that the 2014 shares are typical for the period 1990-2014. After increasing emissions between 1990 and 1998, the emissions fluctuate between 1998 and 2006 without any significant trend. After 2006 emissions show a decreasing trend while still showing fluctuations driven by the mean temperatures of winter seasons and fuel prices. In 2014, emissions reach an all time low due to the exceptionally warm winter season.



ES Figure 1-2 Trend of Liechtenstein's greenhouse gas emissions by gases 1990–2014. CO_2, CH_4 and N_2O correspond to the respective total emissions excluding LULUCF.

Over the period 1990-2014, the share of CO_2 fluctuated between 88.1% (1993) and 78.8% (2014). The share of CH_4 increased from 8.3% in 1990 to 10.2% in 2014. Simultaneously, the share of N_2O slightly increased from 4.9% (1990) to 5.1% (2014) and the share of F-gases clearly increased from 0.0% (1990) to 6.0% (2014). See ES Table 1-2.

ES Table 1-2 Summary of Liechtenstein's GHG emissions in CO_2 equivalent (kt) by gas, 1990–2014. The last column shows the percentage change in emissions in 2014 as compared to the base year 1990. The percentage change of HFCs amounts 116'335%.

Greenhouse Gas Emissions	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	CO_2 equivalent (kt)									
CO_2 emissions including net CO_2 from LULUCF	203.0	213.3	213.9	222.4	208.9	211.3	213.6	226.7	237.4	234.7
CO_2 emissions excluding net CO_2 from LULUCF	198.8	206.1	206.8	214.9	201.0	204.1	205.8	218.2	229.1	226.4
CH_4 emissions including CH_4 from LULUCF	19.1	18.9	18.5	17.7	17.8	17.7	18.1	17.8	17.6	16.9
CH_4 emissions excluding CH_4 from LULUCF	19.1	18.9	18.5	17.7	17.8	17.7	18.1	17.8	17.6	16.9
N_2O emissions including N_2O from LULUCF	11.5	11.7	11.6	11.4	11.3	11.2	11.2	11.2	10.9	10.7
N_2O emissions excluding N_2O from LULUCF	11.2	11.4	11.3	11.1	11.0	10.9	10.9	10.9	10.6	10.3
HFCs	0.0	0.0	0.1	0.2	0.5	1.4	1.7	2.1	2.7	3.3
PFCs	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SF_6	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.0
Total (including LULUCF)	233.6	244.0	244.1	251.7	238.6	241.6	244.7	257.8	268.6	265.7
Total (excluding LULUCF)	229.0	236.5	236.7	243.8	230.3	234.0	236.6	249.1	260.0	257.1

Greenhouse Gas Emissions	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	CO_2 equivalent (kt)									
CO_2 emissions including net CO_2 from LULUCF	224.8	224.0	229.6	239.5	239.0	238.5	239.7	209.6	228.6	219.9
CO_2 emissions excluding net CO_2 from LULUCF	216.8	214.6	219.9	229.3	229.3	229.0	231.2	200.9	219.7	205.6
CH_4 emissions including CH_4 from LULUCF	16.7	17.3	17.6	17.8	17.9	18.6	19.3	19.7	20.0	19.7
CH_4 emissions excluding CH_4 from LULUCF	16.7	17.3	17.6	17.8	17.9	18.6	19.3	19.7	20.0	19.7
N_2O emissions including N_2O from LULUCF	10.6	10.6	10.8	10.8	10.5	10.7	10.8	10.9	11.1	11.0
N_2O emissions excluding N_2O from LULUCF	10.2	10.3	10.4	10.4	10.1	10.3	10.4	10.5	10.7	10.6
HFCs	4.1	4.9	5.5	6.1	7.0	7.4	7.8	8.5	9.2	9.3
PFCs	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
SF_6	0.1	0.2	0.2	0.2	0.3	0.3	0.1	0.1	0.3	0.1
Total (including LULUCF)	**256.2**	**257.1**	**263.7**	**274.5**	**274.6**	**275.4**	**277.7**	**248.9**	**269.3**	**260.1**
Total (excluding LULUCF)	**247.9**	**247.3**	**253.7**	**263.9**	**264.5**	**265.5**	**268.9**	**239.8**	**260.0**	**245.4**

Greenhouse Gas Emissions	**2010**	**2011**	**2012**	**2013**	**2014**	**1990-2014**
	CO_2 equivalent (kt)					**%**
CO_2 emissions including net CO_2 from LULUCF	205.4	188.2	196.9	204.1	172.6	-15.0%
CO_2 emissions excluding net CO_2 from LULUCF	191.0	177.1	185.6	192.9	161.5	-18.7%
CH_4 emissions including CH_4 from LULUCF	19.1	19.6	20.0	19.2	20.9	9.3%
CH_4 emissions excluding CH_4 from LULUCF	19.1	19.6	20.0	19.2	20.9	9.3%
N_2O emissions including N_2O from LULUCF	10.7	11.1	11.1	10.8	10.8	-5.6%
N_2O emissions excluding N_2O from LULUCF	10.3	10.7	10.6	10.4	10.4	-7.0%
HFCs	10.3	10.8	11.5	12.0	12.1	see caption
PFCs	0.1	0.1	0.1	0.1	0.0	---
SF_6	0.0	0.0	0.0	0.2	0.1	---
Total (including LULUCF)	**245.6**	**229.8**	**239.5**	**246.3**	**216.7**	**-7.3%**
Total (excluding LULUCF)	**230.8**	**218.2**	**227.8**	**234.6**	**205.1**	**-10.5%**

ES Table 1-3 represents the GHG emissions and removals by categories. Sector 1 Energy is the largest source of national emissions, contributing to 80.1% of the emissions (excluding LULUCF) in 2014. Emissions caused within the energy sector decreased by 18.3% over the period 1990-2014. The emissions from sector 2 Industrial processes and product use increased by a factor of almost 27 (2'664%) due to a more frequent use of F-gases. Compared to total emissions, F-gas emissions still are of a minor importance. In sector 3 Agriculture, emissions are below the 1990 level (-4.4%). Emissions and removals in the sector 4 LULUCF form a net source in 2014 and show an increase of 152.3% compared to 1990. The emissions from sector 5 Waste have also increased since 1990, but notably they encompass only a small amount of emissions because municipal solid waste is exported to a Swiss incineration plant.

ES Table 1-3 Summary of Liechtenstein's GHG emissions by source and sink categories in CO_2 equivalent (kt), 1990–2014. The last column indicates the percent change in emissions in 2014 as compared to the base year 1990.

Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
1 Energy	**201.1**	**208.6**	**209.4**	**217.6**	**203.6**	**206.8**	**208.6**	**221.2**	**232.1**	**229.4**
1A1 Energy industries	0.2	0.9	1.9	2.0	1.8	2.1	2.6	2.5	2.9	2.9
1A2 Manufacturing industries and construction	36.3	36.0	36.3	37.6	35.6	35.7	35.8	37.6	40.4	39.9
1A3 Transport	76.7	90.1	89.4	87.2	79.9	81.9	83.2	86.8	86.4	90.5
1A4 Other sectors	87.4	81.3	81.3	90.2	85.7	86.5	86.4	93.5	101.6	95.3
1A5 Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8
2 IPPU	**0.5**	**0.4**	**0.5**	**0.6**	**0.9**	**1.7**	**2.1**	**2.4**	**3.0**	**3.6**
3 Agriculture	**25.5**	**25.5**	**24.8**	**23.8**	**23.8**	**23.7**	**23.9**	**23.5**	**23.0**	**22.1**
5 Waste	**2.0**	**1.9**	**1.9**	**1.9**	**2.0**	**1.9**	**2.0**	**1.9**	**1.9**	**1.9**
Total (excluding LULUCF)	**229.0**	**236.5**	**236.7**	**243.8**	**230.3**	**234.0**	**236.6**	**249.1**	**260.0**	**257.1**
4 LULUCF	**4.6**	**7.4**	**7.4**	**7.9**	**8.2**	**7.5**	**8.1**	**8.8**	**8.6**	**8.6**
Total (including LULUCF)	**233.6**	**244.0**	**244.1**	**251.7**	**238.6**	**241.6**	**244.7**	**257.8**	**268.6**	**265.7**

Source and Sink Categories	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
1 Energy	**219.9**	**217.6**	**222.8**	**232.2**	**232.0**	**231.8**	**234.1**	**203.9**	**222.8**	**208.6**
1A1 Energy industries	2.8	2.9	2.5	2.8	3.0	3.1	2.9	2.6	2.9	3.0
1A2 Manufacturing industries and construction	36.5	36.4	37.9	41.2	39.9	39.2	40.6	33.9	36.4	27.6
1A3 Transport	91.4	88.0	83.9	83.7	82.3	82.0	79.5	83.7	88.2	82.2
1A4 Other sectors	88.4	89.3	97.6	103.4	105.8	106.3	110.0	82.4	94.0	94.6
1A5 Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	0.8	0.9	0.9	1.0	1.0	1.2	1.2	1.2	1.3	1.2
2 IPPU	**4.5**	**5.4**	**6.0**	**6.7**	**7.5**	**7.9**	**8.2**	**8.9**	**9.8**	**9.7**
3 Agriculture	**21.5**	**22.5**	**22.9**	**23.0**	**23.0**	**23.5**	**24.6**	**24.9**	**25.1**	**25.0**
5 Waste	**2.0**	**1.9**	**2.0**	**2.1**	**2.0**	**2.2**	**2.0**	**2.1**	**2.3**	**2.0**
Total (excluding LULUCF)	**247.9**	**247.3**	**253.7**	**263.9**	**264.5**	**265.5**	**268.9**	**239.8**	**260.0**	**245.4**
4 LULUCF	**8.4**	**9.8**	**10.0**	**10.6**	**10.1**	**9.9**	**8.9**	**9.1**	**9.3**	**14.7**
Total (including LULUCF)	**256.2**	**257.1**	**263.7**	**274.5**	**274.6**	**275.4**	**277.7**	**248.9**	**269.3**	**260.1**

Source and Sink Categories	2010	2011	2012	2013	2014	1990-2014
	CO_2 equivalent (kt)					%
1 Energy	**194.1**	**180.1**	**188.7**	**195.9**	**164.3**	**-18.3%**
1A1 Energy industries	3.3	3.1	2.8	3.0	2.5	1329.1%
1A2 Manufacturing industries and construction	26.1	23.6	25.8	26.4	27.2	-25.2%
1A3 Transport	78.1	77.3	80.3	80.0	74.4	-3.1%
1A4 Other sectors	85.4	74.9	78.6	85.1	59.0	-32.5%
1A5 Other	NO	NO	NO	NO	NO	
1B Fugitive emissions from fuels	1.2	1.2	1.2	1.2	1.2	229.6%
2 IPPU	**10.5**	**11.0**	**11.8**	**12.4**	**12.5**	**2663.6%**
3 Agriculture	**24.2**	**24.9**	**25.1**	**24.0**	**24.4**	**-4.4%**
5 Waste	**2.0**	**2.2**	**2.2**	**2.3**	**4.0**	**95.2%**
Total (excluding LULUCF)	**230.8**	**218.2**	**227.8**	**234.6**	**205.1**	**-10.5%**
4 LULUCF	**14.8**	**11.5**	**11.8**	**11.7**	**11.6**	**152.3%**
Total (including LULUCF)	**245.6**	**229.8**	**239.5**	**246.3**	**216.7**	**-7.3%**

KCA:
In 2014, 12 among 196 categories were identified as key categories in level and trend analysis for Liechtenstein (excluding LULUCF), covering 96.2% of total greenhouse gas (GHG) emissions (CO_2 equivalent). There are three major sources, all from the energy sector, category 1A Fuel combustion, summing up to a contribution of 64.3% of the national total emissions:

- 1A3b Road transportation, CO_2,
- 1A4 Other sectors, liquid fuels, CO_2,
- 1A4 Other sectors, gaseous fuels, CO_2.

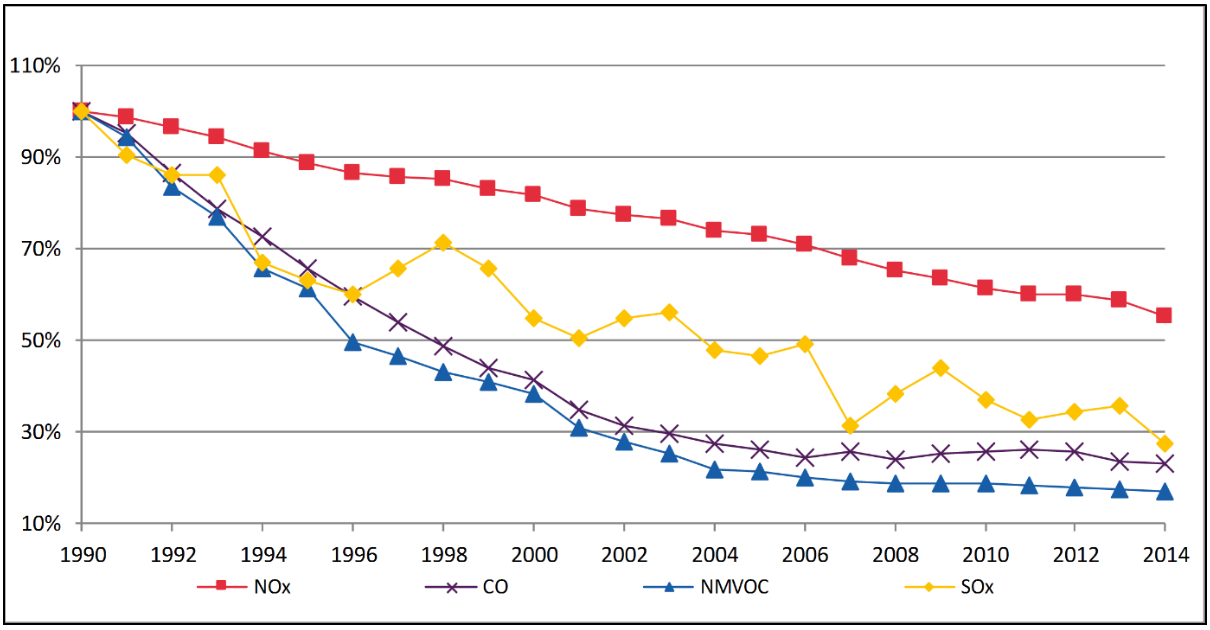
When including LULUCF categories in the analysis, 21 among 223 categories are key. Seven of the key categories are from the LULUCF sector. The largest category is 4B1 Cropland remaining cropland.

ES.3.2 KP-LULUCF activities

See ES 2.2 for KP-LULUCF overview.

ES.4. Other information

Liechtenstein is member to the Geneva Convention on Long-range Transboundary Air Pollution (CLRTAP) and submits emission data on precursor gases. For the substances NO_x, CO and NMVOC as well as for the gas SO_2, the emissions are shown in ES Figure 1-3 (and described in chp. 2), but they are not integrated in the reporting tables under the UNFCCC (CRF). Note that a number of improvements had been carried out for the submissions of 15th and 22nd February 2016 to the CLRTAP resulting in a recalculation of the time series of several pollutants. In addition, further improvements were realised since February, which has the consequence that the numbers in ES Figure 1-3 slightly deviate from those submitted to CLRTAP.



ES Figure 1-3 Trend of emissions of precursor gases NO_x, CO, NMVOC and SO_2 1990-2014.

Acknowledgement

Liechtenstein’s Office of Environment (OE) highly appreciates the generous support by the members of the GHG Inventory Core Group at the Swiss Federal Office of Environment (FOEN). The free use of methods and tools developed by the FOEN has been essential during the permanent development of Liechtenstein’s GHG inventory and its NIR.

The OE also gratefully acknowledges the support of the Agroscope Reckenholz-Tänikon Research Station. The use of the model developed by Agroscope greatly facilitated the calculation process of agricultural emissions and their uncertainties. 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 political level.

The OE also thanks the data suppliers of Liechtenstein: Office of Economic Affairs (OEA), Office of Statistics (OS), Office of Construction and Infrastructure (OCI), Liechtenstein's Gas Utility (LGV) and Electric Power Company (LKW), Liechtenstein’s Wastewater Administration Union (AZV), Swiss Helicopter AG, Swiss Federal Office of Civil Aviation (FOCA), Swiss Federal Office for the Environment (FOEN), the sectoral experts and the NIR authors. Their effort made it possible to finalise the inventory and the NIR even under difficult circumstances in the year 2016.

PART 1
Annual inventory submission

1 Introduction

1.1 Background information on Liechtenstein's greenhouse gas inventory, climate change and supplementary information of the Kyoto Protocol (KP)

1.1.1 Background information on climate change

In recent years, various research programs on the effects of global climate warming in the alpine region have been conducted (e.g. CH2014-Impacts 2014; CH2011 2011). The development so far and projections indicate that noticeable effects are to be expected. Changes to the permafrost line and water drainages will play a central role in this regard (North et al. 2007). Liechtenstein is also affected by these developments.

The expected impacts of climate change have primarily been studied in Switzerland, which is beside Austria one of the two neighbouring countries of Liechtenstein, and draw to a large extent on the findings of reports prepared by the Swiss Advisory Body on Climate Change (OcCC 2007; OcCC 2008; OcCC 2012) and the latest findings by the CH2014-Impacts study (CH2014-Impacts 2014) and the CH2011 (CH2011 2011) report, which documents the present state of knowledge. Also results of a report of the International Bodensee Conference have been considered with specific findings for Liechtenstein (IBK 2007).

In 2013 the Swiss Federal Office for the Environment FOEN and Meteoswiss (the Federal Office of Meteorology and Climatology) published a report, which shows the numerous indicators that demonstrate the changes in the climate in Switzerland, whether in the cryosphere, the hydrosphere, vegetation, human health, the economy or the society (FOEN/Meteoswiss 2013). Impacts are analysed quantitatively in the CH2014-Impacts (2014) study. The results are also representative for Liechtenstein. In addition, a climate risk analysis has been done for the alpine region of Switzerland (INFRAS/Egli Engineering 2015) in particular for the canton of Uri. The conditions in Liechtenstein are comparable with them of the Swiss Alps. The results can therefore give valuable insights about climate change related future risks.

Impacts

The mean annual temperature of Liechtenstein (location Vaduz) currently is 10.1°C (MeteoSwiss 2015a) for the reference period 1981-2010. The mean annual temperature increased by 0.7°C compared to the reference period 1961-1990 (MeteoSwiss 2015b). According to the Swiss Climate Change Scenarios CH2011 (2011) the future climate of Liechtenstein is expected to change significantly from present and past conditions. Depending on the scenarios the mean temperature will very likely increase by 2.7-4.8 °C until the end of the century. Figure 1-1 illustrates the past and future changes in seasonal temperature (left) and precipitation (right) over northeastern Switzerland. Summer mean precipitation is projected to decrease by 18-28%, depending on the considered scenario.

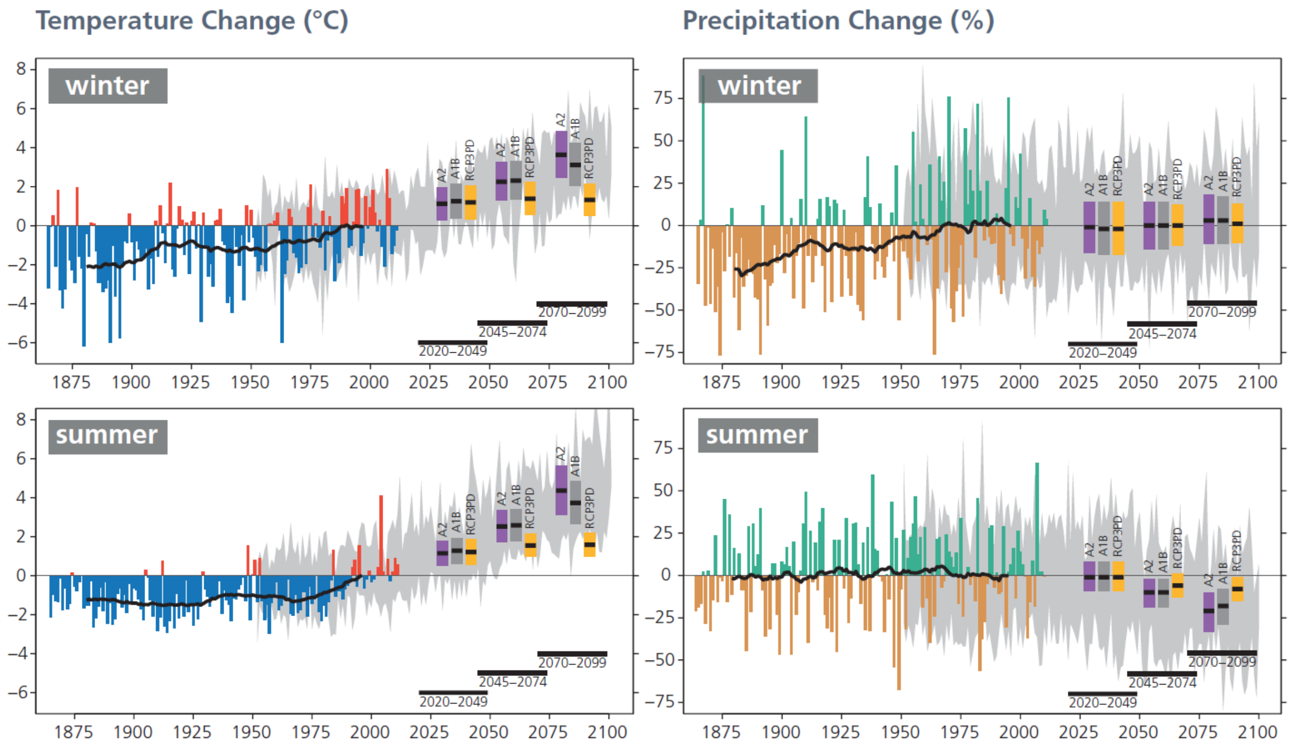


Figure 1-1 Past and future changes in seasonal temperature (°C) and precipitation (%) over northeastern Switzerland. The changes are relative to the reference period 1980-2009. The thin coloured bars display the year-to-year differences with respect to the average of observations within the reference period, the heavy black lines are the corresponding smoothed 30-year averages. The grey shading indicates the range of year-to-year differences as projected by climate models for the A1B climate scenario. The thick coloured bars show best estimates of the future projections, and associated uncertainty ranges, for selected 30-years time-periods and for three greenhouse gas emission scenarios (from CH2011, 2011).

Along with these changes in the mean temperature and precipitation, the nature of extreme events is also expected to change towards more frequent, intense and longer-lasting summers and heat waves (accompanied with drought events). The number of cold winter days and nights is expected to decrease. It is documented that the days with snow have decreased by 5 days per decade since 1960 in Switzerland (FOEN/Meteoswiss 2013). In addition, a shift from solid (snow) to liquid (rain) precipitation is expected, which would increase flood risk primarily in the lowlands (CH2011 2011).The warming trend and changing precipitation patterns are also expected to have significant effects on ecosystems. The Biodiversity Monitoring Switzerland[1] reports that impacts of climate change are being observed even within limited time frames. For instance, typical alpine vascular plants have shifted their distribution in the uphill direction during the past few years and phenological observations show that the biological beginning of spring has been advancing by 1.5 – 2.5 days per decade.

The expected increased intensity of storms and reduced snowfall and snow cover duration are particularly important for alpine areas, tourism and forestry due to more frequent floods, landslides and debris flows and an increase of threats by avalanches.
A risk analysis in Switzerland for the alpine canton Uri in Switzerland shows increasing risks for infrastructures because of rising flood and landslide intensity as well as an increasing number of hot days for the lower parts of the canton with significant impacts on human health (INFRAS/Egli

[1] http://www.biodiversitymonitoring.ch/en/home.html

Engineering 2015). The climate-related risks for Liechtenstein are expected to be similar but are not yet studied in detail.

Vulnerability assessments

It is difficult to transfer the consequences of global climate warming calculated on the basis of models to the spatial scale of Liechtenstein (160 km^2). The available climate models are not yet able to predict detailed regional consequences. Overall, the following general effects can be expected as a consequence of further increasing CO_2 concentrations and the associated rise in temperature.

Health: the increase in intensity of heat waves in combination with high tropospheric ozone concentrations represents the greatest risk that climate change poses to people's health (see INFRAS/Egli Engineering 2015). Another important health risk of climate change is the occurrence of vector-borne diseases. There is still predominant uncertainty about what future developments will trigger further health issues.

Ecosystems: temperature warming changes the composition of forest and grasslands vegetation. Deciduous trees may become more important than today. Additional weather instabilities (e.g. storms, avalanches, and debris flows) may have further negative effects on forest and vegetation in general. The invasion of non-native species is a further unknown risk in terms of the overall forest and grassland composition. The same risks apply to the fauna.

Water cycles and soil: the increasing weather instabilities may lead to floods in winter and droughts in summer time. A great danger in this regard exists in the narrow Alpine valleys (mountain streams), where various protective measures (e.g. rock fall barriers and water course corrections) become vital. A further danger is posed by the Rhine: Although regulated, the river may endanger the intensively used valley floor in the event of a flood.

Tourism: within the next decades Liechtenstein's tourism sector will have to deal with great challenges caused by climate change related developments in Liechtenstein's ecosystems. Especially winter tourism will be hit by higher temperatures and the rise of the freezing level will lead to higher snow lines.

Other economic sectors: global climate warming will affect further economic sectors in Liechtenstein. Because of the processes described above, agriculture and forestry will be affected directly. A rise in temperature may have a negative effect on the productivity of grain cultivation in the long term but could also bring positive effects. The expected increase in elevation of the snow lines and increasing weather instability also have an effect on the economically important recreation resorts in Malbun and Steg. The international engagement of the insurance sector will likely suffer the most severe negative consequences from an increase in the probability of losses.

Adaptation/mitigation

The projected consequences of an ongoing climate change require the immediate implementation of the so called Two-Pillar-Strategy – Mitigation (Pillar1) and Adaptation (Pillar 2).

Mitigation: reduction of greenhouse gas emissions can only be achieved if concrete measures are implemented in due time. Liechtenstein has launched a set of measures to address the problem of growing greenhouse gas emissions such as the most recent Energy Strategy 2020 (Government 2012), Emissions Trading Act (Government 2012), Energy Efficiency Act (Government 2008), CO_2-Act (OE 2013b), Environmental Protection Act (OEP 2008b), National Transport Policies, National Climate Protection Strategy (Government 2015) and Action Plan on Air (OEP 2007e). Liechtenstein's climate policy goal is – in the midterm – to fulfil the obligations originating from the Kyoto Protocol. The mitigation measures however will be further developed, especially with respect to sectors that have not yet been totally included into strict climate change regulation (e.g. traffic and transportation).

Adaptation: it is already known that certain consequences related to climate change will become irreversible. Therefore, pillar 2 deals with the question of how these future threats could be addressed and how potential future damages can be limited or even avoided. Liechtenstein's Climate Change Adaptation strategy is currently in preparation.

Natural hazard: Liechtenstein has established so called "Geological Risk Maps" with a special focus on residential areas. These maps provide regional information on specific risks from avalanches, rock- and landslides and flooding.

Agriculture: identified adaptation measures are an increased use of appropriate corn provenances that have already anticipated future conditions of the changing environment. However, the use of genetically modified crops is not foreseen. Irrigation of agricultural fields will increase resulting in conflicts with other public interests, especially during longer draught periods.

Forestry: increase of draught periods with respective damages caused by insects, pathogens (viruses, bacteria, fungus), fire or storms will lead to a decrease of the protection functions of forests in Liechtenstein. Adaptation measures that address the problems of these projected situations and which are already implemented are the conversion of spruce and fir stocks into mixed deciduous and coniferous forests.

Tourism: in this sector further efforts need to be considered within the next years. The production of artificial snow, as currently practiced, is not considered to be a sustainable solution to address the lack of snow in skiing resorts. Various municipalities and institutions have already introduced new options for winter and summer tourism in order to counter potential revenue losses. Thereby, the focus lies on strategies to promote a "gentle tourism".

1.1.2 Background information on greenhouse gas inventory

Framework

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. On 23 April 2015 Liechtenstein submitted its "Intended Nationally Determined Contribution (INDC)" to the UNFCCC, which aims at a reduction of greenhouse gases by 40% compared to 1990 by 2030.

Former submissions and submissions under the first commitment period (2008-2012)

In 1995, 2001, 2005, 2010 and 2014 Liechtenstein submitted its National Communication Reports to the secretariat of the UNFCCC. Greenhouse Gas Inventories and National Inventory Reports were submitted in the following years:

- 2005: The first Greenhouse Gas Inventory of Liechtenstein was submitted in the Common Reporting Format (CRF) without National Inventory Report.
- 2006: The first submission took place on May 31 including the national greenhouse gas inventory for 1990 and 2004 as well as the National Inventory Report. A re-submission on 22 December 2006 contained the national greenhouse gas inventory for the whole time period 1990–2004, the National Inventory Report 2006 (OEP 2006) and the Initial Report under Article 7, paragraph 4 of the Kyoto Protocol including a Corrigendum (OEP 2006a, 2007a, 2007b).
- 2007: Submission of the Greenhouse Gas Inventory 1990–2005 together with the National Inventory Report 2007 on 10 May 2007 (OEP 2007).

- 2008: Submission of the Greenhouse Gas Inventory 1990–2006 together with the National Inventory Report 2008 prepared under the UNFCCC and under the Kyoto Protocol on 29 February 2008 (OEP 2008).
- 2009: Submission of the Greenhouse Gas Inventory 1990–2007 together with the National Inventory Report 2009 prepared under the UNFCCC and under the Kyoto Protocol on 2 April 2009 (OEP 2009). Furthermore, the Standard Electronic Format application (SEF) was submitted.
- 2010: Submission of the Greenhouse Gas Inventory 1990–2008 together with the National Inventory Report 2010 prepared under the UNFCCC and under the Kyoto Protocol on 11 March 2010 (OEP 2010). Additionally, the Standard Electronic Format application (SEF) was submitted. Submission 2010 incorporated the new guidelines: Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol (IPPC 2009).
- 2011: Submission of the Greenhouse Gas Inventory 1990–2009 together with the National Inventory Report 2011 prepared under the UNFCCC and under the Kyoto Protocol on 11 March 2011 (OEP 2011). Additionally, the Standard Electronic Format application (SEF) was submitted.
- 2012: Submission of the Greenhouse Gas Inventory 1990–2010 together with the National Inventory Report 2012 prepared under the UNFCCC and under the Kyoto Protocol on 11 March 2012 (OEP 2012b). Additionally, the Standard Electronic Format application (SEF) was submitted.
- 2013: Submission of the Greenhouse Gas Inventory 1990–2011 together with the National Inventory Report 2013 prepared under the UNFCCC and under the Kyoto Protocol on 15 March 2013 (OE 2013). Additionally, the Standard Electronic Format application (SEF) was submitted.
- 2014: Submission of the Greenhouse Gas Inventory 1990–2012 together with the National Inventory Report 2014 prepared under the UNFCCC and under the Kyoto Protocol on 15 March 2014 (OE 2014). Additionally, the Standard Electronic Format application (SEF) was submitted. The submission 2014 was simultaneously the ending of the first commitment period.

Review processes of former submissions and submissions under the first commitment period (2008-2012)

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). The consequences are documented in the reports of the review of the initial report of Liechtenstein (FCCC/IRR 2007) and of the individual review of the greenhouse gas inventory of Liechtenstein submitted in 2006 (FCCC/ARR 2007). Due to the recalculation, the time series of the national total of emissions slightly changed and therefore, Liechtenstein's assigned amount has been adjusted by -0.407%. The modifications are documented in a Response by Party and a Corrigendum to the Initial Report (OEP 2007a, 2007b).

Furthermore, in September 2008, a centralized review of Liechtenstein's GHG inventories and NIRs of 2007 and 2008 took place in Bonn, Germany with results documented in FCCC/ARR (2009). Further centralized reviews took place in September 2009 (inventory and NIR of 2009, FCCC/ARR 2010), in September 2010 (inventory and NIR 2010, FCCC/ARR 2010a), in September 2011 (inventory 1990–2009 and NIR 2011, FCCC/ARR 2011) and in September 2012 (inventory 1990–2010 and NIR 2012, FCCC/ARR 2012).

Between 2 and 6 September 2013 a second individual (in-country) review took place in Vaduz. Again, the submission documents, GHG inventory 1990-2011 including CRF tables and the National

Inventory Report were examined during the review. Following the recommendations of the expert review team, numerous improvements were implemented in the submission 2014. Amongst others, this included methodological changes where data is delineated from the Swiss inventory (sectors Energy, Industrial processes and Solvents) and complementation of the text in the NIR for transparency reasons. The recommendations by the ERT are documented in the report of the individual review of the greenhouse gas inventory of Liechtenstein submitted in 2013 (FCCC/ARR 2013). However, since the report was finalized late in the update phase of the NIR, not all of the recommendations were already implemented for the submission 2014. Furthermore recommendations from ARR 2012 and from discussions during the in-country review were considered for the report 2014. From the in-country review no Friday Paper[2] resulted and no resubmission of the inventory 2011 was requested for the submission 2014.

The latest centralized review took place in September 2014 focused on issues related to the end of the first commitment period 2008-2012 and compliance of the guidelines (FCCC/ARR 2014). The ERT found potential underestimations within the agricultural, LULUCF and waste sectors. Liechtenstein followed the recommendations of the ERT and recalculated the emissions of these specific sectors. The resubmission of 03 November 2014 took the specific recommendations into account (OE 2014b).

Submissions under the second commitment period (2013-2020)

During its October 2014 session the Liechtenstein Parliament approved the second commitment period of the Kyoto Protocol accepting a 20% reduction until 2020.

- 2016: Submission of the Greenhouse Gas Inventory 1990-2013 together with the National Inventory Report 2015 prepared under the UNFCCC and under the Kyoto Protocol on 15 April 2016 (OE 2016a).
- The present report is Liechtenstein's 11th National Inventory Report, NIR 2016, prepared under the UNFCCC and under the Kyoto Protocol. The present report includes, as separate files, Liechtenstein's 1990–2014 Inventory in the CRF Reporter format and the updated Standard Electronic Format application (SEF). As there were no CP2 transactions so far, no SEF reports for CP2 were submitted.

Review processes and the second commitment period (2013-2020)

No review has been conducted so far under the second commitment period. The review of the GHG inventory and NIR 2015 will take place simultaneously to the review of the GHG inventory and NIR 2016 due to the postponed submission 2015.

1.1.3 Background information on supplementary information required under Art. 7.1. KP

Chapter 11 of this NIR and Liechtenstein's Second Initial Report under the Kyoto Protocol (Government 2016) provide information on KP-LULUCF.

Liechtenstein only accounts for the mandatory activity Forest Management under Article 3, paragraph 4 of the Kyoto Protocol. In accordance with Annex I to Decision 2/CMP.7 (Annex I, Para 13), credits from Forest Management are capped in the second commitment period. Thus for Liechtenstein the cap amounts to 3.5% of the 1990 emissions (excluding LULUCF).

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[2] A list of potential problems from the ERT formulated at the end of the 2013 review, for which party's responses to the ERT are required within 6 weeks.

Liechtenstein will choose to account over the entire commitment period for emissions and removals from activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol. In addition to the mandatory submission of the inventory years 2013 and 2014, data for the years 2008-2012 are available and shown in Liechtenstein's NIR.

1.2 National inventory arrangements

1.2.1 Institutional, legal and procedural arrangements

The Office of Environment (OE) is in charge of compiling the emission data and bears overall responsibility for Liechtenstein's national greenhouse gas inventory. In addition to the OE, the Office of Economic Affairs (OEA), the Office of Statistics (OS) and the Office of Construction and Infrastructure (OCI) 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 37'366 inhabitants (2014) and with an area of 160 km^2. Liechtenstein and its neighbouring country Switzerland form a customs and monetary union governed by a customs treaty (Government 1980). 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 European Economic Area. The Customs Union Treaty with Switzerland impacts greatly on environmental and fiscal strategies. Many Swiss levies and regulations for special goods, for example, environmental standards for motor vehicles and quality standards for fuels 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 Environment (OE) 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.

1.2.2 Overview of inventory planning, preparation and management

Note that the inventory planning for the current submission 2016 was performed in a different manner than in the preceding years of the first commitment period. Due to the transition to the new UNFCCC and IPCC guidelines (see chp. 1.2.4) and subsequent delay in the preparation of the CRF Reporter software, the preparation and the submission of the GHG inventory was shifted accordingly for several months from autumn/winter 2015/2016 to winter/spring 2016:

- January-March 2016 Emission modelling, CRF tables
- April 2016 QC GHG inventory, KCA; uncertainty analysis
- April-May 2016 NIR editing, internal review, QA/QC procedures
- end of May 2016 Submission of GHG inventory and NIR

For the former inventory cycles, the process of inventory planning, preparation and management in Liechtenstein is well-established. Inventory planning, preparation, and management follow an annual cycle according to an official schedule (Table 1-1). The planning of the inventory starts with the initial reporting meeting in June where the head of the inventory group and quality manger, the project manager and NIC, the project manager assistant as well as the emission modeler and the NIR authors participate. At the initial meeting the work scheduled and priorities with regard to inventory development are set. Decisions regarding planned improvements are taken as well using the latest key category analysis to prioritize the enhancements. Source and sink categories which are key categories and hence need an additional improvement because of the recommendation by the ERT are usually planned to implement in the next annual submission (priority 1) unless specified otherwise. All other potential improvements are planned to implement (priority 2) depending on available resources (see IDP in Annex 8.3). The entire data compilation process lasts from June to October including multiple quality control activities, in particular including quality checks of different versions of the reporting tables (CRF) from October to December. At the end of the annual process, the official UN review process in August and September provides further input for inventory improvements and therefore, also for the inventory development plan (IDP).

After inventory preparation the NIR is passed through a multistage quality control cycle too (see Table 1-1). NIR authors, the emission modeler, the head of the inventory group, the project manager and the project manager assistant as well as additional people of the Office of Environment (OE) and sector experts review the drafts of the NIR mutually. Thus, a maximum of quality assurance can be achieved. If the internal review suggests large revisions, they are taken up in the inventory development plan for future improvements too. Archiving of inventory material is made after submission by the OE and sectoral experts, by the contributing authors and by the QA/QC officer.

Table 1-1 Annual cycle of inventory planning, preparation and management. The inventory cycles in 2015 and 2016 deviated uniquely (see text) due to the transition to the new UNFCCC and IPCC guidelines.

Process	Month											
	June	July	August	September	October	November	December	January	February	March	April	May
Initial meeting	■											
Data compilation	■	■	■	■	■							
CRF as 1st draft version					■							
QC of the CRF 1st draft version					■							
CRF as complete draft						■						
QC of the complete CRF draft						■						
Final CRF version						■	■					
Preparation of the NIR				■	■	■	■	■	■	■		
1st draft version NIR							■					
QC 1st draft version NIR								■				
2nd draft version NIR										■		
QC 2nd draft version NIR										■		
Final version NIR										■		
Submission final NIR and final CRF's											■	
Official UN review process			■	■								
Archiving												■

Further inventory preparation and management activities are described in chapter 1.3.

1.2.3 Quality assurance, quality control and verification plan

According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) the major elements of a QA/QC and verification system are:

- Participation of an inventory compiler who is also responsible for coordinating QA/QC and verification activities and definition of roles/responsibilities within the inventory;

- A QA/QC plan;
- General QC procedures that apply to all inventory categories;
- Category-specific QC procedures;
- QA and review procedures;
- QA/QC system interaction with uncertainty analyses;
- Verification activities;
- Reporting, documentation, and archiving procedures.

The implementation status 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 needs to be established by a formal agreement due to short "distances" within the administration and due to a high degree of acquaintance between the persons involved. Therefore, the National System manages with little number of written documents.

The QA/QC activities are coordinated by the quality manager of the GHG Inventory Group. The responsible person is Mr. Andreas Gstoehl, head of the Environmental Protection unit (e-mail: Andreas.gstoehl@llv.li, phone: +423 236 61 86) in the Office of Environment (OE). The QA/QC activities are organised within the Inventory Group, see National System depicted in Figure 1-2.

Operational tasks are delegated to the NIR lead author. He distributes checklists to the project manager being also the National Inventory Compiler, to the sectoral experts and to other NIR authors. They fill in the procedures that they carried out. The lists are then sent back to the quality manager, who confirms the performance of the QA/QC activities. The activities are documented in the NIR (see Annex 8).

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.

1.2.3.1 Quality assurance/quality control (QA/QC) procedures applied

Quality assurance (QA)

According to IPCC (2006) quality assurance (QA) comprises activities outside of the actual inventory compilation. QA procedures include reviews and audits to assess the quality of the inventory, to determine the conformity of the procedures taken and to identify areas where improvements could be made. QA procedures are used in addition to the general and category-specific QC procedure. It is important to use QA reviewers that have not been involved in preparing the inventory (IPCC 2006).

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 2006 IPCC Guidelines (IPCC 2006).

Liechtenstein carries out the following QA activities:

- Internal review: The draft NIR is passing an internal review. The project manager also being the NIC, the project manager assistant, specialised staff members of the climate unit and other staff member of the OE are proofreading the NIR or parts of it (all personnel not directly involved in the preparation of a particular section of the inventory). They document their findings in checklists, which are sent back to the NIR authors (see Annex 8).
- The Swiss inventory management involves 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 as well, the results of the Swiss QA activities are checked and analysed by Liechtenstein's experts as well. Positive reviews may be interpreted as positive for Liechtenstein too, and problematic findings must not only be taken into account in Switzerland but also in Liechtenstein. The following sectors have already been reviewed:
    - A consulting group (not involved in the GHG emission modelling) was mandated to review the two sectors Energy and former Industrial Processes with respect to methods, activity data, emission factors, CRF tables and NIR chapters (Eicher and Pauli 2006). The results were documented in a review report and communicated to Liechtenstein's Inventory Group. Regarding the topics, influencing GHG emissions, only minor issues were identified. The main issue of the Swiss inventory was the problem of transparency which has been solved in recent years. Concerning Industrial Processes of Liechtenstein, emissions in 2F1 and 2F7 were affected from the findings above. Other industrial processes are not occurring in Liechtenstein. The consequences for the main findings were evaluated for Liechtenstein's GHG inventory and for the NIR for submission December 2006.
    - The Swiss Federal Institute of Technology (ETH) was mandated to review the methane emissions of agriculture with respect to methods, activity data and emission factors. The results were documented in two reports (Soliva 2006, 2006a) 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.
    - The waste sector of Switzerland was reviewed by a peer expert group in 2009. The reviewers concluded that waste related emissions are calculated in a plausible way and that results from the report are plausible. The emission factors as well as activity data are based on reliable and solid sources. For details see Rytec (2010). Furthermore in the so called FOCAWIN study by EMPA (Mohn 2011), the share of fossil matter in municipal waste in 2011, has been reviewed. The consequences for the main findings had been evaluated for Liechtenstein's GHG inventory and had been accounted for in the submission April 2013.
    - An expert peer review of the LULUCF sector of the Swiss GHG inventory took place in 2010. The reviewers concluded that "the LULUCF sector of the Swiss greenhouse gas inventory is proved to be of superior quality, good applicatory characteristics and scientifically sound applied definitions and methodology". For details see vTI (2011).
    - Furthermore, in 2012 a Swiss national review of the former sector 2 Industrial Processes took place (CSD 2013). The final report has been evaluated and suggestions for improvement were implemented in the subsequent submissions of both, Switzerland's and Liechtenstein's, reports.

- For the Swiss NIR, an annual internal review takes place 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. If methods and results are affected, which are relevant for Liechtenstein too, the consequences are taken into account accordingly. This procedure has been performed in the last and the current submissions (May and December 2006, May 2007, February 2008 and in April for the years 2009-2016). It will also be repeated for future submissions.

- The applicability of Swiss methodologies and emission factors to Liechtenstein's GHG inventory was reviewed as well: before Swiss methods were applied, they were discussed with the experts of Liechtenstein's administration. This process had taken place before the submission in December 2006 for the sectors energy, former industrial processes, former solvent and other product use, agriculture and waste, for the sector LULUCF before the submission in February 2008. Since then, the issue is a permanent point on the agenda of the annual kick-off meetings of the Inventory Group. Potential modifications or updates of the Swiss emission factors are discussed and checked upon their applicability for Liechtenstein's GHG inventory
- For the sector LULUCF a new external reviewer were mandated in 2012 (Meteotest 2012). The entire LULUCF sector was revised and brought in line with the IPCC methodology.

Quality control (QC)

General QC procedures include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory source and sink categories (IPCC 2006).

The following QC activities are carried out:

- The annual cycle for inventory preparation contains meetings of the inventory group and meetings of governmental and other data suppliers with the OE. In these meetings the activities, responsibilities and schedule for the inventory preparation process are being organised and determined.
- Regular meetings within the Office of Environment (OE) in particular between Heike Summer (project manager) and Andreas Gstöhl (head of the Environmental Protection unit / head of the inventory group / quality manager) take place. Beside technical issues also political topics are discussed. As needed, important information is referred to the department or ministry. To this regular meetings between Andreas Gstöhl and Helmut Kindle (chief officer/ national focal point) take place as well.

The project manager, also operating as the national inventory compiler (NIC), the sectoral experts, and the NIR authors accomplish a number of QC activities:

- The NIR authors check the emission results produced by the sectoral experts, for consistency of cross-cutting parameters, correctness of emissions aggregation, and completeness of the GHG inventory. They compare the methods used with 2006 IPCC Guidelines (IPCC 2006), 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 as well as the completeness of references in the NIR. Furthermore, they are responsible for the correctness of the key source, the uncertainty analysis and the complete implementation of specific planned improvements of the inventory development plan.

- The sectoral experts check the description of methods, numbers and figures in the NIR. They further incorporate recommendations by the ERT into respective text passages.
- The NIC checks the integrity of the database files, the consistency of time series, the correct and complete inputs into the CRF Reporter. A final data check is done by comparison of random data fields with the provided data data modelling.
- Further staff members of the OE carry out a proof reading of single sectors.
- The project manager executes an overall checking function for the GHG inventory and the NIR: monitoring of the GHG emission modelling and key category analysis. The project manager checks the NIR for correctness, completeness, transparency and quality, checks for the complete archiving of documents and the completeness of the CRF submission documents.
- It may be mentioned that the OE raised its number of staff in the Climate Protection unit in the beginning of 2007 by two employees. They are responsible for emission modelling, GHG inventory, implementation of the emission trading system, national emissions trading registry, national allocation of emission quotas and the Kyoto mechanisms (JI, CDM).
- In order to provide an overview and to increase transparency, all authors, experts, and involved staff members of Liechtenstein's government are listed in a separate table together with specific descriptions about their responsibilities. This table is available for the entire reporting period and helps to improve the QC management in general.
- The CRF Reporting Tables for the current submission, exported from the CRF Reporter software, underwent an iterative quality control in a triple check:
    - The emissions of the year 2014 were compared with those of the year 2013 within the current Reporting Table Summary2.
    - The emissions of the year 2013 were compared between the current Reporting Table Summary2 of submission 2016 and the Reporting Table Summary2 of submission 2015.
    - The emissions of the base year 1990 were compared between the current Reporting Table Summary2 and the Reporting Table Summary2 of the submission 2015.

  The CRF Reporting Tables Summary2 are compared using Excel. For the comparable emissions and sinks the ratios in percent were calculated and the deviations from 100% were analysed. The findings due to this check were discussed among the core group members and the modelling specialists. Anomalies in data were investigated and explanations for those were sought. This procedure led to the identification of several errors in data, which were subsequently corrected before the current submission.

The current NIR passes several quality controls. Table 1-1 illustrates the official quality control procedure of Liechtenstein's NIR. The first internal NIR draft is cross-checked by the NIR authors in terms of correctness, completeness, consistency and layout. The Office of environment (OE) and the emission modeller review the entire NIR as external experts because experts of the OE are not directly involved in updating the NIR. They check the first draft of the NIR in detail and provide a detailed feedbacks on data, interpretation, completeness, consistency, transparency and implementation of the issues given by Liechtenstein's inventory development plan (see chapter 1.2.3.2). The review forms for the OE experts and the emission modeller are attached in Annex 8. Afterwards, the NIR authors improve the NIR considering the revisions made by the OE experts and prepare the second internal draft, which also undergoes an internal cross-check. This second NIR draft again is reviewed by the OE and the emission modeller. Their inputs are implemented within the NIR too. The NIR authors complete the final NIR version including last internal cross-checks. The

Office of Environment (OE) then submits the official National Inventory Report (NIR). This process guarantees the compliance of the QA/QC requirements according to the IPCC guidelines (IPCC 2006).

1.2.3.2 QA/QC plan

The QA/QC activities are well established and part of the entire inventory process. For detailed information see chapters above. Planned improvements are also documented in Liechtenstein's inventory development plan (IDP). The IDP summarizes all issues resulted from internal and external QA/QC activities, in particular from recommendations made by the ERT. As described above, future improvements are prioritized according to the latest key category analysis.

The inventory development plan (IDP) has been revised for submission 2016. Beside information about the current improvements also information about improvements of previous submissions has been included in the IDP (see Annex 8.3 and 8.4).

Former reviews and recommendations made by the ERT

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 changed and therefore, Liechtenstein's assigned amount has been adjusted by -0.407%. After this correction, Liechtenstein's assigned amount has been fixed to 1055.623 Gg CO_2 equivalents.

Between 2nd and 6th September 2013 the second in-country review was conducted in Vaduz as mentioned in Chapter 1.1.2. The recommendations by the ERT are documented in the report of the individual review of the greenhouse gas inventory of Liechtenstein submitted in 2013 (FCCC/ARR 2013).

In September 2008, 2009, 2010, 2011, 2012 and 2013 centralized reviews of Liechtenstein's GHG inventories and NIRs of 2007/2008, 2009, 2010, 2011, 2012 and 2013 took place in Bonn, Germany. Important recommendations were integrated in former versions of Liechtenstein's IDP.

The latest centralized review of Liechtenstein's GHG inventory and NIR of the submission 2014 took place in September 2014. The findings were summarized in the latest ARR (FCCC/ARR 2014). Although the report was published before the final submission 2015 not all recommendations are incorporated in the current inventory development plan due to focus on the implementation of Liechtenstein's emissions into the current CRF reporter as well as on the implementation of the requirements related to the new reporting guidelines (IPCC 2006) in the NIR. More details see next paragraph.

Inventory development plan (IDP)

In the NIR 2015, IDP tables depicted recommendations and encouragements from the ERT and other improvements concerning the NIR which

- had been incorporated into the NIR 2015, see pp. 32-35 of OE 2016a,
- planned improvements for future submissions, p. 273 of OE 2016a
- improvements not yet implemented, see p. 275 of OE 2016a
- improvements that will not be implemented, see pp. 276-277 of OE 2016a

- improvements that had been implemented in former submissions (2104 and before), see pp. 273-283 of OE 2016a

From the planned improvements mentioned above the following have been realised for the current submission 2016:

- Sector Energy: Liechtenstein plans to use NCV and CO_2 emission factors according to the official energy statistics (see chp.3.2.4.1).
- Sector Energy and Waste: Implementation of biogas production from a waste water treatment plant including processing of the sewage gas to the quality of natural gas and supply into the gas distribution system.

Planned improvements see sector chapters and a summary in chp. 10.4 of this NIR. Improvements that will not be implemented, see. Annex A8.3.

Switzerland's QC-plan with implications for Liechtenstein

In addition, Liechtenstein will also benefit from Switzerland's future QA activities and its QA plan, as described in chp. 1.2.3.1. Because all important sectors were already reviewed by external experts, no future reviews are planned so far.

1.2.3.3 Verification activities

Verification activities were conducted in various steps of the development of the inventory. As Liechtenstein compiles its inventory in close collaboration with Switzerland concerning the methods and models used, continuous comparison between the two inventories is taking place.

In many cases the same emission factors as in the Swiss NIR are applied. Therefore, those factors are checked when copied from the Swiss NIR and correlation thus depends on activity data. As both countries have used similar methodologies, comparable economic structure, similar liquid/gaseous fuels mixes and vehicle fleet composition, the comparison of total per capita CO_2 emission indicates completeness of source categories:

- If the national total emissions (without LULUCF) of the two countries are compared, very similar and highly correlated trends may be found. In 1990, Liechtenstein's emissions were 0.430% of the Swiss emissions. After a slight increase between 1993 and 2009, the share in 2014 reached 0.422%. In the same period, the share of inhabitants increased slightly from 0.43% to 0.45%. This correlation may be interpreted as a simple form of verification, since Liechtenstein has used the same or similar methods and EF for many sectors, in which activity data is linked to the number of inhabitants.
- Another indirect verification may be derived from the ambient air pollutant concentration measurements. Liechtenstein is integrated in a monitoring network of the Eastern cantons of Switzerland (www.ostluft.ch). The results are commonly analysed and published (OSTLUFT 2015). They show that the local air pollution levels of NO_2, O_3 and PM10 in Liechtenstein vary in the same range as in the Swiss neighbouring measurement sites.

1.2.3.4 Treatment of confidentiality issues

In Liechtenstein all activity data and emission factors are publicly available and not subject to confidentiality treatment. However, some emission factors used from Switzerland might see confidentiality restrictions in the Swiss NIR and thus also for this report.

1.2.4 Changes in national inventory arrangements since previous inventory submission

Changes to institutional, legal and procedural arrangements (24/CP.19, 22. (a))

There are no changes to arrangements with other institutions. The agreements regarding responsibilities and deliverables are maintained. On the other hand, the NIR authors and the emission modeller remained the same as for previous submissions[3]. This also guaranteed continuity in inventory preparation.

Changes in staff and capacity (24/CP.19, 22. (b)

No changes.

Changes to national entity with overall responsibility for the inventory (24/CP.19, 22. (c))

No changes.

Changes to the process of inventory planning (24/CP.19, 22.(d,e)/23./24.)

No changes.

Changes to the process of inventory preparation (24/CP.19, 25./26.)

Due to the new reporting guidelines and the new CRF Reporter, changes in the emission modelling database and its export functionality were required. Delays and errors in CRF releases also affected the regular inventory preparation cycle of the current submission. It was not possible to start with regular reporting process until (presumably) September 2015. Therefore, the final submission was delayed by approximately 8 months.

Changes to the process of inventory management (24/CP.19, 27.)

No changes.

1.3 Inventory preparation, and data collection, processing and storage

1.3.1 GHG Inventory and KP-LULUCF inventory

Figure 1-3 gives a schematic overview of the institutional setting of the process of inventory preparation within the NIS.

[3] For the current submission, M. Sommerhalder is a “new” author, but he actually acted as NIR author of the submissions from 2006 to 2009.

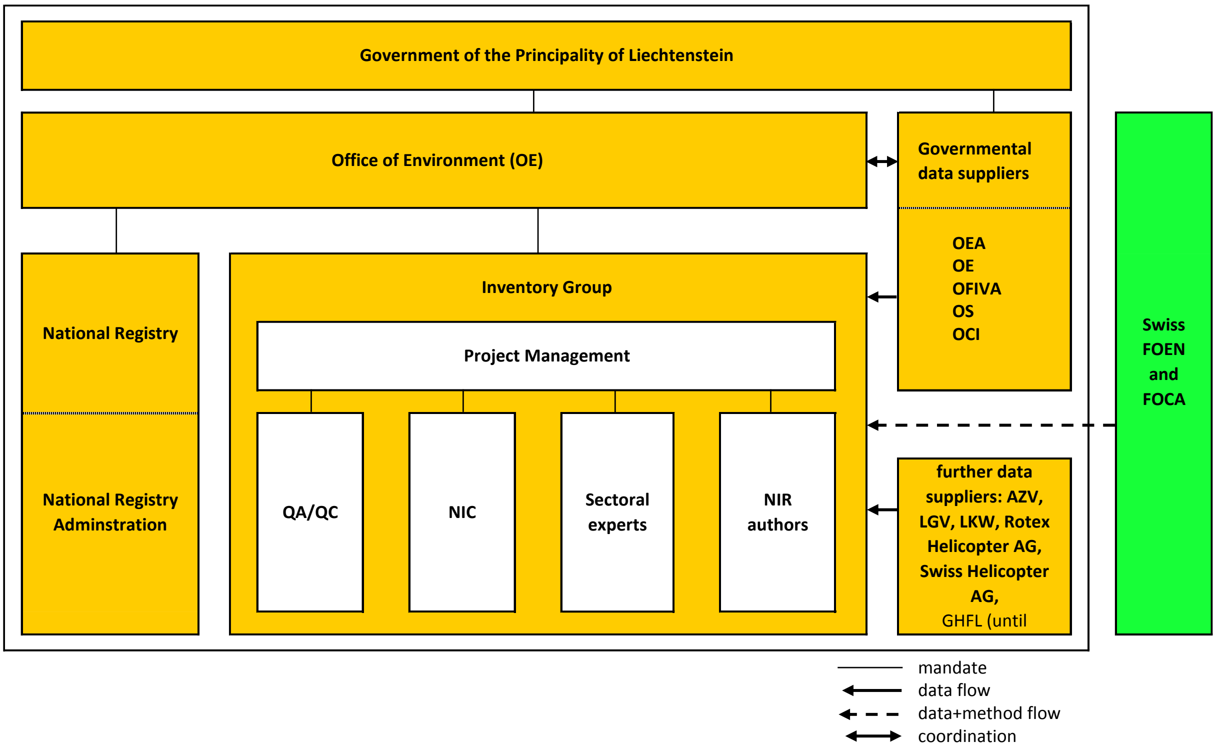

Figure 1-2 National Inventory System: Institutional setting and data suppliers. OE: Office of Environment; OEA: Office of Economic Affairs; OFIVA: Office of Food Inspections and Veterinary Affairs; OS: Office of Statistics: OCI: Office of Construction and Infrastructure; AZV: Liechtenstein's wastewater administration union; GHFL: Coorporate society for the Storage of Gas Oil in the Principality of Liechtenstein; LGV: Liechtenstein's gas utility; LKW: Liechtenstein's electric power company; FOEN: Swiss Federal Office of the Environment; FOCA: Swiss Federal Office of Civil Aviation.

The Government of the Principality of Liechtenstein bears the overall responsibility for the NIS. By Liechtenstein's Emission Trading Act (Emissionshandelsgesetz, Government 2012), the Office of Environment (OE) 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 OE for establishing the NIS is also described in the report of the Government to the parliament for ratifying the Kyoto Protocol. The Government mandated the realisation of the NIS to its Office of Environment (OE). Please note that the Office of Environment is reorganized since 2013. The Office of Agriculture (OA), the Office of Forest, Nature and Land Management (OFNLM) and the Office of Environmental Protection (OEP) have been merged to the Office of Environment (OE). The former Office of Land Use Planning (SLP) is reorganized since 2013 and the Local Land Use Planning Bureau is now incorporated into the Office of Construction and Infrastructure (OCI).

The Office of Environment (OE) plays a major role in the National Inventory System and is acting as the National Registry Administrator. Its representative, the head of the OE, is the registered National Focal Point. 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 person responsible for the QA/QC activities, the National Inventory Compiler (NIC) who is represented by the project manager and his assistant. 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 are

- Office of Economic Affairs (OEA)
- Office of Statistics (OS)

- Office of Construction and Infrastructure (Local Land Use Planning Bureau)
- Office of the Environment (OE)

Further data suppliers are

- Liechtenstein's Gas Utility / Liechtensteinische Gasversorgung (LGV)
- Electric power company / Liechtensteinische Kraftwerke (LKW)
- Abwasserzweckverband (AZV)
- Heliport Balzers (Swiss Helicopter AG and Rotex Helicopter AG)
- Swiss Federal Office for the Environment (FOEN)
- Swiss Federal Office of Civil Aviation (FOCA)

In former years, the cooperative society for the storage of gas oil in the Principality of Liechtenstein (Genossenschaft für Heizöl-Lagerhaltung im Fürstentum Liechtenstein, GHFL) delivered data about the annual storage of fuels. However, the cooperative society was closed in 2008.

Cooperation with the Swiss Federal Office for the Environment

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 OE cooperate in the inventory preparation.

- Due to the Customs Union Treaty of the two states, the import statistics in the Swiss overall energy statistics (SFOE 2015) also includes the fossil fuel consumption of the Principality of Liechtenstein, except for gas consumption of Liechtenstein, which is excluded from SFOE (2015). FOEN therefore corrects its fuel consumption data by subtracting Liechtenstein's liquid fuel consumption from the data provided in the Swiss overall energy statistics to avoid double-counting. To that aim, OE calculates its energy consumption and provides FOEN with the data.
- FOEN, on the other hand, provides a number of methods and emission factors to OE, mainly for transportation, agriculture, LULUCF, F-gases, and industrial processes and product use. Liechtenstein has benefited to a large extend from the methodological support by the inventory core group within the FOEN and its willingness to share data and spreadsheet-tools in an open manner. Its kind support is herewith highly appreciated.

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

Figure 1-4 illustrates the simplified data flow leading to the CRF tables required for reporting under the UNFCCC and under the Kyoto Protocol. For roles and responsibilities of the contributors see Figure 1-3

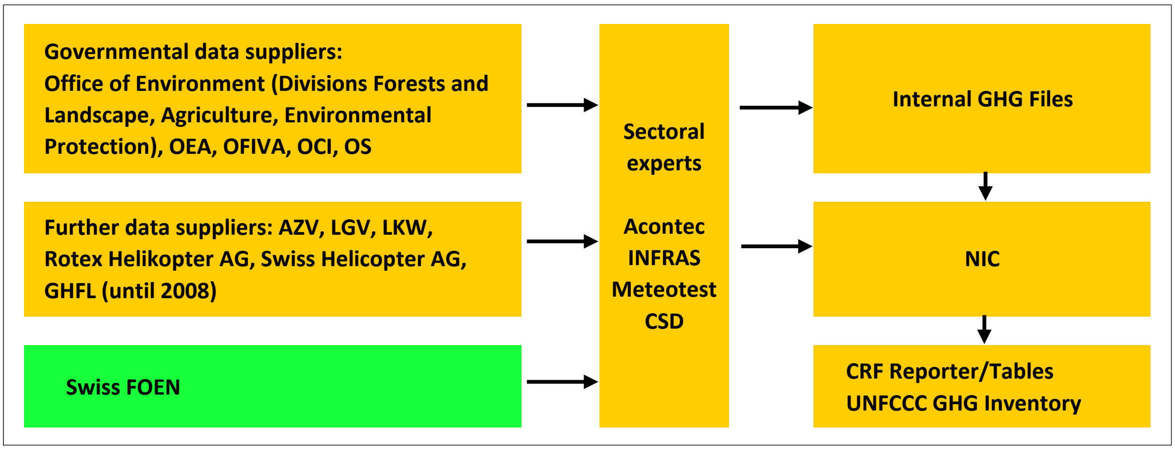

Figure 1-3 Data suppliers and data collection for setting up the UNFCCC GHG Inventory (see Glossary for abbreviations).

Documentation and archiving procedures

For the submission 2008, the QC activities had been documented for the first time through the use of checklists. These lists are now updated for the current submission and are shown in Annex 8. The classification of the QC activities follows the IPCC Guidelines (IPCC 2006). The following persons are involved in the QC activities:

- Sectoral experts
- NIC / Project manager
- NIR authors

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

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 Environment, are connected to a central network. The data of the server systems, file-clusters and database servers, are being saved in a tape-library. For safety reasons, the tape-library is not in the computing centre but in the national police building: In case of a total loss 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 are 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 AG, 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). Also, the data generated in the NIR compilation process such as the NIR itself, QA/QC documents, KCA files, uncertainty analysis, review documents are safed by INFRAS within its archiving system that is maintained in the ISO 9001 quality management system by INFRAS (IQNet 2014).

Finally, the entire information exchange by email between all people involved in updating the NIR 2014 is stored in the so-called PST format.

Therefore, archiving practices are in line with paragraph 16(a) of the annex to decision 19/CMP.1

1.4 Methodologies and data sources

1.4.1 GHG inventory

1.4.1.1 General description

The emissions are mainly calculated based on the standard methods and procedures of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) as adopted by the UNFCCC in its Decision 24/CP.19 (UNFCCC 2014).

The emissions are modelled by using country-specific activity data. Country-specific emission 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 after checking their applicability. In those cases, the emission factors are reported as country-specific. 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 1.2.1). 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. **Therefore, a number of emission factors are adopted from Switzerland assuming that the Swiss emission factors actually represent the emission standards more accurately than default emission factors.** This assumption especially holds for:

- the sector Energy due to the same fuel quality standards and regulations standards for exhaust gases of combustion and motor vehicles,
- the emission of F-gases due to similar consumer’s product and attitude,
- agriculture emissions due to similar stock farming and cultivation of land,
- the sector LULUCF due to – again – similar geographic, meteorological and climatic circumstances for forestry.

In the following paragraph, a short summary of the methods used is given for each sector.

1 Energy

- Emissions from 1A Fuel combustion: Activity data is taken from the National Energy Statistics (including consistency modifications) and from census for the fuel sales of gasoline and diesel oil. The methods are country-specific.
- Emissions from 1B Fugitive emissions from fuels: The Swiss method is applied corresponding to country-specifics.

2 Industrial processes and product use

- HFC and PFC emissions from 2F1 Refrigeration and air conditioning are reported and are calculated with the rule of proportion applied on the Swiss emissions using country-specific activity data as representative for the conversion (e.g. no. of inhabitants).
- SF_6 emissions from 2G1 Electrical equipment are reported based on country-specific data.

- N_2O emissions from product uses (2G3) are reported and are calculated with the rule of proportion applied on the Swiss emissions using country-specific activity data (no. of inhabitants) as representative for the conversion.
- CO and NMVOC emissions from 2D3b Road paving with asphalt and 2D3c Asphalt roofing. The emissions are estimated from the Swiss emissions using the number of inhabitants as a reference value for the rough estimate of Liechtenstein's emissions
- Emissions 2D3: The NMVOC emissions are delineated from the Swiss emissions using the number of inhabitants as a reference value for the rough estimate of Liechtenstein's emissions.
- Other emissions from industrial processes and product use (CO_2, CH_4, N_2O) are not occurring.

3 Agriculture

- Emissions are reported for 3A Enteric fermentation, 3B Manure management and 3D Agricultural soils by applying Swiss methods (country-specific) combined with Liechtenstein specific activity data as far as available.

4 LULUCF

- Emissions and removals are reported for 4A to 4G, 4(III) and 4(IV). Most of the methods and the emission factors are adopted from Switzerland, for forest land also data from Liechtenstein's National Forest Inventory are used (country-specific).

5 Waste

- 5A is estimated by applying a FOD Model according to IPCC (1997) and specific activity data for Liechtenstein. Emissions in the sector 5B-5E are calculated by applying Swiss methods (country-specific) combined with Liechtenstein specific activity data.

1.4.1.2 Specific assumptions for the year 2014

For the modelling of its emissions, Liechtenstein uses several emission factors originating from the Swiss GHG inventory. Currently, the emissions 2014 of the Swiss inventory 2016 were available in the EMIS (Swiss Emission Information System)database of the Swiss Federal Office for the Environment dated from April 2016 corresponding to the emission data which Switzerland submitted in April 2016 in its NIR to the UNFCCC.

Table 1-2 Notation keys for applied methods and emission factors 2014 (see also CRF tables Summary3s1, Summary3s2).

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
1. Energy	D,T1,T2	CS,D	D,T1,T2,T3	CS,D	D,T1,T2,T3	CS,D
A. Fuel combustion	D,T1,T2	CS,D	D,T1,T2,T3	CS,D	D,T1,T2,T3	CS,D
1. Energy industries	T2	CS	T2	CS	T2	CS,D
2. Manufacturing industries and construction	T1,T2	CS,D	T1,T2	CS	T1,T2	CS,D
3. Transport	D,T1,T2	CS,D	D,T2,T3	CS,D	D,T2,T3	CS,D
4. Other sectors	T1,T2	CS,D	T1,T2	CS	T1,T2	CS,D
B. Fugitive emissions from fuels	NA	NA	T3	CS	NA	NA
1. Solid fuels	NA	NA	NA	NA	NA	NA
2. Oil and natural gas	NA	NA	T3	CS	NA	NA
C. CO2 transport and storage	NA	NA				
2. Industrial processes	NA	NA	NA	NA	CS	CS
A. Mineral industry	NA	NA				
B. Chemical industry	NA	NA	NA	NA	NA	NA
C. Metal industry	NA	NA	NA	NA		
D. Non-energy products from fuels and solvent use	NA	NA	NA	NA	NA	NA
G. Other product manufacture and use	NA	NA	NA	NA	CS	CS
H. Other						
3. Agriculture			D,T2	CS,D	T1b	D
A. Enteric fermentation			D,T2	CS,D		
B. Manure management			T2	D		
C. Rice cultivation			NA	NA		
D. Agricultural soils(3)					T1b	D
F. Field burning of agricultural residues			NA	NA	NA	NA
G. Liming	NA	NA				
I. Other carbon-containing fertilizers	NA	NA				
4. Land use, land-use change and forestry	T2	CS,NA			T2	CS
A. Forest land	T2	CS			NA	NA
B. Cropland	T2	CS,NA			T2	CS
C. Grassland	T2	CS			T2	CS
D. Wetlands	NA	NA			NA	NA
E. Settlements	T2	CS			T2	CS
F. Other land	T2	CS				
G. Harvested wood products	T2	CS				
5. Waste	CS	CS	CS,T2	CS	CS,D	CS,D
A. Solid waste disposal	NA	NA	T2	CS		
B. Biological treatment of solid waste			CS	CS	CS	CS
C. Incineration and open burning of waste	CS	CS	CS	CS	CS	D
D. Waste water treatment and discharge			CS	CS	D	D
6. Other (as specified in summary 1.A)	D	D	D	D	D	D

2. Industrial processes	HFCs		PFCs		SF_6	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
E. Electronic industry	NA	NA				
F. Product uses as ODS substitutes	CS	CS	CS	CS	CS	CS
G. Other product manufacture and use					T3	CS

1.4.1.3 Reference approach for the energy sector

Liechtenstein carried out the reference approach to estimate energy consumption and CO_2 emissions for the energy sector. The results are shown in 3.2.1.

1.4.2 KP-LULUCF Inventory

The information in this Inventory is provided in accordance with Decision 2/CMP.7 and the KP-Supplement (IPCC 2014) and based on the information given in Liechtenstein's Initial Report (OEP 2006a), the Corrigendum to the Initial Report of 19 Sep 2007 (OEP 2007b) and Liechtenstein's second Initial Report (OE 2016).

Liechtenstein had to determine for each activity of the LULUCF sector whether removal units (RMUs) shall be issued annually or for the entire commitment period. Liechtenstein will choose to account over the entire commitment period for emissions and removals from activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (see OE 2016).The decision remains fixed for the entire second commitment period.

Liechtenstein adopts the forest definition of the Swiss Land Use Statistics (AREA) of the Swiss Federal Statistical Office. AREA provides an excellent data base to derive accurate, detailed information not only for forest areas, but for all types of land use and land cover. Thus, AREA offers a comprehensive, consistent and high quality data set to estimate the surface area of the different land use categories in reporting under the Kyoto Protocol. For Liechtenstein, the Land Use Statistics has been built up identically to Switzerland (same method and data structures, same realisation).

The following forest definition has been used (OEP 2007b):

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

1.5 Brief Description of Key Categories

The key category analysis (KCA) is performed based on the automatic KCA implemented in the CRF Reporter Software. The software indicates to every source and sink category whether it is key or not. The method corresponds to an Approach 1 level and trend assessment methodology with the proposed threshold of 95% as recommended by the 2006 IPCC Guidelines (IPCC 2006).The result of the KCA performed by the CRF Reporter (CRF Table7) was not correct in Liechtenstein's CRF re-submission after the 15^{th} April 2016. However, Table 7 displayed correct results as it was exported separately in the CRF app. The KCA for the current submission was performed according to this separate version of CRF Table7.

The analyses lead to four results:

- Base year 1990 level assessment without LULUCF categories
- Base year 1990 level assessment with LULUCF categories
- Reporting year 2014 level and trend assessment without LULUCF categories
- Reporting year 2014 level and trend assessment with LULUCF categories

To every source and sink category identified as key, the corresponding emission or sink is attributed. The data of the four analyses are shown in Table 1-3 to Table 1-6.

An Approach 2 level and trend assessment has not been carried out in the current submission. The identified key categories and especially new key categories are analysed in more detail in order to identify the reasons of the category to be key as well as possible needed improvements.

1.5.1 GHG Inventory

1.5.1.1 KCA excluding LULUCF categories

For 2014, among a total of 196 categories, 12 have been identified as Approach 1 key categories by the CRF Reporter Software (see Table7 of the reporting tables) with an aggregated contribution of 96.2% of the national total emissions (see Table 1-3). 11 categories are key categories according to level assessment and 9 according to trend assessment.

From 12 key categories, 6 are from the energy sector, contributing 78.7% to total CO_2 equivalent emissions in 2014. The other key categories are from the sectors Agriculture (11.2%), Industrial Processes and Product Use IPPU (5.8%) and Waste (0.5%).

The three major sources, all from the energy sector, sum up to a contribution of 64.3% of the national total emissions:

- 1A3b Road transportation, CO_2,1A4 Other sectors, liquid fuels, CO_2,
- 1A4 Other sectors, gaseous fuels, CO_2.

Compared to the previous submission for the reporting year 2013, two categories are not key anymore in 2014:

- 1B2b Fugitive emissions from fuels, Oil and natural gas and other emissions from energy production, CH_4,
- 3B Manure management, N_2O.

On the other hand, one additional category is key in 2014:

- 5D Wastewater treatment and discharge, CH_4.

Further details are shown in Table 1-3 below.

For the base year 1990, the level key category analysis is given in Table 1-4 below. There are 8 level key categories. Compared to the previous submission, one category is not key anymore in 1990:

- 3D2 Indirect N_2O emissions from managed soils, N_2O

Table 1-3 List of Liechtenstein's Approach 1 key categories 2014 excluding LULUCF. Sorted by share of total emissions.

Key Category Analysis 2014 (excluding LULUCF) IPCC Source Categories (and fuels if applicable)	GHG	Emissions 2014 [kt CO_2eq]	Share of Total Emissions	Cumulative Total	Result of Assessment
1.A.3.b Road Transportation	CO2	73.72	35.9%	35.9%	KC Level & KC Trend
1.A.4 Other Sectors - Liquid Fuels	CO2	29.25	14.3%	50.2%	KC Level & KC Trend
1.A.4 Other Sectors - Gaseous Fuels	CO2	28.93	14.1%	64.3%	KC Level & KC Trend
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	15.51	7.6%	71.9%	KC Level & KC Trend
3.A Enteric Fermentation	CH4	13.54	6.6%	78.5%	KC Level & KC Trend
2.F.1 Refrigeration and Air conditioning	F-gases	11.95	5.8%	84.3%	KC Level & KC Trend
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	11.52	5.6%	89.9%	KC Level & KC Trend
3.D.1 Direct N2O Emissions From Managed Soils	N2O	4.81	2.3%	92.3%	KC Level
3.B Manure Management	CH4	2.72	1.3%	93.6%	KC Level
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO2	2.48	1.2%	94.8%	KC Level & KC Trend
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	1.90	0.9%	95.7%	KC Level
5.D Wastewater Treatment and Discharge	CH4	0.97	0.5%	96.2%	KC Trend

Table 1-4 List of Liechtenstein's Approach 1 key categories in 1990 excluding LULUCF. Sorted by share of total emissions.

Key Category Analysis 1990 (excluding LULUCF) IPCC Source Categories (and fuels if applicable)	GHG	Emissions 1990 [kt CO_2eq]	Share of Total Emissions	Cumulative Total	Result of Assessment
1.A.4 Other Sectors - Liquid Fuels	CO2	76.71	33.5%	33.5%	KC Level
1.A.3.b Road Transportation	CO2	75.29	32.9%	66.4%	KC Level
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	20.99	9.2%	75.5%	KC Level
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	15.20	6.6%	82.2%	KC Level
3.A Enteric Fermentation	CH4	13.66	6.0%	88.1%	KC Level
1.A.4 Other Sectors - Gaseous Fuels	CO2	10.21	4.5%	92.6%	KC Level
3.D.1 Direct N2O Emissions From Managed Soils	N2O	5.19	2.3%	94.9%	KC Level
3.B Manure Management	CH4	3.06	1.3%	96.2%	KC Level

1.5.1.2 KCA including LULUCF categories

According to 2006 IPCC Guidelines (IPCC 2006), 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. The KCA including LULUCF categories is performed as an automatic approach by the CRF Reporter.

The Approach 1 key category analysis for the submission year 2016 including LULUCF categories consists of a total of 223 categories. Seven categories are identified key from the LULUCF sector and contribute with a total of 6.8% to total emissions:

- 4A2 Land converted to forest land, CO_2,
- 4B1 Cropland remaining cropland, CO_2,
- 4C1 Grassland remaining grassland, CO_2,
- 4C2 Land converted to grassland, CO_2,
- 4E2 Land converted to settlements, CO_2,
- 4F2 Land converted to Other Land, CO_2,
- 4G Harvested wood products, CO_2.

Additionally, two categories from the sectors energy and agriculture are key when performing the KCA including LULUCF categories:

- 1B2b Fugitive emissions from fuels, Oil and natural gas and other emissions from energy production, CH_4,
- 3B Manure management, N_2O.

Compared to the Key Category Analysis in the previous submission 2015 for the reporting year 2013, one additional LULUCF category is key:

- 4A2 Land converted to forest land, CO_2.

Further details are shown in Table 1-5.

In the KCA 1990 including LULUCF categories, three key categories contributing 4.8% to total emissions are identified from the LULUCF sector (see Table 1-6):

- 4B1 Cropland remaining cropland, CO_2,
- 4E2 Land converted to settlements, CO_2,
- 4G Harvested wood products, CO_2.

Table 1-5 List of Liechtenstein's Approach 1 key categories 2014 including LULUCF. Sorted by share of total emissions.

Key Category Analysis 2014 (including LULUCF) IPCC Source Categories (and fuels if applicable)	GHG	Emissions 1990 (absolute value) [kt CO_2eq]	Share of Total Emissions	Cumulative Total	Result of Assessment
1.A.3.b Road Transportation	CO2	73.72	33.3%	33.3%	KC Level & KC Trend
1.A.4 Other Sectors - Liquid Fuels	CO2	29.25	13.2%	46.6%	KC Level & KC Trend
1.A.4 Other Sectors - Gaseous Fuels	CO2	28.93	13.1%	59.7%	KC Level & KC Trend
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	15.51	7.0%	66.7%	KC Level & KC Trend
3.A Enteric Fermentation	CH4	13.54	6.1%	72.8%	KC Level & KC Trend
2.F.1 Refrigeration and Air conditioning	F-gases	11.95	5.4%	78.2%	KC Level & KC Trend
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	11.52	5.2%	83.4%	KC Level & KC Trend
3.D.1 Direct N2O Emissions From Managed Soils	N2O	4.81	2.2%	85.6%	KC Level
4.B.1 Cropland Remaining Cropland	CO2	3.98	1.8%	87.4%	KC Level
4.E.2 Land Converted to Settlements	CO2	3.09	1.4%	88.8%	KC Level
3.B Manure Management	CH4	2.72	1.2%	90.0%	KC Level
4.C.2 Land Converted to Grassland	CO2	2.55	1.2%	91.2%	KC Level & KC Trend
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO2	2.48	1.1%	92.3%	KC Level & KC Trend
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	1.90	0.9%	93.2%	KC Level
4.C.1 Grassland Remaining Grassland	CO2	1.45	0.7%	93.8%	KC Level
4.G Harvested Wood Products	CO2	1.40	0.6%	94.5%	KC Level & KC Trend
3.B Manure Management	N2O	1.37	0.6%	95.1%	KC Level
4.F.2 Land Converted to Other Land	CO2	1.29	0.6%	95.7%	KC Trend
4.A.2 Land Converted to Forest Land	CO2	1.28	0.6%	96.2%	KC Trend
1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	1.21	0.5%	96.8%	KC Trend
5.D Wastewater Treatment and Discharge	CH4	0.97	0.4%	97.2%	KC Trend

Table 1-6 List of Liechtenstein's Approach 1 key categories 1990 including LULUCF. Sorted by share of emissions.

Key Category Analysis 1990 (including LULUCF) IPCC Source Categories (and fuels if applicable)	GHG	Emissions 1990 (absolute value) [kt CO_2eq]	Share of Total Emissions	Cumulative Total	Result of Assessment
1.A.4 Other Sectors - Liquid Fuels	CO2	76.71	31.3%	31.3%	KC Level
1.A.3.b Road Transportation	CO2	75.29	30.7%	62.0%	KC Level
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	20.99	8.6%	70.6%	KC Level
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	15.20	6.2%	76.8%	KC Level
3.A Enteric Fermentation	CH4	13.66	5.6%	82.3%	KC Level
1.A.4 Other Sectors - Gaseous Fuels	CO2	10.21	4.2%	86.5%	KC Level
3.D.1 Direct N2O Emissions From Managed Soils	N2O	5.19	2.1%	88.6%	KC Level
4.G Harvested Wood Products	CO2	4.70	1.9%	90.5%	KC Level
4.B.1 Cropland Remaining Cropland	CO2	4.10	1.7%	92.2%	KC Level
3.B Manure Management	CH4	3.06	1.2%	93.5%	KC Level
4.E.2 Land Converted to Settlements	CO2	2.94	1.2%	94.7%	KC Level
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	2.37	1.0%	95.6%	KC Level

1.5.2 KP-LULUCF inventory

Liechtenstein identified three key categories for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (Forest Management, Deforestation and Harvested Wood Products). The approach relies on full inventory KCA (with LULUCF), KP - CRF association and qualitative assessment. A detailed description is presented in chapter 11.6.1 and in Table 11-3.

1.6 Uncertainty evaluation

1.6.1 GHG inventory

1.6.1.1 Approach

In the current inventory, Approach 1 uncertainty is evaluated with level (2014) and trend (1990-2014) analyses.

For the current submission a simplified uncertainty analysis has been carried out. The simplification means that uncertainty analysis individually accounts for the key categories, whereas the rest of the sources was aggregated by gas and treated as four “rest” categories CO_2, CH_4, N_2O and F-gases, to which a semi-quantitative uncertainty (see below, Table 1-7) was attributed.

In the automatic KCA of the CRF Reporter, the aggregation level of the categories is not identical to the aggregation level as applied in previous uncertainty analyses. Therefore, a small number of categories, for which the uncertainty is available, had to be aggregated in a preparing step by Gaussian error propagation, to the level of the corresponding key category.

1.6.1.2 Uncertainty estimates

Data on uncertainties is not provided explicitly for most emission sources and sink by the OE. Therefore, the authors and the involved expert of Acontec generated first estimates of uncertainties based on uncertainty data from the Swiss NIR (FOEN 2016) 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 for Approach 1 analysis.

For a number of categories individual uncertainties are used based on Liechtenstein’s previous NIR (Submission 2015). For the remaining categories qualitative estimates of uncertainties are applied. The terms used are “high”, “medium” and “low” data quality. To each term, quantitative uncertainties as shown in Table 1-7 are used. They are motivated by the comparison of uncertainty analyses of several countries carried out by de Keizer et al. (2007), as presented at the 2nd Internat. Workshop on Uncertainty in Greenhouse Gas Inventories (Vienna 27-28 Sep 2007).

Table 1-7 Semi-quantitative uncertainties (95% level) for categories, for which no explicit uncertainty is known. Note that there is no source of NF_3, for which a semi-quantitative uncertainty values is required.

Gas	Uncertainty category	Relative uncertainty
CO_2	low	2%
	medium	10%
	high	40%
CH_4	low	15%
	medium	30%
	high	60%
N_2O	low	40%
	medium	80%
	high	150%
HFC	medium	20%
PFC	medium	20%
SF_6	medium	20%

Note that uncertainties in the GWP-values were not taken into account in the inventory uncertainty estimates.

1.6.1.3 Results of Approach 1 uncertainty evaluation

The quantitative uncertainty analysis Approach 1 has been carried out following the 2006 IPCC Guidelines Approach 1 methodology (IPCC 2006, vol. 1, chp. 3, Table 3.2).

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.

The Approach 1 level uncertainty (2014) in the national total annual CO_2 equivalent emissions **excluding LULUCF** is estimated to be 5.46%, trend uncertainty (1990-2014) is 5.49%.

The Approach 1 level uncertainty (2014) in the national total annual CO_2 equivalent emissions **including LULUCF** is estimated to be 5.38%, trend uncertainty (1990-2014) is 5.43%.

Compared to the **previous submission 2015 (reporting year 2013)**, the results of Approach 1 analyses show a slight increase of level uncertainties and a clear decrease of trend uncertainties:

- Level uncertainty 2013: 5.37% (excluding LULUCF) and 5.28% (including LULUCF)
- Trend uncertainty 1990-2013: 6.60% (excluding LULUCF) and 6.64% (including LULUCF)

The slight increase of level uncertainty is an effect of the reduced activity data in fuel combustion activities due to the warm temperatures in 2014, which augments the weight of the high uncertainty values in sector 3 Agriculture (mainly 3D1, 3D2). On the other hand, the decline of trend uncertainties is mainly due to a decline of the type B sensitivity of liquid fuels in category 1A4.

Still, the overall uncertainty in Liechtenstein is to some extent determined by the 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 own customs statistics of imports of oil products, and activity data has to be based on inquiries with suppliers, being of heterogeneous quality.

Table 1-8 Approach 1 level (2014) and trend (1990-2014) uncertainty excluding LULUCF.

A		B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category		**Gas**	**Base year emissions or removals**	**Year 2014 emissions or removals**	**AD unc.**	**EF unc.**	**Comb. unc.**	**Contr. to variance by Category in 2014**	**Type A sensitivity**	**Type B sensitivity**	**Unc. in trend in nat. emissions introduced by EF unc.**	**Unc. in trend in nat. emissions introduced by AD unc.**	**Unc. introduced into the trend in total national emissions**
(categories excluding LULUCF)			kt CO_2 eq	kt CO_2 eq	%	%	%	-	%	%	%	%	-
1A1	1. Energy; A. Fuel combustion activities; 1. Energy industries; Gaseous F.	CO2	0.12	2.48	5.0	3.1	5.9	0.005	0.01	0.01	0.03	0.08	0.007
1A2	1. Energy; A. Fuel combustion activities; 2. Manufacturing industries and construction; Liquid F.	CO2	20.99	11.52	20.0	0.5	20.0	1.264	0.03	0.05	0.02	1.42	2.026
1A2	1. Energy; A. Fuel combustion activities; 2. Manufacturing industries and construction; Gaseous F.	CO2	15.20	15.51	5.0	3.1	5.9	0.198	0.01	0.07	0.03	0.48	0.230
1A3b	1. Energy; A. Fuel combustion activities; 3. Transport; Road Transp.	CO2	75.29	73.72	8.7	0.8	8.7	9.851	0.03	0.32	0.02	3.96	15.674
1A4	1. Energy; A. Fuel combustion activities; 4. Other Sectors; Liquid F.	CO2	76.71	29.25	15.8	0.4	15.8	5.099	0.17	0.13	0.07	2.86	8.177
1A4	1. Energy; A. Fuel combustion activities; 4. Other Sectors; Gaseous F.	CO2	10.21	28.93	3.6	2.2	4.2	0.353	0.09	0.13	0.19	0.64	0.445
2F1	2. IPPU; F. Product uses as substitutes for ODS; 1. Refrigeration and air conditioning	F-gases	0.00	11.95	10.6	10.6	15.0	0.763	0.05	0.05	0.55	0.78	0.918
3A	3. Agriculture; A. Enteric Ferment.	CH4	13.66	13.54	6.4	16.9	18.1	1.431	0.01	0.06	0.10	0.54	0.299
3B	3. Agriculture; B. Manure Managemen t	CH4	3.06	2.72	6.4	54.0	54.4	0.521	0.00	0.01	0.00	0.11	0.012
3D1	3. Agriculture; D. Agricultural Soils; 1. Direct Soil Emissions	N2O	5.19	4.81	16.8	96.3	97.7	5.245	0.00	0.02	0.07	0.50	0.254
3D2	3. Agriculture; D. Agricultural Soils; 2. Indirect Emissions	N2O	2.37	1.90	27.9	172.2	174.4	2.617	0.00	0.01	0.16	0.33	0.134
5D	5. Waste; D. Wastewater treatment and discharge	CH4	0.05	0.97	42.4	42.4	60.0	0.081	0.00	0.00	0.17	0.25	0.094
non-key rest		CO2	0.25	0.13	1.4	1.4	2.0	0.000	0.00	0.00	0.00	0.00	0.000
		CH4	2.31	3.63	21.2	21.2	30.0	0.282	0.01	0.02	0.14	0.48	0.247
		N2O	3.62	3.68	56.6	56.6	80.0	2.065	0.00	0.02	0.11	1.29	1.668
		F-gases	0.00	0.36	14.1	14.1	20.0	0.001	0.00	0.00	0.02	0.03	0.001
Total			**229.03**	**205.10**				**29.77**					**30.19**
							Percentage uncertainty in total inventory:	**5.46**				*Trend uncertainty:*	**5.49**

Table 1-9 Approach 1 level (2014) and trend (1990-2014) uncertainty **including** LULUCF.

A		B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category		**Gas**	**Base year emissions or removals**	**Year 2014 emissions or removals**	**AD unc.**	**EF unc.**	**Comb. unc.**	**Contr. to variance by Category in 2014**	**Type A sensitivity**	**Type B sensitivity**	**Unc. in trend in nat. emissions introduced by EF unc.**	**Unc. in trend in nat. emissions introduced by AD unc.**	**Unc. introduced into the trend in total national emissions**
(categories including LULUCF)			kt CO_2 eq	kt CO_2 eq	%	%	%	-	%	%	%	%	-
1A1	1. Energy / A. Fuel combustion activities / 1. Energy industries / Gaseous F.	CO2	0.12	2.48	5.0	3.1	5.9	0.005	0.01	0.01	0.03	0.08	0.007
1A2	1. Energy / A. Fuel combustion activities / 2. Manufacturing ind. & constr. / Liquid F.	CO2	20.99	11.52	20.0	0.5	20.0	1.133	0.03	0.05	0.02	1.40	1.947
1A2	1. Energy / A. Fuel combustion activities / 2. Manufacturing ind. & constr. / Gaseous F.	CO2	15.20	15.51	5.0	3.1	5.9	0.177	0.01	0.07	0.02	0.47	0.221
1A3b	1. Energy / A. Fuel combustion activities / 3. Transport; Road Transp.	CO2	75.29	73.72	8.7	0.8	8.7	8.828	0.02	0.32	0.01	3.88	15.065
1A4	1. Energy / A. Fuel combustion activities / 4. Other Sectors / Liquid F.	CO2	76.71	29.25	15.8	0.4	15.8	4.569	0.18	0.13	0.07	2.80	7.860
1A4	1. Energy / A. Fuel combustion activities / 4. Other Sectors / Gaseous F.	CO2	10.21	28.93	3.6	2.2	4.2	0.316	0.08	0.12	0.18	0.63	0.427
1B2b	1. Energy / B. Fugitive emissions from fuels / 2. Oil, nat. gas, other em. from energy prod.	CH4	0.37	1.21	35.4	35.4	50.0	0.078	0.00	0.01	0.13	0.26	0.084
2F1	2. IPPU / F. Prod. uses as subst. for ODS / 1. Refriger. & air cond.	F-gases	0.00	11.95	10.6	10.6	15.0	0.684	0.05	0.05	0.54	0.77	0.882
3A	3. Agriculture / A. Enteric Ferment.	CH4	13.66	13.54	6.4	16.9	18.1	1.283	0.00	0.06	0.06	0.53	0.283
3B	3. Agriculture / B. Manure Managem.	CH4	3.06	2.72	6.4	54.0	54.4	0.467	0.00	0.01	0.03	0.11	0.012
3B	3. Agriculture / B. Manure Managem.	N2O	1.16	1.37	34.9	175.4	178.9	1.281	0.00	0.01	0.22	0.29	0.133
3D1	3. Agriculture / D. Agricultural Soils / 1. Direct Soil Emissions	N2O	5.19	4.81	16.8	96.3	97.7	4.700	0.00	0.02	0.00	0.49	0.240
3D2	3. Agriculture / D. Agricultural Soils / 2. Indirect Emissions	N2O	2.37	1.90	27.9	172.2	174.4	2.345	0.00	0.01	0.22	0.32	0.150
4A2	4. LULUCF / A. Forest Land / 2. Land converted to forest land	CO2	-1.64	-1.28	20.0	36.0	41.2	0.059	0.00	0.01	0.04	0.15	0.025
4B1	4. LULUCF / B. Cropland / 1. Cropland remaining cropland	CO2	4.10	3.98	5.0	37.5	37.8	0.482	0.00	0.02	0.03	0.12	0.015
4C1	4. LULUCF / C. Grassland / 1. Grassland remaining grassland	CO2	1.47	1.45	5.0	50.0	50.2	0.113	0.00	0.01	0.02	0.04	0.002
4C2	4. LULUCF / C. Grassland / 2. Land converted to grassland	CO2	0.33	2.55	20.0	50.0	53.9	0.403	0.01	0.01	0.48	0.31	0.327
4E2	4. LULUCF / E. Settlements / 2. Land converted to settlements	CO2	2.94	3.09	20.0	50.0	53.9	0.588	0.00	0.01	0.08	0.37	0.146
4F2	4. LULUCF / F. Other land / 2. Land converted to other land	CO2	0.44	1.29	20.0	50.0	53.9	0.102	0.00	0.01	0.19	0.16	0.059
4G	4. LULUCF / G. HWP	CO2	-4.70	-1.40	20.0	57.0	60.4	0.152	0.01	0.01	0.72	0.17	0.550
5D	5. Waste / D. Wastewater treatment and discharge	CH4	0.05	0.97	42.4	42.4	60.0	0.073	0.00	0.00	0.17	0.25	0.090
non-key rest		CO2	1.58	1.55	1.4	1.4	2.0	0.000	0.00	0.01	0.00	0.01	0.000
		CH4	1.94	2.42	21.2	21.2	30.0	0.112	0.00	0.01	0.06	0.31	0.100
		N2O	2.77	2.76	56.6	56.6	80.0	1.039	0.00	0.01	0.05	0.95	0.896
		F-gases	0.00	0.36	14.1	14.1	20.0	0.001	0.00	0.00	0.02	0.03	0.001
Total			**233.61**	**216.65**				**28.99**					**29.52**
							Percentage uncertainty in total inventory:	**5.38**				*Trend uncertainty:*	**5.43**

The level uncertainties are also evaluated by gas according to the results of the approach 1 uncertainty assessment.

Table 1-10: Level uncertainties by gas 2014 for the total national emissions excluding LULUCF.

Gas	Emmissions 2014 (excluding LULUCF) kt CO_2 eq	Mean absolute uncertainty kt CO_2 eq	Mean relative uncertainty
CO2	161.5	8.4	5%
CH4	20.9	3.1	15%
N2O	10.4	6.5	62%
F-gases	12.3	1.8	15%
Total	205.1	11.2	5.46%

Please note that the current results of the Approach 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.
- Uncertainties due to the assumption of constant parameters, e.g. of constant net calorific values for fuels for the entire period since 1990.
- Uncertainties due to methodological shortcomings, such as differences between sold fuels and actually combusted fuels (stock-changes in residential tanks) for liquid fossil fuels.

An Approach 2 uncertainty analysis was not conducted in the current reporting year. However Approach 2 uncertainty results from a previous submission for reporting year 2012 (see box below) show that the Approach 1 results for reporting year 2014 are in a similar range.

Results of the Approach 2 uncertainty analysis for the reporting year 2012

The Approach 2 level uncertainty (2012) in the national total annual CO_2 equivalent emissions **excluding LULUCF** was 4.64% (95% confidence interval from -4.61% to 4.67%), trend uncertainty (1990-2012) was 7.76%.

The Approach 2 level uncertainty (2012) in the national total annual CO_2 equivalent emissions **including LULUCF** was 5.82% (95% confidence interval from -5.80% to 5.84%), trend uncertainty (1990-2012) was 7.71%.

1.6.2 KP-LULUCF inventory

The total combined uncertainty of afforestation, deforestation, forest management and harvested wood products is 52.8%. The net CO_2 emissions are therefore 7.49 kt CO_2eq ± 3.95 kt CO_2eq (see Chapter 11.3.1.5 for details of the calculation).

1.7 Assessment of completeness

1.7.1 GHG inventory

Liechtenstein’s current GHG inventory is complete for all gasses concerning the second commitment period.

1.7.2 KP-LULUCF inventory

Liechtenstein’s current KP-LULUCF Inventory is complete.

2 Trends in greenhouse gas emissions and removals

This chapter provides an overview of Liechtenstein's GHG emissions and removals as well as their trends in the period 1990–2014.

2.1 *Aggregated greenhouse gas emissions 2014*

Liechtenstein's greenhouse gas emissions in the year 2014 amount to 205.1 kt CO_2 equivalent excluding LULUCF sources or sinks. This refers to 0.0055 kt CO_2 equivalent per capita. Total emissions (excl. LULUCF) declined by 10.5% compared to 1990 and by 12.6% compared to 2013.

Among the different greenhouse gases, CO_2 accounts for the largest share of total emissions. The most important emission sources are fuel combustion activities in the Energy sector. Table 2-1 shows the emissions for individual gases and sectors in Liechtenstein for the year 2014. Emissions of CH_4 and N_2O originated mainly from the sector Agriculture, and F-gas emissions stem from the sector 2 Industrial processes and product use (IPPU) by definition.

Table 2-1 Summary of Liechtenstein's GHG emissions in 2014 by gas and sector in CO_2 equivalent (kt). Numbers may not add to totals due to rounding.

Emissions 2014	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**Total**
	CO_2 equivalent (kt)						
1 Energy	161.5	2.0	0.8	0.0	0.0	0.0	164.3
2 IPPU	NO	NO	0.2	12.1	0.0	0.1	12.5
3 Agriculture	0.0	16.3	8.1	0.0	0.0	0.0	24.4
5 Waste	0.0	2.6	1.3	0.0	0.0	0.0	4.0
Total (excluding LULUCF)	**161.5**	**20.9**	**10.4**	**12.1**	**0.0**	**0.1**	**205.1**
4 LULUCF	11.1	NO	0.4	0.0	0.0	0.0	11.6
Total (including LULUCF)	**172.6**	**20.9**	**10.8**	**12.1**	**0.0**	**0.1**	**216.7**
International Bunkers	*1.2*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*1.2*

A breakdown of Liechtenstein's total emissions by gas is shown in Figure 2-1 below. Figure 2-2 shows the contributions of each sector to the different gases.

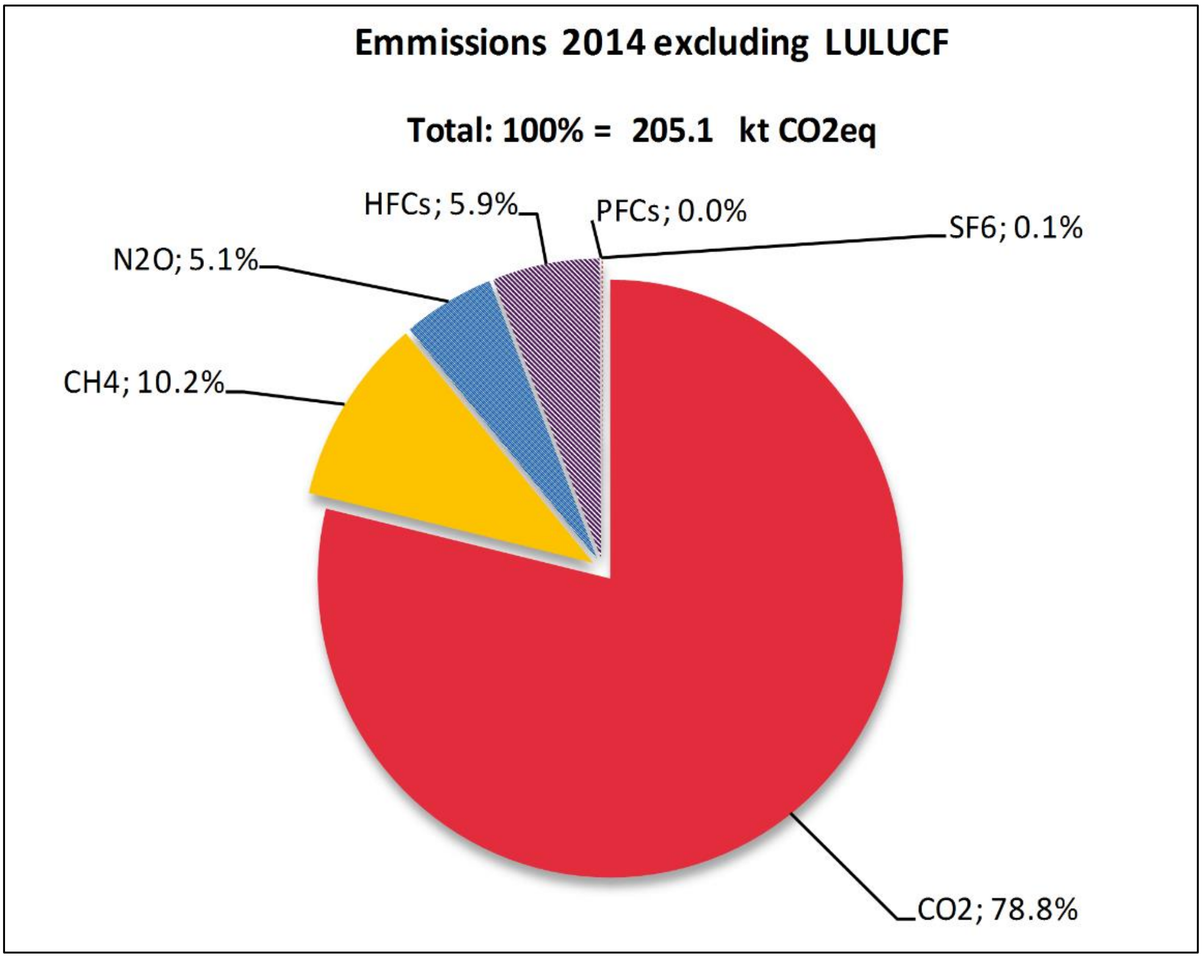

Figure 2-1 Liechtenstein's GHG emissions by gases excluding LULUCF emissions in 2014.

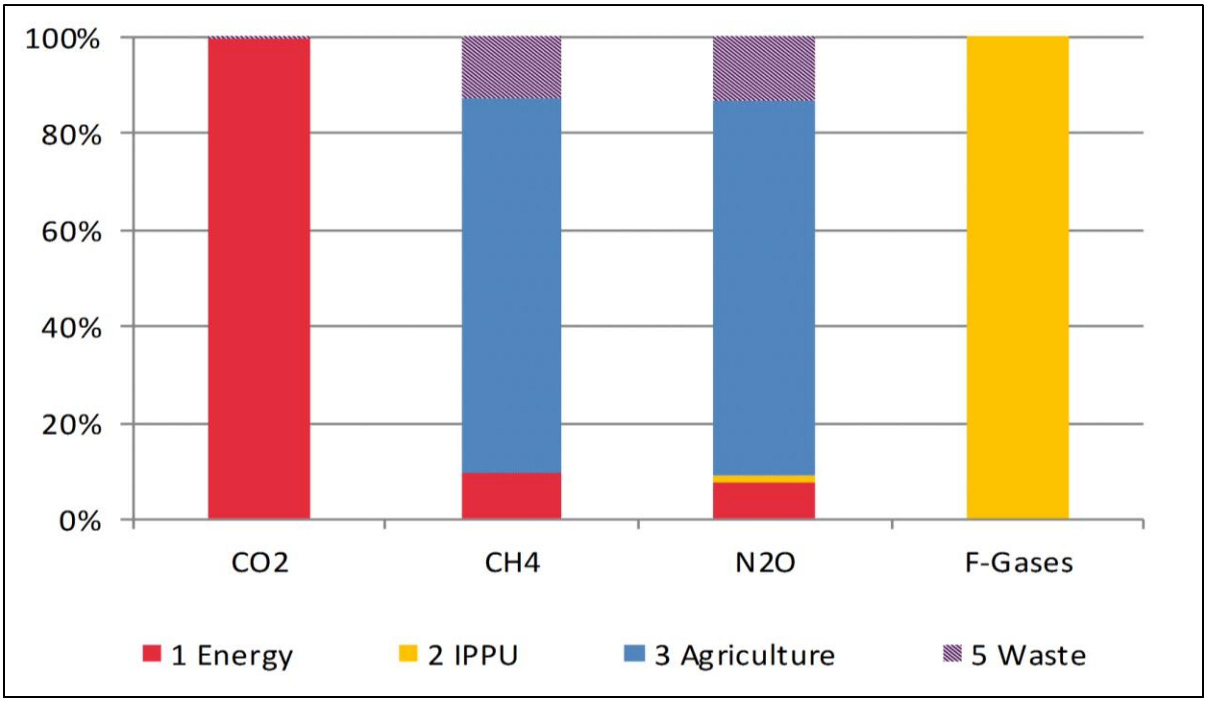

Figure 2-2 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions in 2014.

2.2 Emission trends by gas

Emission trends 1990–2014 by gas are summarised in Table 2-2 and in Figure 2-3.

Table 2-2 Summary of Liechtenstein's GHG emissions in CO_2 equivalent (kt) by gas, 1990-2014. The last column shows the percentage change in emissions in 2014 as compared to the base year 1990. The percentage change of HFCs amounts 116'335%.

Greenhouse Gas Emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO_2 emissions including net CO_2 from LULUCF	203.0	213.3	213.9	222.4	208.9	211.3	213.6	226.7	237.4	234.7
CO_2 emissions excluding net CO_2 from LULUCF	198.8	206.1	206.8	214.9	201.0	204.1	205.8	218.2	229.1	226.4
CH_4 emissions including CH_4 from LULUCF	19.1	18.9	18.5	17.7	17.8	17.7	18.1	17.8	17.6	16.9
CH_4 emissions excluding CH_4 from LULUCF	19.1	18.9	18.5	17.7	17.8	17.7	18.1	17.8	17.6	16.9
N_2O emissions including N_2O from LULUCF	11.5	11.7	11.6	11.4	11.3	11.2	11.2	11.2	10.9	10.7
N_2O emissions excluding N_2O from LULUCF	11.2	11.4	11.3	11.1	11.0	10.9	10.9	10.9	10.6	10.3
HFCs	0.0	0.0	0.1	0.2	0.5	1.4	1.7	2.1	2.7	3.3
PFCs	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SF_6	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.0
Total (including LULUCF)	233.6	244.0	244.1	251.7	238.6	241.6	244.7	257.8	268.6	265.7
Total (excluding LULUCF)	229.0	236.5	236.7	243.8	230.3	234.0	236.6	249.1	260.0	257.1

Greenhouse Gas Emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2 emissions including net CO_2 from LULUCF	224.8	224.0	229.6	239.5	239.0	238.5	239.7	209.6	228.6	219.9
CO_2 emissions excluding net CO_2 from LULUCF	216.8	214.6	219.9	229.3	229.3	229.0	231.2	200.9	219.7	205.6
CH_4 emissions including CH_4 from LULUCF	16.7	17.3	17.6	17.8	17.9	18.6	19.3	19.7	20.0	19.7
CH_4 emissions excluding CH_4 from LULUCF	16.7	17.3	17.6	17.8	17.9	18.6	19.3	19.7	20.0	19.7
N_2O emissions including N_2O from LULUCF	10.6	10.6	10.8	10.8	10.5	10.7	10.8	10.9	11.1	11.0
N_2O emissions excluding N_2O from LULUCF	10.2	10.3	10.4	10.4	10.1	10.3	10.4	10.5	10.7	10.6
HFCs	4.1	4.9	5.5	6.1	7.0	7.4	7.8	8.5	9.2	9.3
PFCs	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
SF_6	0.1	0.2	0.2	0.2	0.3	0.3	0.1	0.1	0.3	0.1
Total (including LULUCF)	**256.2**	**257.1**	**263.7**	**274.5**	**274.6**	**275.4**	**277.7**	**248.9**	**269.3**	**260.1**
Total (excluding LULUCF)	**247.9**	**247.3**	**253.7**	**263.9**	**264.5**	**265.5**	**268.9**	**239.8**	**260.0**	**245.4**

Greenhouse Gas Emissions	2010	2011	2012	2013	2014	1990-2014
	CO_2 equivalent (kt)					%
CO_2 emissions including net CO_2 from LULUCF	205.4	188.2	196.9	204.1	172.6	-15.0%
CO_2 emissions excluding net CO_2 from LULUCF	191.0	177.1	185.6	192.9	161.5	-18.7%
CH_4 emissions including CH_4 from LULUCF	19.1	19.6	20.0	19.2	20.9	9.3%
CH_4 emissions excluding CH_4 from LULUCF	19.1	19.6	20.0	19.2	20.9	9.3%
N_2O emissions including N_2O from LULUCF	10.7	11.1	11.1	10.8	10.8	-5.6%
N_2O emissions excluding N_2O from LULUCF	10.3	10.7	10.6	10.4	10.4	-7.0%
HFCs	10.3	10.8	11.5	12.0	12.1	see caption
PFCs	0.1	0.1	0.1	0.1	0.0	---
SF_6	0.0	0.0	0.0	0.2	0.1	---
Total (including LULUCF)	**245.6**	**229.8**	**239.5**	**246.3**	**216.7**	**-7.3%**
Total (excluding LULUCF)	**230.8**	**218.2**	**227.8**	**234.6**	**205.1**	**-10.5%**

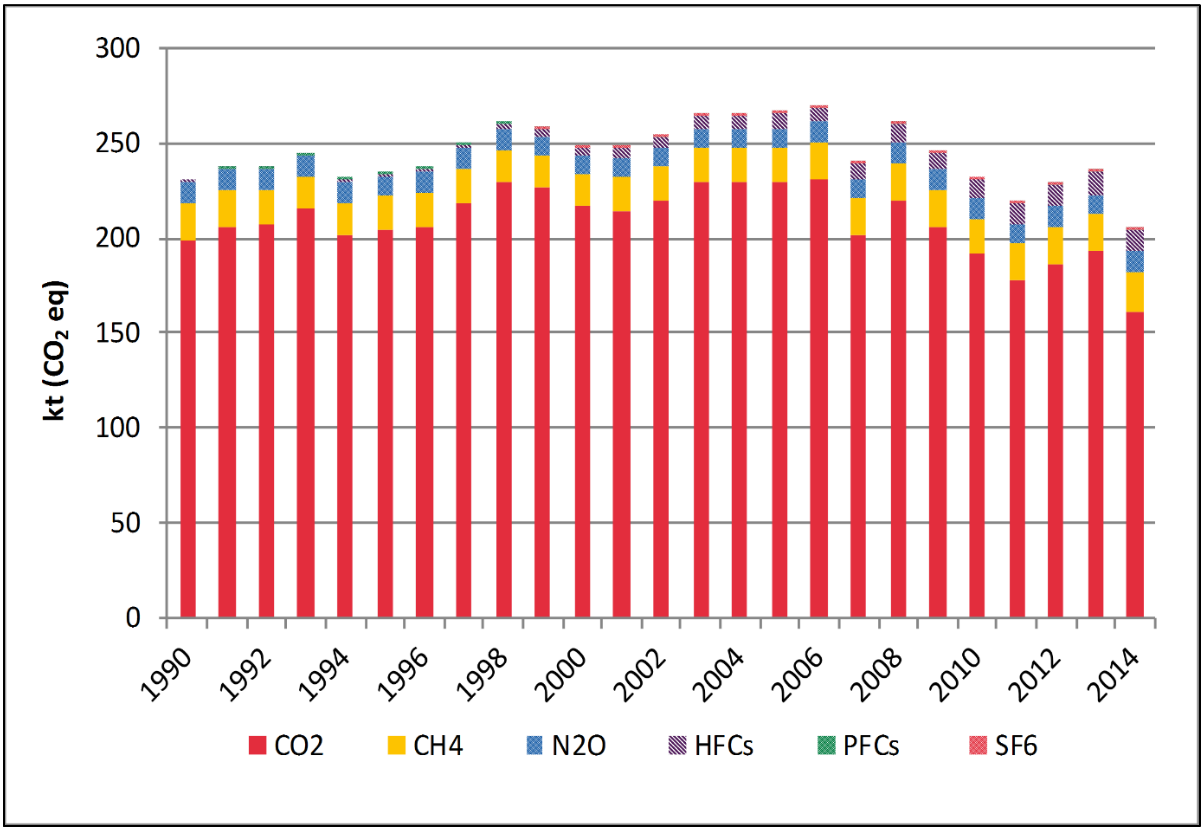

Figure 2-3 Trend of Liechtenstein's greenhouse gas emissions by gases 1990–2014. CO_2, CH_4 and N_2O correspond to the respective total emissions excluding LULUCF.

Emission trends for the individual gases can be described as follows:

- Total emissions (in CO_2 equivalent) excluding LULUCF sources or sinks decreased by 10.5% from 1990 to 2014.
- Total emissions (in CO_2 equivalent) including LULUCF show a decrease of 7.3% in 2014 compared to 1990 levels.
- Accounting for 78.8% of the total emissions, CO_2 is the most dominant greenhouse gas emitted in Liechtenstein. However, it is the first time its share dropped below 80%. CH_4 emissions represent 10.2% and N_2O emissions 5.1% of the total emissions.
- CO_2 emissions (excluding net CO_2 from LULUCF) have declined by 18.7% between 1990 and 2014. In comparison to the previous reporting year 2013, CO_2 emissions (excluding net CO_2 from LULUCF) decreased by 16.2% in 2014. The most important drivers of net CO_2 emissions are fuel prices and warm winters.
- CH_4 emissions (excluding CH_4 from LULUCF) have increased by 9.3% since 1990. Compared to 2013, CH_4 emissions (excluding LULUCF) show an increase by 8.9% in 2014. This effect is mainly triggered by an increase of emissions in source category 5D Wastewater treatment and discharge, which is a new key category in the current submission.
- N_2O emissions (excluding N_2O from LULUCF) have declined by 7% in 2014 compared to 1990. Regarding 2013, N_2O emissions (without LULUCF) remained similar in 2014 and only increased by 0.2%.
- HFC emissions increased due to their role as substitutes for CFCs. SF_6 emissions originate from electrical transformation stations and play a minor role for the total of the synthetic gases (F-

gases). PFC emissions are occurring since 1997 and are increasing on a low level. The share of the sum of all F-gases increased from 0.0% (1990) to 6.0% (2014).

2.3 Emission trends by sector

Table 2-3 shows emission trends for all major source and sink categories. As the largest share of emissions originated from sector 1 Energy, the table shows the contributions of the source categories attributed to the sector 1 Energy in more detail (1A1-1A5, 1B).

Table 2-3 Summary of Liechtenstein's GHG emissions by source and sink categories in CO_2 equivalent (kt), 1990–2014. The last column shows the percent change in emissions in 2014 compared to the base year 1990.

Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
1 Energy	**201.1**	**208.6**	**209.4**	**217.6**	**203.6**	**206.8**	**208.6**	**221.2**	**232.1**	**229.4**
1A1 Energy industries	0.2	0.9	1.9	2.0	1.8	2.1	2.6	2.5	2.9	2.9
1A2 Manufacturing industries and construction	36.3	36.0	36.3	37.6	35.6	35.7	35.8	37.6	40.4	39.9
1A3 Transport	76.7	90.1	89.4	87.2	79.9	81.9	83.2	86.8	86.4	90.5
1A4 Other sectors	87.4	81.3	81.3	90.2	85.7	86.5	86.4	93.5	101.6	95.3
1A5 Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8
2 IPPU	**0.5**	**0.4**	**0.5**	**0.6**	**0.9**	**1.7**	**2.1**	**2.4**	**3.0**	**3.6**
3 Agriculture	**25.5**	**25.5**	**24.8**	**23.8**	**23.8**	**23.7**	**23.9**	**23.5**	**23.0**	**22.1**
5 Waste	**2.0**	**1.9**	**1.9**	**1.9**	**2.0**	**1.9**	**2.0**	**1.9**	**1.9**	**1.9**
Total (excluding LULUCF)	**229.0**	**236.5**	**236.7**	**243.8**	**230.3**	**234.0**	**236.6**	**249.1**	**260.0**	**257.1**
4 LULUCF	**4.6**	**7.4**	**7.4**	**7.9**	**8.2**	**7.5**	**8.1**	**8.8**	**8.6**	**8.6**
Total (including LULUCF)	**233.6**	**244.0**	**244.1**	**251.7**	**238.6**	**241.6**	**244.7**	**257.8**	**268.6**	**265.7**

Source and Sink Categories	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
1 Energy	**219.9**	**217.6**	**222.8**	**232.2**	**232.0**	**231.8**	**234.1**	**203.9**	**222.8**	**208.6**
1A1 Energy industries	2.8	2.9	2.5	2.8	3.0	3.1	2.9	2.6	2.9	3.0
1A2 Manufacturing industries and construction	36.5	36.4	37.9	41.2	39.9	39.2	40.6	33.9	36.4	27.6
1A3 Transport	91.4	88.0	83.9	83.7	82.3	82.0	79.5	83.7	88.2	82.2
1A4 Other sectors	88.4	89.3	97.6	103.4	105.8	106.3	110.0	82.4	94.0	94.6
1A5 Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	0.8	0.9	0.9	1.0	1.0	1.2	1.2	1.2	1.3	1.2
2 IPPU	**4.5**	**5.4**	**6.0**	**6.7**	**7.5**	**7.9**	**8.2**	**8.9**	**9.8**	**9.7**
3 Agriculture	**21.5**	**22.5**	**22.9**	**23.0**	**23.0**	**23.5**	**24.6**	**24.9**	**25.1**	**25.0**
5 Waste	**2.0**	**1.9**	**2.0**	**2.1**	**2.0**	**2.2**	**2.0**	**2.1**	**2.3**	**2.0**
Total (excluding LULUCF)	**247.9**	**247.3**	**253.7**	**263.9**	**264.5**	**265.5**	**268.9**	**239.8**	**260.0**	**245.4**
4 LULUCF	**8.4**	**9.8**	**10.0**	**10.6**	**10.1**	**9.9**	**8.9**	**9.1**	**9.3**	**14.7**
Total (including LULUCF)	**256.2**	**257.1**	**263.7**	**274.5**	**274.6**	**275.4**	**277.7**	**248.9**	**269.3**	**260.1**

Source and Sink Categories	2010	2011	2012	2013	2014	1990-2014
	CO_2 equivalent (kt)					%
1 Energy	**194.1**	**180.1**	**188.7**	**195.9**	**164.3**	**-18.3%**
1A1 Energy industries	3.3	3.1	2.8	3.0	2.5	1329.1%
1A2 Manufacturing industries and construction	26.1	23.6	25.8	26.4	27.2	-25.2%
1A3 Transport	78.1	77.3	80.3	80.0	74.4	-3.1%
1A4 Other sectors	85.4	74.9	78.6	85.1	59.0	-32.5%
1A5 Other	NO	NO	NO	NO	NO	
1B Fugitive emissions from fuels	1.2	1.2	1.2	1.2	1.2	229.6%
2 IPPU	**10.5**	**11.0**	**11.8**	**12.4**	**12.5**	**2663.6%**
3 Agriculture	**24.2**	**24.9**	**25.1**	**24.0**	**24.4**	**-4.4%**
5 Waste	**2.0**	**2.2**	**2.2**	**2.3**	**4.0**	**95.2%**
Total (excluding LULUCF)	**230.8**	**218.2**	**227.8**	**234.6**	**205.1**	**-10.5%**
4 LULUCF	**14.8**	**11.5**	**11.8**	**11.7**	**11.6**	**152.3%**
Total (including LULUCF)	**245.6**	**229.8**	**239.5**	**246.3**	**216.7**	**-7.3%**

A graphical representation of the data in the table above is given in Figure 2-4. For the development of the emissions of sector 1 Energy consult chapter 3.

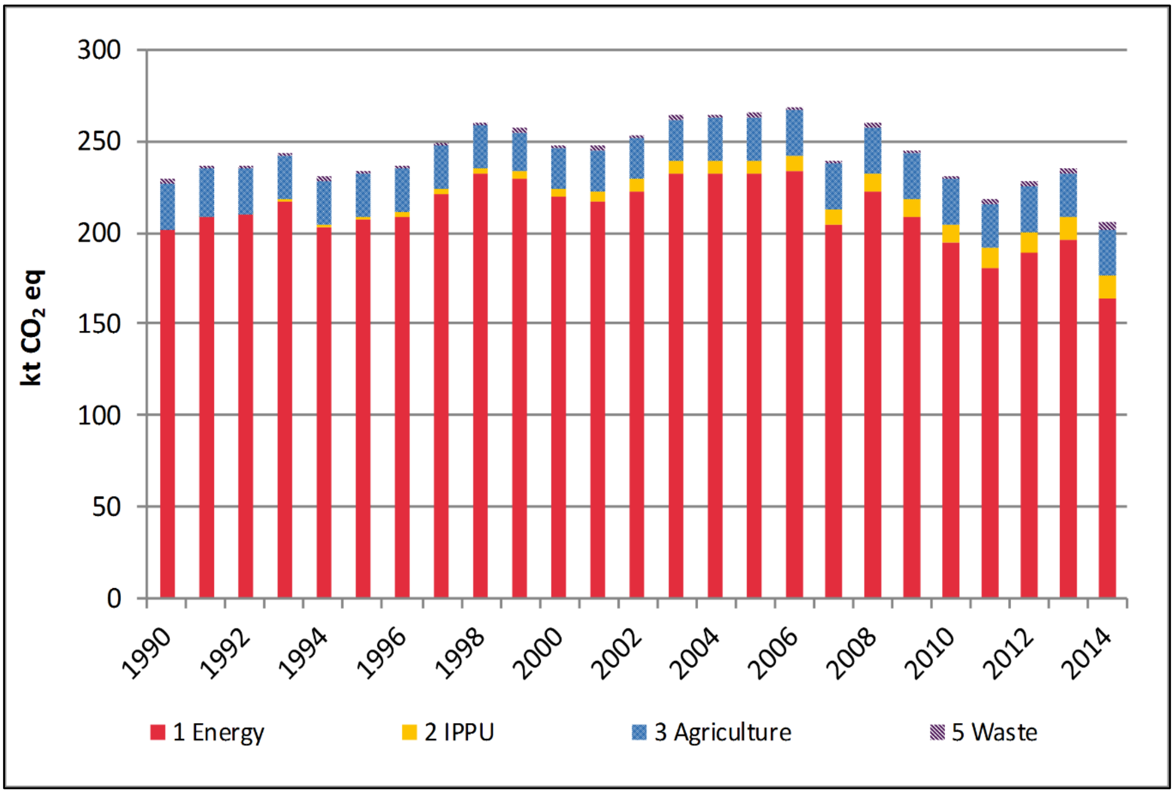

Figure 2-4 Trend of Liechtenstein's greenhouse gas emissions by main source categories in CO_2 equivalent (kt), 1990–2014 (excl. net CO_2 from LULUCF).

The emission trends within the sectors can be characterized as follows.

Sector 1 Energy: In 2014, 80.1% (excluding LULUCF) of Liechtenstein's GHG emissions originate from sector 1 Energy, which is 3.4 percentage points less than in 2013. The share of sector 1 Energy in the total emissions declined by 7.7% since 1990. Also the total emissions of the sector 1 Energy clearly decreased in comparison to 1990 levels (18.3%). The source categories within sector 1 Energy show following trends between 1990 and 2014:

- 1A1 Energy industries: Since 1990, Liechtenstein's gas-grid has been extended and natural gas has replaced gas oil as the main heating fuel in buildings.
- 1A2 Manufacturing industries and construction: Total emissions from this source category have declined by 25.2% since 1990. The consumption of gaseous fuels is the dominant energy carrier. Its emissions slightly increased by 2.1% compared to 1990. At the same time, liquid fuels decreased by 21.7%. Compared to 2013, the consumption of gaseous fuels strongly increased by 33.7%.
- 1A3 Transport: In previous years, fuel consumption in road transportation increased in line with a general increase of road-vehicle kilometres of all vehicle categories. However, in 2014 total emissions have decreased by 3.1% since 1990 and by 7.1% in comparison to 2013. This reduction is partly provoked by the fuel prices, which have decreased in Austria and increased in Liechtenstein between 2013 and 2014.

- 1A4 Other sectors: GHG emissions in source category 1A4 have strongly decreased by 30.7% compared to the previous reporting year 2013. The main reason for this decrease are the climatic conditions, i.e. the low number of heating degree days in 2014. Figure 2-5 shows he substantial correlation of heating degree days and fuel consumption in Liechtenstein (correlation coefficient during the period 1990-2014 is 0.66). Furthermore, various emission reduction measures in Liechtenstein are influencing the fuel consumption, such as the increase of the CO_2-tax in 2010 or the installation of a district heating pipeline, which is suggested by the stronger declining trend of the CO_2 emissions than the trend of the heating degree days. This is also an indication of an increasing decoupling between heating activites and CO_2 emissions.

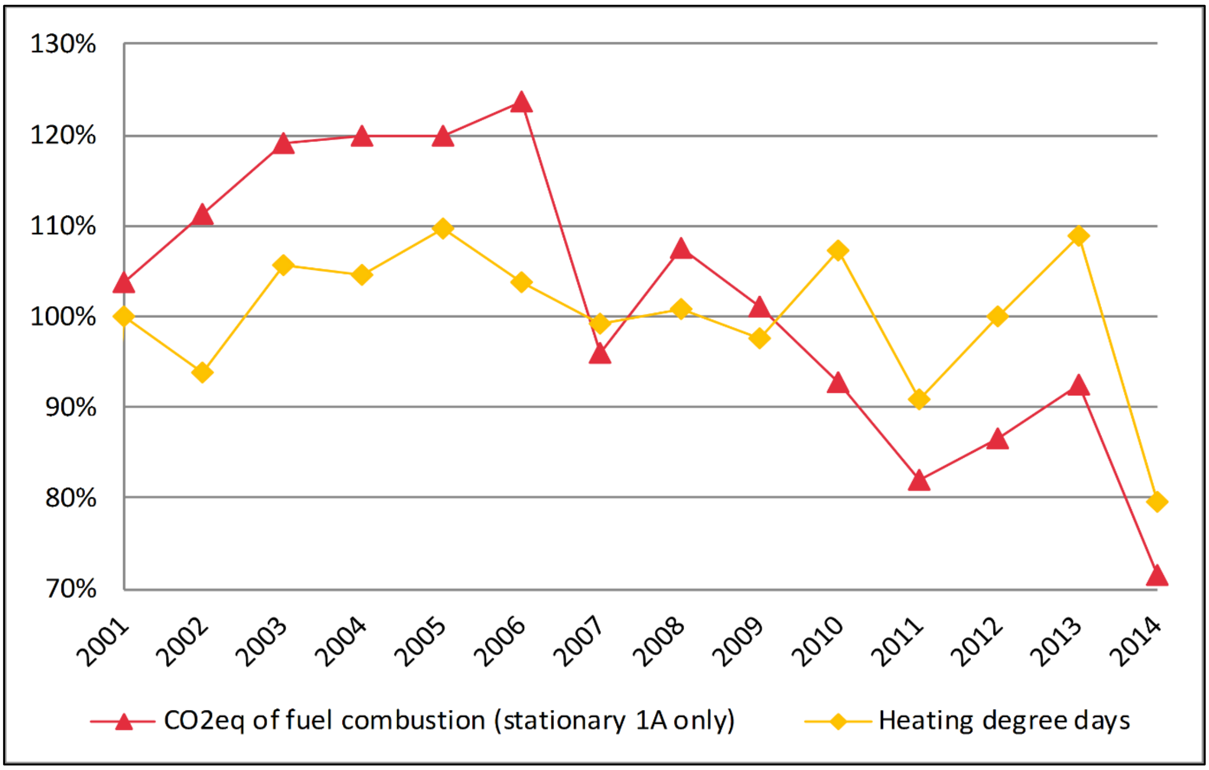

Figure 2-5 Relative trend for CO_2 emissions from 1A Fuel Combustion compared with the number of heating degree days. The drop in 2007 is mainly due to high oil and gas prices and a warmer winter than in the previous years.

- 1A5 Other (mobile): Liechtenstein does not have any emissions under source category 1A5 because Liechtenstein has no army.
- 1B Fugitive emissions from fuels: In parallel with the build-up of Liechtenstein's gas supply network since 1990, the fugitive emissions have strongly increased over the period 1990-2014 (229.6%).
-

Sector 2 Industrial processes and product use: Due to the lack of heavy industry within the borders of Liechtenstein, only small contributors, in particular product use is a relevant source of F-gases. Due to increasing use of F-gases, emissions in sector 2 strongly increased by almost a factor of 27 (2663.6%) between 1990 and 2014. Still, the emissions of sector 2 IPPU are on a low level.

Sector Agriculture: In 2014, the emissions are below the 1990 level by 4.4%. The main parameter influencing emissions in agriculture are animal numbers.

Sector 4 LULUCF: Figure 2-6 shows the net emissions by sources and sinks from LULUCF categories in Liechtenstein. The dominant category when looking at the changes in net CO_2 emissions are source category 4C Grassland and 4G Harvested wood products. The total net emissions increased by 152.3% between 1990 and 2014.

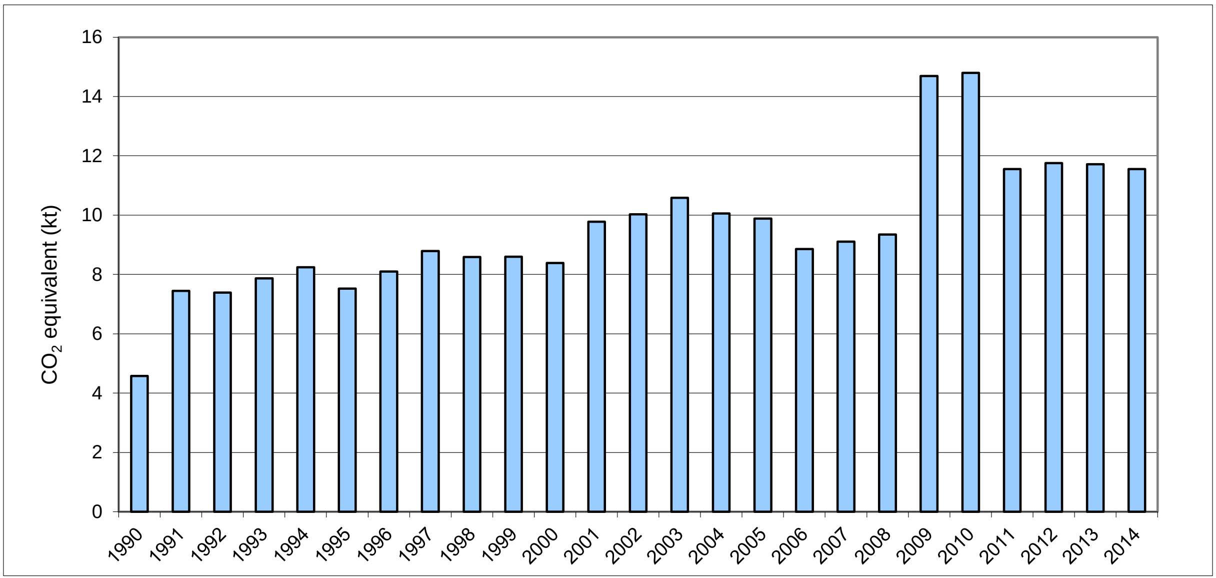

Figure 2-6 Net emissions of CO_2 of source category 4 LULUCF 1990–2014 in kt CO_2 equivalent.

Sector 5 Waste: In Liechtenstein, only few emissions occur from the sector Waste since all municipal solid waste is exported to a Swiss incineration plant. The increasing trend of the emissions compared to 1990 (95.2%) is due to increasing composting activities and an increase in emissions from domestic wastewater treatment.

2.4 Emission trends for precursor greenhouse gases and SO_2

Liechtenstein is member to the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) and submits data on air pollutants including indirect GHG. For the precursor substances NO_x, CO and NMVOC as well as for the gas SO_2, data from the current state of knowledge in air pollution reporting is shown in Table 2-4 (Acontec 2016). Note that a number of improvements had been carried out for the submissions of 15th and 22nd February 2016 to the CLRTAP resulting in a recalculation of the time series of several pollutants. There can be deviations between the numbers in Table 2-4 and the submitted NFR tables of Liechtenstein since the numbers displayed here are more recent and were subject to modifications. The system boundaries for the road transportation sector categories are not the same as under the UNFCCC reporting since Liechtenstein uses, the territorial approach under the CLRTAP and the sales principle for the UNFCCC reporting, which restricts the comparability of the two data sets.

Table 2-4: Development of the emissions of NO_X, CO, NMVOC (in t) and SO_X 1990-2014.

Precursor gases and SO_2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	tonnes									
NO_x	579	571	558	546	530	514	502	497	494	482
CO	2'167	2'063	1'881	1'708	1'576	1'422	1'289	1'172	1'061	952
NMVOC	1'242	1'172	1'037	955	819	764	619	577	535	507
SO_x	73	66	63	63	49	46	44	48	52	48

Precursor gases and SO_2	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	tonnes									
NO_x	473	456	448	443	429	423	410	392	377	368
CO	901	757	679	645	599	570	528	554	522	549
NMVOC	478	386	348	314	274	264	250	241	236	235
SO_x	40	37	40	41	35	34	36	23	28	32

Precursor gases and SO_2	2010	2011	2012	2013	2014	1990-2014
	tonnes					%
NO_x	355	348	347	340	319	-45%
CO	556	565	558	507	504	-77%
NMVOC	233	227	222	217	211	-83%
SO_x	27	24	25	26	20	-73%

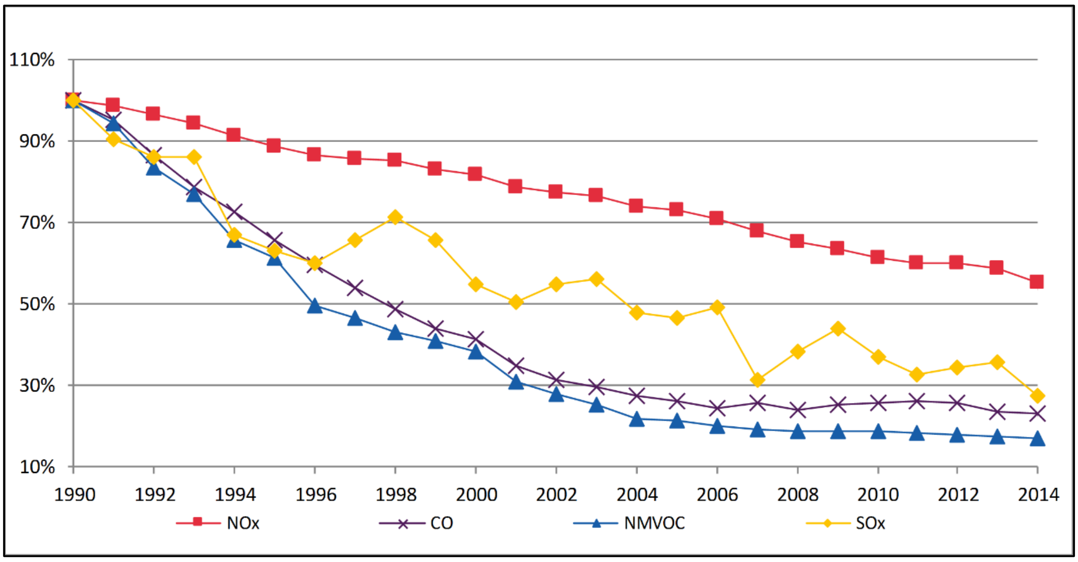

Figure 2-7 Trend of emissions of precursor gases NO_x, CO, NMVOC and SO_x 1990-2014.

The complete CLRTAP Inventory data may be found on the internet (see OE 2016b):
http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2016_submissions/

2.5 Emission trends in KP-LULUCF inventory

Table 2-5 illustrates the total net emissions occurring from activities under KP-LULUCF. Deforestation and emissions of forest management amount to 9.5 kt CO_2 equivalent in 2014. Removals originate from afforestation and reforestation activities as well as from forest management reference level (FMRL) and HWP activities. The total net CO_2 eq removals add up to -2.0 kt. In total, net emissions of 7.4 kt occurred in 2014.

Table 2-5: Summary table afforestation and reforestation, deforestation, forest management and HWP.

Activity year 2014	**Area** kha	**Net CO_2 emission/removal** 2014 kt CO_2 eq
A.1 Afforestation and reforestation	0.036	-0.274
A.2 Deforestation	0.174	4.315
B.1 Forest management (FM)	6.127	5.140
*B.1.1 minus FMRL**	---	-0.360
4.C HWP from FM	---	-1.398
Total net emission/removal		**7.423**

**FMRL: Forest Management Reference Level, incl. Technical corrections*

3 Energy

3.1 Overview

3.1.1 Greenhouse gas emissions

This chapter contains information about the greenhouse gas emissions of sector 1 Energy. In Liechtenstein, the sector 1 Energy is the most relevant greenhouse gas source. 164.3 kt CO_2 equivalents were emitted within this sector, which corresponds to 80.1% of total emissions (205.1 kt CO_2 equivalent, excluding LULUCF). The emissions of the time period 1990–2014 are depicted in Figure 3-1.

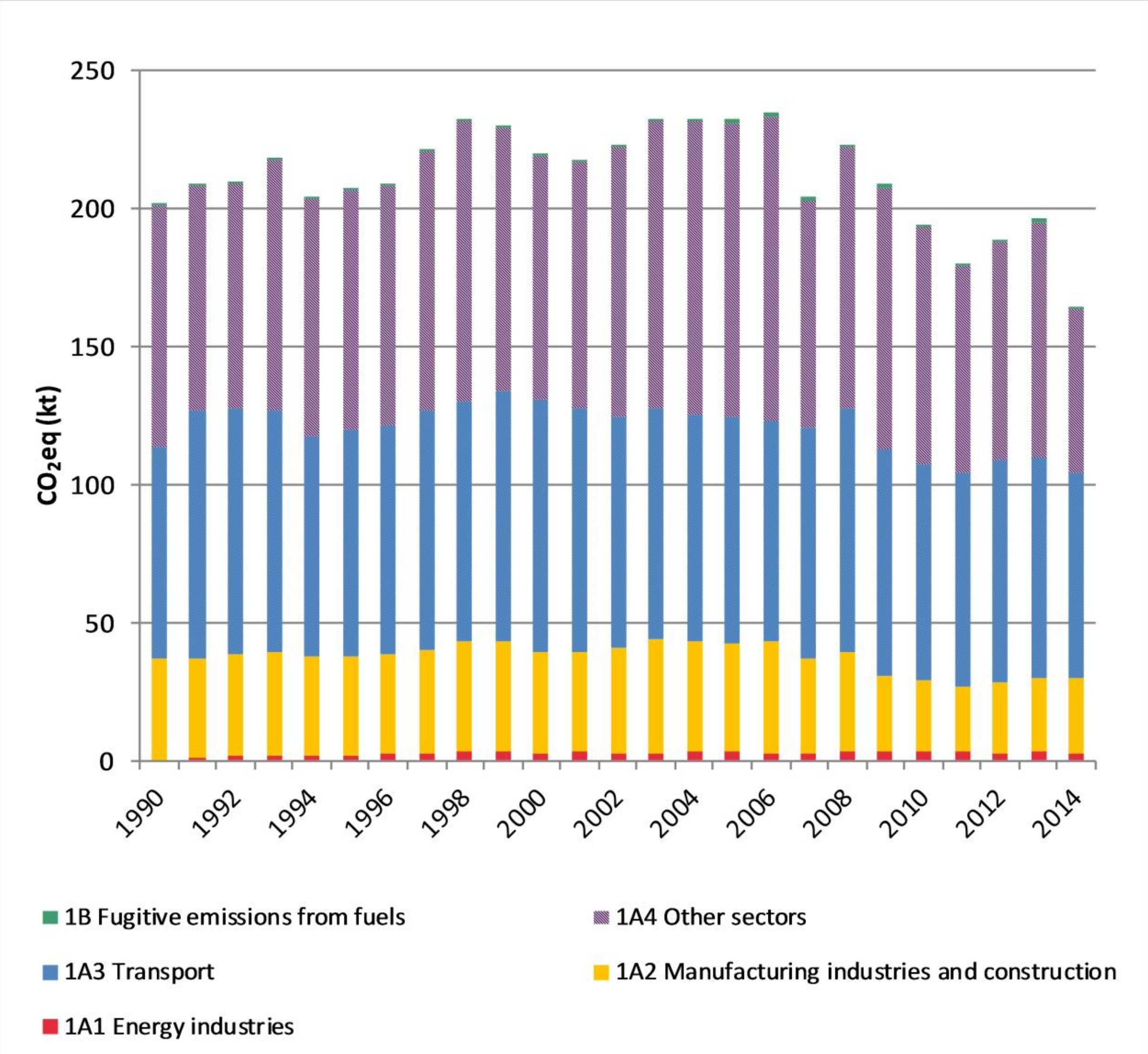

Figure 3-1 Liechtenstein's GHG emissions of the sector 1 Energy from 1990 to 2014 by sub-sectors. Note that there are no emissions in sub-sector 1A5.

Table 3-1 summarises the emissions of sector 1 Energy by individual gases 1990–2014. The numbers do neither include emissions from international bunkers (aviation) nor CO_2 emissions from biomass burning since none of those are accounted for in the UNFCCC and the Kyoto Protocol.

Table 3-1 GHG emissions of source category 1 Energy by gas in CO_2 equivalent (kt), 1990–2014 and the relative increase 1990–2014 (last column).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO_2	198.7	206.1	206.7	214.8	200.9	204.0	205.7	218.2	229.1	226.4
CH_4	1.3	1.3	1.4	1.4	1.3	1.3	1.4	1.4	1.5	1.5
N_2O	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.5
Sum	**201.1**	**208.6**	**209.4**	**217.6**	**203.6**	**206.8**	**208.6**	**221.2**	**232.1**	**229.4**

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2	216.7	214.5	219.9	229.2	229.2	228.9	231.2	200.9	219.6	205.5
CH_4	1.6	1.6	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.1
N_2O	1.5	1.4	1.3	1.3	1.0	1.0	0.9	0.9	1.0	1.0
Sum	**219.9**	**217.6**	**222.8**	**232.2**	**232.0**	**231.8**	**234.1**	**203.9**	**222.8**	**208.6**

Gas	2010	2011	2012	2013	2014	1990-2014
	CO_2 equivalent (kt)					%
CO_2	191.0	177.0	185.6	192.8	161.5	-18.7%
CH_4	2.2	2.2	2.2	2.1	2.0	58.7%
N_2O	0.9	0.9	0.9	0.9	0.8	-29.3%
Sum	**194.1**	**180.1**	**188.7**	**195.9**	**164.3**	**-18.3%**

Table 3-2 shows more details of the emissions of sector 1 Energy in 2014. The table includes emissions from international bunkers (aviation) and from biomass burning in two separate rows, which are both not accounted for in the Convention under the UNFCCC and the Kyoto Protocol.

Table 3-2 Summary of sector 1 Energy, emissions in 2014 in kt CO_2 equivalent (rounded values).

Emissions 2014	CO_2	CH_4	N_2O	Total	
Sources	CO_2 equivalent (kt)				%
1 Energy	**161.5**	**2.0**	**0.8**	**164.3**	***100.0%***
1A Fuel Combustion	161.5	0.8	0.8	163.1	***99.3%***
1A1 Energy industries	2.5	0.0	0.0	2.5	***1.5%***
1A2 Manufacturing industries and construction	27.0	0.0	0.1	27.2	***16.5%***
1A3 Transport	73.8	0.1	0.5	74.4	***45.3%***
1A4 Other sectors	58.2	0.6	0.2	59.0	***35.9%***
1A5 Other	NO	NO	NO	NO	-
1B Fugitive emissions from fuels	**NA,NO**	**1.2**	**NA,NO**	**1.2**	***0.7%***
International Bukers	**1.2**	**0.0**	**0.0**	**1.2**	-
CO_2 Emissions from Biomass	**16.6**	**-**	**-**	**16.6**	-

Emissions from sector 1 Energy may be characterised as follows:

- Concerning the total emissions 2014 (CO_2 eq) from sector 1 Energy, a trend of -18.3% can be observed when compared to emissions in 1990. Also when comparing 2013 to 2014, emissions declined by 16.1%, which is mainly caused by the low number of heating degree days in 2014. The emissions of the sector 1 Energy reached a minimum 2014.
- The three source categories 1A2, 1A3 and 1A4 dominate the emissions of sector 1 Energy and cover altogether 97.7% (160.5 kt CO_2 eq) of its emissions.
    - 1A3 Transport accounts for 45.3% of the emissions and is the largest source of emissions in 2014.
    - 1A4 Other sectors (commercial/institutional, residential) contributes to 35.9% of the total energy-related emissions.
    - 1A2 Manufacturing industries and construction contributes to 16.5% of the emissions.
    - 1A1 Energy industries and 1B Fugitive emissions only play a minor role. In 2014, they cover 1.5% and 0.7%, respectively, of the total sector 1 emissions.
- The only occurring bunker emissions originate from a helicopter base in Balzers, Liechtenstein. Only few flights are domestic, most of them are business flights to Switzerland and Austria, producing bunker emissions of 1.2 kt CO_2 eq.
- CO_2 emissions from biomass add up to 16.6 kt. They include wood burning (heating) and the burning of sewage gas (heating, power) as well as the consumption of biogas produced from sewage gas, which is fed into the general gas network.
- The far most important gas emitted from source category 1 Energy is CO_2. It accounts for 98.8% of the category in 1990 and for 98.3% in 2014.
- In 2014, CH_4 emissions contributed 1.2% to the total emissions of the sector 1 Energy. The increasing trend since 1990 (58.7%) is the result of the extended consumption of natural gas and the subsequent increase of fugitive emissions of methane (increase by 329.6%). Additionally, the CH_4 emissions of source category 1A4 have increased by 310.3% in the same period. The CH_4 emissions from road transportation have changed by -81.8%, mainly due to the growing number of gasoline passenger cars with catalytic converters.
- N_2O emissions remained stable and accounted for 0.5% of the total sector 1 Energy emissions in 1990 and 2014. 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 7 categories within the energy sector (see Chapter 1.5). The emissions in 1990 and 2014 of these categories are depicted in Figure 3-2. Most dominant are the CO_2 emissions from 1A3b Road Transportation.

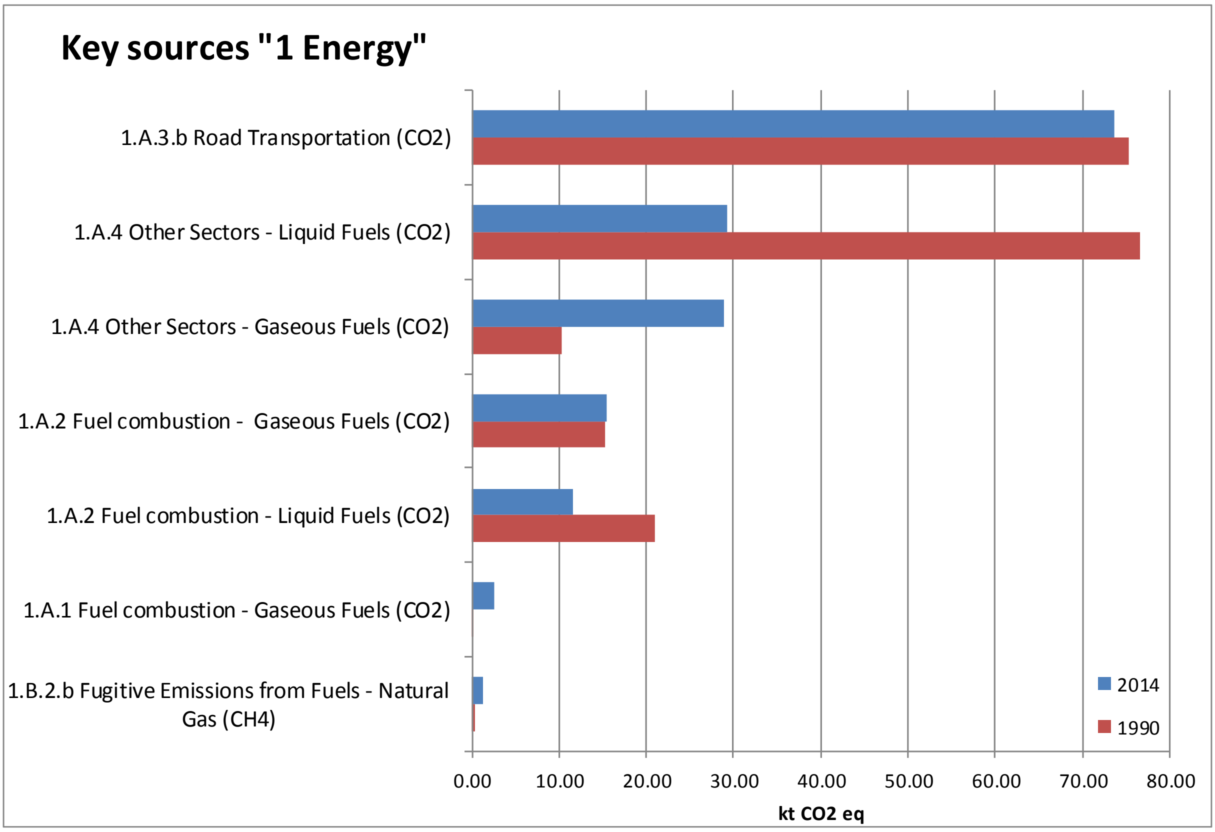

Figure 3-2 Key sources in the energy sector. Emissions in CO_2 equivalents (kt) per key source category in 2014 and in the base year 1990.

3.2 Source category 1A – Fuel combustion

3.2.1 Comparison of the sectoral approach and the reference approach

The reference approach uses Tier 1 methods for the different source categories of the sector 1 Energy, whereas the national (sectoral) approach uses specific methods for the different source categories. For the inventory of the Framework Convention and the Kyoto Protocol the sectoral approach is used. The reference approach is only used for controlling purposes (quality control).

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. The oxidation factor is set to 1.0 because the combustion installations in Liechtenstein have very good combustion properties. Combined emissions of CO and unburnt VOC range between 0.1 and 0.3 % of CO_2 emissions for oil and gas combustion. The assumption of complete oxidation is also in line with the 2006 IPCC Guidelines that recommends the use of an oxidation factor of 1.0 (IPCC 2006).

Coal is not burnt anymore since 2012. For coal an oxidation factor of 1.0 was used as a conservative assumption and because the consumed amount was negligible. This is consistent with the information and assumptions from Switzerland’s inventory.

Conversion factors (TJ/unit) and carbon emission factors (t C /TJ) in 2016 have been taken from Table 3-5 (see reporting table CRF table1.A(b)) and are therefore identical to the ones used for the sectoral approach.

The apparent consumption, the net carbon emissions and the effective CO_2 emissions are calculated for the reference approach as prescribed in the reporting table - CRF table 1A(b). Data is taken from the energy statistics as described in chapter 3.2.4.2. The reference approach covers the CO_2 emissions of all imported fuels minus exported fuels (e.g. natural gas by the gas network).

Table 3-3 and Figure 3-3 show the differences between reference and sectoral (national) approaches 1990–2014. Energy consumption differs by around 0.06%, whereas CO_2 emissions show a maximum difference of 0.08%.

The difference of the energy consumption between the reference and the sectoral approach can be explained by different measurement methods of the both approaches. While for the reference approach the total gas imports and exports are measured, more detailed information of the gas usage from the gas utility are used for the sectoral approach. This disaggregated data varies from the top-down reference approach data due to measuring errors, rounding errors and other assumptions made by the gas utility.

The main explanation of the small differences in CO_2 emissions is that a small fraction of the gas consumed is not burnt but lost in the distribution network leading to higher total of emissions as in the case of a complete burning of the natural gas. Consequently, the results of the reference approach, which considers this fact, become larger compared to the sectoral approach results.

As the consumption of gas is increasing in Liechtenstein the differences between the two approaches are increasing, too.

Table 3-3 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. For calculating the difference in energy consumption between the two approaches, data as reported as “apparent” energy consumption (excluding non-energy use, reductants and feedstocks) are used for the reference approach.

Difference between reference and sectoral approach										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	percent (%)									
Energy consumption	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04
CO_2 emissions	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	percent (%)									
Energy consumption	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.05	0.06
CO_2 emissions	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06

	2010	2011	2012	2013	2014
	percent (%)				
Energy consumption	0.06	0.07	0.07	0.07	0.06
CO_2 emissions	0.06	0.07	0.07	0.06	0.08

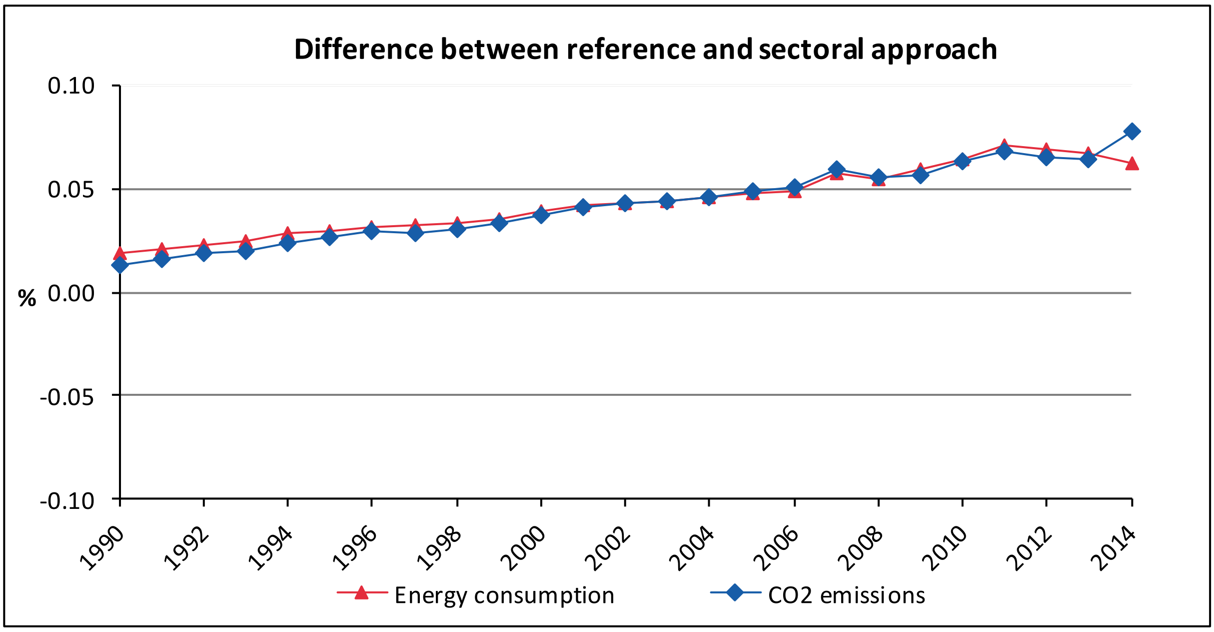

Figure 3-3 Time series for the differences between reference and sectoral approach. Numbers are taken from the table above.

Recalculation in the reference approach

- For this submission, the lower heating values of Gasoil, Natural gas, Hard coal, LPG, Diesel oil and gasoline are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series. The time series for energy consumption and CO_2 emissions has been recalculated for 1990-2013.
- Data on consumption of natural gas are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, which leads to a recalculation for 1990-2012 (CO_2).
- Gaseous fuels/Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore, in the consumption of Natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of Natural gas and Biomass for 2013 (CO_2).

3.2.2 International bunker fuels (1D)

For Liechtenstein, the only source of international bunker emissions is civil aviation originating from one helicopter landing place. Total emissions of civil aviation are calculated as described in section 3.2.7.2 using a Tier 1 method. For the year 2014, the effective consumption for domestic and international flights was provided by the two operating companies of the helicopter landing site (Rotex Helicopter AG and Swiss Helicopter).

In 1995, an estimation was undertaken at the two operating companies that determined the share of international flights to be 85%. A second and more comprehensive estimation was made in 2001 and 2002 that determined a share of 84.3% in 2001 and 86.2% in 2002 (Rotex Helicopter AG 2007). For the years where comprehensive surveys on the split between domestic and international flight exist (1995, 2001, 2002, 2012 and 2013), these estimates are used. Based on this information a linear interpolation between the years 1995 and 2001 is applied for the shares in the years between. For the years before any studies are available (1990-1994) a fixed share of 85%, as determined in 1995, is applied. For the years 2003-2011 a mean value of 85% (best estimate) was applied as well. Since 2012, effective consumption data is available.

Since there are only two helicopters operated in Liechtenstein, activity data is highly dependent on the annual demand for these helicopters and thus emissions change significantly in years with high or low demand for flying (passengers and freight transportation).

Marine bunker emissions are not occurring.

Table 3-4 Kerosene (civil aviation) based on sales principle: International flights (bunker, memo item), domestic flights (reported under 1A3a) and total. Data source: Rotex Helicopter AG (Rotex Helicopter AG 2006-2015)

Kerosene	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	TJ									
International bunkers aviation	5.84	5.84	5.84	5.84	5.84	5.84	6.00	6.16	6.33	6.49
1A3a Domestic aviation	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**

Kerosene	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	TJ									
International bunkers aviation	6.66	6.82	6.12	6.74	4.82	6.52	10.47	10.36	10.14	12.08
1A3a Domestic aviation	1.08	1.09	1.14	1.19	0.85	1.15	1.85	1.83	1.79	2.13
Total	**7.74**	**7.91**	**7.26**	**7.93**	**5.68**	**7.67**	**12.32**	**12.18**	**11.93**	**14.21**

Kerosene	**2010**	**2011**	**2012**	**2013**	**2014**
	TJ				
international (bunker)	10.59	11.34	15.28	14.44	16.20
domestic (1A3a)	1.87	2.00	0.83	0.74	0.85
Total	**12.46**	**13.34**	**16.10**	**15.18**	**17.05**

3.2.3 Feedstocks and non-energy use of fuels

Energy data are taken from Liechtenstein’s energy statistics (OS 2015a). These statistics account for production, imports, exports, transformation and stock changes. Hence all figures for energy consumption, on which the Swiss GHG inventory is based, correspond to apparent consumption figures.

No bitumen and lubricants are produced in Liechtenstein. In 2014 the most relevant source is the use of bitumen in Liechtenstein (asphalt paving).

Bitumen is imported for road paving and NMVOC emissions from bituminous materials are related to road paving and to asphalt roofing and reported in sectors 2D3b and 2D3c. Regarding the use of bitumen, there are sales data available from the main producer and distributor of bituminous matter (based in Switzerland) that also supplies bitumen to Liechtenstein. There are further expert estimates about the shares of material supplied from Austria. Based on this information, further research has been conducted in 2014 to delineate a time series of valid data.
The data are not yet taken into account for the national inventory. It is planned to implement the use of bitumen and lubricants until submission 2017. The ERT recommended this issue in the ARR 2013 paragraphs 26 and 27 (FCCC/ARR 2013).

3.2.4 Country-specific issues

3.2.4.1 CO_2 emission factors and net calorific values (NCV)

The CO_2 emission factors and the net calorific values (NCV) used for the calculation of the emissions 2014 of sector 1 Energy are shown in Table 3-5.

Table 3-5 CO_2 emission factors and net calorific values (NCV) for fuels. The values are assumed to be constant over the period 1990-2014.

Fuel	CO_2 Emission Factor 1990-2014		Net calorific values (NCV)
	t CO_2 / TJ	t CO_2 / t	TJ / t
Hard coal	94.0	2.64	0.0281
Gas oil	73.7	3.16	0.0429
Natural gas	56.1	-	-
Gasoline	73.9	3.15	0.0426
Diesel oil	73.6	3.16	0.0430
Propane/Butane (LPG)	65.5	3.01	0.0460
Jet kerosene	73.2	3.15	0.0430
Alkylate gasoline	73.9	3.14	0.0425
Biofuel (vegetable oil)	73.6	2.77	0.0376
Sewage gas	100.5	1.93	0.0192

The NCV of Hard coal, Jet kerosene and Alkylate gasoline are taken from the Swiss overall energy statistics of the year 2000 (SFOE 2001). The NCV of hard coal, gasoil, natural gas, gasoline, diesel oil and LPG are taken from the energy statistic of Liechtenstein (OS 2015a).

The CO_2 emission factors of fossil fuels are taken from the Swiss overall energy statistics of the year 2000 (SFOE 2001) with the exception of LPG, which is based on FOEN 2015a and natural gas, which is taken from the IPCC 2006 Guidelines.

In 1998, 2008 and 2011 the values have been confirmed by measurement campaigns of NCV and carbon content of fuels (EMPA 1999, Intertek 2008, Intertek 2012) **and show that NCVs are almost constant over the whole reporting period**. The authors write in their report, that only small deviations were found, which are within the range of uncertainties in the measurements[4].

The NCV and emission factor of Biofuel is based on EMIS 2016/1A3b. The emission factor of sewage gas is based on the assumption that 35% of the volume of the sewage gas is CO_2 and 65% CH_4.

Note that the emissions factors for CH_4 and N_2O are not only dependent on the fuel type but on the technology as well. Therefore, they are not integrated in Table 3-5 but are shown in the corresponding sectors and categories.

3.2.4.2 Energy statistics (activity data)

National energy statistics and modifications

In general, the data is taken from Liechtenstein's energy statistics (OS 2015a). 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 3-6.

[4] Original source: „Im Vergleich mit der letzten grösseren Heizwert-Untersuchung von 1998 (EMPA Prüfbericht Nr. 172853) können nur einige kleine Änderungen beobachtet werden, die aber kaum grösser als die Messungenauigkeit sind“ (Intertek 2008, p. 5). English translation: “Compared to the last analyses of NCV, only small differences can be observed, which rarely exceed the uncertainty of the measurements.”

Table 3-6 Time series of Liechtenstein's fuel consumption based on the sales principle, including bunker fuel consumption (kerosene only) and biomass. Data sources: OS (2015a), OEP (2006c, 2008a) and Rotex Helicopter AG (2006– 2015).

Fuel	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	TJ									
Gasoline	819	916	957	947	878	903	910	954	896	919
Diesel	250	339	288	261	230	230	242	252	311	347
Gas Oil	1'264	1'109	1'070	1'182	1'088	1'058	982	1'118	1'201	1'053
Natural Gas	455	552	619	668	679	742	848	823	907	976
LPG	13.3	8.1	15.5	12.1	9.5	8.1	9.8	7.0	7.2	5.8
Hard Coal	1.04	0.98	1.18	1.07	0.76	0.73	0.53	0.56	0.59	0.31
Kerosene (domestic)	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.05	1.06	1.07
Sum	**2'804**	**2'927**	**2'952**	**3'073**	**2'887**	**2'944**	**2'993**	**3'155**	**3'323**	**3'303**
1990=100%	100%	104%	105%	110%	103%	105%	107%	113%	119%	118%
Kerosene (bunker)	5.84	5.84	5.84	5.84	5.84	5.84	6.00	6.16	6.33	6.49
Biomass										
Wood	42.9	29.7	42.8	38.9	49.1	36.2	33.6	40.8	45.7	50.1
Sewage gas	15.6	16.3	17.3	17.3	18.7	17.0	18.1	18.4	20.0	21.5
Biofuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum biomass	58.5	46.0	60.1	56.2	67.8	53.2	51.7	59.3	65.6	71.6

Fuel	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	TJ									
Gasoline	977	946	865	827	800	774	708	712	716	658
Diesel	298	268	288	334	343	369	400	440	495	472
Gas Oil	925	880	995	1'055	1'024	980	1'024	607	775	871
Natural Gas	960	1'063	1'089	1'165	1'231	1'284	1'308	1'259	1'297	1'024
LPG	5.5	3.9	4.2	4.6	4.1	3.7	5.5	6.1	4.7	4.8
Hard Coal	0.67	0.37	0.34	0.37	0.28	0.25	0.17	0.14	0.11	0.06
Kerosene (domestic)	1.08	1.09	1.14	1.19	0.85	1.15	1.85	1.83	1.79	2.13
Sum	**3'168**	**3'163**	**3'242**	**3'387**	**3'403**	**3'411**	**3'448**	**3'025**	**3'289**	**3'033**
1990=100%	113%	113%	116%	121%	121%	122%	123%	108%	117%	108%
Kerosene (bunker)	6.66	6.82	6.12	6.74	4.82	6.52	10.47	10.36	10.14	12.08
Biomass										
Wood	87.9	53.8	56.3	74.4	81.4	90.1	102.9	137.1	138.4	169.9
Sewage gas	21.7	20.9	20.0	20.7	21.6	20.8	22.5	24.3	25.0	23.7
Biofuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.6	0.1
Sum biomass	109.6	74.7	76.3	95.1	103.0	110.9	125.4	162.5	164.0	193.7

Fuel	**2010**	**2011**	**2012**	**2013**	**2014**
	TJ				
Gasoline	594	565	583	563	512
Diesel	475	498	556	578	552
Gas Oil	693	606	634	686	470
Natural Gas	1'079	954	971	1'030	856
LPG	5.3	4.2	4.1	3.9	3.6
Hard Coal	0.06	0.06	0.00	0.00	0.00
Kerosene (domestic)	1.87	2.00	0.83	0.74	0.85
Sum	**2'849**	**2'629**	**2'749**	**2'862**	**2'395**
1990=100%	102%	94%	98%	102%	85%
Kerosene (bunker)	10.59	11.34	15.28	14.44	16.20
Biomass					
Wood	182.9	198.9	202.8	172.5	165.7
Sewage gas	22.2	22.5	22.8	24.3	1.0
Biofuel	0.0	0.0	0.0	0.0	0.0
Sum biomass	205.2	221.4	225.6	196.8	166.7

The following modifications on the original energy statistics data have been carried out for the submission 2016:

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 and distribution companies, such as:

- Direct delivery of gas oil from Switzerland to Liechtenstein: the information provided by Switzerland includes delivery to final consumers and delivery to the main storage facility.

- Delivery from Liechtenstein's main storage facility: information from Liechtenstein's storage facility and its delivery to final customers.

The delivery from the main storage facility is therefore counted twice in the energy statistics 1990-2008. In order to avoid this double counting, the values have been corrected by substracting the amount of gas oil supplied from Switzerland to the storage facility from the overall amount of gas oil supplied, as provided by the energy statistics. Note that the storage facility was closed in 2008 (see below). Data on the amount of gas oil supplied to Liechtenstein's storage facility was collected from the Cooperative Society for the Storage of Gas Oil in the Principality of Liechtenstein (GHFL 2007, GHFL 2008). The actual consumption of gas oil in Liechtenstein is calculated based on the total amount supplied according to national energy statistics minus supply of the stock (see Table 3-7).

Table 3-7 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 stock supply: (*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*).

	Total supply	**Supplied to stock**	**Consumption 1**	**Assumed density**	**Consumption**	**Actual density**	**Consumption 2**	**Consumption**
Source	Energy Statistics	GHFL 2008	Calculated	OS-LIE	Calculated	FOEN 2012	Calculated	Calculated
Year	Gas oil [t]	Gas oil [t]	Gas oil [t]	Gas oil [t/m^3]	Gas oil [m^3]	Gas oil [t/m^3]	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	1'030
2007	14'549	352	14'197	0.840	16'902	0.845	14'282	611
2008	18'120	0	18'120	0.840	21'571	0.845	18'228	779
2009	20'368	0	20'368	0.840	24'248	0.845	20'489	876
2010	16'212	0	16'212	0.840	19'300	0.845	16'309	697
2011	14'183	0	14'183	0.840	16'885	0.845	14'267	610
2012	14'830	0	14'830	0.840	17'655	0.845	14'918	638
2013	15'986	0	15'986	0.840	19'031	0.845	16'081	690
2014	10'957	0	10'957	0.840	13'044	0.845	11'022	473

In 2008, the storage facility was closed down. From 2008 onwards, the amount supplied to the storage facility is therefore zero.

Gas oil supply is measured in volume units (litres, m^3) and later reported to the Office of Environment in mass units (t). This conversion is made with a (rounded) density of 0.840 t/m^3, whereas the more correct density is 0.845 t/m^3 (FOEN 2011). Therefore, the *Consumption 1* is corrected accordingly, resulting in *Consumption 2*, as is shown in Table 3-7. Using country-specific net calorific values provided by the Energy statistics of Liechtenstein (OS 2015a), the actual consumption in energy units results as used in Liechtenstein's GHG inventory. See also Table 3-5**.**

Natural gas

Natural gas consumption as published in the energy statistics (OS 2015a) is based on net natural gas imports. The amount of natural gas leaking from the distribution network (reported under 1B2b) and which 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

A census, carried out by the Office of Economic Affairs (OEA), revealed that values for fuel consumption have large uncertainties. A number of distributors of gasoline and diesel report annually the amount of gasoline and diesel provided to domestic gasoline stations. Since not all distributors are known (they may origin from any Swiss gasoline station and may differ every year), the census may not provide a complete statistics. Therefore, in 2000, the Office of Environmental Protection started a second survey of all public gasoline stations. The results of this new census can be considered as a complete overview of all gasoline and diesel oil sold to passenger cars (including "fuel tourism"[5]) for the years 2000-2014. For the years 1990-1999 (diesel: 1990-2001), data compiled by OEA were collected in their original units (mass and volume units were used) and transformed into energy units by using the related densities and NCV (see Table 3-5). To ensure quality of time-series consistency an outlier and implied emission factor check is carried out as described in 2006 IPCC Guidelines. Both checks revealed that the time series 1990-2014 are consistent.

The data from the energy statistics is used for **gasoline** consumption in 1990. For the years 1991-1999, a moving average over 3 years is applied (e.g. 1991: arithmetic mean of 1990, 1991 and 1992). From 2000 to 2014, the values of the second survey are used (OE 2015c). The resulting time series is shown in Table 3-6 in row “gasoline”.

For **diesel oil** the amount sold at gasoline stations does not yet cover the whole amount consumed.

- There are private diesel stations, which are not part of the OE census covering only publicly 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. As the diesel oil containers are subject to registration, the holders of these private diesel stations are known by the OEA. Based on this registration data, the OE (by that time called OEP) started an additional census of the diesel consumption by these private stations in 2002 (OEP 2006c, OE 2015c).
- Finally, consumption from the agriculture sector is known based on the subsequent information sources:
    - Until 2005: Farmers declared their purchase of diesel fuel and claimed refund of the fuel levy at the General Directorate of Swiss Customs, which was the collecting and refunding institution of fuel levies for fuel purchase in Switzerland and Liechtenstein, and which provided to the OEP information about the amount declared annually by Liechtenstein’s farmers. For simplification reasons, Switzerland has ceased the refunding system.
    - Since 2005: The OEP/OE collects consumption data directly at the level of individual farmers by conducting a specific survey. In winter 2007 the survey was carried out for the first time. The survey provided consumption data for 2005, which was also available

[5] Like in Switzerland, gasoline stations sell relevant amounts of gasoline and diesel to foreign car owners due to fuel price differences between Liechtenstein/Switzerland (same prices) and Austria, Germany. In 2014, the fuel tourism of Liechtenstein amounts to a net export (see FOEN 2016, Table 3-70). This amount of fuel is mainly consumed abroad (therefore called "fuel tourism"), but the amount must be reported as national under 1A3b Road transportation.

from the former method practised by the General Directorate of Swiss Customs. This allowed a quality control check. Since the difference was only 1%[6] (OEP 2006c), both methods are of equal and very high quality. The census is now being repeated annually.

The OEP/OE census for diesel oil therefore consists of three parts: diesel oil of public gasoline stations (in improved 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 data sources, as available since 2002, corresponds to the total diesel oil consumption.

For diesel oil the value in 1990 is taken from the energy statistics. For the years 1991-2001, a moving average over three years is applied (e.g. 1991: arithmetic average of 1990, 1991, 1992), because of low data quality. From 2002 to 2014, the values of the OEP/OE census are used, because for these years data of high quality is available. The resulting time series is shown in Table 3-6 in row “diesel”.

Kerosene

The effective kerosene consumption of the single helicopter base at Balzers is reported in detail for the years 2001-2014 (see Rotex Helicopter AG 2006-2015) and separated in domestic and international/bunker consumption using the method described in 3.2.2. Less detailed information are available for 1995. For all other years in the reporting period, adequate assumptions were made (see section 3.2.7.1).

Bunker

Bunker kerosene consumption see section 3.2.2.

Biomass

A description of the methodology for calculating CO_2 emissions from the combustion of biomass and the consumption of biofuels is included in the relevant chapters 3.2.5.2, 3.2.6.2, 3.2.7.2, 3.2.8.2 (Energy sectors) and 7 (Waste sector).

CO_2 emissions from biomass do not account for the national total emissions and are therefore reported as memo items only.

Energy statistics and contribution to the IPCC source categories

Gas oil

There is currently no data on the specific contribution of source categories 1A2, 1A4a and 1A4b to total gas oil consumption in 1A Fuel combustion available. Therefore, the following shares are roughly estimated based on expert judgement for all years from 1990 to 2014: the Energy Statistics of Liechtenstein (e.g. OS 2015a) only indicates the total consumption of gas oil. That means the distribution between the different sectors had to be evaluated by experts for all years from 1990 until 2014. The experts of Liechtenstein assume that 60% of the gas oil consumption can be attributed to the commercial and institutional sources (1A4a), 20% to the manufacturing industries and construc-tion companies (1A2) and the remaining 20% to residential sources (1A4b). As there has not been any

[6] Consumption based on General Directorate of Swiss Customs: 514'759 litres of diesel oil, based on the survey: 520'618 litres. Difference 5’859 litres (1.1%). Data source OEP 2007f.

significant change in the different sources regarding gas oil consumption nor any switch from the gas oil consumption from one sector to the other, constant shares are assumed between 1990 and 2014.

Table 3-8 Estimated share of source categories in total consumption of gas oil in 1A Fuel combustion.

Source category		Share in consumption of gas oil (1990-2014)
1A2	Manufaturing industries and contruction	20%
1A4a	Other sectors - Commercial/institutional	60%
1A4b	Other sectors - Residential	20%
Total 1A		100%

Natural gas

The data on total consumption of natural gas in Liechtenstein is provided by the gas utility (LGV 2015) and published in the national energy statistics (OS 2015a).

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 attribution is applied:

Table 3-9 Applied allocation between IPCC source categories and categories in Liechtenstein's natural gas (NG) consumption statistics.

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

Gasoline

The entire amount of gasoline sold is attributed to 1A3b Road transportation.

Alkylate gasoline is attributed 20% to 1A4b Residential and 80% to 1A4c Agriculture/forestry/fishing. This attribution is based on an expert estimate which takes into account that most of the alkylate gasoline is used in forestry. The amount of alkylate sold (activity data) is surveyed by a census in 2011 encompassing all selling stations and consumers (OEP 2011c). Data of the year 2011 is then extrapolated for the entire country. To calculate the time series until 1995 when selling of alkylate gasoline in Liechtenstein started, the development of consumption of the two biggest consumers were analysed. Based on this trend, the total sales estimated for Liechtenstein were linearly extrapolated back to 1996. For 1995, the year in which the sales started, it is assumed that only 50% of the amount of 1996 was sold.

Diesel oil

The diesel consumption, which is derived from three different data sources (census of private diesel fuel tanks, National Energy Statistics and census of diesel oil consumption in the agricultural sectors as described above), is attributed to the source categories according to the following assumptions.

Table 3-10 Data sources for the diesel consumption and its attribution to IPCC source categories for the period 1990-2014 (Acontec 2006).

Data source	1A3b Road transportation	1A4c Other sectors - Agriculture/forestry/fishing	1A2g Other - Off-road vehicles and machinery	Sum
Census gasoline stations	100%	0%	0%	100%
Private diesel fuel tanks agriculture	0%	100%	0%	100%
Private diesel fuel tanks industry	70%	0%	30%	100%

Please note that for the Swiss greenhouse gas inventory, the data for source category 1A Fuel combustion from the Swiss Overall Energy Statistics is corrected for the gas oil consumption in Liechtenstein (FOEN 2016). In the Swiss GHG inventory, the gas oil consumption in Liechtenstein is subtracted from the fuel consumption provided by 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.

Additional information on energy consumption

In order to increase the transparency, additional comprehensive data on energy consumption, shares of fuels and their development before 1990 and post-1990 are given in this chapter according to the recommendation of the ERT. Figure 3-4 and Table 3-11 from Liechtenstein's energy statistics 2001 (OS 2001) illustrate the evolution of the energy demand in Liechtenstein between 1964 and 2001. Natural gas consumption started only in the mid-1980s.

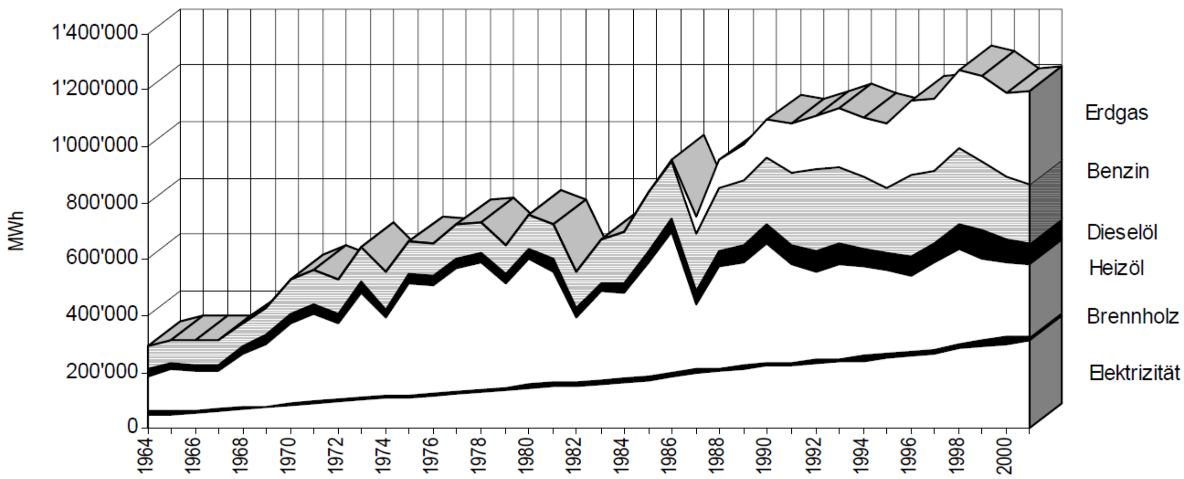

Figure 3-4 Liechtenstein's energy consumption and fuel shares 1964-2001 (OS 2001) in MWh. The fuels are descending: natural gas (Erdgas), gasoline (Benzin), diesel (Dieselöl), gas oil (Heizöl), wood (Brennholz), electricity (Elektrizität).

The electricity production 1990-2001 is given in Table 3-14 and documents the increasing relevance and shares of the natural gas consumption. In 1990, only one natural gas electricity production plant was in operation with a very small production. Older official numbers about the effective electricity production numbers are unfortunately not available. Nevertheless, the numbers indicate that the thermal power plant was installed shortly before 1990. This is also confirmed by an official publication of the Swiss gas organisation (Erdgas Schweiz, see Gasette 2014) about the renovation of the thermal power plant in Triesen (Liechtenstein) after more than 20 years of operation. As per official information from the Office of Environment (OE), the thermal power plant at Triesen was installed between 1989 and 1991 (first only one engine, the second engine was installed in 2000).

Table 3-11 Energy consumption 1964-2001 in MWh (OS 2011). The headers are from left to right: year (Jahr), electricity (Elektrizität), wood (Brennholz), coal (Kohle), gas oil (Heizöl), diesel (Dieselöl), gasoline (Benzin), natural gas (Erdgas), liquid gas (Flüssiggas), total (Total), energy consumption per inhabitant (Verbrauch je Einwohner). *) Consumption, **) Import

Jahr	Elektrizität* (MWh)[1]	Brennholz* (MWh)[2]	Kohle** (MWh)[3]	Heizöl** (MWh)[4]	Dieselöl** (MWh)[4,6]	Benzin** (MWh)[4]	Erdgas** (MWh)[5]	Flüssiggas** (MWh)[4]	TOTAL (MWh)	Verbrauch (MWh) je Einwohner
1964	48'008	13'007	11'396	123'801	22'904	84'880	-	.	303'995	15.9
1965	52'416	11'679	10'175	144'895	24'120	81'662	-	.	324'947	16.8
1966	56'102	9'680	8'425	135'603	25'440	84'514	-	.	319'763	16.1
1967	61'077	8'127	7'570	135'921	20'188	88'031	-	.	320'914	15.7
1968	67'542	7'150	1'718	188'230	25'993	80'730	-	.	371'362	17.5
1969	72'936	6'415	2'414	221'344	30'950	97'639	-	.	431'697	20.6
1970	81'730	4'974	4'197	286'201	33'159	124'336	-	.	534'597	25.0
1971	90'205	4'868	1'626	311'409	32'690	119'477	-	.	560'275	25.6
1972	96'377	4'153	1'474	273'818	33'501	122'647	-	.	531'971	23.7
1973	104'598	4'062	2'638	370'211	41'234	124'145	-	.	646'888	27.9
1974	108'639	6'546	2'638	274'601	32'089	130'398	-	.	554'910	23.4
1975	110'434	5'495	1'644	401'263	29'676	115'263	-	.	663'774	27.7
1976	117'675	4'885	1'198	385'138	31'365	114'864	-	.	655'126	27.1
1977	125'571	4'487	334	441'294	32'620	121'692	-	10'484	736'481	29.8
1978	132'655	4'991	1'064	449'510	36'546	104'731	-	12'643	742'139	29.3
1979	137'883	6'287	988	372'071	30'582	103'741	-	14'397	665'948	25.8
1980	144'955	11'625	1'661	443'941	37'863	121'175	-	27'101	788'320	31.3
1981	151'393	13'927	2'556	389'538	44'149	125'309	-	35'058	761'929	29.2
1982	152'065	14'024	1'038	229'320	34'774	126'871	-	28'957	587'048	22.3
1983	155'928	15'166	731	315'312	30'320	152'252	-	29'297	699'006	26.4
1984	163'813	15'120	1'074	302'185	35'647	182'093	-	32'642	732'575	27.5
1985	171'234	12'411	1'005	402'985	44'913	205'279	-	33'277	871'104	32.2
1986	182'414	15'212	699	500'256	48'184	200'490	3'316	31'788	982'358	35.9
1987	196'093	11'852	500	232'765	49'975	202'000	57'889	21'575	772'648	27.9
1988	203'943	10'111	423	358'878	58'847	222'536	100'974	6'338	962'050	34.1
1989	214'283	8'449	466	366'686	58'124	233'613	124'785	3'581	1'009'987	35.5
1990	221'176	12'407	304	420'929	69'417	233'050	140'705	3'684	1'101'673	37.9
1991	224'944	8'583	282	346'817	67'648	260'837	170'770	2'256	1'082'137	36.8
1992	233'000	12'376	338	309'409	75'887	288'369	191'330	4'291	1'115'000	37.3
1993	234'762	11'239	311	338'451	74'124	267'672	206'522	3'364	1'136'444	37.5
1994	241'159	14'186	221	319'434	61'602	252'767	209'830	2'621	1'101'820	36.0
1995	252'593	10'471	215	296'574	63'460	229'090	229'370	2'254	1'084'027	35.1
1996	259'303	9'715	155	273'432	68'058	288'913	262'318	2'703	1'164'597	37.4
1997	263'372	11'803	163	313'640	66'066	258'271	254'441	1'938	1'169'694	37.3
1998	283'639	13'202	170	340'423	87'166	267'017	280'459	1'989	1'274'065	39.8
1999	295'031	14'490	90	293'844	101'850	239'545	301'711	1'619	1'248'180	38.5
2000	302'018	25'419	195	260'123	79'646	223'819	296'992	1'530	1'189'742	36.2
2001	313'450	15'553	106	250'243	76'397	212'314	328'647	1'084	1'197'794	35.9

1 Bis 1994: Verbrauch im Landesnetz. Ab 1995 Verbrauch im Inland
2 Forstamtlicher Rechenschaftsbericht (Forstamtliches Jahr: 1. Juli - 30. Juni) (Holzverwertung)
3 Erhebung bei den Liechtensteiner Händlern
4 Erhebung bei den Liechtenstein beliefernden Grossisten
5 Meldungen der Liechtensteinischen Gasversorgung
** Verbrauch*
*** Import*

Table 3-12 Electricity production and the increasing natural gas consumption of Liechtenstein 1990-2001 (OS 2001). The headers are from left to right: year (Jahr), hydropower (Wasserkraft), natural gas (Erdgas), biogas (Biogas), photovoltaics (Fotovoltaik), total (Total). All numbers are given in MWh. 1) since 1995 in operation, 2) since 2000 in operation.

Jahr	Wasserkraft					Erdgas	Biogas	Fotovoltaik	Total
	Lawena und Samina	Jenny-Spoerry	Schlosswald 1	Letzana 2	Steia 2	Blockheiz-kraftwerke	Blockheiz-kraftwerke		
1990	54'674	738	.	.	.	123	.	.	55'535
1991	53'777	961	.	.	.	928	58	.	55'724
1992	59'655	2'061	.	.	.	2'309	871	.	64'896
1993	64'880	2'638	.	.	.	2'272	871	8	70'669
1994	61'339	2'503	.	.	.	2'243	1'070	18	67'173
1995	64'854	3'035	1'812	.	.	2'458	873	32	73'064
1996	59'516	2'752	1'991	.	.	3'080	1'082	40	68'461
1997	58'170	2'596	1'974	.	.	2'859	1'236	63	66'898
1998	63'826	2'380	1'985	.	.	3'352	1'302	71	72'916
1999	66'963	3'003	2'180	.	.	3'018	1'341	74	76'579
2000	71'492	2'308	2'280	495	10	2'960	1'424	66	81'035
2001	70'872	1'973	2'223	981	219	2'874	1'392	69	80'603

3.2.5 Source category 1A1 – Energy industries

3.2.5.1 Source category description: Energy industries (1A1)

Key categories 1A1
CO_2 from the combustion of Gaseous Fuels in Energy Industries (1A1) is a key category 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, source category 1A1 includes only emissions from the production of heat and/or electricity for sale to the public in 1A1a Public electricity and heat production. Petroleum refining (1A1b) and Manufacture of solid fuels and other energy industries (1A1c) do not occur (see Table 3-13).

Table 3-13 Specification of source category 1A1 Energy industries

1A1	Source	Specification
1A1a	Public electricity and heat production	This source consists of natural gas or biogas used for public co-generation units.
1A1b	Petroleum refining	Not occurring in Liechtenstein.
1A1c	Manufacture of solid fuels and other energy industries	Not occurring in Liechtenstein.

In 2014, 10% of Liechtenstein's electricity consumption was produced domestically and 90% was imported (see Table 3-14). In absolute values, the electricity consumption 2014 amounts to 395 GWh. This corresponds to a slight decrease of 2.1% since 2013. Domestic electricity generation decreased by 53% due to maintenance work in one of the hydropower plants. Correspondingly the electricity imports increased by 11% compared to 2013.

Table 3-14 Electricity consumption, generation and imports in Liechtenstein in 2014. Data source: Energy Statistics 2014 (OS 2015a).

Electricity consumption, generation and imports in Liechtenstein 2014	MWh	Share
Total electricity consumption in Liechtenstein	395'307	100%
Electricity generation in Liechtenstein 2014	40'386	10%
Hydro power	22'255	6%
Natural gas co-generation	2'522	0.6%
Biogas co-generation	45	0.0%
Photovoltaic	15'564	3.9%
Electricity imports in Liechtenstein 2014	354'921	90%

Liechtenstein's domestic electricity generation is dominated by hydroelectric power plants (see Figure 3-5). Other electricity sources are photovoltaic plants as well as fossil and biogas fueled combined heat and power generation plants.

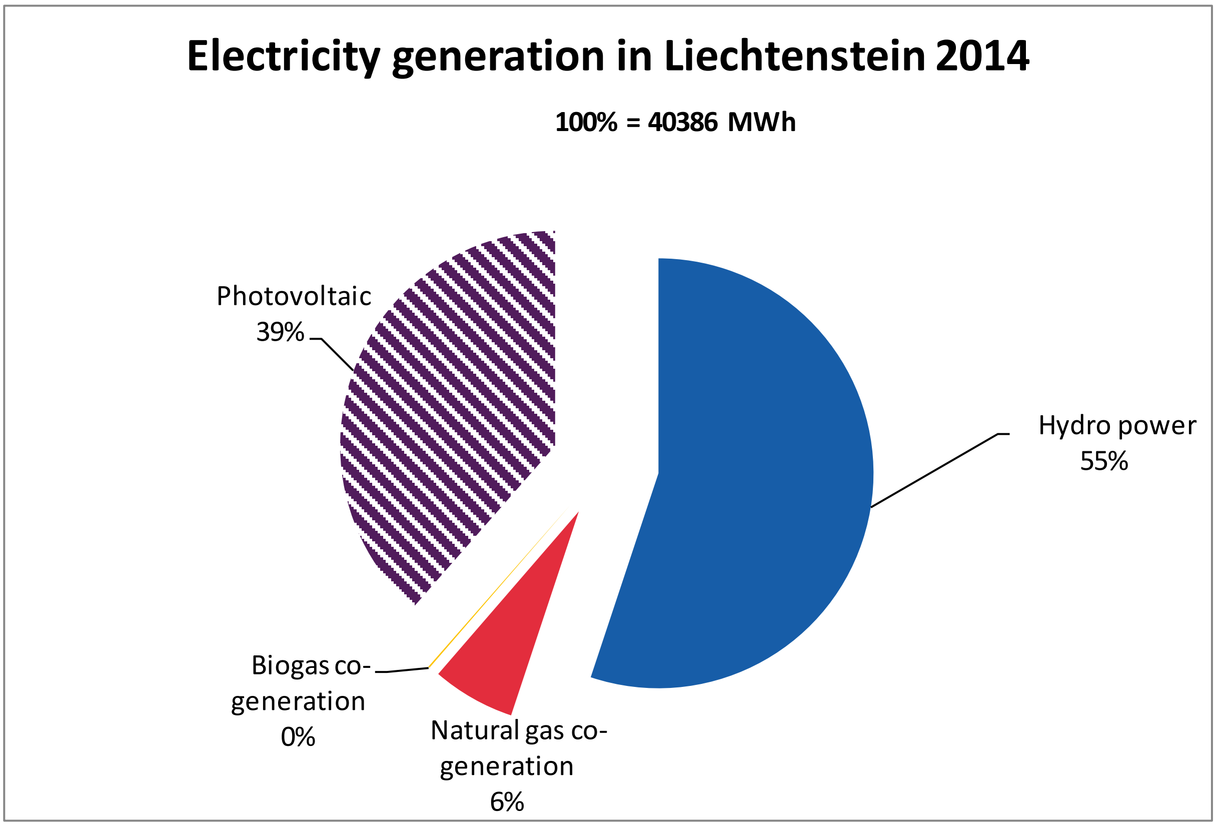

Figure 3-5 Structure of electricity generation in Liechtenstein 2014. Data source: Energy Statistics 2014 (OS 2015a).

Renewable sources account for 93.8% of domestic electricity generation in Liechtenstein. Compared to 2014, the electricity produced by photovoltaic plants has increased by 22% from 12'676 MWh to 15'564 MWh. Photovoltaic is thus representing 39% of the total domestic electricity production in 2014.

Waste incineration plants do not exist in Liechtenstein and municipal solid waste is exported to Switzerland for incineration. Therefore, no heat and/or electricity production from waste incineration plants is occurring in Liechtenstein.

As discussed above, electricity generation is based on natural gas and biogas co-generation. Therefore, source category 1A1 includes only emissions from gaseous fuels and biogas from wastewater treatment plants.

3.2.5.2 Methodological issues: Energy industries (1A1)

Methodology

For fuel combustion in 1A1a Public electricity and heat production, the only occurring source within 1A1 Energy industries, a Tier 2 method is used. Aggregated fuel consumption data from the Energy Statistics of Liechtenstein (OS 2015a) is used to calculate emissions. As mentioned above, only natural gas and biomass (sewage gas) are occurring within this source category 1A1a. The sources are characterised by similar industrial combustion processes and the same emission factors for all processes of this source category are applied.

Emission factors

Natural gas

The CO_2 emission factor of natural gas corresponds to the IPCC default value (IPCC 2006). The CH_4 emission factor of natural gas is country-specific and representative for engines used in Switzerland and Liechtenstein (lean fuel-air-ratio). Hence, emission factors have been taken from Switzerland (SAEFL 2005e). For more details have a look on the assumptions below. The N_2O emission factor corresponds to the default value from IPCC (2006).

Biomass

Country-specific emission factors for biogas from wastewater treatment plants are taken from SAEFL (2005e). The emission factor of biogenic CO_2 has been adapted to take into account CO_2 being present in the biogas as a product of fermentation already prior to combustion[7]. The following table presents the emission factors used in 1A1a.

Table 3-15 Emission factors for 1A1a Public electricity and heat production in energy industries for 2014 (public co-generation).

Source/fuel	CO_2 [t/TJ]	CO_2 biogenic [t/TJ]	CH_4 [kg/TJ]	N_2O [kg/TJ]
1A1a Public electricity and heat production				
Natural gas	56.1	NO	25.0	0.1
Biomass (Biogas from WWTP)	NO	56.1	25.0	0.1
Biomass (Sewage gas)	NO	100.5	6.0	11.0

[7] The CO_2 emission factor of 100.5 t biogenic CO_2 / TJ sewage gas is based on the assumption that 35% of the volume of the sewage gas is CO_2 and 65% CH_4.

Activity data

Activity data on natural gas consumption (in TJ) for Public electricity and heat production (1A1a) is extracted from the energy statistics (OS 2015a). Activity data on sewage gas consumption from waste water treatment plants is provided by plant operators (for data see section 7.5.2)[8]. In 2014, natural gas presents 85% and 5% of public electricity and heat fuel consumption. Table 3-16 documents the increase of heat fuel consumption in Liechtenstein for fossil fuels (natural gas) and biomass (sewage gas). Natural gas consumption increased by a factor of about 20 from 1990 to 2014. The rapid increase in the years 1990 – 1992 is due to the significant expansion of the natural gas network and increasing connections within Liechtenstein. This increase in natural gas consumption and the related increase in emissions is the reason why gaseous fuels of 1A1 is a key category regarding trend.

Biomass consumption increased from 1990 to 2013. Between 2013 and 2014 there is a strong decrease in biomass consumption, since the sewage gas is processed to biogas since November 2013. The biogas produced is fed to the general gas network. While in 1990, biomass contributed with 88% to electricity production and heat fuel consumption, in 2014 it only represents about 5% as mentioned above.

Table 3-16 Activity data for natural gas and biomass consumption in 1A1a Public electricity and heat production.

Source/fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A1a Public electricity and heat production					TJ					
Natural gas	2.16	14.04	32.40	33.48	31.32	35.64	44.64	43.56	50.40	50.40
Biomass	15.57	16.32	17.28	17.28	18.75	16.98	18.12	18.44	19.96	21.49

Source/fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A1a Public electricity and heat production					TJ					
Natural gas	47.52	50.40	43.20	48.60	50.76	54.00	48.96	44.28	50.04	51.12
Biomass	21.70	20.87	20.00	20.73	21.64	20.82	22.54	24.26	25.03	23.66

Source/fuel	2010	2011	2012	2013	2014
1A1a Public electricity and heat production			TJ		
Natural gas	56.16	52.56	48.24	52.13	44.24
Biomass	22.24	22.49	22.79	24.40	2.13

3.2.5.3 Uncertainties and time-series consistency

Uncertainties are analysed on an aggregated level for the entire source category 1A since no customs statistics exist that would provide reliable data on fuel imports into Liechtenstein. The aggregated uncertainty analysis is presented in chapter 3.2.10.

3.2.5.4 Category-specific QA/QC and verification

Information about category-specific QA/QC activities and verification processes are provided in chapter 3.2.11.

3.2.5.5 Category-specific recalculations

1A1a Gaseous fuels, Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore in the consumption of natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of natural gas and biomass for 2013 (CO_2, CH_4, N_2O).

[8] Activity data for biogas is provided in m^3. A density of 1.2 kg/m^3 and a lower calorific value of 19.2 MJ/kg are used to calculate the energy content.

3.2.5.6 Category-specific planned improvements

According to Liechtenstein's inventory development plan no future improvements are planned under source-category 1A1.

3.2.6 Source category 1A2 – Manufacturing industries and construction

3.2.6.1 Source category description: Manufacturing industries and construction (1A2)

Key categories 1A2
CO_2 from the combustion of gaseous fuels and of liquid fuels in manufacturing industries and construction (1A2) is a key category regarding both level and trend.

In source category 1A2 Manufacturing industries and construction only 1A2e Food processing, beverages and tobacco and 1A2g Other - Non-road vehicles and other machinery occur in Liechtenstein. In the category 1A2e all emissions from the combustion of fuels in stationary boilers, gas turbines and engines are included as well as on-site production of heat and electricity.

Note that In Liechtenstein, there are two companies participating in the European Emission Trading Scheme (EU-ETS):

- Hilcona AG in Schaan
- Herbert Ospelt Anstalt in Bendern.

The emissions of the EU-ETS companies represent only a small part of the source category emissions (In 2014 only 0.31 kt CO_2eq, representing approximately 2.5% of source category 1A2). As the contribution of emissions is very limited and the information of these companies is confidential, the EU-ETS emission reports are not used in the framework of the GHG inventory so far. It is planned to include the EU-ETS companies in Liechtenstein's GHG inventory from 2017 onwards (see chapter 3.2.6.6 for further information).

Table 3-17 Specification of source category 1A2 Manufacturing industries and construction

1A2	Source	Specification
1A2a	Iron and steel	Not occurring in Liechtenstein.
1A2b	Non-ferrous metals	Not occurring in Liechtenstein.
1A2c	Chemicals	Not occurring in Liechtenstein.
1A2d	Pulp, paper and print	Not occurring in Liechtenstein.
1A2e	Food processing, beverages and tobacco	Contains emissions of the food processing, beverages and tobacco industry such as meat production, milk products, convenience food, etc.
1A2f	Non-metallic minerals	Not occurring in Liechtenstein.
1A2g	Other non-road machinery	Contains emissions of non-road machinery in construction and industry.

3.2.6.2 Methodological issues: Manufacturing industries and construction (1A2)

Methodology

Food processing, beverages and tobacco (1A2e)

A top-down method based on aggregated fuel consumption data from the energy statistics of Liechtenstein (OS 2015a) is used to calculate emissions under 1A2e. The emission sources are characterised by rather similar industrial combustion processes and assumingly homogeneous emission factors. Thus a top-down approach is feasible. Therefore, identical emission factors for each fuel type are applied for these sources. The unit of emission factors refers to fuel consumption (in TJ). In addition, the industrial sector is rather small in Liechtenstein and therefore, the energy use for heating is an important emission source within this category. An oxidation factor of 100% is assumed for all combustion processes and fuels because technical standards for combustion installations in Liechtenstein are relatively high (see section 3.2.1).

Other – Non-road machinery (1A2g)

An Tier 2 method is used for non-road machinery in construction and industry. It is assumed that 30% of Liechtenstein's diesel consumption is attributed to activity from construction vehicles and machinery as well as industrial non-road vehicles and machinery (see Table 3-10). Emission factors are taken from the Swiss non-road study (INFRAS 2015).

Emission factors

CO_2 emission factors and NCV values are country-specific and have been determined based on the Swiss overall energy statistics of the year 2000 (SFOE 2001). In 1998, 2008 and 2011, the values have been confirmed by measurement campaigns of NCV and carbon content of fuels (EMPA 1999, Intertek 2008, Intertek 2012). For further information see chapter 3.2.4.1. For the N_2O emissions the default emission factors from IPCC 2006 have been used.

CO_2 emissions from combustion of natural gas are also calculated using the IPCC default emission factors (IPCC 2006) instead of country-specific values. Emission factors for CH_4 however are country-specific based on an analysis of industrial boilers documented in SAEFL 2000 (pp. 14-27). For biogas produced from sewage gas the same emission factors are used as for natural gas. Table 3-18 shows the emission factors used for the sources in category 1A2.

Table 3-18 Emission factors for sources in 1A2 in 2014.

Source/fuel	CO_2 [t/TJ]	CO_2 biogenic [t/TJ]	CH_4 [kg/TJ]	N_2O [kg/TJ]
1A2e Food processing, beverages and tobacco				
Gas oil	73.7		1.0	0.6
Natural gas	56.1		6.0	0.1
Biomass (Biogas from WWTP)		56.1	6.0	0.1
1A2g Other off-road vehicles and machinery				
Diesel	73.6		0.7	2.9

Activity data

1A2e Food processing, beverages and tobacco (1A2e)

Activity data on fuel consumption (TJ) are based on aggregated fuel consumption data from the energy statistics of Liechtenstein (OS 2015a). In Liechtenstein, no heavy industries with high furnaces or other processes are occurring. Industries in Liechtenstein using fuels are of minor importance and consist mainly of small businesses. The Industry sector includes machinery, equipment manufacturing, production of dental products, transport equipment and food production but most of the manufacturing processes depend on electric energy and steam generation. Since 2009, steam is imported from the waste incineration plant in Buchs (Switzerland) and is not produced on-site from fossil fuels. Fuel consumption of source category 1A2e is mostly determined by the heating activities by Liechtenstein's companies.

It is further assumed that 20% of the Liechtenstein's gas oil consumption can be attributed to the food processing, beverages and tobacco industry.

1A2g Other – Non-road machinery (1A2g)

Activity data includes the consumption of diesel oil from non-road machineries in construction and industry.

It is assumed that the fleet composition in Liechtenstein is similar to the Swiss fleet composition (vehicle category, size class, age distribution).

The resulting disaggregated fuel consumption of source category 1A2 for the entire time series 1990-2014 is given in the table below.

Table 3-19 Activity data of Liechtenstein's fuel consumption in 1A2e Food processing, beverages and tobacco as well as in 1A2g Other non-road vehicles and machinery 1 from 1990 to 2014.

Source/fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	TJ									
1A2e Food processing, beverages and tobacco										
Gas oil	252.8	221.8	214.0	236.3	217.7	211.7	196.4	223.6	240.1	210.7
Natural gas	270.9	296.5	312.4	314.6	307.0	317.4	337.8	329.7	349.6	375.7
Biomass (Biogas from WWTP)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2g Other off-road vehicles and machinery										
Diesel	32.1	38.8	39.6	32.7	30.7	29.7	30.4	34.3	39.8	42.1

Source/fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	TJ									
1A2e Food processing, beverages and tobacco										
Gas oil	185.0	176.0	199.0	210.9	204.8	196.0	204.8	121.4	154.9	174.1
Natural gas	351.5	370.5	362.5	393.4	384.4	375.5	385.9	383.0	378.6	195.6
Biomass (Biogas from WWTP)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2g Other off-road vehicles and machinery										
Diesel	40.3	34.6	37.6	46.9	41.6	48.1	50.0	45.9	49.0	49.8

Source/fuel	2010	2011	2012	2013	2014
	TJ				
1A2e Food processing, beverages and tobacco					
Gas oil	138.6	121.3	126.8	137.2	94.0
Natural gas	218.8	188.7	208.2	206.7	276.5
Biomass (Biogas from WWTP)	NO	NO	NO	0.3	6.8
1A2g Other off-road vehicles and machinery					
Diesel	47.8	54.0	62.9	62.8	62.4

Table 3-19 documents the decrease of gas oil consumption by 63% from 1990 to 2014. This decrease is correlated with the extension of the natural gas grid in Liechtenstein which led to a corresponding substitution of gas oil as the main heating fuel in buildings (see also chapter 3.2.5.2). The consumption of liquid fuels showed a sharp decrease in 2007 followed by an increase in 2008 and

2009 and another decrease in 2010 and 2011 which are discussed below under source category 1A4 Other sectors.

During the same period, the consumption of gaseous fuels decreased by 28.9% including a sharp decrease of 48% in 2009. This significant decrease in the natural gas consumption can be explained by the installation of the new district heating pipeline. This new district heating facility, installed in 2009, delivers heat from the onsite waste incineration plant in Buchs (Switzerland). Related emissions are occurring in Switzerland and therefore reported in the inventory of Switzerland. Fluctuations in the natural gas consumption are a result of the changing heating needs in cold or warm winters. For example, the increase in natural gas consumption in 2010, 2012 and 2013 is illustrated by the increased heating needs as these were relatively cold winters.

This shift in fuel mix is the reason for CO_2 emissions from gaseous and liquid fuels in category 1A2 being key categories with regards to the trend 1990-2014.Between 2013 and 2014 there is a strong increase in biomass consumption, since sewage gas is processed to biogas since November 2013. The biogas produced is fed to the general gas network thus leading to an increase in biomass consumption in source category 1A2e.

3.2.6.3 Uncertainties and time-series consistency

Uncertainties are analysed on an aggregated level for the entire source category 1A since no customs statistics exist that would provide reliable data on fuel imports into Liechtenstein. The aggregated uncertainty analysis is presented in chapter 3.2.10.

3.2.6.4 Category-specific QA/QC and verification

Information about category-specific QA/QC activities and verification processes are provided in chapter 3.2.11.

3.2.6.5 Category-specific recalculations

- 1A2e Gaseous fuels: Data on consumption of natural gas are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, leading to a recalculation for 1990-2012 (CO_2, CH_4, N_2O).
- 1A2e NCV Gas oil, Natural gas: Data on net calorific values are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series (CO_2, CH_4, N_2O).
- 1A2e Gaseous fuels, Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore in the consumption of Natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of Natural gas and Biomass for 2013 (CO_2, CH_4, N_2O).

3.2.6.6 Category-specific planned improvements

According to Liechtenstein's inventory development plan no future improvements are planned under source-category 1A2.

3.2.7 Source Category 1A3 - Transport

3.2.7.1 Source category description: Transport (1A3)

Key categories 1A3b
CO_2 from the combustion of fuels in Road transportation (1A3b) is a key category regarding both level and trend.

The source contains road transport and national civil aviation. Civil aviation in fact is only a very small contribution resulting from only one helicopter base in Liechtenstein. Railway is not producing emissions (see below). Navigation and other transportation are not occurring in Liechtenstein. Further non-road transportation is included in source categories 1A2g Other non-road machinery and 1A4c Other sectors non-road transport in agriculture and forestry.

Table 3-20 Specification of Liechtenstein's source category 1A3 Transport.

1A3	Source	Specification
1A3a	Domestic aviation	Helicopters only.
1A3b	Road transportation	Light and heavy motor vehicles, coaches, two-wheelers.
1A3c	Railways	Fully electrified system, but no electricity infeed, no diesel locomotives, switchyard
1A3d	Domestic navigation	Not occurring in Liechtenstein.
1A3e	Other transportation	Not occurring in Liechtenstein.

3.2.7.2 Methodological issues: Transport (1A3)

Methodology

Domestic aviation (1A3a)

A Tier 1 method was applied for the calculation of emissions (see activity data below for additional information or chapter 3.2.2). Liechtensteins's emissions are calculated based on the fuel consumption, flying hours and the fleet composition of its single helicopter base at Balzers. Emission factors are constant for the entire time series (see Table 3-21). Kerosene consumption is available as real measured usage of the two helicopter companies Rotex Helicopter AG and Swiss Helicopter AG (see Rotex Helicopter AG 2015) for the years 2012-2014. Before 2012, kerosene consumption was estimated.

Note 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 the Swiss modelling scheme. All resulting emissions from helicopters are reported in the Swiss inventory as domestic emissions. The amount of emissions from the Balzers helicopter base is very small compared to the total of all other Swiss helicopter emissions. Therefore, Switzerland refrains from subtracting the small contribution of emissions from its inventory. Nevertheless, for Liechtenstein these emissions are not negligible.

Road transportation (1A3b)

The emissions are calculated with a Tier 2 method (top-down) as suggested by 2006 IPCC Guidelines (IPCC 2006) using Swiss implied emission factors. The CO_2 emission factors are derived from the carbon content of fuels (see Table 3-5). For CH_4 and N_2O, the country-specific 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 3.2.4.2. 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). Furthermore a large number of Austrian and German citizens are working in Liechtenstein (2014: 36’680 registered employees, 19’551 commuters, whereof 46% are non-Swiss citizens) and buying their gasoline in Liechtenstein (OS 2015b). 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.

Railways (1A3c)

There is a railway line crossing the country, where Austrian and Swiss railways are passing by. 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 relevant emissions occurring in terms of the GHG inventory.

Domestic navigation (1A3d)

Domestic navigation is not occurring in Liechtenstein, since there are no lakes. The river Rhine is not navigable on the territory of Liechtenstein. Therefore, no emissions are occurring in this sector.

Emissions factors

Domestic aviation (1A3a)

The emission factors used for emission calculations of 1A3a Domestic aviation are illustrated in Table 3-21. The CO_2 emission factor for kerosene is taken from Table 3-5 (stemming from SFOE 2001). The CH_4 and N_2O emission factors are default values given by IPCC (2006).

Table 3-21 Emission factors used for estimating emissions of helicopters. The values are used for the entire time series 1990-2014.

Source/fuel	CO_2 [t/TJ]	CH_4 [kg/TJ]	N_2O [kg/TJ]
1A3a Domestic aviation (helicopters only)			
Kerosene	73.2	0.5	2.3

Road transportation (1A3b)

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

- CO_2 for fossil gasoline, diesel oil and natural gas: The emission factors are taken from Table 3-5. They are kept constant over the entire time period 1990–2014 (see chp. 3.2.4.1).
- CO_2 for natural gas: emission factor corresponds to the IPCC default value (IPCC 2006).

- CO_2 for biofuel and biogas: Since 2013, Liechtenstein produces biogas from sewage gas treatment and uses a part of this biogas in road transportation. In the past, there was one distributor in Liechtenstein who imported biofuels in the years 2007-2009, mixed them with other fuel types and then sold the fuel. This is not considered to be a “production of biofuels” and thus in CRF Table 1A(b) there is only data provided for import and export of the biogenic compounds of the fuel. The fuel was based on recycling of waste vegetable oil consisting mainly of canola. A small fraction of fossil diesel oil was added to the vegetable fuel. The fossil fraction is contained in the diesel sold and therefore has not to be accounted again, whereas the biogenic fraction is not reported under 1A3b but under Memo items “biomass” for respective years. An emission factor of 73.6 t/TJ is assumed (FOEN 2016). However, in 2010 the importer ceased activity and thus in Liechtenstein no sale of biofuels occurs anymore.
- CH_4, N_2O for gasoline and diesel oil: the implied emission factors of the Switzerland are used for the whole period 1990-2014 (FOEN 2016). Note that the regulation for emission concepts of the two countries is identical: Switzerland and Liechtenstein adopt the same limit values for pollutants on the same schedule as the countries of the European Union. The fleet composition of the two countries, the CO_2 emissions of light motor vehicles (passenger cars, light duty vehicles, motorcycles) and the emissions of 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) reveals that 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 based on the territorial principle. From the viewpoint of the sales principle, both numbers would be higher due to tank tourism, but in Liechtenstein, the increase would be stronger since tank tourism is more pronounced in Liechtenstein than in Switzerland. It can therefore be expected that if tank tourism was considered, the two figures 80% and 85% would converge even more. This comparison underpins the applicability of Swiss implied emission factors for Liechtenstein. Annual variation in the implied emission factors may reach a few percent. But since the emission factors for CO_2 remain unchanged, the deviation of the emission total of source category 1A3b is very small.
- CH_4, N_2O for natural gas:
  CH_4: The lower default emission factor from 2006 IPCC Guidelines, 50 kg/TJ, is used
  N_2O: default emission factor from 2006 IPCC Guidelines for mobile combustion, 3.0 kg/TJ, is used.

For biofuels, the following assumptions are made:

- For biogas from sewage gas treatment, implied emission factors 1A3b for natural gas are used. The values for 2014 are the following:

  CO_2 56.1 t/TJ; CH_4 50.0 kg/TJ; N_2O 3.0 kg/TJ

  Please note that there is an error concerning emission factors for biomass in CRF Table1.A(a)s3. See planned improvement in chp. 3.2.7.6 or Annex 8 for further information.
- No more liquid biofuel is used in road transportation in Liechtenstein since 2010.

Table 3-22 Emission factors for road transport. The values for gasoline, diesel oil and biofuels are adopted from the Swiss GHG inventory (FOEN 2015). For gaseous fuels, IPCC default values are used (IPCC 2006). For biofuel (waste vegetable oil for 2007-2009) and biogas (sewage gas treatment since 2013), the CO_2 emission factor refers to biogenic emissions. Please note that there is an error concerning emission factors for biomass in CRF Table1.A(a)s3. See planned improvement in chp. 3.2.7.6 or Annex 8 for further information.

Gas	unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
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
CH_4	kg/TJ	31.4	28.5	25.8	23.7	21.4	19.7	18.3	17.0	15.7	14.6
N_2O	kg/TJ	2.9	3.1	3.3	3.5	3.8	4.0	4.1	4.1	4.0	3.9
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
CH_4	kg/TJ	1.8	1.8	1.8	1.7	1.7	1.6	1.5	1.5	1.4	1.3
N_2O	kg/TJ	0.52	0.54	0.57	0.60	0.64	0.67	0.73	0.79	0.85	0.92
Gaseous fuels											
CO_2	t/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
CH_4	kg/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
N_2O	kg/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
Biofuel / Biogas											
CO_2	t/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
CH_4	kg/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
N_2O	kg/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE

Gas	unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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
CH_4	kg/TJ	13.6	12.8	11.9	11.0	10.5	10.0	9.3	9.0	8.6	8.3
N_2O	kg/TJ	3.7	3.5	3.3	2.9	1.8	1.7	1.5	1.4	1.2	1.1
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
CH_4	kg/TJ	1.2	1.1	0.95	0.86	0.76	0.70	0.62	0.55	0.46	0.41
N_2O	kg/TJ	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.6	1.8	1.9
Gaseous fuels											
CO_2	t/TJ	NO,IE	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1
CH_4	kg/TJ	NO,IE	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
N_2O	kg/TJ	NO,IE	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Biofuel / Biogas											
CO_2	t/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	73.6	73.6	73.6
CH_4	kg/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	0.5	0.5	0.4
N_2O	kg/TJ	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	1.6	1.8	1.9

Gas	unit	2010	2011	2012	2013	2014
Gasoline						
CO_2	t/TJ	73.9	73.9	73.9	73.9	73.9
CH_4	kg/TJ	8.1	7.9	7.6	7.4	7.1
N_2O	kg/TJ	1.1	1.0	0.89	0.79	0.59
Diesel						
CO_2	t/TJ	73.6	73.6	73.6	73.6	73.6
CH_4	kg/TJ	0.37	0.35	0.32	0.30	0.26
N_2O	kg/TJ	2.0	2.1	2.2	2.3	2.5
Gaseous fuels						
CO_2	t/TJ	56.1	56.1	56.1	56.1	56.1
CH_4	kg/TJ	50.0	50.0	50.0	50.0	50.0
N_2O	kg/TJ	3.0	3.0	3.0	3.0	3.0
Biofuel / Biogas						
CO_2	t/TJ	NO,IE	NO,IE	NO,IE	56.1	56.1
CH_4	kg/TJ	NO,IE	NO,IE	NO,IE	50.0	50.0
N_2O	kg/TJ	NO,IE	NO,IE	NO,IE	3.0	3.0

The following paragraph provides a couple of explanations to the origin of the Swiss emission factors for road transportation. As described here, a model by INFRAS (2010) was implemented for the present submission:

Swiss emission factors (excerpt from NIR CH, chp. 3.2.8.2.b, FOEN 2013):

"The emission factors for fossil CO_2 and other gases are country-specific and based on measurements and analyses of fuel samples. Emission factors for the further gases are country-specific derived from "emission functions" which are determined from a compilation of measurements from various European countries with programs using similar driving cycles (legislative as well as standardized real-world cycles, like "Common Artemis Driving Cycle" (CADC). The method has been developed in 1990-1995 and has been extended and updated in 2000, 2004 and 2010. These emission factors are compiled in a so called "Handbook of Emission Factors for Road Transport" (SAEFL 1995, 2004, 2004a, FOEN 2010i, INFRAS 2004, 2004a, 2010). For documentation see http://www.hbefa.net/. Several reports may be downloaded from there, like a documentation of the general emission factor methodology (INFRAS 2011), and Emission Factors for Passenger Cars and Light Duty Vehicles Switzerland, Germany, Austria, Norway and Sweden (INFRAS 2010; in English),

The resulting emission factors are published on CD ROM ("Handbook of emission factors for Road Transport", INFRAS 2010). The underlying database contains a dynamic fleet compositions model simulating the release of new exhaust technologies and the fading out of old technologies. Corrective factors are provided to account for future technologies.

The CO_2 factors are constant over the whole period 1990–2013. The carbon content of the fuels has not changed. However, the increasing portion of biofuels to the fuels is encompassed by the data time series. 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.

As of the current submission, N_2O emission factors in g/km differentiated by vehicle category and technology from the Handbook of Emission Factors (INFRAS 2010) have been applied, in contrast to previous submissions that applied a constant value in g/TJ fuel consumption. This results in a more realistic change pattern over time of N_2O emissions from road transportation than in earlier submissions.

In contrast to the N_2O emission factors, the measurement sample for CH_4 emission factors remained the same. However, due to updates in the vehicles fleet composition, the implied emission factors changed slightly.

No country-specific EFs for N_2O, gaseous fuels, are available. Therefore, emissions have been estimated using the EFs for alternative fuel vehicles provided in table 3.2.4 on page 3.23 of Volume 2 of the 2006 IPCC Guidelines (IPCC 2006). The value of 101 mg/km from the 2006 IPCC Guidelines was used for urban buses running on CNG only. For the bi-fuel passenger cars, it is assumed that they use gasoline mainly during the start but otherwise run on CNG; therefore the respective CNG emission factor for light duty vehicles of 27 mg/km from the same source was applied. As for all other fuel categories, the emission factor used for tank tourism corresponds to the weighted average of the national transport mix."

Additionally cold start and evaporative emissions are included in the Swiss modelling scheme.

Activity data

Domestic aviation (1A3a)

The two operating companies of the helicopter base provided data on fuel consumption for 1995, 2001–2014 as well as detailed flying hours, shares of domestic and international flights as well as specific consumption of the helicopter fleet for 2001–2014 (Rotex Helicopter AG 2006-2015). The fleet consists of:

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

The kerosene consumption of Liechtenstein's domestic flights in 2014 is based on numbers provided by the two operative helicopter companies Rotex Helicopter AG and Swiss Helicopter AG (see Rotex Helicopter AG 2015). The consumption 1990–1994 was assumed to be constant and equal to 1995 (mean share of 15%) due to missing data. The consumption for 1996–2000 was linearly interpolated between the values for 1995 and 2001 (according to Rotex Helicopter AG 2007: share 2001 15.7%, 2002 13.8%, see also chapter 3.2.2). For 2003-2011, a mean share of domestic flights of 15% was assumed as well (best estimate).

Table 3-23 Activity data for 1A3a Domestic aviation: kerosene consumption 1990-2014 in TJ (only domestic consumption without international bunker fuels).

Source/fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A3a Domestic aviation (helicopters only)					TJ					
Kerosene	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.05	1.06	1.07

Source/fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A3a Domestic aviation (helicopters only)					TJ					
Kerosene	1.08	1.09	1.14	1.19	0.85	1.15	1.85	1.83	1.79	2.13

Source/fuel	2010	2011	2012	2013	2014
1A3a Domestic aviation (helicopters only)			TJ		
Kerosene	1.87	2.00	0.83	0.74	0.85

Road transportation (1A3b)

The amount of gasoline and diesel fuel sold in Liechtenstein serve as activity data for the calculation of the CO_2 emissions (see Table 3-10). For gaseous fuels, the amount reported by gasoline stations is used. The biofuel consumption from imported vegetable oil in Liechtenstein took place only between 2007 and 2009 and from then on, no biofuel is mixed in the imported gasoline and diesel fuels (SCA 2013). However, since 2013 Liechtenstein produces biogas from sewage gas treatment and uses a part of this biogas in road transportation.

Table 3-24 Time series of activity data for 1A3b Road transportation.

Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	TJ									
Gasoline	819	916	957	947	878	903	909	954	896	919
Diesel	200	282	230	211	182	184	195	199	253	286
Natural Gas	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
Biofuel / Biogas	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
Sum	1'020	1'198	1'187	1'159	1'060	1'086	1'104	1'152	1'149	1'205
	100%	118%	116%	114%	104%	107%	108%	113%	113%	118%

Fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	TJ									
Gasoline	977	946	864	826	800	773	707	711	715	658
Diesel	239	215	231	267	281	302	331	374	426	403
Natural Gas	NO,IE	14	31	32	31	32	36	49	54	55
Biofuel / Biogas	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	1.12	0.59	0.11
Sum	1'216	1'175	1'126	1'125	1'111	1'107	1'075	1'135	1'196	1'116
	119%	115%	110%	110%	109%	109%	105%	111%	117%	109%

Fuel	2010	2011	2012	2013	2014
	TJ				
Gasoline	593	564	583	563	512
Diesel	409	430	479	495	473
Natural Gas	59	57	23	23	19
Biofuel / Biogas	NO,IE	NO,IE	NO,IE	0.03	0.48
Sum	1'061	1'051	1'085	1'081	1'005
	104%	103%	106%	106%	99%

The share of gasoline decreased from 80% in 1990 to 51% in 2014, while diesel oil increased from 20% to 47%. Natural gas reaches a share of 2% (2014). The consumption of liquid biofuel only occurred in the period 2007 to 2010 (imported biofuel from vegetable oil), however, since 2013 biogas produced from sewage gas is used in road transportation (share < 0.1% in 2014).

The Office of Environmental Protection (OEP) conducted a study in order to estimate the territorial fuel consumption based on kilometres travelled (OEP 2002). This approach is substantiated by a model which uses input data from transport statistics and traffic counting. The CO_2 emissions were more than 40% lower in the base year and 30% lower in 2004 than the emissions reported in respective GHG inventories. 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 for Liechtenstein and not using data derived from the territorial principle.

Note that hat consumption of lubricants is included in the global gasoline sales reported in the national energy statistics.

3.2.7.3 Uncertainties and time-series consistency

Uncertainties are analysed on an aggregated level for the entire source category 1A since no customs statistics exist that would provide reliable data on fuel imports into Liechtenstein. The aggregated uncertainty analysis is presented in chapter 3.2.10.

3.2.7.4 Category-specific QA/QC and verification

Information about category-specific QA/QC activities and verification processes are provided in chapter 3.2.11.

3.2.7.5 Category-specific recalculations

- 1A3b Gaseous fuels, Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore in the consumption of natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of natural gas and biomass for 2013.
- 1A3bi Gaseous fuels: The emission factor for N_2O has been changed to 3.0 kg/TJ according to the default value for mobile combustion in the IPCC 2006 Guidelines, leading to a recalculations for the years between 1990 and 2013.

3.2.7.6 Category-specific planned improvements

An error occurred within Table 1.A(a)s3. Emission factors for biomass concerning CO_2, CH_4 and N_2O are overestimated for the years 2013 and 2014.

The error will be corrected for submission 2017.

3.2.8 Source category 1A4 – Other sectors (commercial/institutional, residential, agriculture/forestry/fishing)

3.2.8.1 Source category description: Other sectors (1A4)

Key category 1A4
CO_2 from the combustion of gaseous and of liquid fuels in Other Sectors (1A4) are key categories regarding both level and trend.

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

Table 3-25 Specification of source category 1A4 Other sectors.

1A4	Source	Specification
1A4a	Commercial/institutional	Emissions from fuel combustion in commercial and institutional buildings.
1A4b	Residential	Emissions from fuel combustion in households.
1A4c	Agriculture/forerstry/fishing	Emissions from fuel combustion of agricultural machineries.

3.2.8.2 Methodological issues: Other sectors (1A4)

Methodology

Commercial/institutional (1A4a) and residential (1A4b)

For fuel combustion in commercial and institutional buildings (1A4a) as well as in households (1A4b), a Tier 2 method is used and cross-checked with the estimate on the gas oil consumption based on expert judgement (see sub-section 3.2.4.2 energy statistics and contribution to the IPCC source categories). A top-down method based on aggregated fuel consumption data from the energy statistics of Liechtenstein (OS 2015a) is used to calculate emissions. The sources of source category 1A4a and 1A4b are characterised by rather similar combustion processes and therefore, the same emission factors are implemented. An oxidation factor of 100% is assumed for all combustion processes and fuels (see sub-section 3.2.1).

Agriculture/forestry/fishing (1A4c)

For source category 1A4c, a Tier 1 method is used. Emissions stem from fuel combustion in agricultural machinery. Implied emission factors from a Swiss non-road study (INFRAS 2015) are used. The activity data is derived from the information provided by the General Directorate of Swiss Customs (refunding institution of fuel levies until 2005) and by OEP census (OEP 2012c). For more details see section 3.2.4.2, paragraph gasoline/diesel oil.

Emission factors

Commercial/institutional (1A4a) and residential (1A4b)

CO_2 emission factors and NCV values are country-specific and are based on the Swiss overall energy statistics of the year 2000 (SFOE 2001). In, 1998, 2008 and 2011, the values have been confirmed by measurement campaigns of NCV and carbon content of fuels (EMPA 1999, Intertek 2008, Intertek 2012). See Table 3-5.

Liechtenstein is a very small country and strongly linked with Switzerland on several aspects. Therefore, the technology providers are mostly the same for both countries and it can be assumed, that the technologies used as well as the consumption properties are the same. Therefore, the coal emission factor for CO_2 refers to the emission factor of hard coal in Switzerland (SFOE 2001). As Liechtenstein is a small neighboring country of Switzerland, it is assumed that similar coal is used as in Switzerland.

Emission factors for CH_4 are country-specific and are based on analysis of combustion boilers in the residential, commercial institutional and agricultural sectors, documented in SAEFL 2000 (pp. 42-56) and SAEFL 2005e. The country-specific emission factor for CH_4 emissions from Liquefied Petroleum Gas (LPG) is from UBA 2004. Emission factors for biomass are also country-specific and based on SAEFL 2000 (pp. 26ff).

It is assumed that the emission factor for alkylate gasoline is the same as the emission factor for gasoline (see section 3.2.4.1). Since the contribution of stationary engines to total fuel consumption is rather small, emission factors for combustion boilers are used for all sources and fuels considered.

Table 3-26 shows the emission factors used in 1A4a and 1A4b:

Table 3-26 Emission factors for 1A4a and 1A4b: Commercial/institutional and residential in Other sectors for the year 2014.

Source/fuel	CO_2 fossil [t/TJ]	CO_2 biogenic [t/TJ]	CH_4 [kg/TJ]	N_2O [kg/TJ]
1A4a/b Other sectors - Commercial/institutional and Residential				
Gas oil	73.7	-	1.0	0.6
LPG	65.5	-	2.5	0.1
Alkylate gasoline	73.9	-	7.1	0.6
Coal	94.0	-	300	1.6
Natural gas	56.1	-	6.0	0.1
Biomass (Biogas from WWTP)	-	56.1	6.0	0.1
Biomass (Wood combustion 1A4a)	-	92.0	8.0	1.6
Biomass (Wood combustion 1A4b)	-	92.0	300.0	1.6

Agriculture/forestry (1A4c)

Emission factors for the use of diesel in non-road vehicles and machinery (agriculture and forestry) are country-specific and are taken from INFRAS 2015. For alkylate gasoline the same emission factors as for gasoline in 1A3b are applied (see Table 3-22).

Table 3-27 Emission factors for 1A4c: Other sectors – Agriculture/forestry for the year 2014. All emission factors except those for alkylate gasoline are constant since 1990.

Source/fuel	CO_2 fossil [t/TJ]	CO_2 biogenic [t/TJ]	CH_4 [kg/TJ]	N_2O [kg/TJ]
1A4c Other sectors - Agriculture/forestry				
Diesel	73.6	-	0.6	2.6
Alkylate gasoline	73.9	-	7.1	0.6

Activity data

Commercial/institutional (1A4a) and residential (1A4b)

Activity data on fuel consumption (TJ) are based on aggregated fuel consumption data from the energy statistics of Liechtenstein (OS 2015a). A description of the modifications and the disaggregation of data from energy statistics are provided in section 3.2.4.2.

Activity data for consumption of alkylate gasoline have been determined by a census carried out by the Office of Environment (OE 2015a). 20% of alkylate gasoline is allocated to households and reported in 1A4b Residential whereas 80% of alkylate gasoline is allocated to Agriculture and forestry and reported in 1A4c.

The resulting disaggregation is given in the table below.

Table 3-28 Activity data in 1A4a Commercial/institutional and 1A4b Residential. Biomass consumption comprises consumption of biogas from waste water treatment plants and consumption of wood.

Source/fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	TJ									
1A4a Commercial/institutional	**938.28**	**865.44**	**843.99**	**929.59**	**887.59**	**881.27**	**881.23**	**941.42**	**1'024.88**	**941.01**
Gas oil	758.40	660.25	644.27	707.86	649.28	629.90	585.69	664.47	714.18	624.62
LPG	13.29	13.29	13.29	13.29	13.29	13.29	13.29	13.29	13.29	13.29
Natural gas	140.84	166.15	160.68	182.68	199.27	212.33	256.50	237.91	271.65	277.35
Coal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75
1A4b Residential	**312.23**	**310.33**	**345.70**	**390.19**	**379.17**	**403.38**	**420.03**	**452.25**	**494.42**	**503.45**
Gas oil	252.80	221.80	214.04	236.34	217.70	211.68	196.41	223.59	240.10	210.69
Alkylate gasoline	NO	NO	NO	NO	NO	0.05	0.10	0.10	0.10	0.10
Natural gas	41.22	75.68	113.36	137.23	141.08	176.43	209.54	211.66	235.36	272.30
Coal	1.04	0.98	1.18	1.07	0.76	0.73	0.53	0.56	0.59	0.31
Biomass	17.17	11.87	17.12	15.55	19.63	14.49	13.44	16.33	18.27	20.05

Source/fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	TJ									
1A4a Commercial/institutional	**907.37**	**878.74**	**965.06**	**1'023.85**	**1'046.93**	**1'057.68**	**1'111.92**	**845.52**	**951.53**	**928.41**
Gas oil	560.55	532.06	601.28	637.30	618.50	591.61	619.92	370.28	469.52	527.27
LPG	5.52	3.91	4.23	4.55	4.14	3.68	5.52	6.12	4.74	4.83
Natural gas	288.54	310.49	325.80	337.35	375.47	408.34	424.75	386.87	394.26	294.34
Coal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	52.75	32.28	33.75	44.64	48.82	54.05	61.73	82.25	83.02	101.97
1A4b Residential	**493.86**	**515.47**	**548.78**	**594.97**	**626.88**	**646.39**	**658.44**	**571.68**	**630.92**	**670.24**
Gas oil	185.01	176.05	199.01	210.92	204.79	195.98	204.80	121.39	154.93	174.15
Alkylate gasoline	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12
Natural gas	272.91	317.43	326.82	353.81	389.16	414.01	412.20	395.20	420.42	427.94
Coal	0.67	0.37	0.34	0.37	0.28	0.25	0.17	0.14	0.11	0.06
Biomass	35.17	21.52	22.50	29.76	32.55	36.03	41.16	54.83	55.35	67.98

Source/fuel	2010	2011	2012	2013	2014
	TJ				
1A4a Commercial/institutional	**799.90**	**728.02**	**768.32**	**792.29**	**516.62**
Gas oil	415.84	363.79	380.39	411.48	282.03
LPG	5.34	4.23	4.14	3.86	3.63
Natural gas	268.97	240.66	262.08	273.12	128.39
Coal	NO	NO	NO	NO	NO
Biomass	109.76	119.34	121.71	103.83	102.57
1A4b Residential	**687.40**	**616.47**	**636.86**	**681.73**	**557.29**
Gas oil	138.61	121.26	126.80	137.16	94.01
Alkylate gasoline	0.13	0.12	0.14	0.14	0.14
Natural gas	475.43	415.47	428.78	474.83	387.37
Coal	0.06	0.06	NO	NO	NO
Biomass	73.18	79.56	81.14	69.60	75.77

Table 3-28 documents a pronounced decrease in consumption in natural gas between 2013 and 2014 due to a warmer winter in 2014 (see also chapter 3.2.4.2).

Gas oil consumption decreased by approximately 60 % for both categories 1A4a and 1A4b over the same period. The significant decline in 2007, followed by an increase of the gas oil consumption between 2008 and 2009 and another decrease in 2010 and 2011, are caused by two different reasons: First special fluctuation of prices for fossil fuels and second warm winters with low number of heating degree days. As stock changes in residential fuel tanks are not taken into account, high prices of fossil fuels therefore led to a smaller apparent consumption of fossil fuels in 2007, when stocks were depleted, and higher apparent consumption in 2008, when fuel tanks were refilled. In 2009, the lower prices raised the demand of gas oil and the launch of the CO_2-Levy on January 1 2010 induced the commercial consumers to refill their fuel tanks at the end of 2009. In 2012, the cold winter (high number of heating degree days) led to a small increase of gas oil consumption in these source categories 1A4a and 1A4b. The explained shift in fuel mix is the reason for CO_2 emissions from the use of gaseous and liquid fuels in category 1A4a and 1A4b being key categories regarding level and trend.

Agriculture/forestry/fishing (1A4c)

The activity data related non-road machinery is shown in Table 3-29. Besides diesel, the consumption of alkylate gasoline is also accounted for (20% in 1A4b and 80% in 1A4c). The consumption of alkylate fuels in 2014 has been derived from an annual census carried out by the Office of Environment (OE 2015c).

Table 3-29 Activity data in 1A4c Agriculture/forestry/fishing.

Source/fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A4c Other Sectors - Agriculture/forestry	TJ									
Alkylate gasoline	NO	NO	NO	NO	NO	0.20	0.40	0.40	0.41	0.41
Diesel	17.91	18.32	18.01	17.42	17.51	17.04	16.68	18.69	17.57	19.00

Source/fuel	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1A4c Other Sectors - Agriculture/forestry	TJ									
Alkylate gasoline	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.47	0.48	0.49
Diesel	17.92	18.62	18.69	20.13	20.73	18.70	19.51	20.17	19.41	19.45

Source/fuel	2010	2011	2012	2013	2014
1A4c Other Sectors - Agriculture/forestry	TJ				
Alkylate gasoline	0.50	0.49	0.56	0.56	0.56
Diesel	19.03	14.09	14.89	20.08	16.91

Assumptions

Agriculture/forestry (1A4c)

As Liechtenstein is a small neighboring country of Switzerland, it is assumed that the same emission factor can be applied as for the Swiss inventory.

3.2.8.3 Uncertainties and time-series consistency

Uncertainties are analysed on an aggregated level for the entire source category 1A since no customs statistics exist that would provide reliable data on fuel imports into Liechtenstein. The aggregated uncertainty analysis is presented in chapter 3.2.10.

3.2.8.4 Category-specific QA/QC and verification

Information about category-specific QA/QC activities and verification processes are provided in chapter 3.2.11.

3.2.8.5 Category-specific recalculations

- 1A4a / 1A4b Gaseous fuels: Data on consumption of natural gas are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, which leads to a recalculation for 1990-2012 (CO_2, CH_4, N_2O).
- 1A4b Biomass: The CH_4 emission factor for wood combustion was adapted from 350 to 300 kg/TJ based on IPCC 2006 Guidelines. The conversion from gas volumes to energy units is now based on the lower heating value (instead of the upper heating value) (CH_4).
- 1A4b Biomass: Activity data for wood combustion are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, which leads to a recalculation for 1990-2012 (CH_4, N_2O).
- 1A4b Gaseous fuels/Biomass: Due to new information from Liechtenstein's gas utility (LGV) regarding the partitioning of gaseous fuels and biomass to different sectors, the entire time series 1990-2013 were recalculated (CO_2, CH_4, N_2O).
- 1A4a/1A4b Gaseous fuels/Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore in the consumption of natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of Natural gas and Biomass for 2013 (CO_2, CH_4, N_2O).

- 1A4a / 1A4b NCV Gasoil, natural gas, hard coal, LPG: Data on net calorific values are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series (CO_2, CH_4, N_2O).

3.2.8.6 Category-specific planned improvements

According to Liechtenstein's inventory development plan no future improvements are planned for activities in source category 1A4 Other sectors.

3.2.9 Source category 1A5 – Other

3.2.9.1 Source category description: Other (1A5)

Emissions of source category 1A5 do not occur in Liechtenstein.

3.2.10 Uncertainties and time-series consistency 1A

3.2.10.1 Uncertainties 1A – Fuel combustion activities

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted individually for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. The key categories 1A1, 1A2 liquid fuels, 1A2 gaseous fuels, 1A3b, 1A4 liquid fuels, 1A4 gaseous fuels are treated individually, whereas the remaining categories are included in the "rest" categories with mean uncertainty.

Uncertainty in aggregated fuel consumption activity data (1A)

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) fuel imports into Liechtenstein. However, the data on fuel consumption originates at the aggregated level of sales figures. It is disaggregated using simple expert judgement leading to the consumption in different branches (see Section 3.2.4.2, energy statistics and contribution to the IPCC source categories). For liquid fuels, the uncertainties have been estimated for four fuel types separately, because methods to determine fuel consumption and associated uncertainties differ for each fuel type (see also section 1.6.1.3 and 3.2.4.2).

Details about the uncertainty analysis of the activity data (fuel consumption) in 1A are based on expert judgements. The dominant contributor to overall uncertainty is liquid fuel consumption. Since import customs statistics of oil products do not exist, this data is based on surveys with oil suppliers, carried out earlier by OEA and in recent years by OEP/OE.

Comparing different liquid fuels, the uncertainty for gasoline is lowest because activity data is based on surveys at all filling stations in Liechtenstein and the uncertainty is estimated to be 10%. Diesel consumption is also based on surveys at filling stations but small unknown quantities may be imported directly from construction companies and farmers. Therefore, the uncertainty is estimated to be 15% for diesel. The uncertainty for gas oil and LPG consumption is estimated to be the highest among liquid fuels, because fuel is provided by direct delivery to homes by several companies, which is more difficult to monitor. Their uncertainties are estimated to be 20%. Uncertainty of gaseous fuels is estimated to be 5% as the quantities of gas can be determined on a detailed level. Solid fuels and other fuels do have a relatively high uncertainty of 20%. Uncertainty for jet kerosene is estimated to be 15%.

Uncertainty of CO_2 emission factors in Fuel combustion activities (1A)

Liechtenstein and Switzerland form a customs and monetary union governed by a customs treaty. Therefore, all gas oil is supplied by Swiss suppliers and no taxation accrues at the borders for the import to Liechtenstein. It is therefore 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 2015):

For the uncertainty analysis, the following emission factors uncertainty have been applied (in square bracket, the value of the previous submission is indicated)

- Natural gas (1A1, 1A2, 1A4): U(EF CO_2) = 3.1% [3.1%] - unchanged
- Liquid fuels (1A2, 1A4): U(EF CO_2) = 0.51% [0.51%] - unchanged
- Gasoline (1A3b): U(EF CO_2) = 1.36% [1.36%] - unchanged
- Diesel oil (1A3b): U(EF CO_2) = 0.47% [0.47%] - unchanged

Note that 1A3b/CO_2 is not differentiated in the KCA of the CRF Reporter by fuel type but is considered as a key category as sum of gasoline and diesel oil. For the uncertainty analysis, the uncertainty of the aggregated category has to be calculated via error propagation from the uncertainty inputs given above: AD 10% and 15% for gasoline and diesel oil respectively and EF (CO_2) 1.36% and 0.47%. In Annex 7 it is shown how the aggregation is performed. The results are:

1A3b: U(AD) = 8.7%, U(EF) = 0.78%.

Anologously, the uncertainties of the aggregated key categories 1A4 liquid fuels, 1A4 gaseous fuels are derived:

1A4 liquid/CO_2: U(AD) = 15.8%, U(EF) = 0.40%
1A4 gaseous/CO_2: U(AD) = 3.6%, U(EF) = 2.2%

All the non-key categories of 1A (1A1a/CH_4, 1A1a/N_2O, 1A2e/CH_4 etc.) are summed up in the rest categories CH_4, N_2O to which medium uncertainties are attributed (see explanation in chapter 1.6.1).

3.2.10.2 Consistency and completeness 1A - Fuel combustion activities

Consistency

The applied methods for the calculations of Liechtenstein's GHG emissions are the same for the years 1990-2014. The entire time series are therefore consistent.

Completeness

The emissions for the entire time series 1990–2014 have been calculated and reported. The data on emissions of the Kyoto gases for sector 1 Energy (CO_2, CH_4, N_2O) are also complete.

3.2.11 Category-specific QA/QC and verification of 1A – Fuel combustion activities

General QA/QC activities

The category-specific QA/QC activities have been carried out as mentioned in section 1.2.3.1 also including triple checks of Liechtenstein's reporting tables (CRF tables). The triple check includes a detailed comparison of current and last year emissions by two NIR authors and by the specialist from the Office of Environment. In addition, the activity data has been counter-checked with the data in Liechtenstein's energy statistics as well as with the annual report of the gas distribution of Liechtenstein (LGV 2015).

Road transportation (1A3b)

The international project for the update of the emission factors for road vehicles is overseen by a group of external and international experts that guarantees an independent quality control. For the update of the modelling of Switzerland's road transport emissions, which was carried out between 2008 and 2010 and which is also used for Liechtenstein, several experts from the federal administration have conducted the project. The results have undergone large plausibility checks and comparisons with earlier estimates.

The emission factors for CH_4 and N_2O used for the modelling of 1A3b Road transportation are taken from the handbook of emission factors (INFRAS 2010), which is also applied in Germany, Austria, Netherlands and Sweden. The Swiss emission factors for CH_4 and N_2O used in 1A3b were additionally compared with those depicted in the CRF from Germany and a high consistency was found. Possible small differences might result from a varying fleet composition.

3.2.12 Category-specific recalculations

No other recalculations have been carried out.

3.3 Source category 1B – Fugitive emissions from solid fuels and oil and natural gas and other emission from energy production

3.3.1 Source category 1B1- Fugitive emissions from solid fuels

Fugitive emissions from source category 1B1 Fugitive emissions from solid fuels do not occur in Liechtenstein.

3.3.2 Source category 1B2- Fugitive emissions from oil and natural gas and other emissions from energy production

3.3.2.1 Source category description: fugitive emissions from oil and natural gas and other emissions from energy production (1B2)

Key category 1B2b
Source category 1B2b Fugitive emissions from natural gas is **not a key category.**

Intentional or unintentional release of greenhouse gases may occur during the extraction, processing and delivery of fossil fuels to the point of final use. These are known as fugitive emissions (IPCC 2006). According to the IPCC guidelines (IPCC 2006), the term fugitive emissions is broadly applied in 1B2 and means all greenhouse gas emissions from oil and gas systems except contributions from fuel combustion. Oil and natural gas systems comprise all infrastructure required to produce, collect, process or refine and deliver natural gas and petroleum products to market. The system begins at the well head, or oil and gas source, and ends at the final sales point to the consumer (IPCC 2006).

In Liechtenstein only emissions from gas pipelines occur. Table 3-33 shows the sources for which fugitive emissions are accounted for.

Table 3-30 Specification of source category 1B2 Fugitive emissions from oil and natural gas and other emissions from energy production.

1B2	Source	Specification
1B2a	Oil	Not occurring in Liechtenstein.
1B2b	Natural gas	Emissions from gas pipelines only.
1B2c	Venting and flaring	Not occurring in Liechtenstein.
1B2d	Other	Not occurring in Liechtenstein.

3.3.2.2 Methodological issues: Fugitive emissions from oil and natural gas and other emissions from energy production (1B2)

Methodology

For source 1B2b Natural gas, the emissions of CH_4 leakages from gas pipelines are calculated with a Tier 3 method. 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. For the calculation of the fugitive emissions of the transmission pipelines data in Table 3-33 and Table 3-34 are considered. Regarding density, NCV and share of methane within natural gas, the following values are applied for the time series 1990-2014:

- Net calorific value (NCV): 36.3 MJ/m^3 (under norm conditions of 0°C and 1013 mbar)
- Density of methane: 0.717 kg/m^3 (under norm conditions of 0°C and 1013 mbar)
- Content of methane in natural gas: 92.6 %

According to expert information of Liechtenstein's gas utility (LGV), the losses identified within the NIR are generally overestimated as the natural gas pipeline has a very high quality based on its new pipeline system compared to other natural gas systems.

For the calculation approach the points below have also be considered:

- In Liechtenstein's approach, the total amount of natural gas transported through the pipeline is not relevant. For the estimation of the fugitive emissions, the amount of natural gas transported is not used and only the length as well as the type and pressure of the gas pipelines are considered.
- Additionally, several aspects as for example the emissions of the components at the household connection, emissions from the network maintenance as well as from components in the transmission pipeline (e.g. valves) are also considered in Liechtenstein's calculation.

Therefore, the calculation is defined as **the length of the pipeline (km of pipeline) x emission factor of losses (EF / km of pipeline)**. Additionally, losses of the household connections as well as different components in the transmission pipeline (in % of the leakage per pipeline calculated) are added as well.

Within the reporting tables (CRF) the data for distribution is included in the energy unit GJ. Therefore, the emissions calculations described above are at the end converted into energy unit GJ in order to provide the data needed in the CRF.

Emission factors

The emission factors for gas distribution losses (source 1B2b) depend on the type and pressure of the natural gas pipeline (see Table 3-31) and are provided by literature and base mostly on the study of Batelle 1994 that provides specific emission factors for different sources of fugitive emissions based on measurements of 1998 in Germany. Specific data for Switzerland (and Liechtenstein) is provided by a study of Xinmin (2004), but also these emission factors are mostly based on Batelle (1994). The CH_4 emissions due to gas meters are accounted for by applying an emission factor of 5.11 m^3 CH_4 per gas meter and year. Liechtenstein is a very small country and strongly linked with Switzerland in several aspects. Therefore, the technology providers are mostly the same for both countries and it can be assumed that the technologies used are the same. Therefore, the CH_4 emission factors are based on Swiss studies (e.g. Battelle 1994 and Xinmin 2004).

Table 3-31 CH_4 emission factors for 1B2b Fugitive emissions from natural gas in 2014 (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 (*italic*) shows the value for 2001 and following years. Data between 1993 and 2001 are linearly interpolated between the two values.

Source/fuel	< 100 mbar [m^3/h/km]	1-5 bar [m^3/h/km]	> 5 bar[m^3/km*year]	Gas meters [m^3/number*year]
1B2b Fugitive emissions from natural gas				
Steel cath.	-	-	249	-
HDPE (polyethylene)	0.0080	0.0024 *0.0006*	-	-
Gas meters	-	-	-	5.11

Activity data

The activity data such as length and type of the pipelines in the distribution network for the calculation of methane leaks have been extracted from the annual reports of Liechtenstein's Gas Utility (LGV 2015). The emissions are attributed on one hand to the activity data of the steel cath. pipelines of >5 bar pressure as part of the transmission of natural gas and on the other hand to pipelines of the distribution network (HDPE pipelines).

Table 3-32 Activity data for 1B2 Fugitive emissions from oil and natural gas and other emissions from energy production. Activity data include the length of natural gas pipelines and the number of connections to customers.

Source/fuel		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1B2b Fugitive emissions from natural gas	Unit										
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
HDPE (Polyethylene) < 100 mbar	km	28.5	28.5	28.3	28.5	29.2	29.5	29.8	30.0	34.1	35.8
HDPE (Polyethylene) 1-5 bar	km	67.0	84.3	96.5	109.0	122.4	135.9	147.6	162.7	179.3	192.0
Connections	number	479	698	890	1'060	1'221	1'398	1'584	1'782	1'984	2'195

Source/fuel		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1B2b Fugitive emissions from natural gas	Unit										
Steel cath. > 5 bar	km	26.3	26.3	26.6	26.6	26.6	26.6	26.6	26.6	26.6	26.6
HDPE (Polyethylene) < 100 mbar	km	37.3	37.4	36.0	38.9	45.3	45.6	49.3	49.7	50.1	50.8
HDPE (Polyethylene) 1-5 bar	km	206.0	218.7	238.5	252.0	264.9	276.3	289.1	297.6	304.6	308.6
Connections	number	2'460	2'657	2'863	3'067	3'271	3'464	3'659	3'801	3'948	4'045

Source/fuel		2010	2011	2012	2013	2014
1B2b Fugitive emissions from natural gas	Unit					
Steel cath. > 5 bar	km	26.6	26.6	26.7	26.7	26.7
HDPE (Polyethylene) < 100 mbar	km	51.0	51.5	51.6	51.9	52.1
HDPE (Polyethylene) 1-5 bar	km	312.8	319.3	323.8	328.8	336.1
Connections	number	4'116	4'209	4'311	4'337	4'411

Table 3-32 documents the continuous increase of Liechtenstein's gas supply network since 1990. The number of connections installed have increased by more than factor 9 by 2014 compared to those from 1990.

Table 3-33 Natural gas volumes of Liechtenstein's natural gas distribution network as additional information and not applied directly for calculations.

Source/fuel		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1B2b Fugitive emissions from natural gas	Unit										
Natural gas volume industry	Mio. m^3	7.5	8.2	8.6	8.7	8.5	8.8	9.3	9.1	9.6	10.4
Natural gas volume other	Mio. m^3	5.1	7.1	8.5	9.8	10.3	11.7	14.1	13.6	15.4	16.6
Sum natural gas volume	Mio. m^3	**12.6**	**15.2**	**17.1**	**18.4**	**18.7**	**20.5**	**23.4**	**22.7**	**25.0**	**26.9**

Source/fuel		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1B2b Fugitive emissions from natural gas	Unit										
Natural gas volume industry	Mio. m^3	9.7	10.2	10.0	10.9	10.6	10.4	10.7	10.6	10.5	5.4
Natural gas volume other	Mio. m^3	16.8	19.1	20.0	21.3	23.4	25.1	25.5	24.2	25.4	22.9
Sum natural gas volume	Mio. m^3	**26.5**	**29.3**	**30.1**	**32.2**	**34.0**	**35.4**	**36.1**	**34.7**	**35.8**	**28.3**

Source/fuel		2010	2011	2012	2013	2014
1B2b Fugitive emissions from natural gas	Unit					
Natural gas volume industry	Mio. m^3	6.0	5.2	5.8	5.7	7.6
Natural gas volume other	Mio. m^3	23.7	21.1	21.1	22.7	16.0
Sum natural gas volume	Mio. m^3	**29.8**	**26.3**	**26.8**	**28.4**	**23.6**

3.3.2.3 Uncertainties and time-series consistency

Uncertainty in fugitive CH_4 emissions from natural gas pipelines in 1B2

Following 2006 IPCC Guidelines (IPCC 2006) the uncertainty range of the emission factor for methane is given as -20% to +500%, the uncertainty for the AD 5%. These values do not seem to fit for Liechtenstein, therefore an expert estimate of 50% is assumed for the combined uncertainty 1B2.

The time series are consistent.

3.3.2.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

3.3.2.5 Category-specific recalculations

1B2 Gaseous fuels: Data on consumption of natural gas are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, leading to a recalculation for 1990-2012 (CH_4).

3.3.2.6 Category-specific planned improvements

According to Liechtenstein's inventory development plan no future improvements are planned for activities in source category 1B2 - Fugitive emissions from oil and natural gas and other emissions from energy production.

3.4 Source category 1C – CO_2 transport and storage

Source category 1C is not occurring in Liechtenstein.

4 Industrial processes and product use

4.1 Overview

Industrial processes and product use (IPPU), covers greenhouse gas emissions occurring from industrial processes, from the use of products, and from non-energy uses of fossil fuel carbon. The former section Solvent and Other Product has been incorporated in this section (IPCC 2006). According to IPCC guidelines (IPCC 2006), 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 in source category 1A2.

Only GHG emissions of two IPCC source categories among the IPPU sector occur in Liechtenstein. Sources in the following categories do not occur in Liechtenstein at all:

- Mineral industry (2A)
- Chemical industry (2B)
- Metal industry (2C)
- Non-energy products from fuels and solvent use (2D)
- Electronics industry (2E)
- Other (2H)

GHG emissions from 2F Product uses as ODS substitutes, in particular HFC and PFC emissions from 2F1 Refrigeration and air conditioning, HFC emissions from 2F2 Foam blowing agents and HFC emissions under 2F4 Aerosols, as well as from 2G Other product manufacture and use, including N_2O emissions from 2G3a Medical applications and 2G3b Other propellant for pressure and aerosol products, are reported under source category 2 IPPU. In addition, SF_6 emissions from 2G1 Electrical equipment are reported. NF_3 emissions are nor occurring.

The emissions of source category 2 Industrial processes and product use have increased from 1990 to 2014, as shown in Table 4-1.

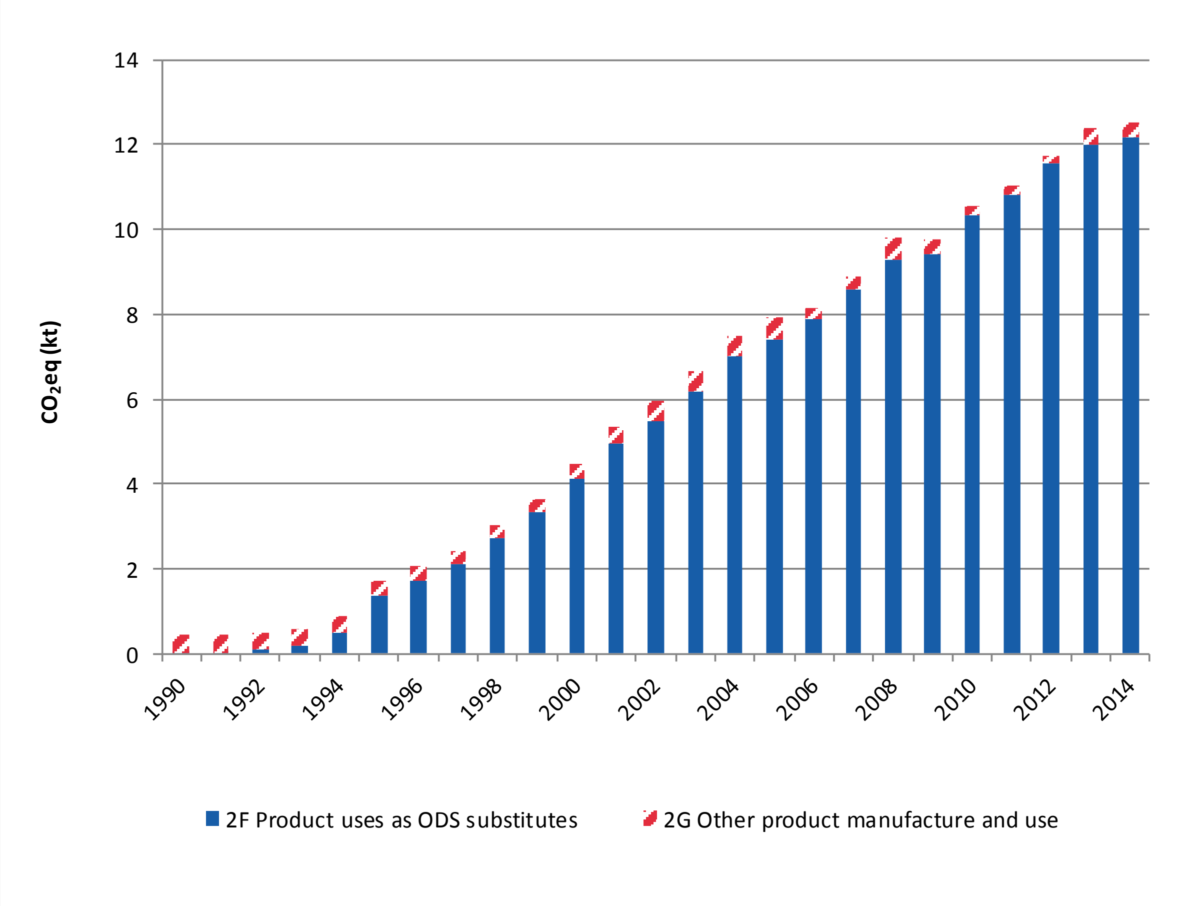

Figure 4-1 Liechtenstein's GHG emissions of sector 2 Industrial processes and product use. Note that there are emissions only in sectors 2F and 2G.

Table 4-1 GHG emissions of source category 2 Industrial processes and product use 1990–2014 by gases in CO_2 equivalent (kt).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
N_2O	0.45	0.44	0.42	0.40	0.38	0.36	0.34	0.32	0.30	0.28
F-Gases	0.00	0.01	0.09	0.20	0.52	1.35	1.72	2.12	2.74	3.36
Sum	**0.45**	**0.45**	**0.51**	**0.60**	**0.90**	**1.72**	**2.06**	**2.44**	**3.04**	**3.64**

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
N_2O	0.26	0.24	0.23	0.24	0.23	0.23	0.22	0.21	0.20	0.20
F-Gases	4.20	5.12	5.73	6.42	7.27	7.68	7.95	8.69	9.62	9.55
Sum	**4.46**	**5.36**	**5.97**	**6.65**	**7.50**	**7.92**	**8.17**	**8.90**	**9.82**	**9.75**

Gas	2010	2011	2012	2013	2014	1990-2014
	CO_2 equivalent (kt)					%
N_2O	0.20	0.19	0.20	0.20	0.20	-56%
F-Gases	10.34	10.84	11.55	12.19	12.30	11784665%
Sum	**10.54**	**11.04**	**11.75**	**12.38**	**12.50**	**2664%**

The most relevant emissions are those of HFCs followed by N_2O, SF_6 and PFC emissions, which are of minor importance. The use of HFC started to be relevant in 1992 when these substances were introduced as substitutes for CFCs.

The total emissions of sector 2 Industrial processes and other product use (IPPU) account for 12.5 kt CO_2 equivalent in 2014. Emissions of the IPPU sector play therefore a minor role in Liechtenstein's inventory and contribute to 5.8% of the total emissions excluding LULUCF. 12.3 kt CO_2 equivalent were emitted in sector 2F Product uses as ODS substitutes and another 0.3 kt CO_2 equivalent in sector 2G Other product manufacture and use. The total emissions increased by a factor of almost 27 (2664%) since 1990. This trend is in particular dominated by the increase in HFC emissions. N_2O emissions even decreased (56%) between 1990 and 2014. Since 2013, the total F-gas emissions increased by 1%. At the same time, HFC emissions increased by 1.6% and PFC emissions decreased by 30.6% and SF_6 emissions by 33.6%. Between 2004 and 2006 there is a stagnating Trend in Liechtenstein, while this is not the case in Switzerland, since there is a stagnation in total passenger cars, which are used as activity data for the emission estimation (see FCCC/ARR 2014, paragraph 51).

4.2 Source category 2A – Mineral industry

4.2.1 Source category description: Mineral industry (2A)

Greenhouse gas emissions from source category 2A are not occurring in Liechtenstein.

4.3 Source category 2B – Chemical industry

4.3.1 Source category description: Chemical industry (2B)

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

4.4 Source category 2C – Metal industry

4.4.1 Source category description: Metal industry (2C)

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

4.5 Source category 2D – Non-energy products from fuels and solvent use

4.5.1 Source category description: Non-energy products from fuels and solvent use (2D)

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

Bitumen is imported for road paving and NMVOC emissions from bituminous materials are related to road paving and to asphalt roofing and reported in sectors 2D3b and 2D3c (see chp. 3.2.3.). In addition, NMVOC emissions from solvent use are reported in sector 2D3a.

4.6 Source category 2E – Electronic industry

4.6.1 Source category description: Electronic industry (2E)

Greenhouse gas emissions from source category 2E are not occurring in Liechtenstein. This also holds for NF_3, which would have to be reported under the revised UNFCCC Guidelines (UNFCCC 2014). Therefore, emissions of NF_3 are not occurring in Liechtenstein.

4.7 Source category 2F – Product uses as ODS substitutes

4.7.1 Source category description: Product uses as ODS substitutes (2F)

Key category 2F1
Source category 2F1 aggregated F-gases from Refrigeration and Air conditioning is a key category regarding level and trend.

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

Table 4-2 Specification of source category 2F Product uses as substitutes for ODS.

2F	Source	Specification
2F1	Refrigeration and air conditioning	Emissions from Refrigeration and Air Conditioning Equipment (inclusive heat pumps and tumble dryers)
2F2	Foam blowing agents	Emissions from foam blowing, incl. Polyurethan spray
2F3	Fire protection	Not occuring in Liechtenstein.
2F4	Aerosols	Emissions from use as aerosols, incl. Metered dose inhalers
2F5	Solvents	Not occuring in Liechtenstein.
2F6	Other applications	Not occuring in Liechtenstein.

4.7.2 Methodological issues: Product uses as ODS substitutes (2F)

Methodology

Data on HFC and PFC emissions are not available for Liechtenstein. Therefore, these emissions are derived from data from Switzerland's national inventory database EMIS (FOEN 2016a) as a best estimate.

In order to derive Liechtenstein's emissions under source category 2F, the most relevant source categories were determined using a relative threshold in a first step. Every single emission source given in Switzerland's national inventory database EMIS was analyzed with respect to a threshold, which is defined as follows:

Every single emission source, separated by gas, is evaluated with respect to its contribution to the corresponding superior source category (on the level of 2F1, 2F2, 2F4). Only emission sources and gases that contribute more than 10% are taken into account for Liechtenstein's GHG inventory under source category 2F.

In a second step, emissions from the sources identified as relevant are transformed into Liechtenstein specific emissions by applying the rule of proportion based on the emissions reported by Switzerland and specific indicators such as the number of inhabitants or the number of employees. The Swiss emissions are then divided by the Swiss indicators in order to get Swiss specific emissions per inhabitant or per employee etc. and are then multiplied by the corresponding indicator of Liechtenstein. This underlying assumption allows an estimate of emissions under source category 2F. 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.

Refrigeration and air conditioning (2F1)

In the Swiss Inventory PFC emissions, under 2F1, result from Commercial Refrigeration and Transport Refrigeration. More details of the underlying data models are documented in the National Inventory Report for Switzerland (FOEN 2016).

Manufacturing of refrigeration and air conditioning equipment is not occurring in Liechtenstein. Disposal of retired equipment falling under the categories of Domestic Refrigeration, Mobile Air Conditioning and Transport Refrigeration is collected mostly through a single recycling company in Liechtenstein (Elkuch Recycling AG). The recycling company collects and exports the equipment to Switzerland or Austria without recovering of F-gases in the refrigeration or Air Conditioning units. Nevertheless, Liechtenstein's emissions 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 rule of proportion should be restricted to product life emissions and the Swiss manufacturing emissions should be excluded from the calculation. Since the manufacturing emissions in Switzerland are of low relative importance, this bias is neglected. The inclusion of emissions from disposal is a conservative estimate for Liechtenstein. As the statistical basis for a more detailed analysis is not available, the effect is also neglected and the conservative estimation is accepted.

The following methodological explanation is taken from the Swiss NIR (FOEN 2016). It is considered as valid for Liechtenstein as well, since Liechtenstein's data are based on Switzerland's national inventory database EMIS (FOEN 2016a):

The inventory under source category 2F1 includes the following types of equipment: domestic refrigeration, commercial and industrial refrigeration, transport refrigeration, stationary air conditioning, mobile air conditioning, heat pumps and tumble dryers. For each of these types of equipment, individual emission models are used for calculating actual emissions as per the 2006 IPCC Guidelines Tier 2a approach (emission factor approach). In order to obtain the most reliable data for the calculations, two different approaches are applied to get the stock data needed for the model calculations: 'top down' using import amount of refrigerant and available statistics or estimations on the Swiss market from experts and associations and 'bottom up' through questionnaires sent to companies active in importation, production and service of appliances. In a first step the refrigerant need for the production and maintenance of equipment is calculated for most applications based on the bottom up calculations of stock. The reported import amount of bulk refrigerant is split in a second step top down to different applications based on the results of the bottom up approach and *considering the surplus of imported refrigerant for the production and maintenance of industrial and commercial refrigeration equipment.*

The import data as reported to FOEN are adjusted for imported substances to be used in Liechtenstein. This is to eliminate double counting with the inventory data of Liechtenstein. Under source category 2F1 import data which is related to commercial and industrial refrigeration equipment are split between Switzerland and Liechtenstein from the year 2008 onwards. The split factor is based on the proportion of employees in the industrial and service sector (share of import for Liechtenstein <1%). For other equipment types no scope for double counting with the inventory of Liechtenstein was identified and therefore no adjustment is required.

Table 4-3 Indicators used in calculating Liechtenstein's emissions for source category 2F1 on basis of Switzerland's emissions by applying rule of proportion.

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 C3F8	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

Foam blowing agents (2F2)

As manufacturing of foams is not occurring in Liechtenstein, only emissions during life of product and disposal are considered. Emissions under source category 2F2 are related to hard foams only. For soft foams, manufacturing using HFC is not occurring in Switzerland or Liechtenstein. As soft foams emissions are only occurring during production, emissions from soft foams are NO.

More details of the underlying data models are documented in the National Inventory Report for Switzerland (FOEN 2016), given below.

In Switzerland no production of open cell foam based on HFCs is reported by the industry. Therefore, only closed cell PU and XPS foams, PU spray applications and further closed cell applications as sandwich elements are relevant under source category 2F2.

The emission model (Tier 2a) for foam blowing has been developed 'top down' based on import statistics for products, industry information and expert assumptions for market volumes and emission factors. Emissions from further not specified applications – so far assumed to be sandwich elements - have been calculated (Tier 1a) as residual balance between FOEN import statistics and consumption in PU spray, PU and XPS foams.

Aerosols (2F4)

To restrict the complexity of the estimation model for Liechtenstein, gases with very low emissions in Switzerland are neglected, as described above. The relevance of the absolute emissions reported under 2F4 is very low (less than 0.1 kt CO_2eq) and therefore, inaccuracies in the estimation model are considered negligible.

More details of the underlying data models are documented in the National Inventory Report for Switzerland (FOEN 2016), given below.

The Tier 2a emission model for Aerosol / MDI is based on a 'top-down' approach using import statistics for HFCs.

Emission factors

Refrigeration and air conditioning (2F1)

Liechtenstein's emissions are estimated based on specific emission factors described above (e.g. emissions per inhabitant, emissions per employee, emissions per car, etc.) and the corresponding indicators. Underlying emission factors are taken from Switzerland's national inventory database EMIS (FOEN 2016a). The following explanations are taken from Switzerland's National Inventory Report 2015 (FOEN 2016):

Emission factors for manufacturing, product life and disposal as well as average product lifetime are established on the basis of expert judgement and literature. Direct monitoring of the product life emission factors is only done at the company level for internal use (i.e. retailers such as Coop and Migros). The product life factors are used to make the allocation of imported F-gases to new products and maintenance activities.

In 2008 the revised Chemical Risk Reduction Ordinance (Swiss Confederation 2005) was introduced. As part of this revision, an obligation for operators handling equipment containing more than 3 kg of HFCs was introduced to provide information to FOEN on the date of operation start, type of equipment, type and amount of refrigerant and date of disposal. This data source provides valuable information and has been used to improve the estimates used for modelling emissions under source category 2F. However, it did not allow to directly draw the stock data or emission factors for the national inventory. With the versions of the revised Chemical Risk Reduction Ordinance introduced in 2013 and 2015 the obligatory registration of HFC containing equipment was replaced with a ban on HFC for specific equipment type and capacity. CO_2 *compensation programs have been introduced on the other hand with a focus on the early replacement of HFC in installed equipment.*

Table 4-4 displays the detailed model parameters used for the present submission. Changes of model parameters within the period 1990 to 2014 are indicated with values in brackets. The parameters in brackets are applied for the inventory 2014. For product life emission factors of some equipment types a dynamic model is applied, which implies that emission decrease linearly between 1995 and 2014 due to improved production technologies and the continuous sensitisation of service technicians. The start/end values are based on expert statements, UBA (2005, 2007) and Schwarz (2001, 2005). The charge at end of life for different applications has been analysed considering the technical minimal charge of equipment and the expected frequency of maintenance (UBA/Ökorecherche 2012). Disposal losses are calculated based on expert assumption on portion of broken equipment (100% loss) and assumptions on disposal losses for professional recovery at site or waste treatment by specialized companies.

Table 4-4 *Typical values of lifetime, charge and emission factors used in model calculations 1990 to 2014 for refrigeration and air conditioning equipment. Changes of model parameters within this time period are indicated with the starting year of application in brackets (for example a charge of 4.7–7.5 kg was applied for heat pumps until 2000 and a lower charge of 2.8–4.5 kg from 2000 onwards. A linear interpolation is applied for the product life emission factor of commercial and industrial refrigeration, stationary air conditioning and for the emission factor of mobile air conditioning between 1990 and 2014 (FOEN 2016).*

Equipment type	Product life time	Initial charge of new product	Manufacturing emission factor	Product life emission factor	Charge at end of life *)	Export of retiring equipment **)	Disposal loss emission factor ***)
	[a]	[kg]	[% of initial charge]	[% per annum]	[% of initial charge of new product]	[% of retiring equipment]	[% of remaining charge]
Domestic refrigeration	16	0.1	NO	0.5	92	0-5 (2014:3)	19 ****)
Commercial and industrial refrigeration	10	NR	0.5	Sinking from 12 in 1990 to 6.7 in 2014	78-90	NA	19
Transport refrigeration: trucks/vans	10	1.8-7.8	1.5	15	86	90	28
Transport refrigeration: wagons	16	NR	NO	10	100	NA	28
Stationary air conditioning: direct cooling systems	15	NR	3 (2005: 1)	Sinking from 10 in 1995 to 4 in 2010	74-89	NA	28
Stationary air conditioning: indirect cooling systems	15	NR	1	Sinking from 6 in 1995 to 4 in 2010	85-89	NA	19
Stationary air conditioning: heat pumps	15	4.7-7.5 (2000: 2.8-4.5)	3 (2005: 1)	2	86	NA	19
Stationary air conditioning: tumble dryers	15	0.4	0.5	2	74	NA	19
Mobile air conditioning: cars	15	Sinking from 0.84 1990 to 0.55 in 2014	NO	8.5	58	31-72 (2014: 44)	50
Mobile air conditioning: truck/van cabins	12	1.1	NO	10 (2010: 8.5)	69-73	90 trucks (50 vans)	50
Mobile air conditioning: buses	12	7.5	NO	20 (2001: 15)	100	50	50
Mobile air conditioning: trains	16	20	NO	5.5	100	NA	20

*) Calculated value taking into account annual loss and portion refilled over the whole product life where applicable.

**) allocation of disposal losses to export country

***) Calculated value taking into account share of total refrigerant loss and emission factor of professional disposal. Disposal losses of HFC and PFC occur from 2000 onwards (introduction of HFCs and PFCs starting 1991 and 10 to 16 years lifetime of equipment). The value of 50% for mobile air conditioning is based on UBA 2005 and expert assumptions on share of total refrigerant loss, e.g. due to road accident.

****) takes into account HFC-134a content in foams, based on information from the recycling organisation SENS.

NR = not relevant as only aggregate data is used

NO = Not occurring (only import of charged units)

NA = Not available

Foam blowing agents (2F2)

Liechtenstein’s emission factors are the derived indicators described above (e.g. emissions per inhabitant, emissions per employee, emissions per car, etc.). The underlying emission factors are provided by Switzerland’s national inventory database EMIS (FOEN 2016a). The following explanations are taken from Switzerland’s National Inventory Report 2016 (FOEN 2016):

For emission factors and lifetime of XPS and PU foam, expert estimates and default values according to the 2006 IPCC Guidelines (IPCC 2006, Volume 3, p. 7.37) are used. For PU spray, expert estimates and specific default values according to the 2006 IPCC Guidelines (IPCC 2006, Volume 3, p. 7.37) are used. Unknown applications are evaluated following the Gamlen model recommended in the 2006 IPCC Guidelines (IPCC 2006). First-year losses are allocated to the country of production.

Table 4-5 *Typical values on lifetime, charge and emission factors used in model calculations for foam blowing (from FOEN 2016).*

Product	**Product lifetime**	**Charge of new product**	**Manufacturing emission factor**	**Product life emission factor**	**Charge at end of life**
Foam type	years	% of product weight	% of initial charge	% per annum	% charge of new product
PU foam	50	4.5	NR	NR	Calculated charge minus emissions over lifetime (so far not relevant, products still in use)
XPS foam HFC-134a	50	6.5	NR	NR / 0.7**	
XPS foam HFC-152a				100 / 0**	
PU spray all HFC	50	13.6 / 0 *	<1%	95 / 2.5 **	
Unknown use:					
HFC 134a, HFC 227ea, HFC 365 mfc	20	NR	10	10 / 4.5 **	
HFC 152a			100	100 / 0 **	

* *The first value represents the charge of HFC 1995 (start of HFC use as substitutes for ozone depleting substances). The HFC amount was reduced continuously between 1995 and 2008. Since 2009 the production of PU spray is HFC free in Switzerland.*

** *Data for 1st year / following years (HFC-152a all emissions allocated to production)*

NR *Not relevant (PU foam: no substances according to this protocol have been used; XPS foam: emissions occur outside Switzerland; unknown use: calculations are based on the remaining propellant import amount).*

Aerosols (2F4)

Liechtenstein’s emissions are estimated based on specific emission factors described above (e.g. emissions per inhabitant, emissions per employee, emissions per car, etc.) and the corresponding indicators. Underlying emission factors are taken from Switzerland’s national inventory database EMIS (FOEN 2016a). The following explanations are taken from Switzerland’s National Inventory Report 2016 (FOEN 2016):

A manufacturing emission factor of 1% is applied. For product life emission factor the model assumes that 50% of the remaining substance is emitted in the first year and 50% in the second year respectively, which is in line with the 2006 IPCC Guidelines.

Activity data

Refrigeration and air conditioning (2F1)

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:

Table 4-6 Figures used as indicators for calculation of activity data by applying rule of proportion.

	1990		2014	
Number of households				
Liechtenstein	10’556	Source: National census 1990 (OEA 2010)	16’388	Source: National census 2010 with trend extrapolation (OEA 2010)
Switzerland	2’859’766	Source: National census 1990 (SFSO 2005, Acontec 2016a)	3'630’755	Source: National census 2000 with trend extrapolation (SFSO 2005, Acontec 2016a)
Conversion Factor CH→LIE	0.0036912		0.0045137	
Number of employees in industrial and service sector				
Liechtenstein	19’554	Source: Statistical Yearbook Liechtenstein (OS 2016c)	36’397	Source: Statistical Yearbook Liechtenstein (OS 2016c)
Switzerland	3’658’406	Source: National census of enterprises (SFSO 2016b)	4’743’328	Source: National census of enterprises (SFSO 2016b, Acontec 2016a)
Conversion Factor CH→LIE	0.0053449		0.0076733	
Number of registered passenger cars				
Liechtenstein	16’891	Source: Statistical Yearbook Liechtenstein (OS 2016c)	28’474	Source: Statistical Yearbook Liechtenstein (OS 2016c)
Switzerland	2’985’397	Source: National motorcar statistics for Switzerland (SFSO 2016c)	4'384'490	Source: National motorcar statistics for Switzerland (SFSO 2016c)
Conversion factor CH→LIE	0.0056579		0.00649426	

There is slight fluctuation in the emission data from 2004 to 2010 in the Refrigeration and Air Conditioning sub category. Fluctuations are affiliated with year to year changes in a wide variety of the underlying sub categories of Refrigeration and Air Conditioning. They can be explained by changing consumer behaviour (linked to economic preconditions for demand) for the sub category Mobile Air Conditioning. Detailed explication cannot be provided since an in-depth analysis would be required to flesh out the respective categories and causes of change.

Foam blowing agents (2F2)

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

Table 4-7 Figures used as indicator for calculation of activity data by applying rule of proportion.

Number of Inhabitants in 2014		
Liechtenstein	37'366	Source: OS 2016c
Switzerland	8’237’700	Source: SFSO 2016d
Conversion Factor CH→LIE	0.00453597	

Emissions from the foam blowing subcategory have been declining from 2009 to 2010. There are mainly two reasons for this: firstly, the only Swiss producer of PU-Sprays ceased the use of HFC in 2009 completely. This caused a significant decline in respective emissions. Secondly, a small but continuous declining trend of HFC content in imported goods from Germany can be observed.

Aerosols (2F4)

Activity data for Liechtenstein is calculated based on activity data for Switzerland with the methodology as described above. The figures as seen in Table 4-7 have been used as indicator.

4.7.3 Uncertainties and time-series consistency

There is only one key category as determined by the CRF Reporter from this sector: 2F1/aggregate F-gases. The combined uncertainty that resulted from a Monte Carlo simulation of the Swiss GHG inventory for HFC has already been adopted for Liechtenstein in the former uncertainty analysis in the previous submissions. This approach is also adopted for the uncertainty analysis of the current submission and amounts to 15%. Since 97% of the F-gases emissions are caused by HFC, the value of 15% seems to be justified. In the previous submission, 18.8% uncertainty had been applied for total emissions of F-gases. For the emissions of F-gases of non-key categories, an uncertainty of 20% is assumed (Table 1-7).

The methods for calculating the emissions are consistent for the full time series 1990–2014.

4.7.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in section 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

Under 2F3, emissions from Fire protection are reported as not occurring since no emissions are occurring in this sector within Switzerland. The application of HFC, PFC and SF_6 in fire extinguishers is prohibited by law in Switzerland. For the 2010 GHG inventory of Liechtenstein (OE 2012) validity of this assumption was examined with industry representatives also for Liechtenstein. They confirmed that there is neither production nor disposal or known stocking of fire extinguishers using HFC, PFC or SF_6. Therefore, it can be assumed that the notation key NO is correct for Liechtenstein.

4.7.5 Category-specific recalculations

2F1 Refrigeration and air conditioning: The number of households in 2010 was updated based on the population census data from 2010, which results in updated interpolated values since 2001.

For Switzerland, the following recalculations have been carried out, which also influence Liechtenstein's emission time series:

2F1 Refrigeration and air conditioning: Optimizations of model calculations including number of vehicles in the model of mobile air conditioning of van, extrapolation of emission factor for stationary air conditioning equipment, changes of refrigerant blend applied in transport refrigeration of trains.

4.7.6 Category-specific planned improvements

No category-specific improvements are planned.

4.8 Source category 2G - Other product manufacture and use

4.8.1 Source category description: Other product manufacture and use (2G)

Key categories 2G
Source category 2G "Other product manufacture and use" is **not a key category.**

According to the IPCC guidelines (IPCC 2006) N_2O for anaesthetic use is supplied in steel cylinders and used during anaesthesia for two reasons: a) as an anaesthetic and analgesic and as b) a carrier gas for volatile fluorinated hydrocarbon anaesthetics such as isoflurane, sevoflurane and desflurane. The anaesthetic effect of N_2O is additive to that of the fluorinated hydrocarbon agents. N_2O is also used as a propellant in aerosol products primarily in food industry. Typical usage is to make whipped cream, where cartridges filled with N_2O are used to blow the cream into foam (IPCC 2006).

Liechtenstein emission sources of 2G Other product manufacture and use are given in Table 4-8.

Table 4-8 Specification of source category 2G Other product manufacture and use.

2G	Source	Specification
2G1	Electrical equipment	SF6 emissions used in electrical equipment and released due to disposal.
2G2	SF_6 and PFCs from other product use	Not occuring in Liechtenstein.
2G3	N_2O from product uses	N_2O emissions from anaesthesia use in hospitals as well as N_2O emissions from the use of aerosol cans.
2G4	Other	Not occuring in Liechtenstein.

Source category 2G comprises emissions from SF_6 in electrical equipment as well as N_2O emissions from product applications hospitals (anaesthesia) and households (aerosol cans). Other emissions due not occur in Liechtenstein or are not significant.

4.8.2 Methodological issues: Other product manufacture and use (2G)

Methodology

Electrical equipment

The only SF_6 emissions in Liechtenstein arise from the transformers operated by the utility Liechtensteinische Kraftwerke (LKW). The LKW reports on activity data and emissions with a T3 method. A complete mass balance analysis is conducted by LKW on installation level, which was reconfirmed by LKW in 2011. No production of equipment with SF_6 is occurring.

N_2O from product use

Data availability in Liechtenstein 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 from the source category 2G in Liechtenstein are the product of the specific emissions per inhabitant in Switzerland and the number of inhabitants in Liechtenstein. This basis allows an estimate of emissions. The rationale behind this simple approach is that the general characteristics of Liechtenstein and Switzerland determining emissions are mainly similar.

Emission factors

Electrical equipment

Emission factors for this source category are based on industry information and fluctuate over time due to differences in the gas imports per year, installations of F-gas equipment and differences in refill amounts of SF_s gases. For further information see Table 4-9.

N_2O from product use

Emission factors for N_2O, which correspond to the specific emissions per inhabitant, are taken from Switzerland's national inventory database EMIS (FOEN 2015b). The calculation is done for emission factors under 2G3a Medical applications and 2G3b Other propellant for pressure and aerosol products separately. Table 4-9 illustrates the implied emission factor on aggregated level for the entire source category 2G3. The rationale behind the methodology for source category 2G is that the general characteristics of Liechtenstein and Switzerland determining emissions are similar. As regulatory frameworks, technical standards and legal principles (threshold values, etc.) in the construction sector of Liechtenstein correspond to Swiss standards, it is justified to adopt Switzerland's country-specific methodology and/or emission factors. Therefore, specific emissions per inhabitant in Switzerland (FOEN 2015b) are used as a proxy for Liechtenstein.

Table 4-9 Emission factors of Liechtenstein's SF_6 emissions under source category 2G1 and N_2O emissions under 2G3 for the time series 1990-2014.

Emission factors 2G Other product manufacture and use	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2G1 Electrical equipment - SF_6 product life factor (% per annum)	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.0741
2G3 N_2O from product uses - N_2O (g/inhabitant)	52.278	49.697	47.116	44.535	41.955	39.374	36.793	34.212	31.631	29.051

Emission factors 2G Other product manufacture and use	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2G1 Electrical equipment - SF6 product life factor (% per annum)	0.3597	0.3989	0.4200	0.4278	0.4232	0.4032	0.0873	0.1696	0.5080	0.1959
2G3 N_2O from product uses - N_2O (g/inhabitant)	26.470	23.889	22.944	23.000	22.250	22.500	20.750	20.000	19.250	18.505

Emission factors 2G Other product manufacture and use	2010	2011	2012	2013	2014
2G1 Electrical equipment - SF6 product life factor (% per annum)	0.0329	0.0185	0.0005	0.2006	0.1300
2G3 N_2O from product uses - N_2O (g/inhabitant)	18.769	17.903	17.906	17.888	17.747

Activity data

Table 4-10 illustrates the numbers of inhabitants of Liechtenstein and Switzerland for the entire time series 1990-2014. The number of inhabitants is used in order to derive Liechtenstein's activity data under source category 2G3 (see below for further information).

Table 4-10 Number of inhabitants of Liechtenstein and Switzerland as proxy for activity data calculations concerning emissions under source category 2G3.

Number of inhabitants for AD calculations	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Number of inhabitants									
Liechtenstein	29'032	29'386	29'868	30'310	30'629	30'923	31'143	31'320	32'015	32'426
Switzerland	6'796'000	6'880'000	6'943'000	6'989'000	7'037'000	7'081'000	7'105'000	7'113'000	7'132'000	7'167'000
	percentage [%]									
Liechtenstein / Switzerland	0.43%	0.43%	0.43%	0.43%	0.44%	0.44%	0.44%	0.44%	0.45%	0.45%

Number of inhabitants for AD calculations	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Number of inhabitants									
Liechtenstein	32'863	33'525	33'863	34'294	34'600	34'905	35'168	35'356	35'589	35'894
Switzerland	7'209'000	7'285'000	7'343'000	7'405'000	7'454'000	7'501'000	7'558'000	7'619'000	7'711'000	7'799'000
	percentage [%]									
Liechtenstein / Switzerland	0.46%	0.46%	0.46%	0.46%	0.46%	0.47%	0.47%	0.46%	0.46%	0.46%

Number of inhabitants for AD calculations	2010	2011	2012	2013	2014
	Number of inhabitants				
Liechtenstein	36'149	36'475	36'838	37'129	37'366
Switzerland	7'870'000	7'954'700	8'039'100	8'139'600	8'237'700
	percentage [%]				
Liechtenstein / Switzerland	0.46%	0.46%	0.46%	0.46%	0.45%

Table 4-11 Activity data of source category 2G Other product manufacture and use.

Activity data 2G Other product manufacture and use	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2G1 Electrical equipment - SF_6 amount in operating systems (average annual stocks) in kt	NO	NO	NO	NO	NO	NO	0.0001	0.0002	0.0002	0.0003
2G3 N_2O from product uses - number of inhabitants	29'032	29'386	29'868	30'310	30'629	30'923	31'143	31'320	32'015	32'426

Emission factors 2G Other product manufacture and use	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2G1 Electrical equipment - SF_6 amount in operating systems (average annual stocks) in kt	0.0011	0.0018	0.0025	0.0025	0.0027	0.0028	0.0028	0.0029	0.0030	0.0030
2G3 N_2O from product uses - number of inhabitants	32'863	33'525	33'863	34'294	34'600	34'905	35'168	35'356	35'589	35'894

Emission factors 2G Other product manufacture and use	2010	2011	2012	2013	2014
2G1 Electrical equipment - SF_6 amount in operating systems (average annual stocks) in kt	0.0031	0.0032	0.0037	0.0038	0.0039
2G3 N_2O from product uses - number of inhabitants	36'149	36'475	36'838	37'129	37'366

Electrical equipment

Activity data is based on industry information. Before 1995/1996 a different technology was applied, which did not use SF_6 (see Table 4-11). SF_6 show an increasing trend. Since only one company is involved (LKW), individual changes in emissions become evident. Variability could also be a result of changing reporting periods and/or changes (reductions) in actual maintenance and repair interventions.

N_2O from product use & Other

The activity data is the number of inhabitants in Liechtenstein and is provided in Table 4-11. The number of inhabitants in Liechtenstein is based on OS 2016c. Data on the Swiss inhabitants (see Table 4-10) are published in SFSO 2016d.

4.8.3 Uncertainties and time-series consistency

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. Since 2G is not a key category, its uncertainties are accounted in the "rest" categories with mean uncertainty, which is 20% combined uncertainty for SF_6 emissions.

The time series are consistent.

4.8.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in section 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

For the inventory 2010 (OE 2012), the sum of SF_6 emissions reported by Liechtenstein for 1996-2010 for the former source category 2F8 Electrical Equipment as potential and actual emissions have been checked with the Liechtensteinische Kraftwerke (LKW 2010) and were confirmed to be plausible in view of the installation based data from the electrical equipment operated by the Liechtensteinische Kraftwerke.

4.8.5 Category-specific recalculations

No category-specific recalculations were carried out.

4.8.6 Category-specific planned improvements

No category-specific improvements are planned.

4.9 Source category 2H - Other

4.9.1 Source category description: Other (2H)

Emissions from source category 2H are not occurring in Liechtenstein.

5 Agriculture

5.1 Overview

This chapter provides information on the estimation of the greenhouse gas emissions from sector Agriculture. The following source categories are reported:

- Enteric fermentation (3A) – CH_4 emissions from domestic livestock
- Manure management (3B) – CH_4 and N_2O emissions
- Agricultural soils (3D) – N_2O, NO_x, CO, and NMVOC emissions
- Urea application (3H) – CO_2 emissions

Categories 3C Rice cultivation, 3E Prescribed burning of savannas, 3F Field burning of agricultural residues and 3G Liming do not occur in Liechtenstein and are therefore not reported. Please also note that CO_2 emissions from energy use in agriculture are reported under sector 1 Energy Other sectors (1A4c).

Liechtenstein's emissions within sector 3 Agriculture are calculated according to the Swiss agriculture model. (The ERT noted in its latest Annual Review Report (FCCC/ARR 2014) in paragraph 60, that this approach is appropriate[9]). Country-specific activity data such as livestock, agricultural area, harvest or milk yield are updated on a yearly basis. Specific parameters and variables in the model are revised every 5 years with latest Swiss values and data. The effort updating the model annually is not feasible for a small country such as Liechtenstein. The final model update will be in the last submission year of the commitment period (see also planned improvements).

Greenhouse gas emissions from agriculture amount to 24.4 kt CO_2 equivalents in 2014, which is a contribution of 11.3% to the total of Liechtenstein's greenhouse gas emissions (excluding LULUCF). Main agricultural sources of greenhouse gases in 2014 were enteric fermentation emitting 13.5 kt CO_2 equivalents, followed by agricultural soils with 6.7 kt CO_2 equivalents, manure management with 2.7 kt and urea application with 0.04 kt. A decrease of 4.4% can be observed between 1990 and 2014 regarding overall emissions from agriculture (see Table 5-1 and Figure 5-1). The decreasing trend from 1990 on was interrupted by an increasing period between 2001 and 2008. From 2009 on, emissions are fluctuating while showing a slightly decreasing trend. Nevertheless, compared to the previous reporting year 2013 emissions have slightly increased by around 1.5%.

[9] "60. The inventory data, methodology and assumptions of Liechtenstein generally follow the Swiss GHG inventory because of similarities of soil, climatic and agricultural conditions between Liechtenstein and Switzerland. The ERT considers that such an approach is appropriate in this specific case." (FCCC/ARR 2014)

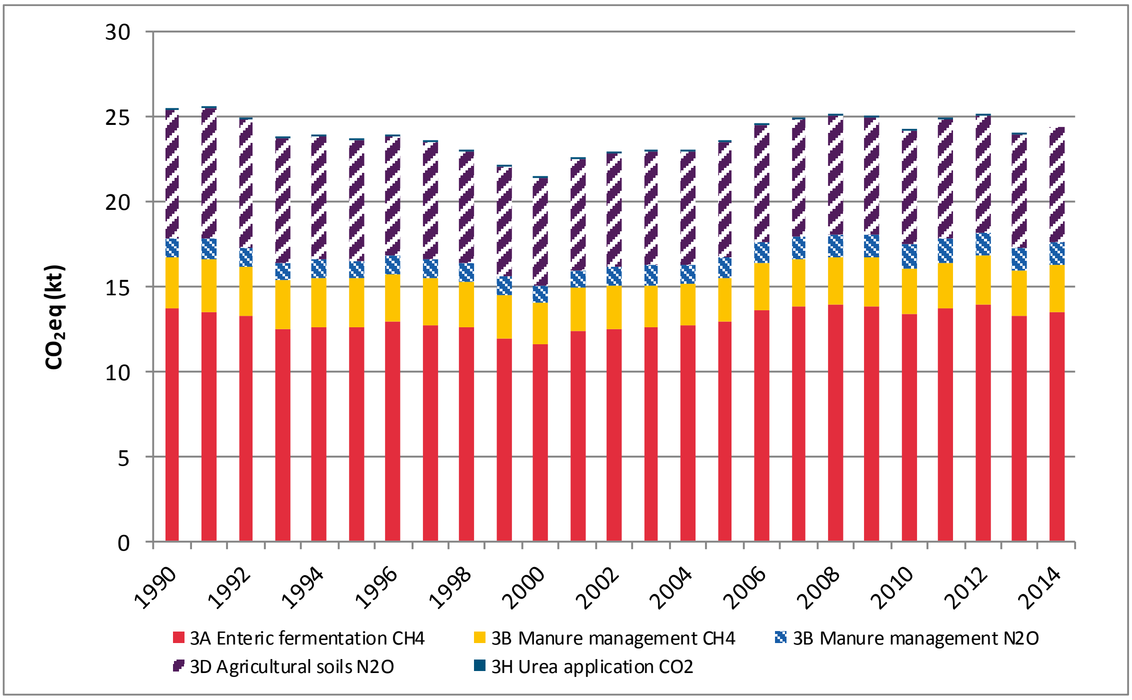

Figure 5-1 Greenhouse gas emissions in kt CO_2 equivalents of agriculture 1990-2014.

Table 5-1 Greenhouse gas emissions in kt CO_2 equivalents of agriculture 1990-2014 (numbers may not add to totals due to rounding).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO_2	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04
CH_4	16.72	16.63	16.16	15.35	15.48	15.46	15.74	15.44	15.23	14.51
N_2O	8.71	8.83	8.62	8.35	8.31	8.16	8.09	8.04	7.76	7.53
Sum	**25.50**	**25.52**	**24.83**	**23.75**	**23.85**	**23.67**	**23.87**	**23.53**	**23.03**	**22.08**

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.04
CH_4	14.04	14.89	15.01	15.10	15.13	15.53	16.33	16.59	16.71	16.67
N_2O	7.39	7.58	7.80	7.85	7.80	7.97	8.18	8.26	8.35	8.27
Sum	**21.47**	**22.52**	**22.86**	**23.00**	**22.98**	**23.55**	**24.55**	**24.90**	**25.11**	**24.99**

Gas	2010	2011	2012	2013	2014	1990-2014
	CO_2 equivalent (kt)					%
CO_2	0.04	0.05	0.04	0.04	0.04	-28.82%
CH_4	16.10	16.44	16.79	15.96	16.26	-2.79%
N_2O	8.03	8.41	8.29	8.01	8.08	-7.29%
Sum	**24.17**	**24.90**	**25.12**	**24.01**	**24.38**	**-4.38%**

Figure 5-2 shows the emission trends for CO_2, CH_4 and N_2O within sector 3 Agriculture. Regarding CO_2 emissions, which originate from urea application only, the relative trend is -28.8% between 1990 and 2014. CH_4 emissions are -2.8% below 1990 level, and N_2O emissions also decreased between 1990 and 2014 (7.3%). CH_4 and N_2O emissions are highly dependent on animal populations (see also Figure 5-6).

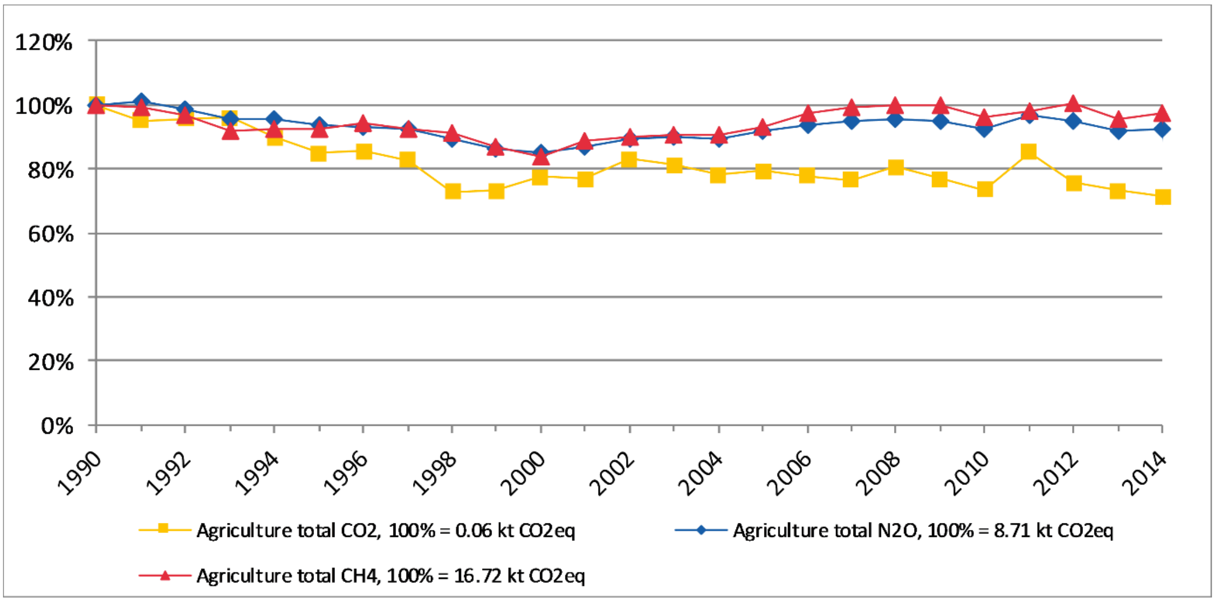

Figure 5-2 Trend of greenhouse gases of the agricultural sector 1990-2014. The base year 1990 represents 100%.

There are five key categories of the inventory out of sector 3 Agriculture. Those categories, including absolute emission numbers for the base year 1990 and the reporting year 2014 are displayed in Figure 5-3.

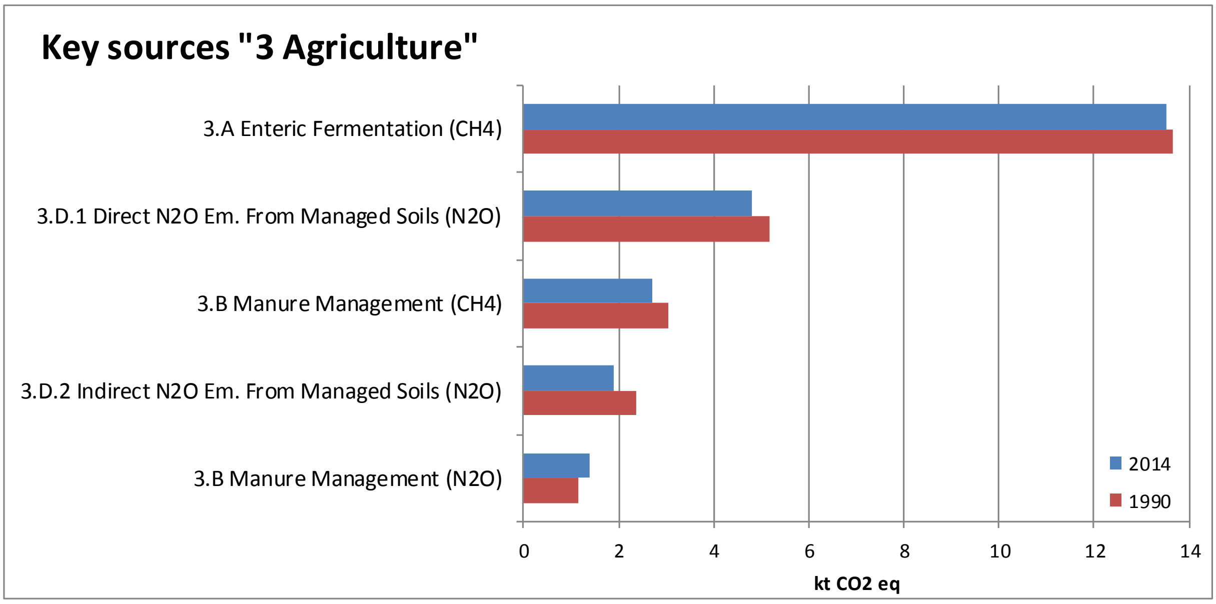

Figure 5-3 Key categories from agriculture. Emissions in CO_2 equivalents (kt) in 2014 and in the base year 1990.

5.2 Source category 3A – Enteric fermentation

5.2.1 Source category description: Enteric fermentation (3A)

Key category 3A The CH_4 emissions from 3A Enteric fermentation are a key source by level and trend.

This emission source comprises the domestic livestock population cattle, sheep, swine, and other livestock such as goats, horses, mules and asses, and poultry (see also Table 5-2).

As illustrated in Figure 5-1, CH_4 emissions from source category 3A Enteric fermentation have decreased between 1990 and 2000 and then again increased from 2001 to 2014 back to the level of 1990. They are basically following the cattle population number, as emissions from cattle contribute to over 90% of the enteric fermentation emissions. A second relevant development in 3A Enteric fermentation is the increasing productivity of dairy cattle's (high-yield cattle), which results in higher (per animal) emission factors.

Table 5-2 Specification of source category 3A Enteric fermentation.

3A	Source	Specification
3A1	Cattle	Mature dairy cattle Other mature cattle Growing cattle (fattening calvew, pre-weaned calves, breeding cattle 1st year, breeding cattle 2nd year, breeding cattle 3rd year, fattening cattle)
3A2	Sheep	Sheep
3A3	Swine	Swine
3A4a	Goats	Goats
3A4b	Horses	Horses < 3 years Horses > 3 years
3A4c	Mules and Asses	Mules and Asses
3A4d	Poultry	Poultry

5.2.2 Methodological issues: Enteric fermentation (3A)

According to the decision tree in the 2006 IPCC Guidelines (IPCC 2006) chapter 10, Figure 10.2, a Tier 2 approach was applied for CH_4 emissions from domestic livestock. As done for previous submission, Liechtenstein adopted the methodology of Switzerland (for further information see chp. 5.1) in order to calculate emissions originating from source category 3A Enteric fermentation.

Detailed Swiss specific data on nutrient requirements, feed intake and CH_4 conversion rates for specific animals and feed types were used. For mature dairy cattle a detailed feeding model was applied, predicting gross energy intake based on animal performance and diet chemical composition. The methane conversion rate (Y_m) for mature dairy cattle was derived from a series of studies representing Swiss specific feeding conditions.

Activity data are adjusted to Liechtenstein's circumstances.

5.2.2.1 Emission factors

All emission factors applied for source category 3A Enteric fermentation are based on the country specific emission factors of Switzerland from the inventory submission 2015 (FOEN 2015). The method is based on the IPCC 2006 Guidelines (IPCC 2006), equation 10.21:

$$EF = \frac{GE * (Y_m \div 100) * 365\ days / y}{55.65\ MJ / kg\ CH_4}$$

EF = annual CH_4 emission factor (kg/head/year)

GE = gross energy intake (MJ/head/day)

Y_m = methane conversion rate: fraction of gross energy in feed converted to methane (%)

55.65 MJ/kg = energy content of methane.

Gross energy intake (GE) (compare FOEN 2016 page 268)

For calculating the gross energy intake (GE), the Swiss-specific methods based on available data on requirements of net energy, digestible energy and metabolisable energy were applied. The different energy levels used for energy conversion from energy required for maintenance and production to GE intake are illustrated in Figure 5-4. The respective conversion factors are given in Table 5-3.

For the **cattle categories** detailed estimations for energy requirements are necessary. As the Swiss Farmers Union (SBV) does not provide these estimates on a detailed cattle sub-category level, specific requirements were calculated following the feeding recommendations for Switzerland provided in RAP (1999) and Morel et al. (2015). These RAP recommendations are also used by the Swiss farmers as the basis for their cattle feeding regimes and for filling in application forms for direct payments; they are therefore highly appropriate.

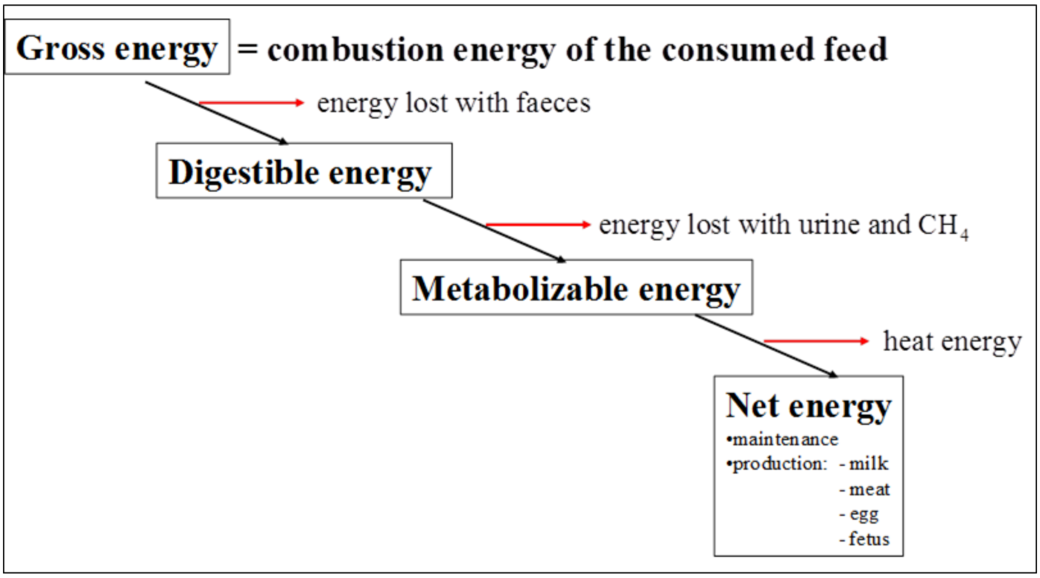

Figure 5-4 Levels of feed energy conversion (Soliva 2006a).

Table 5-3 Conversion factors used for the calculation of energy requirements of individual livestock categories (Soliva 2006a). GE: Gross energy; DE: Digestible energy; ME: Metabolisable energy; NEL: Net energy for lactation; NEV: Net energy for growth. Conversion factors used for calculation of energy requirements of individual livestock categories. Reference: Soliva 2006a. GE: Gross energy; DE: Digestible energy; ME: Metabolisable energy; NEL: Net energy for lactation; NEV: Net energy for growth.

Livestock Category		**Conversion Factors**	
Mature Dairy Cattle		NEL to GE	0.340
Other Mature Cattle		NEL to GE	0.275
Growing Cattle	*Fattening Calves*	*ME to GE*	*0.930*
	Pre-Weaned Calves	*NEL to GE*	*0.291*
	Breeding Cattle 1st Year	*NEL to GE*	*0.328*
	Breeding Cattle 2nd Year	*NEL to GE*	*0.313*
	Breeding Cattle 3rd Year	*NEV to GE*	*0.313*
	Fattening Cattle	*NEV to GE*	*0.384*
Sheep	*Fattening Sheep*	*NEV to GE*	*0.350*
	Milksheep	*NEL to GE*	*0.287*
Swine		DE to GE	0.682
Goats		NEL to GE	0.283
Horses		DE to GE	0.700
Mules and Asses		DE to GE	0.700
Poultry		ME to GE	0.700

Gross energy intake of **mature dairy cattle** is primarily dependent on animal performance, i.e. body weight and milk yield. Accordingly the respective GE was assessed with a detailed model within the Swiss GHG inventory (Agroscope 2014c). Using the respective model outputs, simple linear regression equations were applied to estimate GE of mature dairy cattle for Liechtenstein. It was assumed that no differences exist concerning body weight and feeding strategies between Switzerland and Liechtenstein. Hence the resulting linear regression given below and in Figure 5-5 include only milk yield as driving parameter:

- milk production per year < 6’000 kg: GE = 0.0252*Milk + 135.83
- milk production per year > 6’000 kg: GE = 0.0152*Milk + 196.34

With
GE = gross energy intake (MJ/head/day)
Milk = amount of milk produced (kg/head/year)

To achieve yearly milk yields higher than 6’000 kg, cows have to be fed with an increasing share of feed concentrates that have a substantially higher net energy (NE) density than the basic feed ration. The model reproduces this behaviour. Due to the increasing ratio of net energy to gross energy the increase of GE with increasing milk yields is slower above 6’000 kg*year^{-1} (red line in Figure 5-5). In Liechtenstein this transition occurred around 1997.

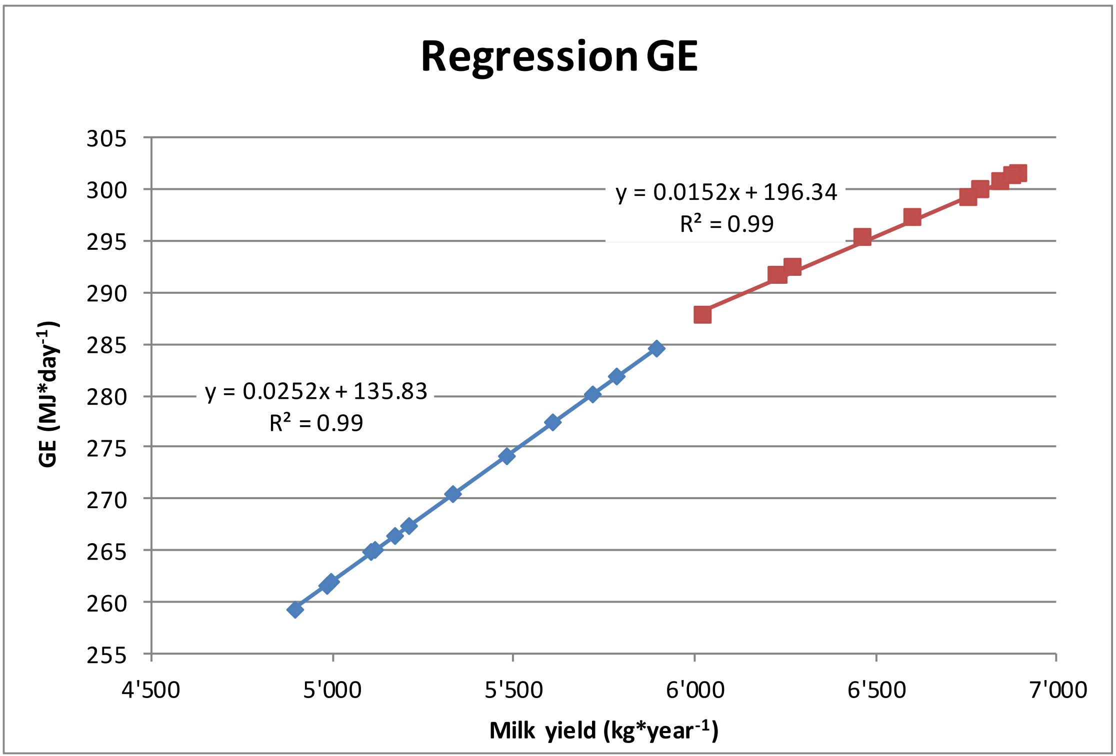

Figure 5-5 Linear regressions relating gross energy intake (GE) to milk yield for mature dairy cattle's (based on FOEN 2015).

Milk production (see Table 5-4) of mature dairy cattle increased from 5'792 kg per head and year in 1990 (18.99 kg per head for 305 days) to 6'759 kg per head and year in 2014 (22.16 kg per head for 305 days). Statistics of annual milk production are provided by Liechtenstein's Office for Food-control and Veterinary (Amt für Lebensmittelkontrolle und Veterinärwesen) in corporation with the Division of Agriculture for values from 2002 onwards (OFIVA/OE 2015) and from the Office of Agriculture (see OA 2002) for years before 2002. Milk production includes marketed milk, milk consumed by calves on farms and milk sold outside the commercial industry. It should be noted that daily milk yield refers to milk production during lactation (305 days) and not during the whole year (365 days). Accordingly, milk production and energy requirement for lactation was zero during the two remaining months when the cows are dry.

Table 5-4 Average daily milk production during lactation in Liechtenstein 1990-2014. The unit kg/head/day does not refer to a full year, but only to 305 days (energy requirement for lactation is assumed zero during two months when cows are dry).

Milk Production Cattle		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Population Size Mature Dairy Cattle	head	2'850	2'843	2'747	2'601	2'677	2'643	2'652	2'622	2'614	2'589
Lactation Period	day	305	305	305	305	305	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	18.99	19.05	19.26	19.41	18.94	19.19	19.23	19.70	20.02	20.19
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20

Milk Production Cattle		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Population Size Mature Dairy Cattle	head	2'440	2'639	2'560	2'543	2'460	2'489	2'589	2'593	2'579	2'565
Lactation Period	day	305	305	305	305	305	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	20.72	21.60	21.83	21.93	22.54	22.24	22.11	22.09	22.29	21.70
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20

Milk Production Cattle		2010	2011	2012	2013	2014
Population Size Mature Dairy Cattle	head	2'425	2'435	2'456	2'363	2'367
Lactation Period	day	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	21.87	22.09	22.40	22.19	22.16
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	8.20	8.20	8.20

For **other mature cattle** and **growing cattle** Liechtenstein follows the Swiss approach in order to determine GE. The method is based on the feeding requirements according to RAP (1999). In the calculation of the NE data, the animal's weight, daily growth rate, daily feed intake (dry matter), daily feed energy intake, and energy required for milk production and pregnancy for the respective sub-categories were considered. The method is described in detail in Soliva (2006a). NE is further subdivided into NE for lactation (NEL) and NE for growth (NEV) (Table 5-3). For some of the growing cattle categories NEL is used, rather than NEV that would seem logical. However, cattle-raising is often coupled with dairy cattle activities and therefore the same energy unit (NEL) is used in these cases. Exceptions are the fattening calves (milk-fed calves), whose requirement for energy is expressed as metabolisable energy (ME).

The gross energy intake for **other mature cattle** is significantly higher than IPCC default values, since the category "other mature cattle" only includes mature cows that produce offspring for meat (so-called "suckler cows" or "mother cows"). Milk production of other mature cattle is 2500 kg per head and year (305 days of lactation) and has not changed over the inventory time period (RAP 1999).

The gross energy intake of **growing cattle** was calculated separately for all sub-categories displayed in Table 5-5 (in italics) and subsequently averaged (weighted average). The values for all 6 sub-categories are constant over time and based on the respective estimates in the Swiss Inventory (FOEN 2015). In the case of *breeding cattle 1st* year and *fattening cattle*, no further disaggregation was conducted as in the Swiss inventory. Since the composition of the young cattle category changed over time (e.g. more pre-weaned calves, see Table 5-6), the average gross energy intake for growing cattle also changes slightly.

Table 5-5 Gross energy intake per head of different livestock groups. Highly disaggregated categories not contained in the CRF-Tables are displayed in *italic*.

Gross Energy Intake	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	MJ/head/day												
Cattle													
Mature Dairy Cattle	281.8	283.3	292.4	299.4	298.8	298.7	299.7	296.9	297.7	298.7	300.2	299.2	299.2
Other Mature Cattle	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1	205.1
Growing Cattle (weighted average)	101.8	99.4	99.8	97.4	96.7	94.7	95.3	96.3	97.6	96.9	95.8	96.5	97.3
Fattening Calves	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*
Pre-Weaned Calves	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*	*55.7*
Breeding Cattle 1st Year	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*	*67.6*
Breeding Cattle 2nd Year	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*
Breeding Cattle 3rd Year	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*	*129.1*
Fattening Cattle	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*	*103.6*
Sheep	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Swine	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
Goats	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5
Horses (weighted average)	107.5	107.7	108.0	108.2	108.1	108.2	108.4	108.2	108.3	108.3	107.9	108.2	108.3
Horses <3 years	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*	*101.4*
Horses >3 years	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*	*109.0*
Mules and Asses	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6
Poultry [1)]	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3

1) Poultry data is not Gross Energy intake (GE) but Metabolizable Energy intake (ME)

Energy requirements and GE intake of **sheep**, **swine**, **goats** and **poultry** correspond to the respective mean values for the first commitment period (1990-2012) in the Swiss inventory. Yearly fluctuations in the Swiss inventory are statistical artefacts and do not reflect actual changes of feeding practices. The data is based on the estimates of the feedstuff balance of the Swiss Farmers Union (SBV 2014, Giuliani 2014). These estimates are not officially published anymore in the statistical yearbooks (e.g. SBV 2014) but are still available from background data and are based on the same method as earlier published energy requirement statistics (e.g. SBV 2007).

Gross energy intake for **horses** and **mules and asses** were estimated by Stricker (2012), mainly based on Meyer and Coenen (2002).

Resulting estimates of gross energy intakes are provided in Table 5-5.

Methane conversion rate (Y_m) (compare FOEN 2016 page 272)

For the methane conversion rate (Y_m), only limited country-specific data exist. The same approach as in the Swiss inventory was applied for all animal categories.

For **cattle** and **sheep** default values recommended by the IPCC for developed countries in Western Europe were mainly used (IPCC 2006: Table 10.12, 10.13, 10A.2, 10A.3).

Due to the great importance of **mature dairy cattle**, Liechtenstein follows the Swiss country-specific approach. A Y_m of 6.9% was adopted based on a series of measurements conducted under Swiss specific feeding and husbandry conditions at the Federal Institute of Technology in Zürich (based on data compiled in Zeitz et al. (2012) and additional measurements described in Estermann et al. (2001), Külling et al. (2002) and Staerfl et al. (2012)). For all juvenile cattle consuming only milk (i.e. fattening calves) the methane conversion rate is assumed to be zero.

According to table 10.13 in IPCC (2006) two different Y_m were used for **sheep**, namely 4.5 % for lambs < 1 year and 6.5% for mature sheep. Since no detailed data on the sheep population structure in Liechtenstein is available, overall Y_m was weighted according to the population structure of Switzerland, resulting in an average value of 5.7%.

For **Swine** a rather low methane conversion rate of 0.6% was used. This value has been suggested by Crutzen et al. (1986) and was confirmed by the compilation of references in Minonzio et al. (1998). Since the 2006 IPCC Guidelines do not provide a default value for **goats**, an Y_m of 6% was adopted based on the work of Martínez-Fernández et al. (2014) and Fernández et al. (2013). For **Horses**, and **mules and asses** an Y_m of 2.45% was used, which corresponds to a methane energy loss of 3.5% of digestible energy (Vermorel et al. 1997, Minonzio et al. 1998) and a feed digestibility of 70% (Stricker 2012). For **poultry** a country-specific value (0.16% of metabolisable energy) was used. This value was evaluated in an in vivo trial with broilers (Hadorn and Wenk 1996).

5.2.2.2 Activity data

The activity data was obtained from Liechtenstein's Office for Food-control and Veterinary (Amt für Lebensmittelkontrolle und Veterinärwesen) in cooperation with the Division of Agriculture (OFIVA/OE 2015, for all years since 2002) and from the Office of Agriculture (OA 2002, for the years before 2002). Data for the livestock categories mature dairy cattle, sheep, goats and swine are available annually for the whole time series. For all the other livestock categories data are available for the years 1990 and 2000 as well as for 2002 onward. Data in between was interpolated. From 2002 onward, data for all livestock categories is available on an annual basis.

Any deviation from FAO figures is due to the fact that **Liechtenstein is not a FAO member** and has no obligation to report livestock numbers to FAO. Consequently, FAO makes its own estimates regarding Liechtenstein livestock numbers.

Activity data are provided in Table 5-6.

Table 5-6 Activity data for Liechtenstein (OFIVA/OE 2015, OA 2002).

Population size		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011
		1000 head									
Cattle		6.33	5.86	4.95	5.57	5.83	6.03	6.05	6.08	5.99	6.15
Mature Dairy Cattle		2.85	2.64	2.44	2.49	2.59	2.59	2.58	2.57	2.43	2.44
Other Mature Cattle		0.02	0.05	0.07	0.36	0.41	0.47	0.45	0.43	0.38	0.45
Growing Cattle (weighted average)		3.46	3.17	2.43	2.72	2.83	2.97	3.01	3.08	3.19	3.27
	Fattening Calves	*0.05*	*0.08*	*0.11*	*0.08*	*0.06*	*0.11*	*0.08*	*0.10*	*0.08*	*0.08*
	Pre-Weaned Calves	*0.02*	*0.04*	*0.01*	*0.27*	*0.28*	*0.34*	*0.34*	*0.29*	*0.28*	*0.33*
	Breeding Cattle 1st Year	*1.14*	*1.06*	*0.65*	*0.60*	*0.72*	*0.69*	*0.72*	*0.72*	*0.81*	*0.82*
	Breeding Cattle 2nd Year	*0.90*	*0.70*	*0.54*	*0.68*	*0.67*	*0.68*	*0.66*	*0.73*	*0.81*	*0.81*
	Breeding Cattle 3rd Year	*0.63*	*0.58*	*0.34*	*0.35*	*0.40*	*0.32*	*0.37*	*0.37*	*0.46*	*0.46*
	Fattening Cattle	*0.72*	*0.73*	*0.77*	*0.74*	*0.70*	*0.84*	*0.84*	*0.86*	*0.74*	*0.76*
Sheep		2.78	2.63	2.98	3.06	3.69	3.68	3.85	3.96	3.66	3.63
Swine		3.25	2.43	1.99	1.70	1.72	1.74	1.76	1.81	1.69	1.79
Goats		0.17	0.15	0.16	0.32	0.36	0.32	0.43	0.45	0.43	0.46
Horses (weighted average)		0.17	0.16	0.16	0.27	0.29	0.28	0.30	0.31	0.34	0.33
	Horses <3 years	*0.03*	*0.03*	*0.02*	*0.03*	*0.03*	*0.03*	*0.02*	*0.03*	*0.03*	*0.03*
	Horses >3 years	*0.13*	*0.14*	*0.14*	*0.24*	*0.25*	*0.25*	*0.28*	*0.28*	*0.30*	*0.30*
Mules and Asses		0.07	0.13	0.22	0.14	0.14	0.16	0.19	0.19	0.15	0.19
Poultry		4.44	6.25	8.06	10.45	11.87	12.39	12.41	12.17	12.92	12.49

Population size		2012	2013	2014
		1000 head		
Cattle		6.29	6.01	6.21
Mature Dairy Cattle		2.46	2.36	2.37
Other Mature Cattle		0.54	0.46	0.45
Growing Cattle (weighted average)		3.29	3.18	3.40
	Fattening Calves	*0.08*	*0.08*	*0.08*
	Pre-Weaned Calves	*0.40*	*0.34*	*0.33*
	Breeding Cattle 1st Year	*0.79*	*0.79*	*0.88*
	Breeding Cattle 2nd Year	*0.79*	*0.78*	*0.87*
	Breeding Cattle 3rd Year	*0.45*	*0.44*	*0.49*
	Fattening Cattle	*0.79*	*0.75*	*0.75*
Sheep		3.80	3.52	3.58
Swine		1.74	1.66	1.71
Goats		0.39	0.27	0.28
Horses (weighted average)		0.33	0.30	0.31
	Horses <3 years	*0.05*	*0.03*	*0.03*
	Horses >3 years	*0.28*	*0.27*	*0.28*
Mules and Asses		0.18	0.17	0.18
Poultry		12.53	13.03	12.68

Total number of cattle decreased by 22% between 1990 and the beginning of the new millennium, but grew again between 2000 and 2007; from 2007 to 2014 it has stabilised at a slightly lower level than 1990. Other mature cattle have continuously grown in number (from 20 heads in 1990 to 449 heads in 2014), due to an increasing meat demand from extensive livestock production. The drastic decrease of the swine population between 2003 and 2004 was caused by a disease, since 2005 the number of swine remains rather constant. The extraordinary increase in the poultry population is a result of two new poultry farms that were established in Liechtenstein. The figures have more or less stabilized since 2007.

Figure 5-6 illustrates the development of Liechtenstein's animal population size.

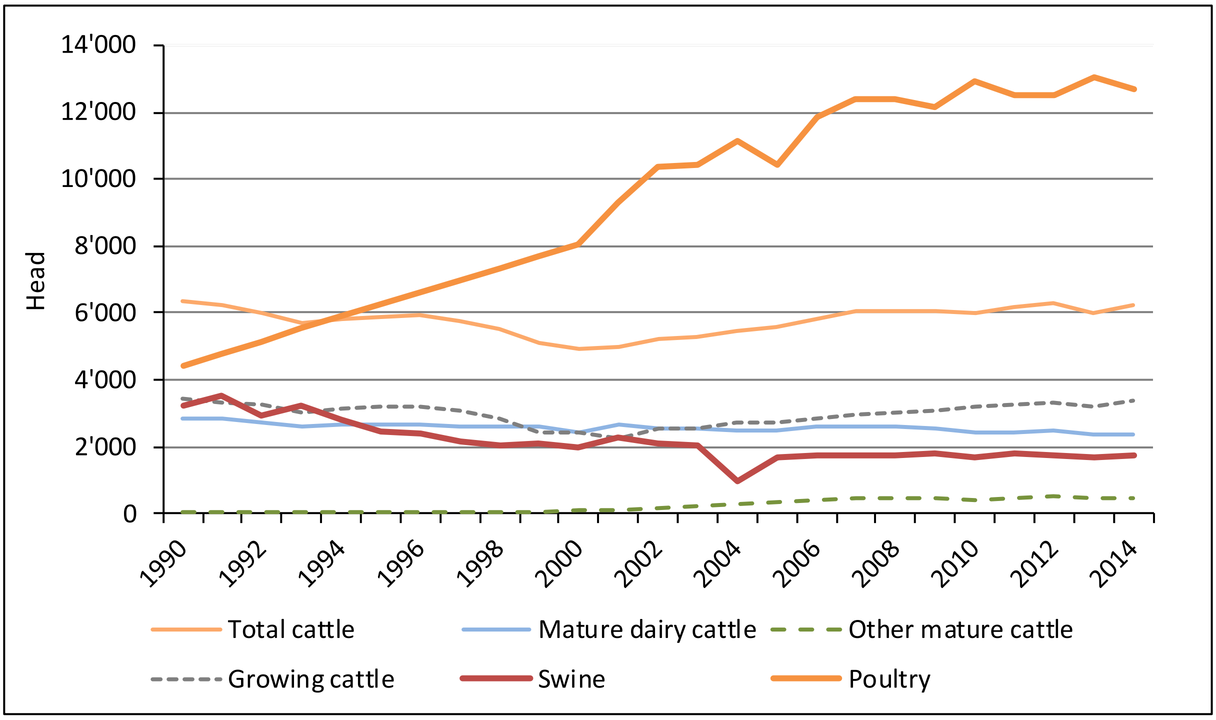

Figure 5-6 Development of population size of main animal categories 1990-2014 (OFIVA/OE 2015, OA 2002).

5.2.3 Uncertainties and time-series consistency

The uncertainty analysis is taken from the Swiss greenhouse gas inventory because the same model was applied for Liechtenstein's GHG inventory. Input data from ART (2008) was used and was updated with current activity and emission data of the Swiss inventory as well as with new default uncertainties of the 2006 IPCC Guidelines (IPCC 2006). The arithmetic mean of the lower and upper bound uncertainty was used for activity data (6.4%) and for emission factors (16.9%), resulting in a combined uncertainty of 18.1% for Approach 1 analysis.

For the current submission no Approach 2 analysis was carried out. Approach 2 will again be performed in later submissions as it has already been the case in the previous submission. Then, asymmetric probability distributions as well as possible correlations of input data will have to be considered. For further uncertainty-results also consult chp. 1.6.

The time series 1990–2014 are consistent, although the following issues should be considered:

- Liechtenstein has only very small animal populations that can fluctuate considerably due to establishment or cessation of farms or agricultural activities.

- Gross energy intakes of some of the aggregated animal categories reveal some fluctuations during the inventory period due to varying shares of the sub-categories.
- Gross energy intakes as well as the implied emission factor for mature dairy cattle increase, mainly as a result of higher milk production (Table 5-4).

5.2.4 Category-specific QA/QC and verification

The category-specific QA/QC activities were carried out as mentioned in section 1.2.3 including triple checks of Liechtenstein's reporting tables (CRF tables). The triple check includes a detailed comparison of current and previous submission data for the base year 1990 and for the year 2013 as well as an analysis of the increase or decrease of emissions between 2013 and 2014 in the current submission.

In addition to the overall triple check a separate internal technical documentation of Liechtenstein's model is available (Bretscher 2015, in German only). The manual also ensures transparency and retraceability of the calculation methods and data sources. Supplementary, a quality control was done by Acontec and INFRAS by a countercheck of the calculation sheets.

Further QA/QC activities are also documented in the Swiss NIR (see FOEN 2016 page 276). The respective conclusions are equally valid for Liechtenstein since the methods used are an adaptation of the Swiss model version. Bottom up inventory estimates in Switzerland agree well with several atmospherically CH_4 measurements, thus verifying the methodological approach applied in the inventory.

The SE, the NIC and the NIR author report their QC activities in a checklist (see Annex 8).

5.2.5 Category-specific recalculations

No category-specific recalculations were carried out.

5.2.6 Category-specific planned improvements

- According to Liechtenstein's inventory development plan (IDP) it is planned (based on a recommendation of the ERT in FCCC/ARR 2014) to change the notation for indicating the feeding situation (set to NE in the past and current submissions) according to Table 10.5 of volume 4 of the 2006 IPCC Guidelines from submission 2017 onwards.
- It is also planned that Liechtenstein's agriculture model will be updated every 5 years with latest Swiss values and data. The effort updating the model annually is not feasible for a small country such as Liechtenstein. The final model update will be in the last submission year of the commitment period.

5.3 *Source category 3B – Manure management*

5.3.1 Source category description: Manure management (3B)

Key source 3B
The CH_4 and N_2O emissions from 3B Manure Management are a key source by level.

The emission source is the domestic livestock population broken down into 3 cattle categories (mature dairy cattle, other mature cattle, growing cattle), sheep, swine, buffalo, goats, horses, mules and asses, and poultry (see Table 5-7). Six (CH_4) respectively five (N_2O) different manure management systems are considered including indirect N_2O emissions from manure management (see Table 5-8). The total emissions from source category 3B Manure management closely follow the development of the cattle population. Significant contributors to CH_4 emissions in 2014 are cattle with approximatively 87%. Likewise, cattle and swine contribute significantly to N_2O emissions with 62% and 12%, respectively (direct emissions only). Approximately 73% of the total N_2O emissions attributed to source category 3B Manure management originate from indirect N_2O emissions.

Table 5-7 Specification of source category 3B Manure Management.

3B	Source	Specification
3B1	Cattle	Mature dairy cattle Other mature cattle Growing cattle (fattening calves, Pre-weaned calves, breeding cattle 1st year, breeding cattle 2nd year, breeding cattle 3rd year, fattening cattle)
3B2	Sheep	Fattening sheep Milk sheep
3B3	Swine	Piglets Fattening pig over 25 kg Dry sows Nursing sows Boars
3B4	Other livestock	Goats Horses (Horses < 3 years, Horses > 3 years) Poultry Mules and Asses

Table 5-8 Specification of source category 3B Manure Management. Note that the encoding items 3B6a, 3B6b, 3B6e are an auxiliary convention in Switzerland's EMIS database, which is also used in Liechtenstein's emission model.

3B	Source	Specification	
3B6a	Direct emissions	Liquid systems	
3B6b		Solid storage and dry lot	
3B / 3D		Pasture, range and paddock	
3B6e		Other	Deep litter
			Poultry system
3B5a	Indirect emissions	Atmospherical deposition	
3B5b		Leaching and run-off	

5.3.2 Methodological issues: Manure management (3B)

5.3.2.1 Methodology

As done for previous submission, Liechtenstein adopted the methodology of Switzerland (for further information see chp. 5.1) in order to calculate emissions originating from source category 3B Manure management. The calculation is based on methods described in the 2006 IPCC Guidelines (CH_4: IPCC 2006 equation 10.23; N_2O: IPCC 2006 equation 10.25).

CH_4 emissions from Manure management were generally estimated using a Tier 2 methodology. For cattle a more detailed method was applied, estimating volatile solids (VS) excretion based on gross energy intake estimates as used for Enteric fermentation. Methane conversion factors (MCF) are from IPCC (2006; solid storage, pasture range and paddock, anaerobic digesters, poultry manure) or were modelled according to Mangino et al. (2001).

N_2O emissions from source category 3B Manure management were estimated using a Tier 2 methodology. Activity data were adjusted to the particular situation of Liechtenstein (see Table 5-9 and activity data given in Table 5-6 and additional information below). Detailed country-specific data on nitrogen excretion rates, manure management system distribution and nitrogen volatilisation were applied in accordance with the Swiss inventory. Emission factors for direct N_2O emissions (EF_3) are based on IPCC (2006) whereas the emission factor for indirect emissions from atmospheric deposition is based on Bühlmann et al. (2015) and Bühlmann (2014). Leaching of NO_3^- from manure management systems was considered negligible and is thus not included in the estimates. Note that N_2O emissions from pasture, range and paddock are reported under 3D Agricultural soils, source category 3Da3 (Urine and dung deposited by grazing animals). For the calculation of CH_4 and N_2O emissions, slightly different livestock sub-categories were used (see Table 5-9). The livestock categories reported in the CRF-tables are the same, but the respective sub-categories as a basis for the calculation are different. The categorization for the estimation of CH_4 emissions had to be adapted to data available for energy requirements, while the categorisation for the estimation of N_2O emissions is determined by the respective categorisation of the Swiss ammonia inventory (AGRAMMON, Kupper et al. 2013, Flisch et al. 2009). Nevertheless, there is no inconsistency in the total number of animals as they are the same both for CH_4 and N_2O emissions. Note that although not growing cattle in the proper sense, bulls are contained in the categories breeding cattle 3rd year or fattening cattle according to their purposes.

Table 5-9 Livestock categories for estimating CH_4 and N_2O emissions from source category 3B Manure management.

3B	**CH_4**		**N_2O**	
Cattle	Mature Dairy Cattle		Mature Dairy Cattle	
	Other Mature Cattle		Other Mature Cattle	
	Growing Cattle	Fattening Calves Pre-Weaned Calves Breeding Cattle 1st year Breeding Cattle 2nd year Breeding Cattle 3rd year Fattening Cattle	Growing Cattle	Fattening Calves Pre-Weaned Calves Breeding Cattle 1st year Breeding Cattle 2nd year Breeding Cattle 3rd year Fattening Cattle
Sheep	Sheep		Fattening Sheep Milk Sheep	
Swine	Swine		Piglets Fattening Pig over 25 kg Dry Sows Nursing Sows Boars	
Goats	Goats		Goat places	
Horses	Horses < 3 years Horses > 3 years		Horses < 3 years Horses > 3 years	
Mules and Asses	Mules an Asses		Mules an Asses	
Poultry	Poultry		Growers Layers Broilers Turkey Other Poultry	

5.3.2.2 Emission factors CH_4

Calculation of CH_4 emissions from manure management is based on methods described in the 2006 IPCC Guidelines (IPCC 2006, equation 10.23):

$$EF_T = VS_T \bullet 365 days/year \bullet B_{0T} \bullet 0.67 kg/m^3 \bullet \sum_S MCF_S \bullet MS_{TS}$$

EF_T = annual CH_4 emission factor for livestock category T (kg/head/year)

VS_T = daily volatile solids (VS) excreted for livestock category T (kg/head/day)

B_{0T} = maximum CH_4 producing capacity for manure produced by livestock category T (m^3/kg)

0.67 kg/m^3 = conversion factor of m^3 CH_4 to kilograms CH_4

MCF_S = CH_4 conversion factors for each manure management system S (%)

MS_{TS} = fraction of livestock category T's manure handled using manure management system S (dimensionless)

Volatile solids excretion (VS) (compare FOEN 2016 page 283)

The daily excretions of volatile solids (VS) for **all cattle sub-categories** were estimated according to equation 10.24 in the 2006 IPCC Guidelines (IPCC 2006):

$$VS = \left[GE \bullet \left(1 - \frac{DE\%}{100} \right) + (UE \bullet GE) \right] \bullet \left[\frac{1 - ASH}{EDF} \right]$$

VS = volatile solids excretion per day on a dry-organic matter basis (kg/day)

GE = gross energy intake (MJ/head/day)

DE = digestibility of the feed (%)

(UE • GE) = urinary energy expressed as fraction of GE

ASH = ash content of manure calculated as a fraction of the dry matter feed intake

EDF = energy density of feed, conversion factor for dietary GE per kg of dry matter (MJ/kg)

Gross energy intake was calculated according to the method described in chapter 5.2.2. For **mature dairy cattle** data on energy density and ash content of feed as well as data on feed digestibility was adopted from Switzerland. To derive these parameters, the Swiss inventory system uses the same Agroscope feeding model that is also used for the estimation of GE (Agroscope 2014c). The digestibility of feed is of crucial importance for the calculation of volatile solids. The modelled values for dairy cows are somewhat higher than the IPCC default and were compared to measurements from feeding trials in Switzerland. The comparison revealed that modelled values are on average slightly higher than measurements. Accordingly, an adjustment was made in order to take account of the high feeding level that is usually above maintenance (Ramin and Huhtanen 2012). High feeding levels may lead to an increase in rumen passage rate and subsequently to lower feed digestibility (Nousiainen et al. 2009). The correction decreased the feed digestibility on average by 2.5 per cent points. Resulting feed digestibility was 72.2% on average, gross energy content (EDF) was 18.26 MJ/kg and ash content was 9.0% each with very small fluctuations along the time series. For urinary energy expressed as fraction of gross energy the default value of 0.04 was adopted (IPCC 2006).

IPCC default values of 65% respectively 60% were taken for the feed digestibility of **calves and other growing cattle**. For the urinary energy expressed as fraction of gross energy and for the energy density of the feed (EDF) the IPCC default values, i.e. 0.04 and 18.45 MJ/kg were adopted. Furthermore, an ash content of 8.0% was used for all these categories.

For VS excretion of the livestock categories **sheep**, **swine**, **goats**, **mules and asses** and **poultry** default values from IPCC were taken (IPCC 2006, Tables 10A-7, 10A-8, 10A-9). Considering the gross energy intake of **horses**, the VS-excretion in the revised 1996 IPCC Guidelines (1.72 kg/head/day) is clearly more appropriate and was thus adopted instead of the default value of the 2006 Guidelines (i.e. 2.13 kg/head/day).

Maximum CH_4 producing capacity (B_0)

For the methane producing capacity (B_o) default values were used (IPCC 2006).

Methane conversion factor (MCF) (compare FOEN 2016 page 284)

For estimating CH_4 emissions from source category 3B manure management, five different manure management systems are distinguished. Liechtenstein has an average annual temperature below

15°C (MeteoSwiss 2015a) and was therefore allocated to the cool climate region without any differentiation.

In the case of **solid manure** and **pasture range and paddock** the default MCF values from table 10.17 of the 2006 IPCC Guidelines were used (Table 5-10).

Liquid/slurry systems are usually responsible for the major part of methane emissions from Manure management. Accordingly the Swiss inventory system uses a more detailed model based on Mangino et al. (2001) to determine the respective MCF. As the manure management and temperature regimes do not differ substantially between Switzerland and Liechtenstein, the model results were also used in the Liechtenstein inventory. The respective MCF-values for liquid/slurry systems decrease slightly from 13.5% to 14.5% along the time series. The variation of the MCF is due to the increasing share of manure dropped on pasture, range and paddock which can be observed in Switzerland as well as in Liechtenstein. As livestock is only grazing during summer, the relative share of low methane conversion factors during the cold winter month increases when summer grazing time increases. Note that for 2014, the MCF of 2013 (13.7%) has been used.

Fattening calves, sheep and goats are kept in **deep litter systems**. A MCF of 10% was adopted, which is the mean value between the IPCC default values for cattle and swine deep bedding < 1 month and > 1 month at 10 °C (IPCC 2006). The choice of a MCF of 10% for deep litter is supported by the specific feeding and manure management regime in Liechtenstein (especially cold winter temperatures) and confirmed by a number of studies representative for the country-specific management conditions (Amon et al. 2001, Külling et al. 2002, Külling et al. 2003, Moller et al. 2004, Hindrichsen et al. 2006, Park et al. 2006 and Sommer et al. 2007, Zeitz et al. 2012).

For all poultry categories a MCF value of 1.5% was used according to the default value for **poultry manure systems** in the 2006 IPCC Guidelines.

Table 5-10 Manure management systems and methane conversion factors (MCFs).

Manure management system		Description	MCF (%)
Pasture		Manure is allowed to lie as it is, and is not managed (distributed, etc.).	1.0
Solid storage		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.	2.0
Liquid/slurry		Combined storage of dung and urine under animal confinements for longer than 1 month.	13.7
Other	Deep litter	Dung and urine is excreted in a barn with lots of litter and is not removed for a long time (months).	10.0
	Poultry system	Manure is excreted on the floor with or without bedding.	1.5

Manure management system distribution (MS) (compare FOEN 2016 page 287)
In Switzerland, the fraction of animal manure handled using different manure management systems (MS) as well as the percentages of urine and dung deposited on pasture, range and paddock was separately assessed for each livestock category (Table 5-11). Since agricultural structures and practices are fundamentally the same, these values were also adopted for Liechtenstein. The fractions are determined by the livestock husbandry system (e.g. tie stall or loose housing system) as defined in Flisch et al. (2009). Estimation is conducted within the framework of the Swiss ammonium model AGRAMMON (Kupper et al. 2013). Values for 1990 and 1995 are based on expert judgement and values from the literature, while values for 2002, 2007 and 2010 are based on extensive farm surveys. The data clearly reproduces the shift towards an increased use of pasture, range and

paddocks and a decrease in solid storage. The changes of the manure management system distribution reflect the shift to a more animal-friendly livestock husbandry in the course of the agricultural policy reforms during the 1990s and the early 21st century (see Liechtenstein's strategy for agriculture/Landwirtschaftliches Leitbild, Government 2004, and OE 2013c).

Table 5-11 Manure management system distribution (MS) for Liechtenstein for selected years.

MS Distribution		1990				1995				2002			
		%				%				%			
		Liquid / Slurry	Solid storage	Pasture range and paddock	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid storage	Pasture range and paddock	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid storage	Pasture range and paddock	Other (Deep litter, Poultry manure)
Mature Dairy Cattle		64.0	27.7	8.3	0.0	65.9	24.5	9.5	0.0	65.7	16.4	18.0	0.0
Other Mature Cattle		41.5	32.2	26.3	0.0	39.5	34.2	26.2	0.0	40.1	20.8	39.1	0.0
Growing Cattle (weighted average)		49.7	32.5	16.3	1.5	50.2	32.1	15.7	2.0	45.6	26.5	26.3	1.6
	Fattening Calves	*14.6*	*0.0*	*0.0*	*85.4*	*15.3*	*0.0*	*0.0*	*84.7*	*22.0*	*0.0*	*0.3*	*77.7*
	Pre-Weaned Calves	*41.5*	*32.2*	*26.3*	*0.0*	*39.5*	*34.2*	*26.2*	*0.0*	*41.5*	*21.2*	*37.3*	*0.0*
	Breeding Cattle 1st Year	*37.3*	*48.6*	*14.1*	*0.0*	*38.3*	*47.5*	*14.2*	*0.0*	*34.0*	*38.9*	*27.0*	*0.0*
	Breeding Cattle 2nd Year	*45.6*	*29.0*	*25.4*	*0.0*	*47.5*	*26.8*	*25.6*	*0.0*	*38.1*	*23.5*	*38.4*	*0.0*
	Breeding Cattle 3rd Year	*50.8*	*29.2*	*20.0*	*0.0*	*51.7*	*28.0*	*20.3*	*0.0*	*42.5*	*22.6*	*34.8*	*0.0*
	Fattening Cattle	*70.4*	*24.2*	*0.0*	*5.5*	*66.6*	*27.7*	*0.0*	*5.6*	*67.7*	*26.9*	*2.2*	*3.2*
Sheep (weighted average)		0.0	0.0	30.7	69.3	0.0	0.0	30.7	69.3	0.0	0.0	33.5	66.5
Swine (weighted average)		100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	99.6	0.3	0.1	0.0
Goats		0.0	0.0	13.6	86.4	0.0	0.0	13.6	86.4	0.0	0.0	12.2	87.8
Horses (weighted average)		0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	78.9	21.1	0.0
Mules and Asses (weighted average)		0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	76.9	23.1	0.0
Poultry (weighted average)		0.0	0.0	0.0	100.0	0.0	0.0	0.6	99.4	0.0	0.0	5.0	95.0

MS Distribution		2007				2010			
		%				%			
		Liquid / Slurry	Solid storage	Pasture range and paddock	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid storage	Pasture range and paddock	Other (Deep litter, Poultry manure)
Mature Dairy Cattle		68.3	13.9	17.7	0.0	68.2	14.8	16.9	0.0
Other Mature Cattle		50.4	20.6	29.0	0.0	49.2	18.4	32.4	0.0
Growing Cattle (weighted average)		49.3	25.3	23.6	1.8	48.2	27.2	23.1	1.5
	Fattening Calves	*22.7*	*0.0*	*0.2*	*77.1*	*18.1*	*0.0*	*0.2*	*81.6*
	Pre-Weaned Calves	*50.9*	*19.0*	*30.1*	*0.0*	*45.9*	*33.3*	*20.9*	*0.0*
	Breeding Cattle 1st Year	*41.9*	*34.9*	*23.3*	*0.0*	*44.6*	*33.9*	*21.5*	*0.0*
	Breeding Cattle 2nd Year	*42.3*	*21.1*	*36.5*	*0.0*	*44.5*	*21.2*	*34.3*	*0.0*
	Breeding Cattle 3rd Year	*46.5*	*21.7*	*31.8*	*0.0*	*47.5*	*21.9*	*30.6*	*0.0*
	Fattening Cattle	*63.2*	*29.5*	*4.3*	*2.9*	*58.9*	*33.7*	*4.0*	*3.5*
Sheep (weighted average)		0.0	0.0	40.2	59.8	0.0	0.0	34.5	65.5
Swine (weighted average)		98.6	0.1	1.3	0.0	99.7	0.2	0.1	0.0
Goats		0.0	0.0	7.1	92.9	0.0	0.0	10.0	90.0
Horses (weighted average)		0.0	79.9	20.1	0.0	0.0	74.8	25.2	0.0
Mules and Asses (weighted average)		0.0	75.2	24.8	0.0	0.0	79.3	20.7	0.0
Poultry (weighted average)		0.0	0.0	7.0	93.0	0.0	0.0	5.9	94.1

5.3.2.3 Activity data CH_4

The activity data was obtained from Liechtenstein's Office for Food-control and Veterinary (Amt für Lebensmittelkontrolle und Veterinärwesen) in cooperation with the Division of Agriculture (OFIVA/OE 2015, for all years since 2002) and from the fomer Office of Agriculture (OA 2002, for the years before 2002). Data for the livestock categories mature dairy cattle, sheep, goats and swine are available annually for the whole time series. For all the other livestock categories data are available for the years 1990 and 2000 as well as for 2002 onward. Data in between was interpolated. Data is illustrated in Table 5-6 (see chapter 5.2.2.2).

Any deviation from FAO figures is due to the fact that **Liechtenstein is not a FAO member** and has no obligation to report livestock numbers to FAO. Consequently FAO makes its own estimates regarding Liechtenstein livestock numbers.

5.3.2.4 Emission factors N_2O

Estimation of direct N_2O emissions from Manure management relies basically on the same animal waste management systems as the estimation of CH_4 emissions (see above). All emission factors are based on default values given in table 10.21 of the 2006 IPCC Guidelines (Table 5-12). For liquid/slurry systems a weighted emission factor was calculated based on the share of systems with and without natural crust cover in Switzerland (Kupper et al. 2013, FOEN 2015). Formation of thick and permanent natural crusts on slurry tanks is not widespread in Liechtenstein or in Switzerland. According to the surveys conducted for the Swiss ammonia inventory AGRAMMON (Kupper et al. 2013) the share of systems with crust formation ranges from 0.0 to 7.1% and leads to a N_2O emission factor that ranges from 0.0000 to 0.0004, respectively.

The emission factor for indirect N_2O emissions after volatilisation of NH_3 and NO_x from manure management systems was reassessed during a literature review by Bühlmann et al. 2015 and Bühlmann 2014. Due to the fragmented land use in Switzerland and Liechtenstein, where agricultural land use alternates with natural and semi-natural ecosystems over short distances, the share of volatilised nitrogen that is re-deposited in (semi-)natural habitats is on average higher than 55%. Thus, the assumption made in the 2006 IPCC Guidelines that a substantial fraction of the indirect emissions will in fact originate from managed land cannot be applied here. Accordingly, the overall emission factor for indirect emissions was estimated by calculating an area-weighted mean of the indirect emission factor for managed land (i.e. 0.01 based on IPCC 2006) and the indirect emission factor for (semi-)natural land (as provided in Bühlmann 2014). Due to slightly changing land use over the inventory time period, the resulting emission factor shows some small temporal variation around a mean value of 2.54%. Note that the emission factor for indirect emissions in 2014 is equal to the former reporting year 2013.

Table 5-12 N_2O emission factor for manure management systems (MS) for Liechtenstein.

Animal waste management system	**Emission factor**
	kg N_2O-N / kg N
Liquid/Slurry: with natural crust cover	0.005
Liquid/Slurry: without natural crust cover	0.000
Solid storage	0.005
Cattle and swine deep bedding: no mixing	0.010
Poultry manure	0.001
Indirect emissions due to volatilisation	0.026

5.3.2.5 Activity data N_2O

Activity data for N_2O emissions from source category 3B Manure management was estimated according to equation 10.25 of the 2006 IPCC Guidelines:

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

$N_2O_{D(mm)}$ = direct N_2O emissions from manure management (kg N_2O/year)

$N_{(T)}$ = number of head of livestock species/category *T* (head)

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* (kg N/head/year)

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S*

$EF_{3(S)}$ = emission factor direct N_2O emissions from manure management system *S* (kg N_2O-N/kg N)

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

Livestock population

The activity data was obtained from Liechtenstein's Office for Food-control and Veterinary (Amt für Lebensmittelkontrolle und Veterinärwesen) in cooperation with the Division of Agriculture (OFIVA/OE 2015, for all years since 2002) and from the formerly Office of Agriculture (OA 2002, for the years before 2002). Data for the livestock categories mature dairy cattle, sheep, goats and swine are available annually for the whole time series. For all the other livestock categories data are available for the years 1990 and 2000 as well as for 2002 onward. Data in between was interpolated. Underlying data is given below.

Table 5-13 Liechtenstein's population sizes 1990-2014.

Population sizes Liechtenstein	**1990**	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Fattening Calves	50	81	112	83	63	106	80	104	81	82	82	79	79
Pre-Weaned Calves	15	35	11	266	283	339	341	294	281	329	395	341	330
Breeding Cattle 1st Year	1'136	1'057	649	601	717	688	724	723	814	821	792	789	877
Breeding Cattle 2nd Year	903	699	544	676	668	683	659	727	808	814	786	782	871
Breeding Cattle 3rd Year	631	575	343	348	398	315	372	372	459	462	446	444	494
Fattening Cattle	723	725	774	743	703	839	838	860	743	763	792	748	745
Growing Cattle	3'458	3'172	2'433	2'717	2'832	2'970	3'014	3'080	3'186	3'271	3'293	3'183	3'396
Mature Dairy Cattle	2'850	2'643	2'440	2'489	2'589	2'593	2'579	2'565	2'425	2'435	2'456	2'363	2'367
Other Mature Cattle	20	47	74	362	405	466	454	433	382	448	538	464	449
Total Cattle	**6'328**	**5'862**	**4'947**	**5'568**	**5'826**	**6'029**	**6'047**	**6'078**	**5'993**	**6'154**	**6'287**	**6'010**	**6'212**
Fattening Sheep	1'636	1'079	1'522	2'005	2'049	2'064	2'090	2'081	2'061	2'102	2'154	2'077	2'105
Milksheep	0	0	0	41	51	0	0	0	0	0	0	0	0
Total Sheep	**2'781**	**2'632**	**2'983**	**3'063**	**3'687**	**3'683**	**3'850**	**3'963**	**3'656**	**3'631**	**3'800**	**3'522**	**3'581**
Goat Places	111	100	96	171	198	179	251	266	253	255	217	187	169
Total Goats	**171**	**145**	**164**	**324**	**362**	**319**	**425**	**452**	**434**	**462**	**388**	**269**	**283**
Horses <3 years Agr.	33	27	20	28	32	28	24	30	31	31	46	29	27
Horses >3 years Agr.	133	135	136	237	253	249	277	282	304	301	283	271	282
Total Horses Agr.	**166**	**162**	**156**	**265**	**285**	**277**	**301**	**312**	**335**	**332**	**329**	**300**	**309**
Total Mules and Asses Agr.	**73**	**133**	**223**	**144**	**141**	**164**	**193**	**189**	**154**	**191**	**177**	**166**	**178**
Piglets	506	452	398	222	267	192	218	147	301	143	234	242	114
Fattening Pig over 25 kg	1'006	1'091	1'229	1'162	1'019	1'125	1'098	1'179	1'058	1'152	1'053	1'112	1'180
Dry Sows	207	191	91	96	76	78	79	98	101	89	76	94	72
Nursing Sows	66	62	22	21	32	29	29	29	18	31	28	14	26
Boars	5	5	4	3	4	3	4	3	3	5	4	4	2
Total Swine	**3'251**	**2'429**	**1'992**	**1'703**	**1'723**	**1'735**	**1'758**	**1'811**	**1'690**	**1'789**	**1'739**	**1'655**	**1'712**
Growers	105	53	0	0	9	1	48	0	61	25	15	17	12
Layers	4'145	5'506	6'866	10'112	11'398	11'357	11'766	11'650	12'175	11'862	12'216	12'544	12'509
Broilers	0	500	1'000	250	300	702	350	350	390	362	112	250	5
Turkey	22	55	87	52	35	164	15	3	103	42	0	25	31
Other Poultry (Geese, Ducks, Ostriches, Quails)	163	134	106	39	127	166	229	165	191	203	182	189	123
Total Poultry	**4'435**	**6'248**	**8'059**	**10'453**	**11'869**	**12'390**	**12'408**	**12'168**	**12'920**	**12'494**	**12'525**	**13'025**	**12'680**

Nitrogen excretion (N_{ex}) (compare FOEN 2016 page 291)

Data on nitrogen excretion per animal category (kg N/head/year) is country-specific and is the same as in the Swiss inventory (Kupper et al. 2013) (Table 5-14). These values are based on the “Principles of Fertilisation in Arable and Forage Crop Production” (Flisch et al. 2009) and adjusted according to the livestock census data of the Swiss ammonia model AGRAMMON (Kupper et al. 2013). Unlike to the method in the IPCC Guidelines, the age structure of the animals and the different use of the animals (e.g. fattening and breeding) are considered. Standard nitrogen excretion rates are modified in order to account for changing agricultural structures and production techniques over the years (e.g. milk yield, use of feed concentrates, protein reduced animal feed etc.). This more disaggregated approach leads to considerable lower calculated nitrogen excretion rates compared to IPCC, mainly because lower N_{ex}-rates of young animals are considered explicitly.

The nitrogen excretion rates are given on an annual basis, considering replacement of animals (growing cattle, swine, poultry) and including excretions from corresponding offspring and other associated animals (sheep, goats, swine)(see ART/SHL 2012).

As an exception, nitrogen excretion of **mature dairy cattle** was not adopted from the AGRAMMON model. In order to simulate the effect of milk production and feed properties on nitrogen excretion, an approach based on the results from the Swiss feeding model was chosen (Agroscope 2014c, see also chapter 5.2.2.1). As no separate model runs were performed for Liechtenstein, the respective effects were reproduced by using linear regressions displays the increase in nitrogen excretion with increasing milk yield. Equations for milk yields <6’000 kg*year^{-1} and >6’000 kg*year^{-1} are:

- milk production per year < 6’000 kg: N_{exDC} = 0.00841*Milk + 61.57710
- milk production per year > 6’000 kg: N_{exDC} = 0.00297*Milk + 94.57777

  with
  N_{exDC} = annual average N excretion per mature dairy cattle (kg N/head/year)
  Milk = amount of milk produced (kg/head/year)

To achieve high milk yields cows have to be fed with an increasing share of feed concentrates. Due to the energy dense feed concentrates, the ratio between net energy content and protein content increases. For milk yields above 6’000 kg*year^{-1} the increase in nitrogen excretion rate is thus slower than for lower milk yields. Data on milk yield is contained in Table 5-4.

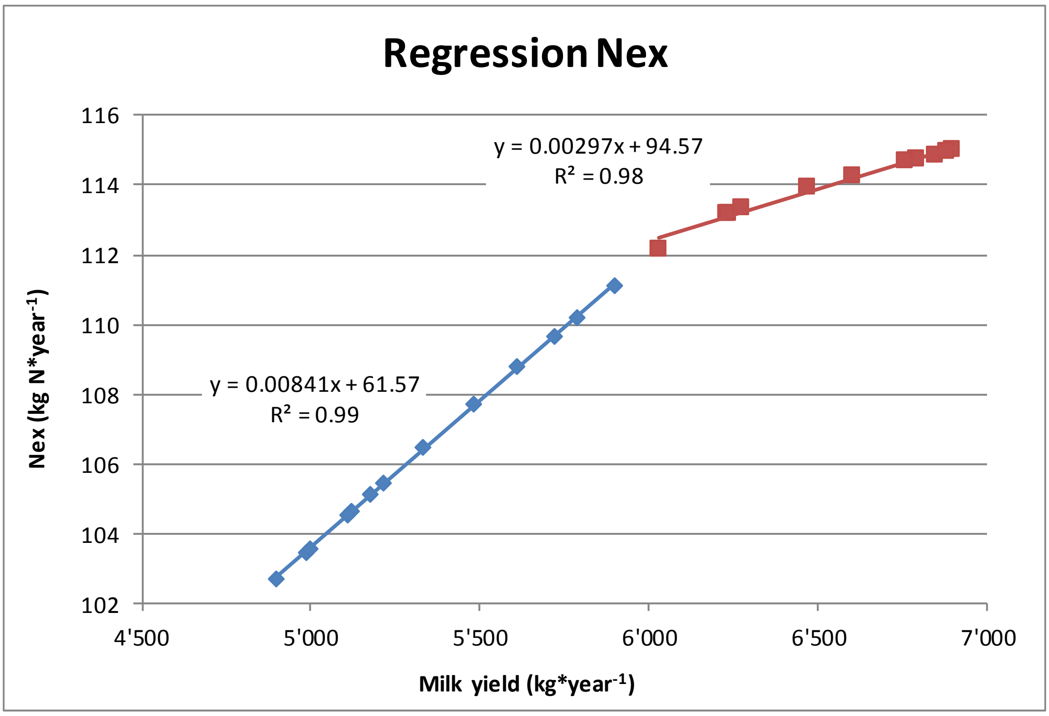

Figure 5-7 Linear regression relating nitrogen excretion (N_{exDC}) of mature dairy cattle's to milk yield (based on FOEN 2015).

Table 5-14 Nitrogen excretion rates of Liechtenstein's livestock, 1990-2014.

Nitrogen Excretion		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011
		kg N/head/year									
Mature Dairy Cattle		110.3	110.8	113.4	114.7	114.6	114.6	114.8	114.2	114.4	114.6
Other Mature Cattle		80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Growing Cattle (weighted average)		35.9	35.4	34.6	35.3	35.4	34.5	34.9	34.9	35.5	35.4
	Fattening Calves	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*
	Pre-Weaned Calves	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*
	Breeding Cattle 1st Year	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*
	Breeding Cattle 2nd Year	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
	Breeding Cattle 3rd Year	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*
	Fattening Cattle	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*
Sheep (weighted average)		8.8	6.1	7.7	10.1	8.6	8.4	8.1	7.9	8.5	8.7
Swine (weighted average)		8.5	11.5	11.0	10.6	9.6	9.8	9.6	9.9	10.0	10.5
Goats		10.4	11.0	9.4	8.4	8.8	9.0	9.4	9.4	9.3	8.8
Horses (weighted average)		43.6	43.7	43.7	43.8	43.8	43.8	43.8	43.8	43.8	43.8
Mules and Asses		15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7
Poultry (weighted average)		0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Nitrogen Excretion		2012	2013	2014
		kg N/head/year		
Mature Dairy Cattle		114.9	114.7	114.7
Other Mature Cattle		80.0	80.0	80.0
Growing Cattle (weighted average)		35.3	35.4	35.6
	Fattening Calves	*13.0*	*13.0*	*13.0*
	Pre-Weaned Calves	*34.0*	*34.0*	*34.0*
	Breeding Cattle 1st Year	*25.0*	*25.0*	*25.0*
	Breeding Cattle 2nd Year	*40.0*	*40.0*	*40.0*
	Breeding Cattle 3rd Year	*55.0*	*55.0*	*55.0*
	Fattening Cattle	*33.0*	*33.0*	*33.0*
Sheep (weighted average)		8.5	8.8	8.8
Swine (weighted average)		9.5	10.3	10.1
Goats		8.9	11.1	9.6
Horses (weighted average)		43.7	43.8	43.8
Mules and Asses		15.7	15.7	15.7
Poultry (weighted average)		0.8	0.8	0.8

Manure management system distribution (MS) (compare FOEN 2016 page 287)

The split of nitrogen flows into the different animal waste management systems and its temporal dynamics are based on the respective analysis of the Swiss AGRAMMON model (Kupper et al. 2013). The distribution is consistent with the allocation of volatile solids used for the calculation of CH_4 emissions from Manure management (see chapter 5.3.2.2).

Volatilisation of NH_3 and NO_x from manure management systems (compare FOEN 2016 page 294)

N_2O emissions from the deposition of volatilised nitrogen from manure management are based on NH_3 and NO_x emissions.

Losses of ammonia from stables and manure storage systems to the atmosphere are calculated according to the Swiss ammonium emission model AGRAMMON (Kupper et al. 2013). It is assumed that the same underlying assumptions on agricultural structures and practices in Switzerland are also valid for Liechtenstein. Specific loss-rates for all major livestock categories are estimated based on agricultural structures and techniques (e.g. stable type, manure management system, measures to reduce NH_3 emissions). Accordingly, the overall fraction of nitrogen volatilised underlies certain temporal dynamics that can be explained by changes in agricultural management practices (e.g. the transition to more animal friendly housing systems). It ranges from 14 to 20%.

For the volatilisation of NO_x default values from the EMEP/EEA air pollutant emission inventory guidebook 2013 (EMEP/EEA 2013) were used, assuming that 50% and 25% of the nitrogen is present in the form of TAN (total ammonia nitrogen) in liquid/slurry and solid storage systems respectively. Accordingly, it is estimated that 0.005% and 0.25% of the total nitrogen in liquid/slurry and solid storage systems are lost to the atmosphere. In this context the management systems “deep litter” and “poultry manure” are treated as solid storage system.

5.3.3 Uncertainties and time-series consistency

Uncertainties of emission factors and activity data are taken from the Swiss greenhouse gas inventory because the same model was applied for Liechtenstein’s GHG inventory. Input data from ART (2008) was used and was updated with current activity and emission data of the Swiss inventory as well as with new default uncertainties from the 2006 IPCC Guidelines (IPCC 2006). The arithmetic mean of the lower and upper bound was used for activity data and for emission factors in the Approach 1 analysis (Table 5-15).

Table 5-15 Uncertainties for source category 3B Manure management 2014. AD: Activity data; EF: Emission factor; CO: Combined

Uncertainty 3B		**Approach 1**		
		AD	**EF**	**CO**
		%		
CH_4		6.4	54.0	54.4
N_2O direct	Liquid/slurry	32.0	75.0	81.5
N_2O direct	Solid storage / Deep bedding / Poultry manure	32.0	75.0	81.5
N_2O indirect	Indirect emissions	46.5	240.0	244.5
N_2O aggregate		34.9	175.4	178.9

For the current submission no Approach 2 analysis was carried out. Approach 2 will again be performed in later submissions as it has already been the case in the previous submission. Then, asymmetric probability distributions as well as possible correlations of input data will have to be considered. For further uncertainty-results also consult chp. 1.6.

The time series 1990–2013 are consistent, although the following issues should be considered:

- For time series consistency of livestock population data and gross energy intake see chapter 5.2.3.
- The MCF for liquid/slurry systems varies according to the development of the grazing management over the years as described under 5.3.2.2
- Input data from the AGRAMMON-model is available for the years 1990 and 1995 (expert judgement and literature) as well as for 2002, 2007 and 2010 (extensive surveys on approximatively 3000 farms). Values in-between the assessment years were interpolated linearly, whereas values beyond 2010 were kept constant and will be updated as new survey results become available.
- Since Liechtenstein has only small animal populations the proportion of the sub-animal categories to each other are highly variable. For that reason the weighted N-excretions also fluctuate from year to year (e.g. swine and goat). The fluctuation can be fully explained with the underlying data structure in the model for Liechtenstein.
- The emission factor for indirect N_2O emissions after volatilisation of NH_3 and NO_x from manure management systems varies according to varying land use as described in Bühlmann (2014).

5.3.4 Category-specific QA/QC and verification

The category-specific QA/QC activities were carried out as mentioned in section 1.2.3.1 including triple checks of Liechtenstein's reporting tables (CRF tables). The triple check includes a detailed comparison of current and previous submission data for the base year 1990 and the year 2013 as well as an analysis of the increase or decrease of emissions between 2013 and 2014 in the current submission.

In addition to the overall triple check a separate internal technical documentation of Liechtenstein's model is available (Bretscher 2015, in German only). The manual also ensures transparency and retraceability of the calculation methods and data sources. Supplementary, a quality control was done by Acontec and INFRAS by a countercheck of the calculation sheets.

Further QA/QC activities are also documented in the Swiss NIR (see FOEN 2016). The respective conclusions are equally valid for Liechtenstein since the methods used are an adaptation of the Swiss model version. Bottom up inventory estimates in Switzerland agree well with several atmospherically CH_4 measurements, thus verifying the respective methodological approach applied in the inventory.

The SE, the NIC and the NIR author report their QC activities in a checklist (see Annex 8).

5.3.5 Category-specific recalculations

No category-specific recalculations were carried out.

5.3.6 Category-specific planned improvements

It is planned that Liechtenstein's agriculture model will be updated every 5 years with latest Swiss values and data. The effort updating the model annually is not feasible for a small country such as Liechtenstein. The final model update will be in the last submission year of the commitment period.

5.4 Source category 3C – Rice cultivation

Rice cultivation does not occur in Liechtenstein.

5.5 Source category 3D – Agricultural soils

5.5.1 Source category description: Agricultural soils (3D)

Key source
Direct (3D1) and indirect (3D2) N_2O emissions from agricultural soils are key sources by level and trend.

The source category 3D includes direct and indirect N_2O emissions from managed soils with a subdivision given in Table 5-16.

The most significant N_2O emission sources in 2013 were animal manure applied to soils (22.6%), nitrogen input from atmospheric deposition (19.3%), nitrogen in crop residues returned to soils (13.5), Urine and dung deposition by grazing animals and inorganic nitrogen fertilizers (13.1%).

Furthermore, NO_x emissions from managed soils as well as NMVOC emissions are estimated.

Table 5-16 Specification of source category 3D Agricultural soils. AD: Activity data; EF: Emission factors.

3D	Source	Specification
3Da	Direct N_2O emissions from managed soils	1. Inorganic N fertilisers 2. Organic N fertilisers (animal manure applied to soils, sewage sludge applied to soils, other organic fertilisers applied to soils) 3. Urine and dung deposited by grazing animals 4. Crop residues (inc. residues from meadows and pasture) 5. Mineralisation/immobilisation associated with loss/gain of soil organic matter 6. Cultivation of organic soils (i.e. histosols) 7. Other (Domestic synthetic fertiliser)
3Db	Indirect N_2O emissions from managed soils	1. Atmospheric deposition 2. Nitrogen leaching and run-off

Direct and indirect N_2O emissions have decreased by 7.4% and 19.6% compared to 1990 levels, respectively. The lowest N_2O emission level was 2000. Since then, total emissions are slightly increasing reflecting the new increase of cattle numbers (see Figure 5-6).

5.5.2 Methodological issues: Agricultural soils (3D)

5.5.2.1 Methodology

As done for previous submission, Liechtenstein adopted the methodology of Switzerland (for further information see chp. 5.1) in order to calculate emissions originating from source category 3D Agricultural soils. The calculation is based on methods described in the 2006 IPCC Guidelines.

For the calculation of N_2O emissions from source category 3D Agricultural soils a country-specific Tier 2 method was applied that is based on the IULIA model from Schmid et al. (2000). 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. IULIA is continuously updated. New values for nitrogen excretion rates, manure management system distribution and ammonium emission factors from the Swiss ammonium model AGRAMMON were adopted (Kupper et al. 2013). Furthermore, the updated version of the "Principles of Fertilisation in Arable and Forage Crop Production" (GruDAF; Flisch et al. 2009) was used instead of obsolete data from FAL/RAC 2001 and Walther et al. 1994. Most recently, new emission factors for indirect N_2O emissions from atmospheric deposition, new estimates for nitrogen leaching and run-off as well as new NO_x emission factors were introduced.

The modelling of the N_2O emissions from agricultural soils is consistent with source category 3B N_2O emissions from Manure management. The model structure is displayed in Figure 5-8 and the corresponding amounts of nitrogen are given in Table 5-17.

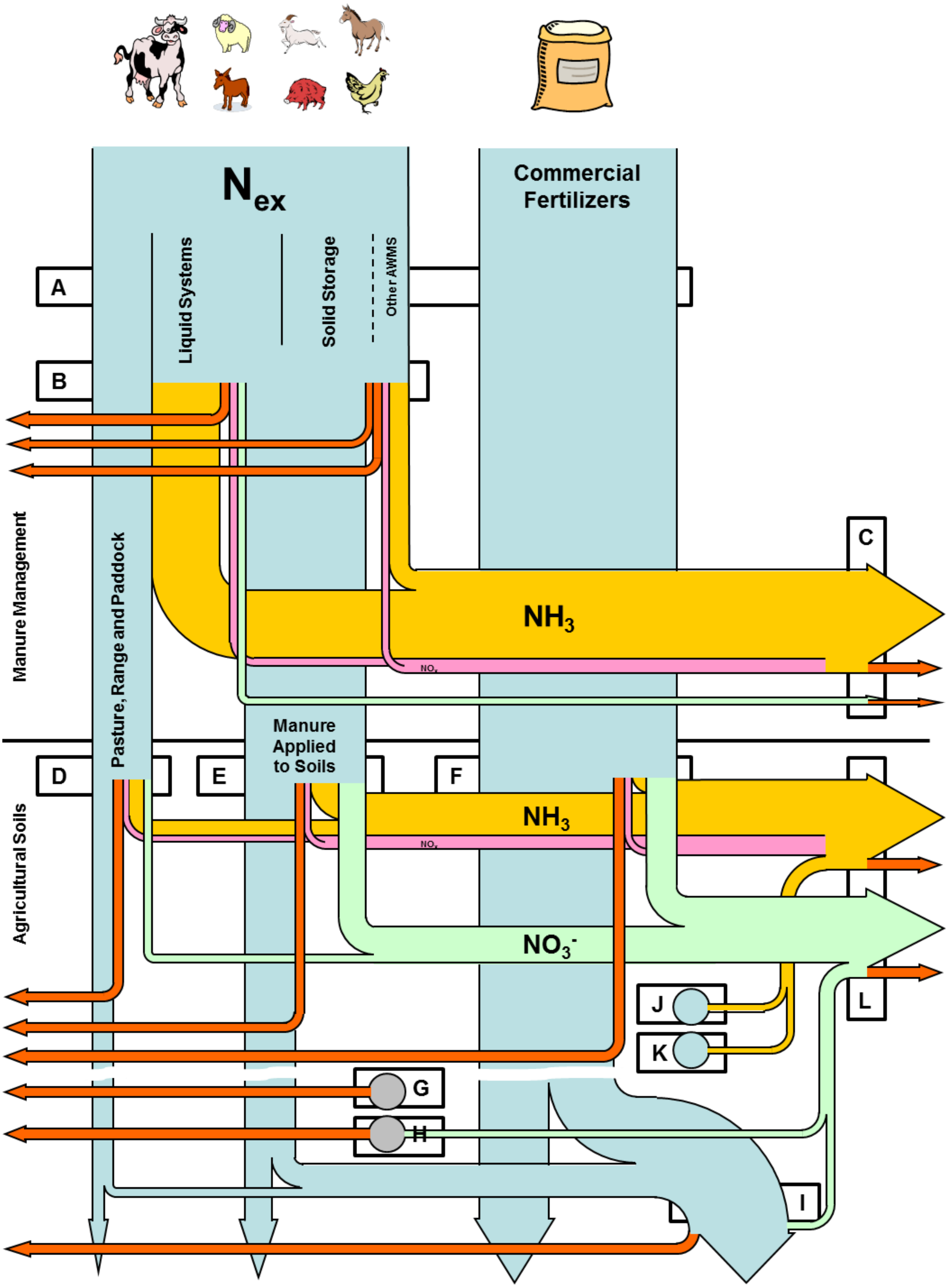

Figure 5-8 Diagram depicting the methodology of the approach to calculate the N_2O emissions in agriculture (red arrows). Black frames and the respective letters refer to the nitrogen flows in Table 5-16. Note that the figure shows explicitly the methodology of the approach and not necessarily the physical nitrogen flows.

Table 5-17 Nitrogen flows of the N-flow model for Liechtenstein's agriculture. Letters refer to the letters in Figure 5-8. Processes refer to the nitrogen flows in the black frames in Figure 5-8 from left to right or from top to bottom.

	Process	Amount of N			CRF table
		1990	2014		
		tN			
A	1 Pasture, range and paddock	54.97	101.70	= B	3.Da3
	2 Liquid/slurry systems	291.46	278.02		3.B(b)
	3 Solid storage	135.74	92.05		3.B(b)
	4 Other AWMS	23.51	34.32		3.B(b)
	5 Commercial fertiliser	277.36	176.07	= F	3.Da1,2,7
B	1 Pasture, range and paddock	54.97	101.70	= A1-A4	3.Da3
	2 NH_3 volatilisation housing	30.50	50.95		3.B(b)5
	3 N_2O emission liquid/slurry	0.00	0.08		3.B(b)
	4 NO_x volatilisation liquid/slurry and digester	0.01	0.01		3.B(b)5
	5 Leaching manure management	0.00	0.00		3.B(b)5
	6 Manure applied to soils	385.74	323.19		3.Da2
	7 N_2O emission solid storage	0.68	0.46		3.B(b)
	8 N_2O emission other AWMS	0.21	0.26		3.B(b)
	9 NO_x volatilisation solid storage and deep litter	0.40	0.32		3.B(b)5
	10 NH_3 volatilisation storage	33.17	29.12		3.B(b)5
C	1 NH_3 deposition manure management	63.67	80.07	= B2+B10	3.B(b)5
	2 NO_x deposition manure management	0.41	0.33	= B4+B9	
	3 Leaching manure management	0.00	0.00	= B5	
D	1 Available N PR&P	38.04	71.89	= B1	
	2 N_2O emission PR&P	1.02	1.88		3.Da3
	3 NO_x volatilisation PR&P	0.30	0.56		
	4 NH_3 volatilisation PR&P	2.73	5.21		
	5 Leaching and run-off PR&P	12.88	22.16		
E	1 Available N animal manure	183.18	169.59	= B6	
	2 N_2O emission application animal manure	3.86	3.23		3.Da2
	3 NO_x volatilisation application animal manure	2.12	1.78		
	4 NH_3 volatilisation application animal manure	106.22	78.18		
	5 Leaching and run-off application animal manure	90.36	70.41		
F	1 Available N com. fertiliser	192.25	128.03	= A5	
	2 N_2O emission application com. fertiliser	2.77	1.76		3.Da1,2,7
	3 NO_x volatilisation application com. fertiliser	1.53	0.97		
	4 NH_3 volatilisation application com. fertiliser	15.84	6.95		
	5 Leaching and run-off application com. fertiliser	64.97	38.36		
G	1 Cultivation of organic soils (ha)	*190.00*	*182.00*		3.Da6
H	1 Mineralisation/immobilisation soil organic matter	0.00	0.00		3.Da5
I	1 N in crop residues pasture, range and paddock	157.79	163.81		3.Da4
	2 N in crop residues arable crops	33.24	29.33		
J	1 NH_3 volatilisation agricultural area	10.56	10.95		
K	1 NH_3 volatilisation alpine area	0.00	0.00		
L	1 NH_3 deposition fertiliser appl. and PR&P	124.79	90.35	= D4+E4+F4	3.Db1
	2 NO_x deposition fertiliser appl. and PR&P	3.95	3.31	= D3+E3+F3	
	3 NH_3 deposition agricultural and alpine area	10.56	10.95	= J+K	
	4 Leaching and run-off fertiliser appl. and PR&P	168.21	130.93	= D5+E5+F5	3.Db2
	5 Leaching and run-off mineralisation SOM	0.00	0.00		
	6 Leaching and run-off crop residues	44.75	42.08		

5.5.2.2 Direct N_2O emissions from managed soils (3Da)

Calculation of Direct N_2O emissions from managed soils is based on IPCC 2006 equation 11.2 including six terms for activity data and three different emission factors:

$$N_2O_{Direct} - N = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \bullet EF_1 + F_{OS} \bullet EF_2 + F_{PRP} \bullet EF_3$$

N_2O_{Direct}-N = annual direct N_2O–N emissions produced from managed soils (kg N_2O–N/year)

F_{SN} = annual amount of synthetic fertiliser N applied to soils (kg N/year)

F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (kg N/year)

F_{CR} = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes of land use or management (kg N/year)

F_{OS} = annual area of managed/drained organic soils (ha)

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (kg N/year)

EF_1 = emission factor for N_2O emissions from N inputs (kg N_2O–N/kg N input)

EF_2 = emission factor for N_2O emissions from drained/managed organic soils (kg N_2O–N/ha/year)

EF_3 = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (kg N_2O–N/kg N input)

Emission factors for direct N_2O emissions

Emission factors for calculating direct N_2O emissions from managed soils are all based on default values as provided in the 2006 IPCC Guidelines (Table 5-18). Due to the lack of data, no fertiliser specific emission factors were applied for EF_1. The emission factor for urine and dung deposited by grazing animals was calculated as the weighted mean between the emission factor for cattle, poultry and pigs ($EF_{3PRP,CPP}$ = 0.02) and the emission factor for sheep and “other animals” ($EF_{3PRP,SO}$ = 0.01) according to the shares of nitrogen excreted on pasture, range and paddock by the respective animals.

Table 5-18 Emission factors for calculating direct N_2O emissions from managed soils (IPCC 2006). Blue: annually changing parameter, value for 2014.

Emission Source	Emission factor
EF_1 Inorganic N fertilisers (kg N_2O-N/kg)	0.0100
EF_1 Organic N fertilisers (kg N_2O-N/kg)	0.0100
EF_1 Crop residue (kg N_2O-N/kg)	0.0100
EF_1 Mineralisation/immobilisation soil organic matter (kg N_2O-N/kg)	0.0100
EF1 Other (domestic synthetic fertilisers) (kg N2O-N/kg)	0.0100
EF_2 Cultivation of organic soils (kg N_2O-N/ha)	8.0000
EF_3 Urine and dung deposited by grazing animals (kg N_2O-N/kg)	0.0185

Activity data for direct N_2O emissions (compare FOEN 2016 page 304)

Activity data for calculation of direct soil emissions includes 1. Inorganic N fertilisers, 2. Organic N fertilisers, 3. Urine and dung deposited by grazing animals, 4. Crop residues, 6. Cultivation of organic soils (i.e. histosols) and 7. Other (i.e. domestic inorganic fertilisers). 5. Nitrogen from mineralisation/immobilisation associated with loss/gain of soil organic matter is not occurring in Liechtenstein.

Emissions from **inorganic nitrogen fertilisers** include urea and other mineral fertilizers (mainly ammonium-nitrate). Data on the application of synthetic fertilizers in Liechtenstein is not available. Consequently N input was estimated multiplying average inorganic N input per ha in Switzerland (FOEN 2015) with the area fertilized in Liechtenstein which is provided by the Division of Agriculture (OE 2015a). The split of mineral fertilizers in urea and other mineral fertilizer is based on the mean value of the respective time series 1990-2012 in the Swiss inventory (see internal technical documentation in Bretscher 2015). Accordingly, a share of 15% was allocated to urea and 85% to other synthetic fertilizers. It is estimated that 4% of the mineral fertilisers are used for non-agricultural purposes (Kupper et al. 2013). These fertilisers are used in public green areas, sports grounds and home gardens. In the CRF-tables they are reported under 3Da7 Other (Domestic synthetic fertilisers) while emission calculation is conducted together with 3Da1. In certain occasions, as for instance for the estimation of indirect N_2O emissions from managed soils, the sum of urea, other mineral fertilisers, sewage sludge (1990-2003 only), other organic fertilisers and domestic fertilisers is referred to as “commercial fertilisers” (see also Figure 5-8 and Table 5-17).

Organic nitrogen fertilisers include animal manure and other organic fertilisers. The amount of nitrogen in **animal manure applied to soils** is calculated according to the methods described in chapter 5.3.2.5. As suggested in chapter 10.5.4. and equation 10.34 of the 2006 IPCC Guidelines (IPCC 2006), all nitrogen excreted on pasture, range and paddock as well as all nitrogen volatilised prior to final application to managed soils is subtracted from the total excreted manure (for the estimation of N-volatilisation see chapter 5.3.2.5, compare also Figure 5-8 and Table 5-20). $Frac_{GASM}$ in reporting table 3.D represents the amount of nitrogen volatilised as NH_3, NO_x and N_2O from housing and manure storage divided by the manure excreted in the stable (liquid/slurry, solid storage, deep litter and poultry manure). The nitrogen input from manure applied to soils under 3Da2a in reporting table 3.D can thus be calculated with the numbers given in reporting table 3.B(b) and 3.D. Nitrogen from bedding material was not accounted for under animal manure applied to soils. The respective nitrogen is included in the nitrogen returned to soils as crop residues.

The amount of **sewage sludge** applied to agricultural soils is provided by the annual report “Rechenschaftsbericht” (CG 2015). Since 2003 the use of sewage sludge as fertiliser is prohibited in Liechtenstein. **Other organic fertilisers** contains compost. Compost data are provided by the Office of Environment (OE). It is assumed that 15% of the total amount of Liechtenstein’s compost is used as agricultural fertilizer.

Calculation of emissions from **urine and dung deposited by grazing animals** is based on equation 11.5 of the 2006 IPCC Guidelines (IPCC 2006). Estimation of total livestock nitrogen excretion was described under 5.3.2.5. The share of manure nitrogen excreted on pasture, range and paddock is the same as in the Swiss AGRAMMON-model (Kupper et al. 2013). For each livestock category the share of animals that have access to grazing, the number of days per year they are actually grazing as well as the number of hours per day grazing takes place was assessed. The estimates are based on values from the literature and expert judgement (1990, 1995) and on surveys on approximatively 3000 Swiss farms (2000, 2007, 2010).

N_2O emissions from **crop residues** are based on the amount of nitrogen in crop residues returned to soil. For **arable crops** data were calculated based on standard values for nitrogen in crop residues per hectare from GruDAF (Flisch et al. 2009) and the corresponding cropland of Liechtenstein (OE 2015a):

$$F_{CR,AC} = \sum_{T} (N_T \cdot A_T)$$

$F_{CR,AC}$ = amount of nitrogen in crop residues from arable crops returned to soils (t N)

N_T = standard nitrogen amount in crop residues per hectare for crop *T* (t N / ha)

A_T = cropland in hectare for crop *T* (ha)

For sugar beet and fodder beet it is assumed that 10% of the crop residues are removed from the fields for animal fodder. For silage corn it is assumed that 5% of the biomass harvested is left as crop residues.

Crop residues from **meadows and pastures** were also assessed. The main part of the agricultural land use consists of grassland which underscores the importance of this source for Liechtenstein:

$$F_{CR,MP} = \sum_{P} \left(A_P \bullet \frac{SY_{DM,P}}{10} \bullet N_{DM,P} \div 1000 \bullet R_P \right)$$

$F_{CR,MP}$ = amount of nitrogen in crop residues from meadows and pastures returned to soils (t N)

A_P = area of meadow and pasture of type P (ha)

$SY_{DM,P}$ = standard dry matter yield per area of meadow and pasture of type P (dt/ha)

$N_{DM,P}$ = dry matter nitrogen content of meadow and pasture of type P (kg/t)

R_P = ratio of residues to harvested yield for meadows and pasture of type P (kg/kg)

Input data on the managed area of meadows and pastures are taken from the Office of the Environment, Division of Agriculture (OE 2015a). Standard dry matter yields per area, nitrogen content of dry matter as well as % yield losses were based on the IULIA model (Schmid et al. 2000).

N_2O emissions from **N-mineralization** are zero (not occurring – NO) in Liechtenstein since net carbon stock changes for mineral soils under cropland remaining cropland are zero (NO) (compare chapter 6.5.2).

Estimates of N_2O emissions from **cultivated organic soils** are based on the area of cultivated organic soils and the IPCC default emission factor for N_2O emissions from cultivated organic soils (IPCC 2006). The area of cultivated organic soils corresponds to the total area of organic soils under cropland and grassland as reported in the reporting tables 4.B and 4.C (see also chapter 6).

Table 5-19 Activity data for calculating direct N_2O emissions from managed soils (1990-2014).

Activity Data		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		t N/yr									
1. Inorganic N fertilisers	Urea	37	35	35	35	33	31	32	31	27	27
	Other mineral fertilisers	200	190	191	192	179	170	171	165	145	146
2. Organic N fertilisers	a. Animal manure	386	390	374	350	356	353	344	338	325	306
	b. Sewage sludge	30	44	37	41	38	31	21	24	21	16
	c. Other organic fertilisers	0	0	0	0	0	0	0	0	0	0
3. Urine and dung deposited by grazing animals		55	55	55	52	53	52	62	67	72	75
4. Crop residues	Arable crops	33	39	39	39	41	43	35	34	32	31
	Residues PR&P	158	159	160	161	161	162	163	163	164	164
5. Min./imm. associated with loss/gain of SOM		0	0	0	0	0	0	0	0	0	0
6. Cultivation of organic soils (ha)		190	190	189	189	188	188	187	187	186	186
7. Other (domestic inorganic fertilisers)		10	9	9	9	9	8	8	8	7	7

Activity Data		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		t N/yr									
1. Inorganic N fertilisers	Urea	29	28	31	30	29	29	29	28	30	28
	Other mineral fertilisers	155	154	166	162	156	158	155	153	161	154
2. Organic N fertilisers	a. Animal manure	294	300	302	303	301	311	324	329	332	331
	b. Sewage sludge	11	6	5	6	0	0	0	0	0	0
	c. Other organic fertilisers	0	0	0	0	0	1	0	0	1	0
3. Urine and dung deposited by grazing animals		73	87	92	93	97	100	104	104	104	102
4. Crop residues	Arable crops	30	30	30	30	30	28	28	28	28	28
	Residues PR&P	165	165	166	170	173	171	170	171	169	169
5. Min./imm. associated with loss/gain of SOM		0	0	0	0	0	0	0	0	0	0
6. Cultivation of organic soils (ha)		185	185	184	184	183	183	183	182	182	182
7. Other (domestic inorganic fertilisers)		8	8	8	8	8	8	8	8	8	8

Activity Data		2010	2011	2012	2013	2014
		t N/yr				
1. Inorganic N fertilisers	Urea	27	31	28	27	26
	Other mineral fertilisers	147	170	151	146	142
2. Organic N fertilisers	a. Animal manure	321	328	333	319	323
	b. Sewage sludge	0	0	0	0	0
	c. Other organic fertilisers	0	0	1	1	0
3. Urine and dung deposited by grazing animals		99	102	105	99	102
4. Crop residues	Arable crops	25	25	26	26	29
	Residues PR&P	165	181	165	164	164
5. Min./imm. associated with loss/gain of SOM		0	0	0	0	0
6. Cultivation of organic soils (ha)		182	182	182	182	182
7. Other (domestic inorganic fertilisers)		7	8	7	7	7

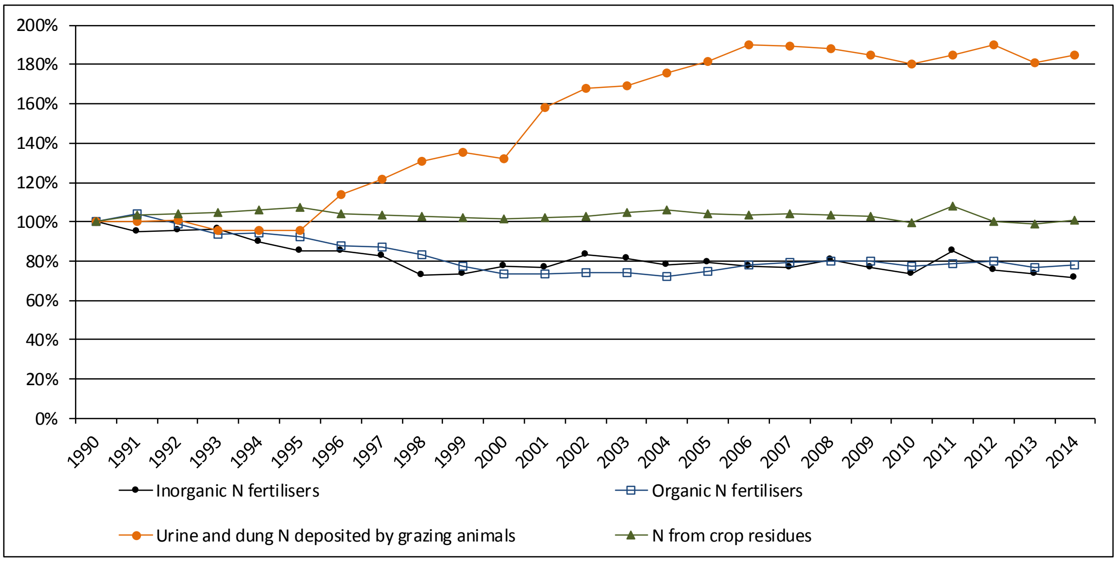

Figure 5-9 Relative development of the most important activity data for source category 3Da direct N_2O emissions from managed soils 1990-2014.

Figure 5-9 depicts the development of the most important activity data for direct N_2O emissions from managed soils. The use of inorganic N-fertiliser declined mainly during the 1990s due to structural changes: Between 1996 and 2011 the number of farms certified by the production labels “BIO” (organic production) and “IP” (integrated production) grew from 80 to 115 (OS 2014d). Simultaneously, nitrogen input from animal manure declined due to declining livestock populations (mainly cattle) and an increasing share of nitrogen deposited on pasture, range and paddock. Urine and dung deposited by grazing animals increased substantially due to the shift to more animal-friendly livestock husbandry in the course of the agricultural policy reforms during the 1990s and the early 20th century (see also chapter 5.3.2). N inputs from crop residues remained more or less constant during the inventory time period due to more or less stable crop production rates.

5.5.2.3 Indirect N_2O emissions from atmospheric deposition of N volatilised from managed soils (3Db1)

N_2O emissions from atmospheric deposition of N volatilised from managed soil were estimated based on equations 11.9 and 11.11 of the 2006 IPCC Guidelines (IPCC 2006). However, the method was adapted to the far more detailed approach of Switzerland and consequently of Liechtenstein:

$$N_2O_{(ATD)} - N = \begin{bmatrix} \sum_i \left(F_{CN_i} \bullet Frac_{GASF_i}\right) \\ + \sum_T \left(F_{AM_T} \bullet Frac_{GASM_T}\right) \\ + \sum_T \left(F_{PRP_T} \bullet Frac_{GASP_T}\right) \end{bmatrix} + \begin{bmatrix} \left(F_{CN} + F_{AM}\right) \bullet Frac_{NOXA} \\ + F_{PRP} \bullet Frac_{NOXP} \end{bmatrix} \bullet EF_4$$

$N_2O_{(ATD)}$-N = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils (kg N_2O–N/year)

F_{CNi} = annual amount of commercial fertiliser N of type *i* applied to soils (kg N/year)

$Frac_{GASFi}$ = fraction of commercial fertiliser N of type *i* that volatilises as NH_3 (kg N/kg N)

F_{AMT} = annual amount of managed animal manure N of livestock category *T* applied to soils (kg N/year)

$Frac_{GASMT}$ = fraction of applied animal manure N of livestock category *T* that volatilises as NH_3 (kg N/kg N)

F_{PRPT} = annual amount of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category *T* (kg N/year)

$Frac_{GASPT}$ = fraction of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category *T* that volatilises as NH_3 (kg N/kg N)

$NH3_{AS}$ = ammonia volatilised from the vegetation cover on agricultural soils (kg N/ha)

F_{CN} = total amount of commercial fertiliser N applied to soils (kg N/year)

F_{AM} = total amount of managed animal manure N applied to soils (kg N/year)

$Frac_{NOXA}$ = fraction of applied N (commercial fertilisers and animal manure) that volatilises as NO_x (kg N/kg N)

F_{PRP} = total amount of urine and dung N deposited on pasture, range and paddock by grazing animals (kg N/year)

$Frac_{NOXP}$ = fraction of urine and dung N deposited on pasture, range and paddock that volatilises as NO_x (kg N/kg N)

EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces (kg N_2O-N/kg N volatilised)

Emission factors for indirect N_2O emissions from atmospheric deposition

The emission factor for indirect N_2O emissions from atmospheric deposition of N volatilised from managed soils is the same as used for the assessment of indirect N_2O emissions after volatilisation of NH_3 and NO_x from manure management systems. The emission factor was reassessed by a literature review by Bühlmann et al. (2015) and Bühlmann (2014). Due to slightly changing land use, the resulting emission factor shows some small variations around a mean value of 2.54%. For further information see chapter 5.3.2.4. For $Frac_{NOXA}$ and $Frac_{NOXP}$, see Stehfest and Bouwman (2006)

Activity data for indirect N_2O emissions from atmospheric deposition (compare FOEN 2016 page 309)

The estimation of volatilisation of ammonia and NO_x was harmonized with the Swiss ammonia model AGRAMMON using the same emission factors and basic parameters (Table 5-20). Losses of commercial fertiliser nitrogen, animal manure N applied to soils, urine and dung N deposited on pasture, range and paddock by grazing animals as well as ammonia losses from agricultural soils due to processes in the vegetation cover, were considered. For the calculation of NH_3 emissions, changes of agricultural structures (e.g. changes to more animal friendly housing systems) and techniques (manure management, measures to reduce NH_3 emissions) are considered and explain temporal dynamics.

Ammonia volatilisation from **commercial fertiliser N** was estimated separately for urea and other synthetic fertilisers, sewage sludge (1990-2003), and other organic fertilisers (compost). Ammonia volatilisation of nitrogen in synthetic fertilisers is 15% for urea and 2% for other synthetic fertilisers. These estimates are based on a literature review by van der Weerden and Jarvis (1997) who examined ammonia emission factors for ammonium nitrate and urea for grassland and cropland soils. The emission factors for all other synthetic fertilisers (as straight and compound fertilisers) were assumed to be similar to that for ammonium nitrate. Ammonia emission factors for sewage sludge range from 20% to 26% depending on the composition of the sludge (Kupper et al. 2013). Other organic fertilisers include compost with an ammonia emission factor of 3.4%.

Total $Frac_{GASF}$ as reported in reporting table 3.D declined considerably from 6.3% in 1990 to 4.5% in 2014 due to a change in the shares of the different commercial fertilisers: the use of urea and sewage sludge (1990-2003), which both have high NH_3 emission factors, has declined since 1990.

Different ammonia loss factors were used for **animal manure N applied to soils** from different livestock categories according to the detailed approach of the AGRAMMON model (Kupper et al. 2013). Overall weighted $Frac_{GASMT}$ for animal manure applied to soils slightly decreased from 27.5% in the early 1990s to 24.2% in 2014.

Ammonia volatilisation from **urine and dung N deposited on pasture, range and paddock by grazing animals** was also assessed individually for each livestock category. Weighted mean loss rates ($Frac_{GASPT}$) range between 4.9% and 5.2%.

As an additional source, **volatilisation of ammonia from the vegetation cover** on agricultural soils was accounted for (Kupper et al. 2013), assuming that 2.0 kg NH_3 -N/ha are emitted from agricultural land (Schjoerring and Mattsson 2001).

Nitrogen pools and flows for calculating indirect N_2O emissions from managed soils are displayed in Table 5-21.

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Table 5-20 Overview of NH_3 an NO_x emission factors used for the assessment of emissions from source category 3Db1 Indirect N_2O emissions from atmospheric deposition (1990-2014).

Emission Factors Volatilisation	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011
	%									
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)	5.71	6.55	5.13	3.95	3.95	3.95	3.95	3.95	3.95	3.95
Urea	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Other Mineral Fertilisers	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Recycling Fertilisers (weighted average)	19.84	23.74	25.21	3.43	3.43	3.43	3.43	3.43	3.43	3.43
Sewage Sludge	20.00	23.94	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07
Compost	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
NH_3 from application of animal manure N ($Frac_{GASMT}$)	27.54	27.67	25.82	25.47	25.71	25.95	25.30	24.69	24.11	24.12
Mature Dairy Cattle	29.41	29.53	28.05	27.76	27.89	28.02	27.39	26.77	26.14	26.14
Other Mature Cattle	27.35	27.05	25.61	26.71	27.25	27.76	27.26	26.75	26.22	26.22
Growing Cattle (weighted average)	27.99	27.99	26.12	26.43	26.90	27.05	26.54	25.95	25.64	25.65
Sheep (weighted average)	8.79	9.35	9.42	10.53	10.94	11.44	11.28	11.13	10.98	10.98
Swine (weighted average)	22.85	22.43	20.58	20.72	20.99	21.35	20.67	20.04	19.36	19.40
Other Livestock (weighted average)	10.17	11.15	10.88	11.30	11.53	11.72	11.64	11.56	11.54	11.52
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)	4.97	4.97	5.03	5.11	5.14	5.15	5.14	5.12	5.12	5.11
Mature Dairy Cattle	4.95	4.93	4.87	4.82	4.81	4.80	4.80	4.80	4.80	4.80
Other Mature Cattle	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Growing Cattle (weighted average)	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98	4.98
Sheep (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Swine (weighted average)	NA	NA	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Other Livestock (weighted average)	5.00	6.03	8.39	10.16	10.82	11.34	10.36	9.63	9.25	9.07
NH_3 from Agricultural Soils (kg/ha/year)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NO_x from applied fertilisers ($Frac_{NOXA}$)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
NO_x from urine and dung N deposited on PR&P ($Frac_{NOXP}$)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Emission Factors Volatilisation	2012	2013	2014
	%		
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)	3.95	3.95	3.95
Urea	15.00	15.00	15.00
Other Mineral Fertilisers	2.00	2.00	2.00
Recycling Fertilisers (weighted average)	3.43	3.43	3.43
Sewage Sludge	26.07	26.07	26.07
Compost	3.43	3.43	3.43
NH_3 from application of animal manure N ($Frac_{GASMT}$)	24.18	24.17	24.19
Mature Dairy Cattle	26.14	26.14	26.14
Other Mature Cattle	26.22	26.22	26.22
Growing Cattle (weighted average)	25.62	25.64	25.71
Sheep (weighted average)	10.98	10.98	10.98
Swine (weighted average)	19.37	19.43	19.48
Other Livestock (weighted average)	11.59	11.76	11.74
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)	5.11	5.13	5.13
Mature Dairy Cattle	4.80	4.80	4.80
Other Mature Cattle	4.98	4.98	4.98
Growing Cattle (weighted average)	4.98	4.98	4.98
Sheep (weighted average)	5.00	5.00	5.00
Swine (weighted average)	14.00	14.00	14.00
Other Livestock (weighted average)	9.24	9.76	9.64
NH_3 from Agricultural Soils (kg/ha/year)	2.00	2.00	2.00
NO_x from applied fertilisers ($Frac_{NOXA}$)	0.55	0.55	0.55
NO_x from urine and dung N deposited on PR&P ($Frac_{NOXP}$)	0.55	0.55	0.55

Table 5-21 Overview of N pools and flows for calculating indirect N_2O emissions from managed soils (1990-2014).

Nitrogen Pools and Flows		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
		t N/yr												
	Animals manure N applied to soils	385.74	352.63	293.83	310.94	323.81	329.11	331.73	331.38	320.97	327.56	332.87	318.67	323.19
	Commercial fertiliser	277.36	241.18	202.49	195.83	192.01	189.20	199.60	190.17	181.59	210.47	187.11	181.23	176.07
	Area of agricultural soils (ha)	5'278.00	5'377.00	5'476.00	5'476.00	5'476.00	5'476.00	5'476.00	5'476.00	5'476.00	5'476.00	5'476.00	5'476.00	5'476.00
Deposition	Sum volatised N (NH_3 and NO_x)	139.29	130.29	104.01	106.33	110.57	112.61	111.58	108.93	103.88	106.99	107.59	103.52	104.60
	NH_3 emissions from commercial fertilisers	15.84	15.79	10.39	7.73	7.58	7.47	7.88	7.51	7.17	8.31	7.39	7.16	6.95
	NH_3 emissions from applied animal manure	106.22	97.59	75.88	79.21	83.26	85.39	83.93	81.83	77.38	79.00	80.48	77.02	78.18
	NH_3 emissions from pasture, range and paddock	2.73	2.61	3.65	5.10	5.36	5.37	5.32	5.21	5.07	5.20	5.34	5.10	5.21
	NH_3 emissions from agricultural soils	10.56	10.75	10.95	10.95	10.95	10.95	10.95	10.95	10.95	10.95	10.95	10.95	10.95
	NO_x emissions from commercial fertilisers	1.53	1.33	1.11	1.08	1.06	1.04	1.10	1.05	1.00	1.16	1.03	1.00	0.97
	NO_x emissions from applied animal manure	2.12	1.94	1.62	1.71	1.78	1.81	1.82	1.82	1.77	1.80	1.83	1.75	1.78
	NO_x emissions from PR&P	0.30	0.29	0.40	0.55	0.57	0.57	0.57	0.56	0.54	0.56	0.57	0.55	0.56
Leaching and run-off	Sum leaching and run-off	212.96	191.62	166.21	175.35	178.21	178.95	181.36	178.54	172.51	184.34	177.69	171.80	173.00
	Leaching and run-off from commercial fertilisers	64.97	54.30	44.12	42.66	41.83	41.22	43.48	41.43	39.56	45.85	40.76	39.48	38.36
	Leaching and run-off from applied animal manure	90.36	79.39	64.01	67.74	70.55	71.70	72.27	72.20	69.93	71.36	72.52	69.43	70.41
	Leaching and run-off from pasture, range and paddock	12.88	11.80	15.81	21.74	22.73	22.70	22.56	22.14	21.56	22.17	22.77	21.64	22.16
	Leaching and run-off from crop residues	44.75	46.12	42.27	43.21	43.11	43.33	43.05	42.77	41.46	44.96	41.63	41.25	42.08
	Leaching and run-off from mineralisation of SOM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 5-10 depicts the development of the most important activity data for indirect N_2O emissions from managed soils. Ammonia emissions from application of commercial fertilisers declined mainly due to reduced fertiliser use and due to the decreasing share of fertilisers with high ammonia emission rates (i.e. urea and sewage sludge) (see chapter 5.5.2.2). Ammonia emissions from applied animal manure declined mainly due to declining livestock populations and hence due to the reductions of available manure N. The fraction of applied animal manure N that volatilises as NH_3 ($Frac_{GASMT}$) declined slightly and also contributed to the decreasing trend.

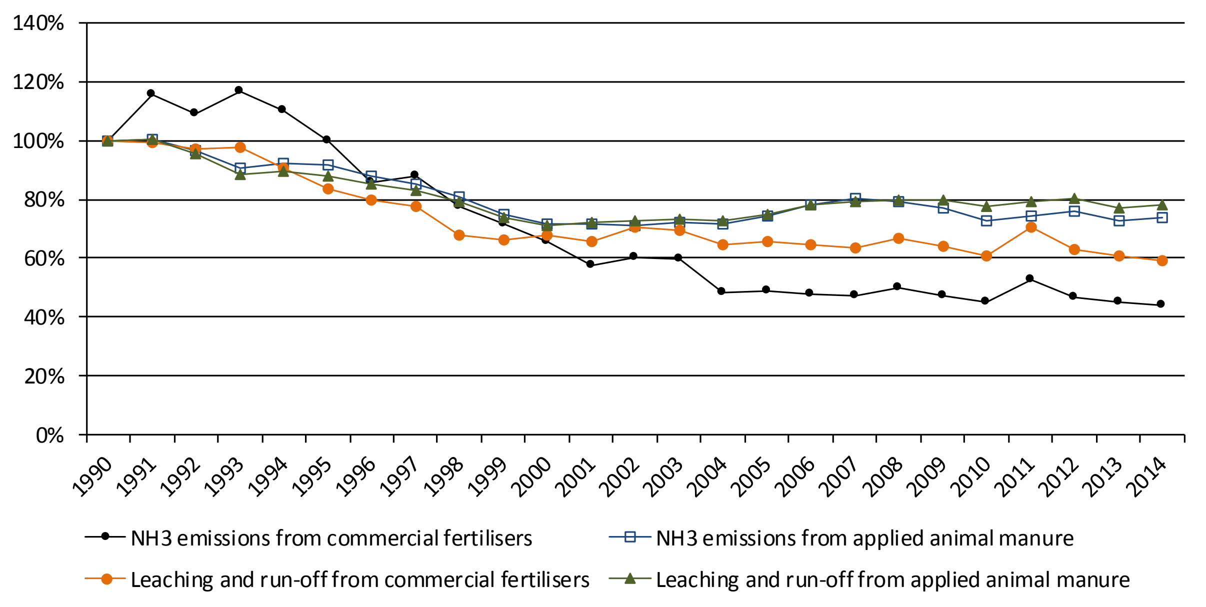

Figure 5-10 Relative development of the most important activity data for source category 3Db indirect N_2O emissions from managed soils 1990-2014.

5.5.2.4 Indirect N_2O emissions from leaching and run-off from managed soils (3Db2)

N_2O emissions from leaching and run-off from managed soils were estimated based on equation 11.10 of the 2006 IPCC Guidelines (IPCC 2006):

$$N_2O_{(L)} - N = (F_{CN} + F_{AM} + F_{PRP} + F_{CR} + F_{SOM}) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

$N_2O_{(L)}$–N = annual amount of N_2O–N produced from leaching and run-off of N additions to managed soils (kg N_2O–N/year)

F_{CN} = annual amount of commercial fertiliser N applied to soils (kg N/year)

F_{AM} = annual amount of managed animal manure N applied to soils (kg N/year)

F_{PRP} = annual amount of urine and dung N deposited by grazing animals (kg N/year)

F_{CR} = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes of land use or management (kg N/year)

$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralised in managed soils that is lost through leaching and runoff (kg N/kg of N additions)

EF_5 = emission factor for N_2O emissions from N leaching and run-off (kg N_2O–N/kg N leached and run-off)

Emission factor for indirect N_2O emissions from nitrogen leaching and run-off

The emission factor for indirect N_2O emissions from leaching and run-off from managed soils is 0.0075 kg N_2O–N/kg N according to the 2006 IPCC guidelines (IPCC 2006).

Activity data for indirect N_2O emissions from nitrogen leaching and run-off (compare FOEN 2016 page 314)

For the calculation of N_2O emissions from leaching and run-off from managed soils, N-leaching from commercial fertilisers (including synthetic fertilisers, sewage sludge and compost), managed animal manure N applied to soils (F_{AM}), urine and dung N deposited by grazing animals (F_{PRP}) and N in crop residues returned to soils (F_{CR}) were accounted for. It is assumed that no nitrogen is mineralised in agricultural soils of Liechtenstein. The method for the assessment of the respective amounts of nitrogen is described in chapter 5.5.2.2 and numbers are contained in Table 5-19.

$Frac_{LEACH}$ was taken from the Swiss GHG inventory. It was estimated for the year 2010 by dividing the available amount of nitrogen by the absolute amount of nitrogen that is lost due to leaching and run-off in Switzerland in the model estimates of Hürdler et al. 2015. The respective loss rate is 21.8% for 2010. According to Spiess and Prasuhn (2006), it can be assumed that loss rates were somewhat higher in the early 1990s. Accordingly, a reduction in the nitrate loss rate of 7% was implemented between 1990 and 1999 leading to a $Frac_{LEACH}$ of 23.4% for 1990. The same loss rates have been applied to all nitrogen pools independent of their origin and composition. The resulting amount of nitrogen that is lost through leaching and run-off is given in Table 5-21.

Figure 5-10 depicts the development of the most important activity data for indirect N_2O emissions from managed soils. Both leaching and run-off from commercial fertiliser and animal manure N declined during the inventory time period due to the reduced nitrogen inputs and the decreasing nitrate loss rates ($Frac_{LEACH}$).

5.5.3 Uncertainties and time-series consistency

The uncertainty analysis is taken from the Swiss greenhouse gas inventory because the same model was applied for Liechtenstein’s GHG inventory. Input data from ART (2008) was used and was updated with current activity and emission data of the Swiss inventory as well as with new default uncertainties of the 2006 IPCC Guidelines (IPCC 2006). The arithmetic mean of the lower and upper bound uncertainty was used for the uncertainty of activity data and emission factors, resulting in combined Approach 1 uncertainties as shown in Table 5-22. For 3Da (Direct N_2O emissions – Fertilisers) the sub-positions 3Da 1, 2, 4, and 7 were combined according to Approach 1 error propagation.

For the current submission no Approach 2 analysis was carried out. Approach 2 will again be performed in later submissions. Then, asymmetric probability distributions as well as possible correlations of input data will have to be considered.

Since there are two aggregate categories 3D direct/N_2O and 3D indirect/N_2O, the uncertainties of fertilisers, organic soils, urine and dung deposited on pasture range and paddock are aggregated (via error propagation) and similar for 3D indirect/N_2O atmospheric deposition and leaching /runoff. The results of the aggregations are given in Table 5-22 and are used in chp. 1.6.1.

Table 5-22 Approach 1 uncertainties for 3D Agricultural soils 2014. AD: Activity data; EF: Emission factor; CO: Combined.

Uncertainty 3D		**Approach 1**		
		AD	**EF**	**CO**
		%		
3D1 Direct soil emissions	Fertilisers	15.0	135.0	135.8
	Organic soils	29.4	137.5	140.6
	Urine and dung deposited on PR&P	68.3	132.5	149.1
	3D1 aggregate	16.8	96.3	97.7
3D2 Indirect soil emissions	Atmospheric deposition	39.6	240.0	243.2
	Leaching and run-off	22.4	163.3	164.9
	3D2 aggregate	27.9	172.2	174.4

For further uncertainty results also consult chp. 1.6.

The time series 1990–2014 are consistent, although the following issues should be considered:

- Input data from the AGRAMMON-model is available for the years 1990 and 1995 (expert judgement and literature) as well as for 2002, 2007 and 2010 (extensive surveys on approximatively 3000 farms). Values in-between the assessment years were interpolated linearly, whereas values beyond 2010 are kept constant and will be updated as new survey results become available.
- The emission factor for indirect N_2O emissions following volatilization of NH_3 and NO_x varies according to varying land use as described in chapter5.3.2.4.
- For more details on time-series consistency see chapter 5.2.3 and 5.3.3.

5.5.4 Category-specific QA/QC and verification

The category-specific QA/QC activities was carried out as mentioned in section 1.2.3.1 including triple checks of Liechtenstein's reporting tables (CRF tables). The triple check includes a detailed comparison of current and previous submission data for the base year 1990 and the year 2013 as well as an analysis of the increase or decrease of emissions between 2013 and 2014 in the current submission.

In addition to the overall triple check a separate internal technical documentation of Liechtenstein's model is available (Bretscher 2015, in German only). The manual also ensures transparency and retraceability of the calculation methods and data sources. Supplementary, a quality control was done by Acontec and INFRAS by a countercheck of the calculation sheets.

Further QA/QC activities are also documented in the Swiss NIR (see FOEN 2016). The respective conclusions are equally valid for Liechtenstein since the methods used are an adaptation of the Swiss model.

The SE, the NIC and the NIR author report their QC activities in a checklist (see Annex 8).

5.5.5 Category-specific recalculations

- The nitrogen-flows from commercial fertilisers were adapted according to the Swiss agriculture model (Swiss NIR 2015), leading to an increase in the years 1990-2013.
- A slight adaptation of the area of agricultural land in the Swiss agriculture model (Swiss NIR 2015) is adopted in Liechtenstein's NIR 2016.

5.5.6 Category-specific planned improvements

It is planned that Liechtenstein's agriculture model will be updated every 5 years with latest Swiss values and data. The effort updating the model annually is not feasible for a small country such as Liechtenstein. The final model update will be in the last submission year of the commitment period.

5.6 Source category 3E – Prescribed burning of savannas

Burning of savannas does not occur (NO) as this is not an agricultural practice in Liechtenstein.

5.7 Source category 3F – Field burning of agricultural residues

Field burning of agricultural residues is not occurring (NO) in Liechtenstein.

5.8 Source category 3G – Liming

Due to a research of the OE, liming is not occurring (NO) in Liechtenstein (OE 2015b).

5.9 Source category 3H – Urea application

5.9.1 Source category description: Urea application (3H)

Key source 3H
No key categories under source category 3H Urea application.

Adding urea to soils during fertilisation leads to a loss of CO_2 that was fixed during the industrial production process of the fertilizer. Emissions in Liechtenstein range from 0.04 to 0.06 kt CO_2 per year with a general decreasing trend from 1990 to 2014.

5.9.2 Methodological issues: Urea application (3H)

Methodology

A simple Tier 1 approach was adopted using estimated amounts of urea applied and IPCC default emission factors.

Emission factors

No country-specific emission factors are available. Consequently, the IPCC default emission factor of 0.20 t of C per t of urea was applied.

Activity data

The amount of urea application in Liechtenstein is not known. Based on the shares of urea and other mineral fertilizers in Switzerland a share of 15% urea of all synthetic fertilizers was assumed (see 5.2.2.2). Input of synthetic fertilizer was estimated according to the method described in chapter 5.2.2.2.

5.9.3 Uncertainties and time-series consistency

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. Since 3H is not a key category its uncertainties are accounted in the "rest" categories with mean uncertainty.

Consistency: Time series for source category 3H Urea application are all considered consistent.

5.9.4 Category-specific QA/QC and verification

General QA/QC measures are described in NIR chapter 1.2.3.

No further category-specific quality assurance activities were conducted.

5.9.5 Category-specific recalculations

- The nitrogen-flows from commercial fertilisers were adapted according to the Swiss agriculture model (Swiss NIR 2015), leading to an increase in the years 1990-2013.
- A slight adaptation of the area of agricultural land in the Swiss agriculture model (Swiss NIR 2015) is adopted in Liechtenstein's NIR 2016.

5.9.6 Category-specific planned improvements

There are no further planned improvements in this area.

5.10 Source category 3I – Other carbon-containing fertilizers

Other carbon-containing fertilizers are not in use (NO) in Liechtenstein.

6 Land Use, Land-Use Change and Forestry (LULUCF)

6.1 Overview of LULUCF

6.1.1 Methodology

Chapter 6 presents estimates of greenhouse gas emissions by sources and removals by sinks from land use, land-use change and forestry (LULUCF). The sector LULUCF also includes emissions and removals from the carbon pool in harvested wood products (HWP). Data acquisition and calculations are based on the Guidelines for National Greenhouse Gas Inventories (IPCC 2006), Volume 4 "Agriculture, Forestry and Other Land Use" (AFOLU). In several sub-categories country-specific emission factors are used. Many of the country-specific methods were adopted from Switzerland.

The land areas in the period 1990-2014 are represented by geographically explicit land-use data with a resolution of one hectare (following approach 3 for representing land areas; IPCC 2006). 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, 2002 and 2008. They are based on the same methodology as the Swiss land-use statistics (SFSO 2006a). Since the submission of 2011 the new 2009 dataset, based on the 2008 Land-use statistics is used.

The six main land-use categories required by IPCC (2006) are: A. Forest Land, B. Cropland, C. Grassland, D. Wetlands, E. Settlements and F. Other Land. These categories were divided in 18 sub-divisions of land use. A further spatial stratification reflects the criteria “altitude” (3 zones) and ”soil type” (mineral, organic).

Country-specific emission factors and carbon stocks for Forest Land were derived from Liechtenstein's National Forest Inventory (LWI 2012), which had been recorded in 2010. The inventory comprehended ca. 400 terrestrial sampling plots, where biomass stock, growth, harvesting and mortality had been measured.

For cropland and grassland, partially country-specific emission factors and carbon stock values were applied. For other land use categories, IPCC default values or expert estimates from Switzerland are used.

6.1.2 Emissions and removals

Table 6-1 and Figure 6-1 summarize the CO_2 equivalent emissions and removals in consequence of carbon losses and gains for the years 1990-2014. The total net emissions of CO_2 equivalent vary between 4.58 kt (1990) and 14.80 kt (2010. Three components of the CO_2 balance are shown separately:

- Gain 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.
- Loss 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, soil and HWP: this is all the rest including carbon removals/emissions due to land-use changes and use of soils, especially of organic soils, as well as the carbon stock changes in harvested wood products (HWP). It also includes the N_2O emissions due to N mineralization in soils (up to 0.46 CO_2 eq) associated with land-conversions (CRF-table 4(III)) and nitrogen leaching and run-off on non-agricultural soils (indirect N_2O emissions; CRF-table 4(IV)).

In all the years, loss of biomass exceeds the gains. Compared to these biomass changes in forests, the net CO_2 equivalent emissions arising from land-use changes, from soils and HWP are relatively small (see Figure 6-1).

Table 6-1 Liechtenstein's CO_2 equivalent emissions/removals [Gg] of the source category 5 LULUCF 1990-2014. Positive values refer to emissions; negative values refer to removals from the atmosphere.

LULUCF	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt CO2 eq									
Gain of living biomass in forest	-51.16	-51.23	-51.30	-51.37	-51.44	-51.52	-51.59	-51.68	-51.77	-51.86
Loss of living biomass in forest	52.05	52.13	52.20	52.27	52.34	52.42	52.49	52.55	52.61	52.67
Land-use change, soil and HWP	3.69	6.55	6.50	6.97	7.34	6.62	7.20	7.92	7.74	7.78
Sector 4 LULUCF (total)	**4.58**	**7.45**	**7.39**	**7.87**	**8.24**	**7.52**	**8.10**	**8.79**	**8.59**	**8.60**

LULUCF	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt CO2 eq									
Gain of living biomass in forest	-51.95	-52.04	-52.13	-52.20	-52.28	-52.36	-52.43	-52.51	-52.59	-52.68
Loss of living biomass in forest	52.73	52.79	52.85	52.94	53.03	53.13	53.22	53.31	53.40	53.50
Land-use change, soil and HWP	7.60	9.02	9.31	9.84	9.30	9.11	8.07	8.31	8.54	13.87
Sector 4 LULUCF (total)	**8.39**	**9.78**	**10.03**	**10.58**	**10.06**	**9.88**	**8.86**	**9.10**	**9.35**	**14.69**

LULUCF	2010	2011	2012	2013	2014	Mean
		kt CO2 eq				
Gain of living biomass in forest	-52.78	-52.87	-52.97	-53.02	-53.05	-52.11
Loss of living biomass in forest	53.60	53.69	53.79	53.84	53.87	52.94
Land-use change, soil and HWP	13.98	10.73	10.93	10.90	10.73	8.74
Sector 4 LULUCF (total)	**14.80**	**11.55**	**11.75**	**11.72**	**11.56**	**9.57**

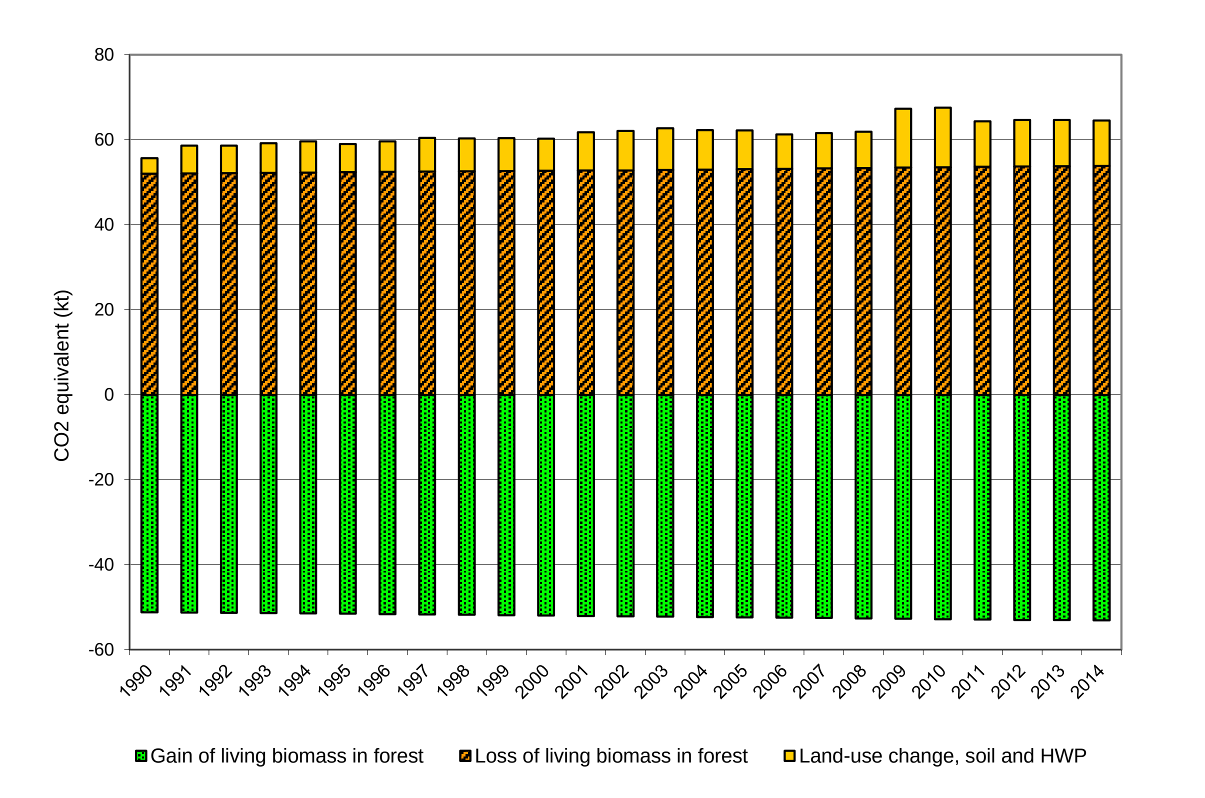

Figure 6-1 The CO_2 removals due to the increase (growth) of living biomass on forest land, the CO_2 emissions due to the decrease (harvest and mortality) of living biomass on forest land and the net CO_2 equivalent emissions due to land-use changes and from use of soils, 1990–2014.

Gain and loss of living biomass in forests are the dominant categories when looking at the CO_2 emissions and removals (refer to Table 6-1 and Figure 6-1). Emissions and removals from forest land are quite stable over time. The dominant category when looking at the changes in net CO_2 removals are grassland and HWP (refer toTable 6-2). It can be observed that land-use conversions to grassland differ significantly between the three time periods 1990 to 1996, 1997 to 2002 and 2003 to 2014. In the period 1997 to 2002 a significant higher conversion from forest land to grassland leads to increased CO_2 emissions. However, the application of a conversion period of 20 years smoothens and delays the effect in time. The net carbon stock change in the HWP pool varies from one year to the other mainly following the production rate of sawnwood.

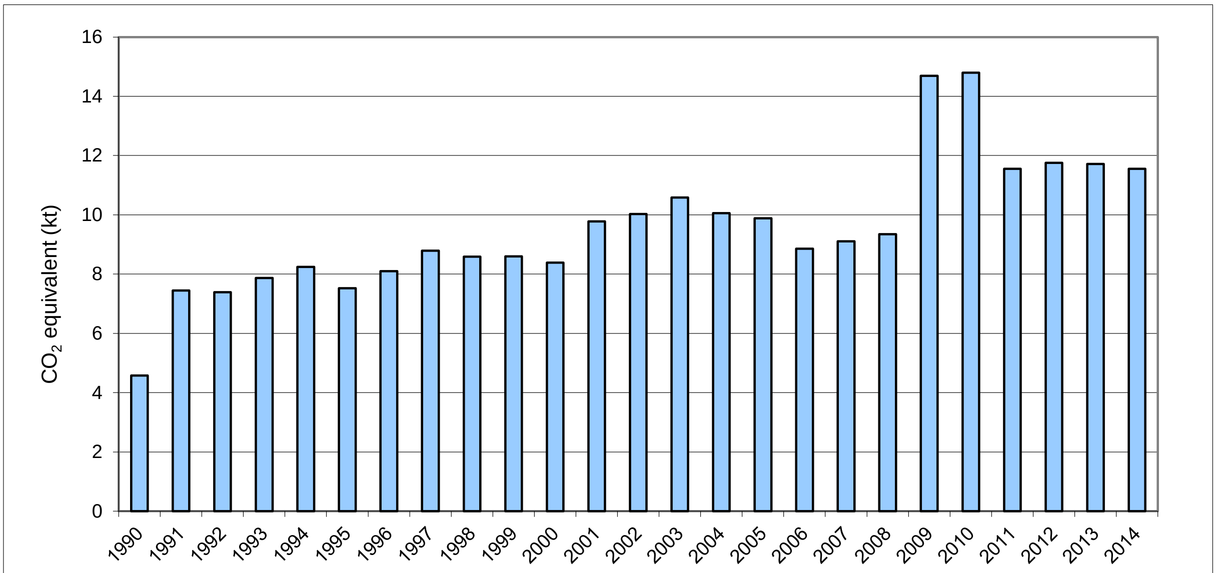

Figure 6-2 Liechtenstein's CO_2 emissions/removals of source category 4 LULUCF 1990–2014 in kt CO_2 equivalent.

Table 6-2 Net CO_2 removals and emissions per land-use category in kt CO_2 equivalent, 1990-2014.

Net CO_2 emissions/removals	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Land-Use Categories	**4.27**	**7.15**	**7.09**	**7.56**	**7.94**	**7.22**	**7.80**	**8.47**	**8.26**	**8.26**
A. Forest Land	**-1.07**	**-1.07**	**-1.07**	**-1.07**	**-1.07**	**-1.06**	**-1.06**	**-1.09**	**-1.12**	**-1.14**
1. Forest Land remaining Forest Land	0.57	0.57	0.57	0.58	0.58	0.58	0.58	0.54	0.50	0.46
2. Land converted to Forest Land	-1.64	-1.64	-1.64	-1.64	-1.64	-1.64	-1.64	-1.63	-1.62	-1.60
B. Cropland	**4.45**	**4.44**	**4.44**	**4.43**	**4.43**	**4.42**	**4.41**	**4.41**	**4.40**	**4.39**
1. Cropland remaining Cropland	4.10	4.09	4.08	4.08	4.07	4.07	4.06	4.06	4.05	4.04
2. Land converted to Cropland	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
C. Grassland	**1.80**	**1.79**	**1.78**	**1.77**	**1.76**	**1.75**	**1.73**	**1.94**	**2.15**	**2.35**
1. Grassland remaining Grassland	1.47	1.46	1.45	1.44	1.43	1.42	1.40	1.40	1.41	1.41
2. Land converted to Grassland	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.53	0.74	0.95
D. Wetlands	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**0.18**	**0.20**	**0.22**
1. Wetlands remaining Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Land converted to Wetlands	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.18	0.20	0.22
E. Settlements	**3.19**	**3.19**	**3.19**	**3.19**	**3.19**	**3.19**	**3.19**	**3.23**	**3.26**	**3.30**
1. Settlements remaining Settlements	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.27	0.28
2. Land converted to Settlements	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.97	3.00	3.02
F. Other Land remaining Other Land	**0.44**	**0.44**	**0.44**	**0.44**	**0.44**	**0.44**	**0.44**	**0.53**	**0.61**	**0.69**
G. Harvested wood products	**-4.70**	**-1.81**	**-1.85**	**-1.36**	**-0.97**	**-1.67**	**-1.08**	**-0.71**	**-1.24**	**-1.56**

Net CO_2- emissions/removals	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total Land-Use Categories	**8.04**	**9.41**	**9.66**	**10.20**	**9.67**	**9.49**	**8.46**	**8.70**	**8.94**	**14.27**
A. Forest Land	**-1.17**	**-1.20**	**-1.22**	**-1.17**	**-1.13**	**-1.08**	**-1.03**	**-0.98**	**-0.94**	**-0.90**
1. Forest Land remaining Forest Land	0.42	0.38	0.33	0.35	0.37	0.39	0.41	0.43	0.45	0.46
2. Land converted to Forest Land	-1.59	-1.57	-1.56	-1.53	-1.50	-1.47	-1.45	-1.42	-1.39	-1.36
B. Cropland	**4.39**	**4.38**	**4.37**	**4.35**	**4.33**	**4.31**	**4.29**	**4.27**	**4.25**	**4.23**
1. Cropland remaining Cropland	4.04	4.03	4.03	4.02	4.01	4.01	4.00	4.00	3.99	3.99
2. Land converted to Cropland	0.35	0.35	0.35	0.33	0.32	0.30	0.29	0.27	0.26	0.24
C. Grassland	**2.56**	**2.76**	**2.97**	**3.08**	**3.19**	**3.30**	**3.41**	**3.52**	**3.63**	**3.72**
1. Grassland remaining Grassland	1.41	1.41	1.41	1.42	1.43	1.43	1.44	1.45	1.46	1.46
2. Land converted to Grassland	1.15	1.36	1.56	1.66	1.76	1.86	1.96	2.06	2.17	2.26
D. Wetlands	**0.24**	**0.26**	**0.29**	**0.29**	**0.30**	**0.30**	**0.31**	**0.31**	**0.32**	**0.34**
1. Wetlands remaining Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Land converted to Wetlands	0.24	0.26	0.29	0.29	0.30	0.30	0.31	0.31	0.32	0.34
E. Settlements	**3.34**	**3.38**	**3.42**	**3.43**	**3.44**	**3.45**	**3.46**	**3.48**	**3.49**	**3.50**
1. Settlements remaining Settlements	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.35	0.36	0.37
2. Land converted to Settlements	3.05	3.08	3.11	3.11	3.12	3.12	3.12	3.12	3.12	3.14
F. Other Land remaining Other Land	**0.77**	**0.85**	**0.94**	**0.97**	**1.00**	**1.03**	**1.06**	**1.09**	**1.12**	**1.16**
G. Harvested wood products	**-2.10**	**-1.03**	**-1.11**	**-0.74**	**-1.45**	**-1.82**	**-3.03**	**-2.97**	**-2.91**	**2.23**

Net CO_2- emissions/removals	2010	2011	2012	2013	2014
Total Land-Use Categories	**14.37**	**11.11**	**11.30**	**11.26**	**11.11**
A. Forest Land	**-0.87**	**-0.84**	**-0.80**	**-0.78**	**-0.81**
1. Forest Land remaining Forest Land	0.46	0.47	0.47	0.47	0.47
2. Land converted to Forest Land	-1.33	-1.31	-1.28	-1.25	-1.28
B. Cropland	**4.22**	**4.21**	**4.19**	**4.18**	**4.17**
1. Cropland remaining Cropland	3.99	3.99	3.99	3.99	3.98
2. Land converted to Cropland	0.23	0.22	0.20	0.19	0.19
C. Grassland	**3.81**	**3.91**	**4.00**	**4.09**	**4.00**
1. Grassland remaining Grassland	1.46	1.45	1.45	1.45	1.45
2. Land converted to Grassland	2.36	2.45	2.55	2.65	2.55
D. Wetlands	**0.35**	**0.37**	**0.39**	**0.41**	**0.39**
1. Wetlands remaining Wetlands	NO	NO	NO	NO	NO
2. Land converted to Wetlands	0.35	0.37	0.39	0.41	0.39
E. Settlements	**3.47**	**3.47**	**3.46**	**3.45**	**3.46**
1. Settlements remaining Settlements	0.37	0.37	0.37	0.38	0.37
2. Land converted to Settlements	3.10	3.10	3.09	3.08	3.09
F. Other Land remaining Other Land	**1.20**	**1.24**	**1.29**	**1.33**	**1.29**
G. Harvested wood products	**2.18**	**-1.25**	**-1.22**	**-1.43**	**-1.40**

6.1.3 Approach for calculating carbon emissions and removals

6.1.3.1 Work steps

The selected procedure for calculating carbon emissions and removals in the LULUCF sector is similar to the approaches used in Switzerland (FOEN 2016). It corresponds to a Tier 2 approach as described in IPCC (2006; Volume 4, chp. 3) and can be summarised as follows:

- Land use categories and sub-divisions with respect to available land-use data (see Table 6-3) 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 Liechtenstein's land-use statistics, which uses the same nomenclature as the Swiss land-use statistics (SFSO 2006a).
- Criteria for the spatial stratification of the land-use categories (altitude and soil type) were taken from Switzerland. Based on these criteria data for the spatial stratification of the land-use categories were collected in Liechtenstein.
- Carbon stocks, gains and losses in living biomass of managed forests were derived from results of Liechtenstein's forest inventory (LWI 2012). For other categories, carbon stocks and carbon stock changes were taken from Swiss data based on measurements and estimations.
- 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 schematically in Figure 6-3.

The distinction between managed and unmanaged land (Table 6-3) is done as follows:

- Forest land is by definition managed land as all forests in Liechtenstein are subject to forest management.
- Land categories which can’t be cultivated, are classified as unmanaged. This holds for stony grassland, unproductive grassland, surface waters, unproductive wetland and other land (rocks, sand, glaciers).

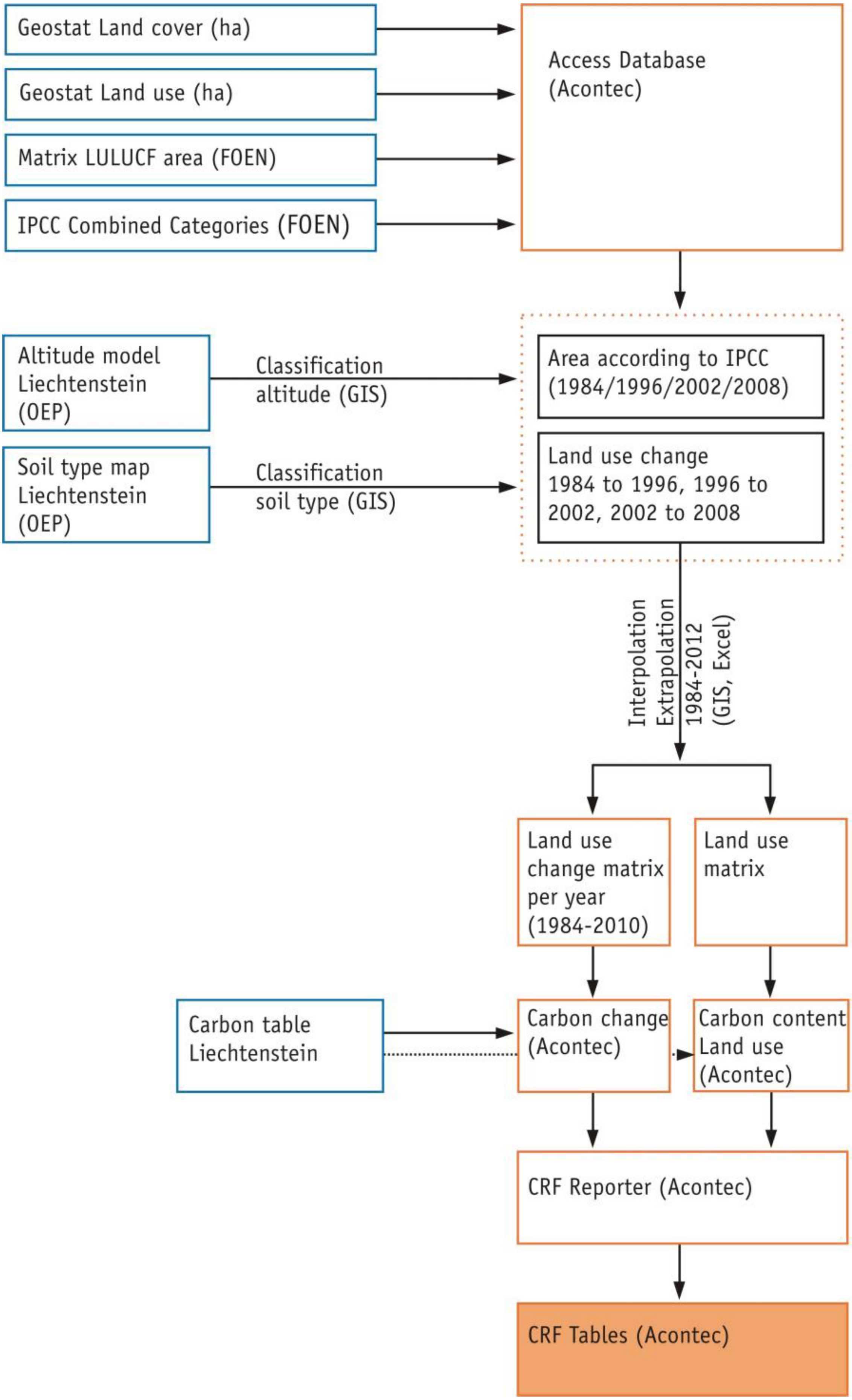

Figure 6-3 Procedure of calculating emissions and removals from LULUCF in Liechtenstein.

Table 6-3 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 seechp. 6.2.1.

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	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*

Note that 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 (Government 1991).

6.1.3.2 Calculating carbon stock changes

The method is based largely on the Swiss procedure according to FOEN (2016).

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 (dead wood and litter)
$stockC_{s,i,CC}$:	carbon stock in soil
$increaseC_{l,i,CC}$:	annual gain (growth) of carbon in living biomass
$decreaseC_{l,i,CC}$:	annual loss (cut & mortality) of carbon in living biomass
$changeC_{d,i,CC}$:	annual net carbon stock change in dead organic matter (dead wood and litter)
$changeC_{s,i,CC}$:	annual net carbon stock change in soil

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 6.1.-6.3 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):

$$deltaC_{l,i,ba} = [\ increaseC_{l,i,a} - decreaseC_{l,i,a} + W_l * (stockC_{l,i,a} - stockC_{l,i,b}) / CT\ ] * A_{i,ba} \quad (6.1)$$

$$deltaC_{d,i,ba} = [\ changeC_{d,i,a} + W_d * (stockC_{d,i,a} - stockC_{d,i,b}) / CT\ ] * A_{i,ba} \quad (6.2)$$

$$deltaC_{s,i,ba} = [\ changeC_{s,i,a} + W_s * (stockC_{s,i,a} - stockC_{s,i,b}) / CT\ ] * A_{i,ba} \quad (6.3)$$

where:

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

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}) or if a and b are unmanaged categories {36,37,41,42,61}; this corresponds to the gain-loss approach.
$W_s = 0.5$	if a or b is ‘Buildings and Constructions’ (a = 51 or b = 51)
$W_l = W_d = W_s = 1$	otherwise; this corresponds to the stock difference approach.

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(see Table 6-7). 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.

The weighting factors W were set to zero in case of changes between unmanaged categories in order to prevent reporting of emissions or sinks on unmanaged land.

For calculating annual carbon stock changes in soils due to land-use conversion, IPCC (2006) suggests a default delay time (CT) of 20 years. In Liechtenstein, a conversion time of 20 years has been applied to all carbon stock changes in soil and biomass. Accordingly, the CRF tables 4A2, 4B2 and 4C2, 4D2, 4E2 and 4F2 contain the cumulative area remaining in the respective category in the reporting year.

There is no consistent data on land-use changes before 1984, but it is known (Broggi 1987, ARE/SAEFL 2001 in Switzerland) that the main trends of the land-use dynamics (e.g. increase of settlements, decrease of cropland) did arise before 1970. Therefore, it was assumed that between 1971 and 1989 the annual rate of all land-use changes was the same as in 1990. Based on this assumption it has been possible to produce the land-use data required for the consideration of the conversion time in that period.

6.1.4 Carbon emission factors and stocks at a glance

Table 6-4 lists all values of carbon stocks, increases, decreases and net changes of carbon specified for land-use category (CC) and associated spatial strata. These values remain constant during the period 1990-2014 for reporting under the UNFCCC. For reporting under the Kyoto Protocol annual values of loss in living biomass of productive forest (CC12) are used (see Chp. 11).

Table 6-4 Carbon stocks and changes in biomass, dead organic matter and soils for the combination categories (CC), stratified for altitude and soil type. These values are valid for the whole period 1990-2014. Highlighted cells show values updated for the Submission 2015 (see main text).

land-use code CC	altitude zone z	carbon stock in living biomass (stockCl,i) 1990	carbon stock in dead wood (stockCd,i)	carbon stock in litter (stockCh,i)	carbon stock in mineral soil (stockCs,i)	carbon stock in organic soil (stockCs,i)	gain of living biomass (gainCl,i)	loss of living biomass (lossCl,i)	net change in dead wood (changeCd,i)	net change in litter (changeCh,i)	net change in mineral soil (changeCs,i)	net change in organic soil (changeCs,i)
	Strata	Stocks (t C ha-1)					Changes (t C ha-1 yr-1)					
11 Afforestations	1	7.84	0	0	66.10	NO	1.63	0	0	0	0	NO
	2	4.30	0	0	75.91	NO	1.09	0	0	0	0	NO
	3	1.61	0	0	95.78	NO	0.57	0	0	0	0	NO
12 Productive forest	1	128.57	8.25	7.51	66.10	NO	3.21	3.49	0	0	0	NO
	2	124.41	9.05	16.29	75.91	NO	2.83	2.96	0	0	0	NO
	3	125.62	11.15	26.21	95.78	NO	2.34	2.39	0	0	0	NO
13 Unproductive forest	1	20.45	0	7.51	66.10	NO	0	0	0	0	0	NO
	2	47.53	0	16.29	75.91	NO	0	0	0	0	0	NO
	3	42.36	0	26.21	95.78	NO	0	0	0	0	0	NO
21 Cropland	all	4.69	0	0	53.40	240.00	0	0	0	0	0	-9.52
31 Permanent Grassland	1	7.08	0	0	62.02	240.00	0	0	0	0	0	-9.52
	2	6.00	0	0	67.50	240.00	0	0	0	0	0	-9.52
	3	7.95	0	0	75.18	240.00	0	0	0	0	0	-9.52
32 Shrub Vegetation	1	20.45	0	0	62.02	NO	0	0	0	0	0	NO
	2	20.45	0	0	67.50	NO	0	0	0	0	0	NO
	3	20.45	0	0	75.18	NO	0	0	0	0	0	NO
33 Vineyards et al.	all	3.74	0	0	53.40	240.00	0	0	0	0	0	-9.52
34 Copse	1	20.45	0	0	62.02	NO	0	0	0	0	0	NO
	2	20.45	0	0	67.50	NO	0	0	0	0	0	NO
	3	20.45	0	0	75.18	NO	0	0	0	0	0	NO
35 Orchards	all	24.32	0	0	64.76	240.00	0	0	0	0	0	-9.52
36 Stony Grassland	all	7.16	0	0	26.31	NO	0	0	0	0	0	NO
37 Unproductive Grassland	all	7.01	0	0	68.23	NO	0	0	0	0	0	NO
41 Surface Waters	all	0	0	0	0	NO	0	0	0	0	0	NO
42 Unproductive Wetland	all	6.50	0	0	68.23	NO	0	0	0	0	0	NO
51 Buildings, Constructions	all	0	0	0	0	NO	0	0	0	0	0	NO
52 Herbaceous Biomass in S.	all	9.54	0	0	53.40	NO	0	0	0	0	0	NO
53 Shrubs in Settlements	all	15.43	0	0	53.40	NO	0	0	0	0	0	NO
54 Trees in Settlements	all	20.72	0	0	53.40	NO	0	0	0	0	0	NO
61 Other Land	all	0	0	0	0	NO	0	0	0	0	0	NO
Legend												
altitude zones:				NO: land-use type does not occur on organic soil								
1	< 600 m											
2	601 - 1200 m											
3	> 1200 m											

On organic soils, a value of 240 t C ha^{-1} for stock C_s was assumed for all land-use categories that occur on organic soils (FOEN 2015, based on Leifeld et al. (2003, 2005) . Thus, when calculating carbon changes in organic soils as a consequence of land-use changes, the difference of carbon stocks is always zero.

For productive forests (CC12), stocks, gains and losses are based on Liechtenstein's NFI (LWI 2012, cells highlighted in blue in Table 6-4). The data for afforestations, unproductive forests, 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. Cells highlighted in orange contain values that were updated according to recent studies in Switzerland (FOEN 2015). The deduction of the individual values is explained in the following chapters.

6.2 Land-use definitions and classification systems

6.2.1 Combination Categories (CC) as derived from land-use statistics

The nomenclature of the Swiss Land Use Statistics (AREA) evaluated by the Swiss Federal Statistical Office (SFSO 2006a) is the basis for the land-use categories and subcategories used for land area representation in Liechtenstein. In the course of the AREA surveys (see chp. 6.3.1) every hectare of Liechtenstein's territory was assigned to a land-use category (LU) and to a land-cover category (LC).

The 46 land-use categories and 27 land-cover categories of the land-use statistics were aggregated to 18 combination categories (CC) implementing the main categories proposed by IPCC as well as by country-specific sub-divisions (see Table 6-5). The first digit of the CC-code represents the main category, whereas the second digit stands for the respective sub-division.

The sub-divisions were defined with respect to possible differentiation of biomass densities, carbon turnover, and soil carbon contents. They were defined in 2006 in an evaluation process involving experts from the FOEN, the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Statistical Office and Agroscope as well as private consultants. The evaluation process resulted in the elaboration of Table 6-5. CC definition was strongly influenced by the land cover and land use (LC/LU) classification and nomenclature of AREA (SFSO 2006a). Most criteria and thresholds as defined therein were adopted.

For Forest Land, e.g., the criteria correspond to the NFI thresholds with respect to minimum area, width, crown cover, and tree height.

For LC 31 (land cover shrub), e.g., the criteria include: vegetation height <3 m, degree of coverage >80%, dominated by shrubs, dwarf-shrubs, and bushes.

For LC32 (land cover brush meadows), e.g., the criteria include vegetation height <3 m, degree of coverage 50-80%, dominated by shrubs, dwarf-shrubs, and bushes.

With regard to carbon content in biomass, there is a strong relation to the vegetation type (i.e. land cover in most cases). This is exemplarily reflected by the mainly horizontal arrangement of the individual CCs in Table 6-5. With regard to carbon turnover and soil organic carbon the CC definition was driven by the consideration that most vegetation units are subject to a similar management that leads to comparable C fluxes in biomass and soil.

For individual CCs (especially Forest Land, i.e. CC11, CC12, CC13) further spatial stratifications were introduced (cf. following chp. 6.2.2) with intent to approximate the real/natural differences in carbon stock, carbon turnover and soil conditions as good as possible.

The underlying criteria to include land-use sub-categories such as Shrub vegetation, Vineyards, Low-stem Orchards, Tree Nurseries, Copse and Orchards (CC32-CC37) under Grassland with woody biomass are: (1) They do not fulfil the criteria for forests; (2) There is an agricultural management in general; (3) They all have woody biomass (i.e. perennial vegetation) with permanent grass understory. Also low-stem orchards and tree nurseries (CC33) and copse (CC34) typically have a permanent grass layer – even in vineyards it is good practice in the country to maintain complete grass cover in order to prevent erosion. Therefore, these categories represent soil management, carbon stocks and carbon dynamics of grassland better than those of cropland. Cropland (CC21) is ploughed on a regular basis.

Table 6-5 Relation between the different land-use and land-cover categories and the combination categories (CC).

18 Combination Categories (CC)

Land Use (NOLU04) acc. to AREA — Settlement and urban areas

Land Cover (NOLC04) acc. to AREA	Building areas								Transport surfaces					Special urban areas							Recreational areas and cemeteries					
	101 Industrial and commercial areas > 1 ha	102 Industrial and commercial areas < 1 ha	103 Residential areas (one and two-family houses)	104 Residential areas (terraced houses)	105 Residential areas (blocks of flats)	106 Public buildings and surroundings	107 Agricultural buildings and surroundings	108 Unspecified buildings and surroundings	121 Motorways	122 Roads	123 Parking areas	124 Railway surface	125 Airports and airfields	141 Energy supply plants	142 Waste treatment plants	143 Other supply or waste treatment plants	144 Dumps	145 Quarries, mines	146 Construction sites	147 Unexploited urban areas	161 Public parks	162 Sport facilities	163 Golf courses	164 Camping areas	165 Garden allotments	166 Cemeteries
10 Artificial areas																										
11 Sealed surfaces	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 Buildings	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 Greenhouses	52	52	52	52	52	52	52	52			52	52	52						52	52	52	52	52	52	52	52
14 Gardens with border and patch structures	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
15 Lawns	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
16 Trees in artificial areas	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 Mix of small structures	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
20 Grass and herb vegetation																										
21 Grass and herb vegetation	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
30 Brush vegetation																										
31 Shrub	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 Brush meadows	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
33 Short-stem fruit trees	53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53
34 Vines	53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53
35 Permanent garden plants and brush crops	52	52	52	52	52	52	52	52	52	52	52	52								52	52				52	52
40 Tree vegetation																										
41 Closed forest	54	54	54	54	54	54	54	54	54		54									54	54	54		54	54	54
42 Forest edges	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54	54	54	54	54
43 Forest strips	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54
44 Open forest	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54
45 Brush forest																					53			53		
46 Linear woods	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
47 Clusters of trees	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
50 Bare land																										
51 Solid rock	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
52 Granular soil	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
53 Rocky areas	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
60 Watery areas																										
61 Water	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 Glacier, perpetual snow																										
63 Wetlands	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
64 Reedy marshes	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42

Land Use (NOLU04) acc. to AREA — Agricultural areas, Forest areas, Unproductive areas

Land Cover (NOLC04) acc. to AREA	Orchards, vineyards, horticulture			Arable and grassland			Alpine grazing areas			Forest (not used for agriculture)				Lakes and rivers			Unproductive land			
	201 Orchards	202 Vineyards	203 Horticulture	221 Arable land, in general	222 Semi-natural grassland, in general	223 Farm pastures, in general	241 Alpine meadows, in general	242 Alpine pastures, in general	243 Alpine sheep grazing pastures, in general	301 Forest	302 Afforestation	303 Lumbering areas	304 Damaged forest	401 Lakes	402 Streams, rivers	403 Flood protection structures	421 Unused	422 Avalanche and rockfall protection structures	423 Alpine sports facilities	424 Landscape intervention
10 Artificial areas																				
11 Sealed surfaces		51	51											51	51	51		51	51	51
12 Buildings																				
13 Greenhouses			21																	
14 Gardens with border and patch structures		21	21	21	21		21			12										
15 Lawns		31	31																	
16 Trees in artificial areas																				
17 Mix of small structures		21	21																	
20 Grass and herb vegetation																				
21 Grass and herb vegetation	31	31	31	21	31	31	31	31	31		11	12	12	37	37	37	37	37	37	31
30 Brush vegetation																				
31 Shrub		32	32								11	12	12	32	32	32	32	32	32	32
32 Brush meadows		32	32		32	32	32	32			11	12	12	32	32	32	32	32	32	32
33 Short-stem fruit trees	33		33																	
34 Vines		33	33																	
35 Permanent garden plants and brush crops			33							12										
40 Tree vegetation																				
41 Closed forest	35									12	11					12		12		
42 Forest edges	35									12	11	12	12			12		12		
43 Forest strips	35									12	11					12		12		
44 Open forest	35				12	12	12	12	13	12	11	12	12			12		12	12	12
45 Brush forest										13						13		13		
46 Linear woods	34	34	34	34	34	34	34	34	34		11	12	12	34	34	34	34	34	34	34
47 Clusters of trees	34	34	34	34	34	34	34	13	34		11	12	12	34	34	34	34	34	34	34
50 Bare land																				
51 Solid rock												13	13	61	61	61	61	61	61	61
52 Granular soil		61	61									12	12	61	61	61	61	61	61	61
53 Rocky areas		36	36			36	36	36			11	13	13	36	36	36	36	36	36	36
60 Watery areas																				
61 Water														41	41	41				41
62 Glacier, perpetual snow																	61			
63 Wetlands					42	42	42	42	42			12	13	42	42	42	42	42	42	42
64 Reedy marshes				21	42	42	42	42	42					42	42	42	42			

Combination Categories (CC):

- 11 Afforestations
- 12 Productive 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

6.2.2 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 (OEP 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 6-4). For cropland and grassland, two soil types (organic and mineral soils) were additionally differentiated.

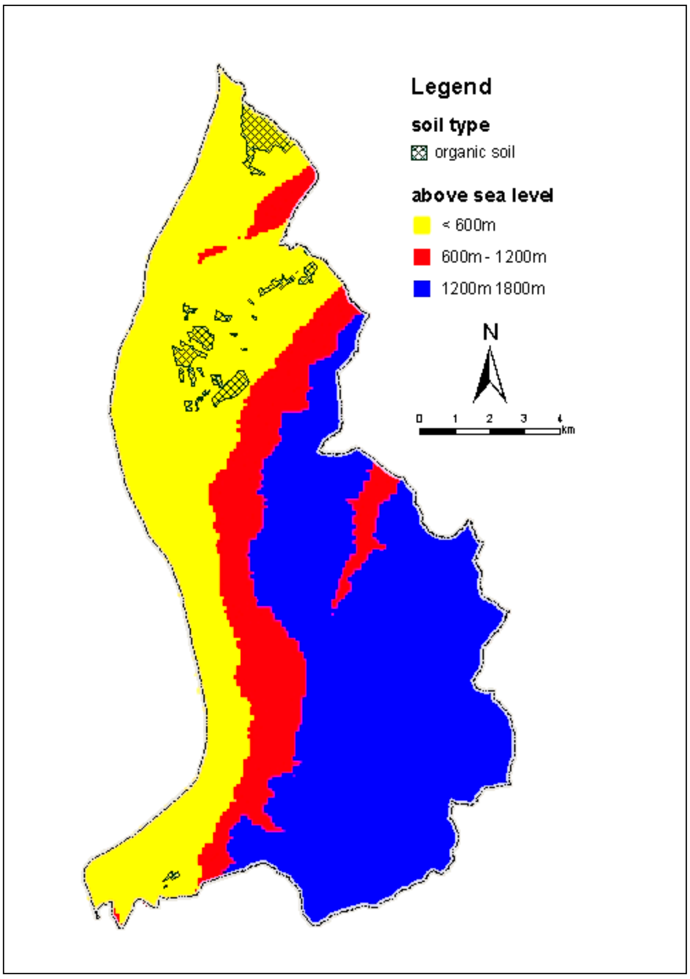

Figure 6-4 Map of Liechtenstein showing the altitude classes and soil types. Reference: OEP 2006d.

6.2.3 The land-use tables and change matrices (activity data)

Table 6-6 shows the trends of land-use changes at the level of the disaggregated land-use categories (CC). The data is resulting from interpolation and extrapolation in time and from spatial stratification (altitude classes and soil types). For example, the areas of afforestation (CC11) decrease in all altitude classes between 78% and 100% from 1990 to 2014, while the area of managed forests (CC12) increases by 4% since 1990 at altitudes over 1200 m. The most significant land-use changes in absolute terms since 1990 can be observed in the categories cropland CC21 (decrease by 219 ha, mineral and organic soils), grassland CC31-37(decrease by 341 ha) and settlements CC51-54 (increase by 433 ha).

Table 6-6 Statistics of land use (CC = combination categories) for the period 1990-2014 (in ha) and change (absolute and relative) between 1990 and 2014.

CC	altitude	soil type	1990	1995	2000	2005	2010	2011	2012	2013	2014	Change 1990-2014 (ha)	Change 1990-2014 (%)
11	≤ 600	n.s.	8	11	7	2	0	0	0	0	0	-8	-100%
	601-1200	n.s.	7	2	2	2	0	0	0	0	0	-7	-100%
	> 1200	n.s.	29	32	19	13	10	9	8	7	6	-23	-78%
12	≤ 600	n.s.	994	996	995	994	993	993	993	993	993	-1	0%
	601-1200	n.s.	1954	1959	1952	1947	1945	1945	1944	1944	1943	-11	-1%
	> 1200	n.s.	2157	2190	2207	2221	2238	2242	2246	2250	2254	97	4%
13	≤ 600	n.s.	0	1	0	1	1	1	1	1	1	1	134%
	601-1200	n.s.	9	9	10	11	11	11	12	12	12	3	39%
	> 1200	n.s.	877	900	916	929	944	947	950	954	957	81	9%
21	n.s.	mineral	1828	1805	1773	1715	1652	1644	1635	1626	1617	-211	-12%
	n.s.	organic	124	123	122	120	117	117	117	116	116	-8	-6%
31	≤ 600	mineral	1132	1095	1077	1086	1098	1096	1094	1092	1091	-41	-4%
	≤ 600	organic	63	61	61	63	64	64	64	64	64	1	2%
	601-1200	mineral	365	355	348	344	340	338	337	336	335	-30	-8%
	601-1200	organic	0	0	0	0	0	0	0	0	0	0	
	> 1200	mineral	1666	1649	1646	1636	1623	1620	1618	1616	1614	-53	-3%
	> 1200	organic	0	0	0	0	0	0	0	0	0	0	
32	≤ 600	n.s.	20	21	23	25	26	26	26	26	27	7	33%
	601-1200	n.s.	10	8	9	11	12	12	13	13	13	3	35%
	> 1200	n.s.	563	528	514	515	513	510	508	505	503	-60	-11%
33	n.s.	mineral	30	32	33	33	33	33	34	34	34	3	11%
	n.s.	organic	0	0	0	0	0	0	0	0	0	0	
34	≤ 600	n.s.	383	375	348	322	301	297	293	289	285	-98	-26%
	601-1200	n.s.	79	77	73	73	73	73	73	72	72	-7	-9%
	> 1200	n.s.	255	256	252	246	242	241	240	240	239	-16	-6%
35	n.s.	mineral	1	0	0	0	0	0	0	0	0	-1	-100%
	n.s.	organic	0	0	0	0	0	0	0	0	0	0	
36	n.s.	n.s.	347	341	345	343	338	338	337	337	336	-10	-3%
37	n.s.	n.s.	398	389	382	374	366	364	362	361	359	-39	-10%
41	n.s.	n.s.	199	183	205	210	204	204	204	204	205	6	3%
42	n.s.	n.s.	160	161	162	162	160	160	160	160	160	0	0%
51	n.s.	n.s.	904	969	1044	1119	1192	1206	1221	1235	1249	346	38%
52	n.s.	n.s.	304	314	327	350	375	379	382	386	389	85	28%
53	n.s.	n.s.	15	12	16	20	23	23	24	24	24	9	62%
54	n.s.	n.s.	143	158	158	147	137	137	137	136	136	-7	-5%
61	n.s.	n.s.	1025	1038	1024	1019	1020	1019	1018	1017	1016	-10	-1%
Sum			16050	16050	16050	16050	16050	16050	16050	16050	16050	0	0%

The annual rates of change in the whole country (change-matrix) are achieved by adding up the annual change rates of all hectares per combination category (CC). Table 6-7 shows an overview of the mean annual changes of all CC in 2010 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 sum of increases and decreases is identical.

For calculating the carbon stock changes, these fully stratified land-use change matrices are used for each year (see chp. 6.2.3.). More aggregated change-matrices are reported in CRF-table 4.1 for each year 1990-2014.

Table 6-7 Land-use change in 2010 (change matrix). Units: ha/year.

From: CC-code	altitude zone z	soil type	To: 11	11	11	12	12	12	13	13	13	21	21	31	31	31	31	31	31	32	32	32	33	33	34	34	34	35	35	36	37	41	42	51	52	53	54	61	Decrease
			1	2	3	1	2	3	1	2	3	n.s.	n.s.	1	1	2	2	3	3	1	2	3	n.s.	n.s.	1	2	3	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	
			n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0	1	0	1	0	1	0	1	n.s.	n.s.	n.s.	0	1	n.s.	n.s.	n.s.	0	1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	
11	1	n.s.	0	0	0	0.47	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	0.5
	2	n.s.	0	0	0	0	0.5	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	0.5
	3	n.s.	0	0	0	0	0	1	0	0	0.11	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	1.1
12	1	n.s.	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	1	0.17	0	0.17	0.17	2.2
	2	n.s.	0	0	0	0	0	0	0	0.86	0	0	0	0	0	0	0	0	0	0	0.67	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	2.0
	3	n.s.	0	0	0	0	0	0	0	0	1.17	0	0	0	0	0	0	0.5	0	0	0	0.64	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.17	3.5
13	1	n.s.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
	2	n.s.	0	0	0	0	0.72	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	0.7
	3	n.s.	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1.08	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	5.4
21	n.s.	0	0	0	0	0	0	0	0	0	0	0	0	7.97	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0.33	0	0	1	1.67	1.67	0	0	0	13.0
	n.s.	1	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
31	1	0	0	0	0	0	0	0	0	0	0	3.67	0	0	0	0	0	0	0	0.33	0	0	0.17	0	1.67	0	0	0	0	0	0.17	0	0	7.19	2.33	0	0	0	15.5
	1	1	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	0.45	0	0	0	0	0	0.4
	2	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.42	0	0	0	0	0.67	0	0	0	0	0	0	0	0.33	0.5	0	0	0	2.1
	2	1	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
	3	0	0	0	0	0	0	0	0	0	2.17	0	0	0	0	0	0	0	0	0	0	3.53	0	0	0	0	0	0	0	1.3	0	0	0	0.5	0.17	0	0	0.81	8.5
	3	1	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	1	n.s.	0	0	0	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0.49	1.6
	2	n.s.	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	1.28	0	0	0	0	0	0	0	0	0	0	0	0	1.6
	3	n.s.	0	0	0	0	0	1.5	0	0	5	0	0	0	0	0	0	1.83	0	0	0	0	0	0	0	0	1	0	0	0.5	1	0	0	0	0	0	0	1	11.8
33	n.s.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
	n.s.	1	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	1	n.s.	0	0	0	0.33	0	0	0	0	0	0.17	0	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	1.5	0.65	0	0	0	7.6
	2	n.s.	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.92	0	0.17	0.17	0	0	0	2.8
	3	n.s.	0	0	0	0	0	2	0	0	0.17	0	0	0	0	0	0	0.17	0	0	0	0.33	0	0	0	0	0	0	0	0.17	0.17	0	0	0	0	0	0	0	3.0
35	n.s.	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	0.0
	n.s.	1	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.	0	0	0.17	0	0	0	0	0	0.17	0	0	0.33	0	0	0	2.03	0	0.17	0.33	1.5	0	0	0	0	0.33	0	0	0	1.67	0	0	0	0	0	0	1.33	8.0
37	n.s.	n.s.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.33	0.17	2.33	0	0	0.33	0	0	0	0	0	0	0	0	0.95	0	0	0	0.03	5.1
41	n.s.	n.s.	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	3.45	3.8
42	n.s.	n.s.	0	0	0	0.5	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0.78	0	1.6
51	n.s.	n.s.	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0.33	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0.17	0	1.83	1.17	0	0	4.2
52	n.s.	n.s.	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.33	0	0	1.67	0	5.5
53	n.s.	n.s.	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	0.28	0.17	0	0.33	0	0.8
54	n.s.	n.s.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	1.5	1.38	0	0	0.2	3.3
61	n.s.	n.s.	0	0	0	0	0	0	0	0	0	0.33	0	0.33	0.17	0	0	0.17	0	0	0.17	0	0	0	0	0	0	0	0	5.15	0	1.95	0	0	0	0	0	0	8.3
Increase			0.0	0.2	0.2	2.1	1.6	7.5	0.2	0.9	8.8	4.2	0.0	13.8	0.5	0.8	0.0	6.3	0.0	1.8	1.8	9.3	0.3	0.0	3.6	2.4	2.3	0.0	0.0	7.6	3.5	4.0	1.6	18.6	9.0	1.2	2.9	8.0	125.0

In accordance with the Guidelines (IPCC 2006, Volume 4, Chapter 3.2) land-use changes between two categories of unmanaged land (e.g. CC36-CC37, stony and unproductive grassland) are not considered for calculating emissions/removals. However, the area of unmanaged land is quantified and tracked over time, so that consistency in area accounting is maintained as land-use change occurs.

6.3 Approaches used for representing land areas and land-use databases

6.3.1 Liechtenstein's 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 (EDI/BFS 2009).

For the reconstruction of the land use conditions in Liechtenstein for the period 1990-2014 four data sets are used:

- Land-Use Statistics 1984
- Land-Use Statistics 1996
- Land-Use Statistics 2002
- Land-Use Statistics 2008

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 and 2008 data the new land-use and land-cover categories were used directly (EDI/BFS 2009).

6.3.2 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, 2002 and 2008). However, the exact year of the land-use change on a specific hectare is unknown. The actual change could 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, 1996 to 2002 and from 2002 to the 2008 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 2008 is estimated by linear extrapolation, assuming that the average trend observed between 1984 and 2008 goes on.

Example (Figure 6-5): 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.

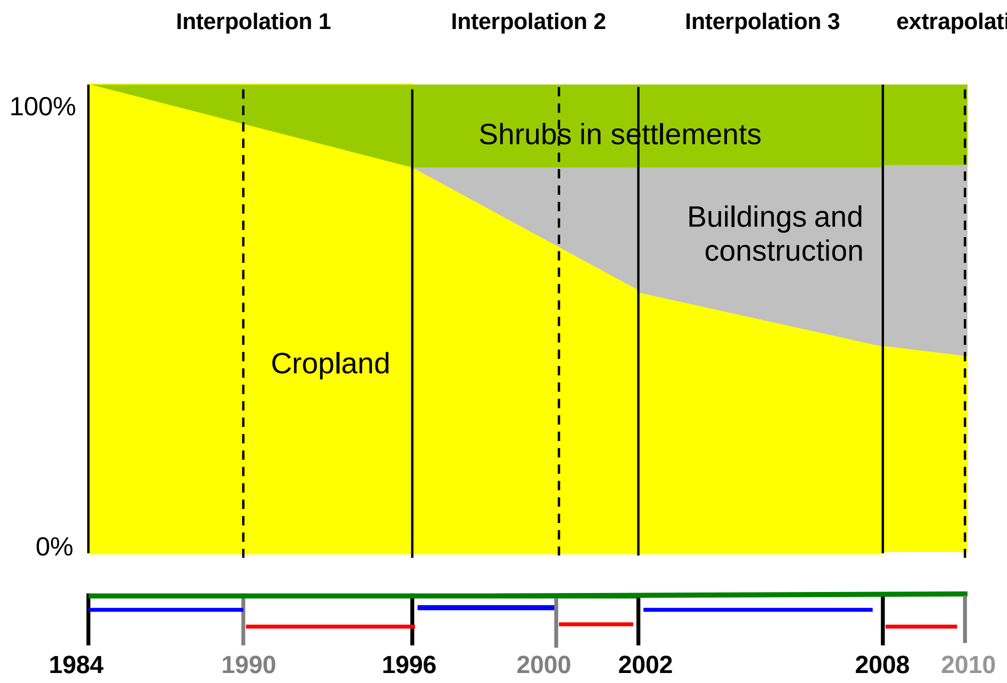

Figure 6-5 Hypothetical linear development of land-use changes between the four different Land Use Statistics (1984, 1996, 2002, 2008) with the example of a hectare changing from “cropland” to “shrubs in settlements” and then twice from "shrubs in settlements" to “buildings and constructions". The dotted lines show how the share of the different land use categories is determined in years between land use statistics and extrapolated after 2008.

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 year 2002 Figure 6-5 as example). Extrapolation after 2008 is done by taking the average trend of the whole time period 1984 to 2008. The ‘status’ for each individual year in the period 1990-2008 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 6-6).

6.3.3 Uncertainties and time-series consistency of activity data

Uncertainties of AREA data are presented in the NIR of Switzerland (FOEN 2015); they are between 2% and 6%. As Liechtenstein applies the same methodology it can be expected that the interpretation uncertainty is the same. The sampling uncertainty is expected to be higher with the smaller sample size in Liechtenstein but quantitative values are not available.

Consistency: Time series for activity data are all considered consistent; they are calculated based on consistent methods for interpolation and extrapolation and homogenous databases.

6.3.4 QA/QC and verification of activity data

The general QA/QC measures are described in Chapter 1.2.3.

The AREA survey is a well-defined and controlled, long-term process in the responsibility of the Swiss Federal Statistical Office (SFSO 2006a).It was assured that the total country area remained constant over the inventory period.

6.3.5 Recalculations of activity data

No category-specific recalculations were carried out.

6.3.6 Planned Improvements for activity data

A new AREA survey is expected to be available in 2017.

6.4 Source Category 4A – Forest Land

6.4.1 Source category description

Key category 4A2
The CO_2 emission from 4A2 Land Converted to Forest Land is key source by trend.

38% of the total area of Liechtenstein is forest land. The total forest area increased by 2.2% between 1990 and 2014. The annual net CO_2 removals range from -1.22 kt CO_2 (2002) to -0.78 kt CO_2 (2013). The source category 4A1 “Forest Land remaining Forest Land” is a net source as the gains in biomass are lower than the sum of cut & mortality. The source category 4A2 “Land converted to Forest Land” is a net sink.

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 (OE 2016):

- Minimum area of land: 0.0625 hectares with a minimum width of 25 m
- Minimum crown cover: 20%
- Minimum height of the dominant trees: 3 m (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 afforestation (CC 11), managed forest (CC 12) and unproductive forest (CC 13) based on the land use and land cover categories (see Table 6-3; SFSO 2006a).

6.4.2 Methodological issues

The activity data collection follows the methods described in chapter 6.2.2. Carbon stocks and carbon stock changes are taken partly from Switzerland and partly from Liechtenstein's NFI. Details are described in the following paragraphs.

6.4.2.1 National Forest Inventory (NFI) data for CC12

For productive forest (CC12), data for carbon stocks in living biomass and dead wood, as well for gain (growth) and loss of living biomass (cut and mortality) was derived from Liechtenstein's National Forest Inventory (see blue cells in Table 6-4). The NFI is based on 403 terrestrial sampling points situated in accessible forest stands (without brush forest) representing a mesh of 354x354 m^2. It was conducted between 1998 and 2010 (LWI 2012). Thus, the carbon fluxes induced by growth, cut and mortality are an average of that 12-year period. Table 6-8 shows important results of the LWI (2012). The average annual rates were 7.9 m^3 ha^{-1} for growth, 5.7 m^3 ha^{-1} for cut and 2.7 m^3 ha^{-1} for mortality. Overall, the growing stock decreased during this period.

In order to simplify the calculation of annual gains and losses in carbon stocks, it is assumed that growth, cut and mortality as well as growing stocks are constant over the whole time period, i.e. the average rates 1998-2010 are applied for all years between 1990 and 2014. However, for the reporting under the Kyoto Protocol annual values of biomass loss by harvesting are used (see Chapter 11).

Table 6-8 Results of Liechtenstein's forest inventory 2010 (LWI 2012).

	Growth [m^3 ha^{-1} yr^{-1}], 1998-2010		
	elevation ≤ 1000 m	elevation > 1000 m	Liechtenstein
Coniferous	4.9	6.4	5.8
Deciduous	4.3	0.7	2.1
Total	9.2	7.1	7.9
	Stocks 2010 [m^3 ha^{-1}]		
	elevation ≤ 1000 m	elevation > 1000 m	Liechtenstein
Growing stock	374	383	379
Dead wood	24	34	30

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 2008). The considered explanatory variables are (see also6.2.2):

- altitude (≤ 600 m, 601-1200 m, > 1200 m)
- tree species (coniferous and deciduous species).

The NFI-report (LWI 2012) presents results separately for coniferous and deciduous trees. The carbon values for CC12 were calculated as volume-weighted averages as AREA cannot distinguish coniferous and deciduous forests.

Furthermore, the NFI report presents results for the altitudinal belts ≤1’000 m and >1’000 m a.s.l. These results were transformed to the three altitudinal belts used for LULUCF calculations (≤ 600 m, 601-1’200 m, > 1’200 m) by weighting with the forest areas measured in the different elevation ranges.

6.4.2.2 Biomass Expansion Factors (BEF)

The Swiss Biomass Expansion Factors were applied in Liechtenstein (FOEN 2013).

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 allometry single-tree functions to all trees measured at the Swiss 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 6-9 shows the BEFs for coniferous and deciduous species stratified for altitude.

Table 6-9 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 (Thürig et al. 2005).

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

To convert round wood over bark (m^3 ha^{-1}) into tons of dry matter ha^{-1} it was multiplied by a species-specific density. Table 6-10 shows the applied densities.

Table 6-10 Wood densities for coniferous and deciduous trees (Vorreiter 1949).

	Wood density [t m^{-3}]
Coniferous trees	0.40
Deciduous trees	0.55

The IPCC default carbon content of solid wood of 50% was applied (IPCC 2006 Table 4.3: mean value from Lamlon and Savidge (2003) for conifers and broadleaved trees in temperate forests).

BEFs, wood densities and carbon contents were used to calculate carbon stocks and fluxes from the volumes measured in the NFI (LWI 2012).

6.4.2.3 Growing C stocks in Unproductive Forests (CC13)

The unproductive forest in Liechtenstein mainly consists of brush forest and inaccessible forest. In unproductive forests, there is no harvesting for economic reasons. Only in special cases (e.g. maintenance of hiking trail) there can be interventions where the log is moved, but not removed from the stand. Therefore, this type of forest is still categorized as managed forest and for transparency reason productive and unproductive forest areas are reported separately.

There is no information on carbon for unproductive forest in the NFIs of Liechtenstein or Switzerland. Therefore, the same carbon stock per hectare as in Switzerland is assumed (see Table 6-4).

The carbon content of unproductive forest was calculated as a weighted average of brush forest, inaccessible stands and other unproductive forest not covered by NFI per spatial stratum (FOEN 2015, Chapter 6.4.2.9). For Liechtenstein, the values of the Swiss NFI-region 3 (Pre-alps) were chosen as that region corresponds to the topographic and climatic conditions in Liechtenstein.

As described in FOEN (2015) brush forests in Switzerland "mainly consist of *Alnus viridis*, horizontal *Pinus mugo var. prostrata* with a percentage cover of 65% and 16%, respectively (Düggelin and Abegg 2011). Following the NFI definition, brush forests are dominated by more than two thirds by shrubs. For brush forests, no NFI data are available to derive their growing stock since only a limited number of attributes are measured on these plots. Düggelin and Abegg (2011) analysed the carbon stock of total living biomass in Swiss brush forests and found an average value of 20.45 t C ha^{-1}."

Inaccessible stands are considered similar to brush forest regarding biomass and carbon stock. Their area is determined based on land cover 'tree vegetation' in typically remote and high-elevation land uses such as avalanche chutes (land use codes 403 and 422 in Table 6-3).

"Unproductive forests not covered by NFI are mainly associated with extensively pastured land where sparse tree vegetation (land cover 44 and 47 in Table 6-3) is found. As those forests are assumed to grow preferably on bad site conditions, an average growing stock (> 7 cm diameter) of 150 m^3 ha^{-1} is assumed. Multiplied by the mean BCEF of 0.69 (see Thürig and Herold 2013), an average biomass for these forests of 102.75 t ha^{-1} was estimated, which translates to 51.38 t C ha^{-1} (using the IPCC default carbon content of 50%)."

Table 6-11 Areal fractions of brush forest, inaccessible forest and forest not covered by NFI, and the resulting weighted carbon content in t C ha^{-1} of unproductive forests (CC13) specified for spatial strata in NFI-region 3 (FOEN 2015).

Altitude [m]	Fraction of brush and inaccessible forest	Fraction of forest not covered by NFI	Weighted carbon stock in living biomass [t C ha^{-1}]
≤ 600	1.00	0.00	20.45
601-1200	0.12	0.88	47.53
> 1200	0.29	0.71	42.36

6.4.2.4 Dead wood

Data from Liechtenstein's NFI (seeTable 6-8) was used to calculate carbon contents in dead wood for productive forest (CC12). Applying the same wood densities, BEFs and carbon content as for the living growing stock, dead wood per spatial stratum was estimated (see Table 6-4).

For unproductive forests (CC13) there is no information available on dead wood and therefore, the Swiss value of 0 t C ha^{-1} (FOEN 2015) is used.

6.4.2.5 Carbon stock and growth of Afforestations (CC11)

Growing stock and growth

The Swiss growing stock and growth rates are applied in Liechtenstein (see Table 6-4). The following paragraph gives some further explanations about the Swiss calculation of carbon stock changes.

Swiss methodology (excerpt from FOEN 2015):

The average growing stock and growth of afforestations were empirically assessed with NFI 1 and 1, 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 2. The NFI data were therefore stratified by altitudinal level. The growing stock of forest stands below 600 m was on average 90 m^3 ha^{-1}. The growing stock on sites between 600 and 1200 m was assumed to be one-third smaller (60 m^3 ha^{-1}) than on sites below 600 m, and two-third smaller on sites above 1200 m (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 below 600 m 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 a logistical growth function. To simulate the development of growing stock on sites above 600 m, growing stock was assumed to develop one-third slower on sites between 600 and 1200 m, and two-thirds slower on sites above 1200 m. 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 6-12 *shows the simulated growing stock and growth for the three altitudinal levels.*

Table 6-12 Estimated average growing stock and annual growth of forest stands in stem wood up to 20 years (CC11) specified for altitude zone.

	≤ 600 m altitude		*601 - 1200 m altitude*		*> 1200 m altitude*	
Stand age *[years]*	***Growing stock*** *[m³ha⁻¹]*	***Growth*** *[m³ ha⁻¹ year⁻¹]*	***Growing stock*** *[m³ha⁻¹]*	***Growth*** *[m³ ha⁻¹ year⁻¹]*	***Growing stock*** *[m³ha⁻¹]*	***Growth*** *[m³ 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*

To convert the estimated growing stock and growth into carbon, the following equations were applied (see results in Table 6-13*):*

*C stock in living biomass = Average growing stock * BCEF * C content*

*Growth of living biomass = Average growth * BCEF * C content*

Table 6-13 Carbon stock in living biomass (stem-wood over bark including stock without branches) and gain of living biomass (growth) in afforestations (CC11) specified per altitudinal zone. BCEF taken from Thürig and Herold (2013).

Altitude **[m]**	**Average stock of living biomass** **[m^3 ha^{-1}]**	**Average gain of living biomass** **[m^3 ha^{-1} yr^{-1}]**	**BCEF**	**Carbon content**	**Carbon stock of living biomass ($stockC_{l,i,11}$)** **[t C ha^{-1}]**	**Gain of living biomass ($gainC_{l,i,11}$)** **[t C ha^{-1} yr^{-1}]**
<601	21.7	4.5	0.72	0.5	7.84	1.63
601-1200	11.8	3	0.73	0.5	4.3	1.09
>1200	4.25	1.5	0.76	0.5	1.61	0.57

6.4.2.6 Soil carbon and litter in all forest categories (CC11-CC13)

As there are no data on forest soils in Liechtenstein, data from Switzerland are used for soil carbon contents and litter. As described in FOEN (2015), Nussbaum et al. (2012, 2014) provided updated data for carbon stocks of litter (organic soil horizons L - litter, F - fermentation and H - humus) and soil organic carbon in Swiss forests. "1’033 sites of a database stored at WSL distributed among different forest types throughout Switzerland were chosen for this study." Further information on the carbon content of L horizons was taken from Moeri (2007). The data for litter and soil carbon stocks are stratified by the five NFI production regions and three elevation levels.

For Liechtenstein, the carbon stocks in litter and mineral soils of the Swiss NFI-region 3 (Pre-Alps) are used as shown in Table 6-4 for afforestations (CC11), productive forest (CC12) and unproductive forest (CC13).

For afforestations (CC11), the amount of carbon in the organic LFH-horizons was conservatively assumed to be zero as most of the afforestations took place on previous grassland or settlements, where no or only very small organic soil layers are expected.

Due to following reasons it is assumed that in the years 1990 to 2014 forest soils in Switzerland, as well as in Liechtenstein, were no carbon source:

- Within the last decades, no drastic changes of management practices in forests have taken place due to restrictive forest laws.
- Fertilization of forests is prohibited in Liechtenstein. Drainage of forests is no 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.

6.4.2.7 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 4(I).

Drainage of forests is no 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 4(II).

6.4.2.8 Emissions from wildfires

Controlled burning of forests is not allowed in Liechtenstein. Wildfires affecting forest did not occur in Liechtenstein since 1985 as confirmed by Nigsch (2012).Therefore, no emissions are reported for forest land in CRF Table 4(V).

6.4.2.9 Land converted to Forest Land

According to the land use statistic the areas switching to forest land are mainly areas that used to be grassland with woody biomass (CC32 and CC34) 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-difference approach, the growing stock of e.g. shrub vegetation (CC32; 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 and the gain-loss approach was applied (see also Chapter 6.1.3.2): I.e., the annual increase of biomass (carbon flux) on these areas was approximated by the annual gross growth rate of the respective forest type (CC11, 12 or 13). The change of soil carbon was not considered and was set to zero.

Cut and mortality was inferred from Liechtenstein's NFI, applying the gain-loss 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 derived by the AREA land use statistics. In these cases the stock-difference approach was applied (see also Chapter 6.1.3.2).

6.4.3 Uncertainties and time-series consistency

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. Emissions and sinks of the category 4A1 are no key category and are therefore part of the "rest" categories with mean uncertainty.

For category 4A2 Land converted to forest land, the AD uncertainty was estimated to 20% (the Swiss value according to FOEN 2011 is 4%, but additional uncertainty is assumed for Liechtenstein due to smaller sample sizes in the AREA survey). The EF uncertainty was set to 36% as in Switzerland (see FOEN 2011).

Time series are consistent.

6.4.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 8).

6.4.5 Category-specific recalculations

For the year 2013 a minor calculation error was corrected (change <0.1 kt CO_2).

6.4.6 Category-specific planned improvements

- It is planned to use annual values of carbon loss by harvesting for productive forest (CC12) as for the reporting under the Kyoto Protocol (see chp. 11).
- A short additional methodological description will be added concerning "uncertainties for the LULUCF sector" by the Office of Environment. The same holds for the other LULUCF sectors.

6.5 Source Category 4B – Cropland

6.5.1 Source category description

Key source 4B1 CO_2 emissions from 4B1 Cropland remaining Cropland is a key source by level.

11% 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 to settlements on the other hand. The total area of cropland decreased between 1990 and 2014 by 11%.

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

6.5.2 Methodological issues

6.5.2.1 Cropland remaining Cropland (4B1)

The activity data collection follows the methods described in chapter 6.3. Carbon stocks and carbon stock changes are taken from Switzerland (FOEN 2015) as shown in Table 6-4. Details are described in the following paragraphs.

a) Carbon in living biomass

When cropland remains cropland, the carbon stocks in living biomass of crops are assumed to be constant. Thus, there is no net change in carbon storage. The carbon stock value given in Table 6-4 (4.69 t C ha^{-1}) represents the average 1990-2012 of Swiss crops. It 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; see FOEN 2015).

b) Carbon in soils

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

c) Changes in carbon stocks

The annual net carbon stock change in organic soils was estimated to -9.52 t C ha^{-1} according to measurements in Europe including Switzerland as compiled by Leifeld et al. (2003, 2005) and rechecked by ART (2009b).

Changes of carbon stocks in mineral soils are assumed to be zero for cropland remaining cropland.

6.5.2.2 Land converted to Cropland (4B2)

The activity data collection follows the methods described in chapter6.3. Carbon factors are displayed in the following paragraphs.

a) Carbon in living biomass

When a conversion of a land to cropland occurs, the stock-difference approach is applied for living biomass.

b) Carbon in soils

When a conversion of a land to cropland occurs, the stock-difference approach is applied for soil carbon.

c) N_2O Emissions from cropland

N_2O emissions from drainage of organic soils on cropland are reported in the agriculture sector.

The calculation of emissions for categories 4III and 4IV (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.5.3 Uncertainties and time-series consistency

The uncertainty for the key category 4B1 is 5% for AD. For the EF (CO_2) it is 37.5% according to the Swiss National Inventory Report (FOEN 2016), see also chapter 1.6 for uncertainty evaluation.

Where available, uncertainties for soil carbon stocks are reflected 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 et. al. 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.

The time-series are consistent.

6.5.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 8). No additional category-specific QA/QC activities have been carried out.

6.5.5 Category-specific recalculations

No category-specific recalculations were carried out.

6.5.6 Category-specific planned improvements

No category-specific improvements are planned.

6.6 Source Category 4C – Grassland

6.6.1 Source category description

Key source 4C1 and 4C2 CO_2 emissions from 4C1 “Grassland remaining Grassland” are a key category regarding level. CO_2 emissions from 4C2 “Land converted to Grassland” are a key category concerning level and trend.

31% of Liechtenstein’s total surface is grassland, whereof 86% is managed and 14% 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 6.4% in 2014 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 (CC31), shrub vegetation (CC32), vineyards, low-stem orchards (‘Niederstammobst’) and tree nurseries (CC33), copse (CC34), orchards (‘Hochstammobst’; CC35), stony grassland (CC36), and unproductive grassland (CC37). The combination categories CC31-35 are considered as managed and CC36-37 as unmanaged grasslands.

As there are no data available from Liechtenstein related to carbon pools in Grassland, data based on experiments, field studies, literature and expert estimates from Switzerland are used (see Chapter 6.6.2). The applicability of those data is justified by the facts that

- the land-use categories used in Liechtenstein are defined in the same way and the same nomenclature (SFSO 2006a) and
- the topographic, climatic and geological conditions in Liechtenstein are very similar to the Region 3 (Pre-Alps) of the Swiss NFI. Region 3 is situated adjacently along the Western border of Liechtenstein, i.e. it extends to the same valley where the main part of Liechtenstein's territory is situated. Further, the management practices of the different grassland types are very similar in Switzerland and Liechtenstein, e.g. related to vineyards, orchards or alpine farming at higher altitudes.

6.6.2 Methodological issues

6.6.2.1 Grassland remaining Grassland (4C1)

The activity data collection follows the methods described in chapter 6.2.2. Carbon stocks are taken from Switzerland (FOEN 2015) as shown in Table 6-4. Details are described in the following paragraphs.

a) Carbon in living biomass

Permanent Grassland (CC31)

Permanent grasslands range in altitude from 400 m to 2’600 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 4A - Forest Land).

Swiss values for carbon stock in living biomass of permanent grassland are applied (FOEN 2015).

The estimation of above-ground carbon stocks is based on annual cumulative yield of differentially managed grasslands (FAL/RAC 2001).Data on root biomass-C was compiled by ART (2011a) based on published data of Swiss grassland. Root biomass is added to above-ground biomass to derive the total living biomass for CC31. The values for the different altitude zones are displayed in Table 6-14.

Table 6-14 Root biomass Croot and total living biomass Cl of permanent grassland (CC31).

Altitude [m]	Croot [t C ha^{-1}]	Cl [t C ha^{-1}]
<601	1.82	7.08
601-1200	2.04	6.00
>1200	5.70	7.95

Shrub Vegetation (CC32) and Copse (CC34)

Swiss values for living biomass in shrub vegetation and copse were applied (FOEN 2015). 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 Chapter 6.4.2.3. Brush forest is assumed to contain 20.45 t C ha^{-1}.

Vineyards, Low-stem Orchards and Tree Nurseries (CC33)

Swiss values for standing carbon stock of living biomass (Cl) for CC33 were applied (FOEN 2015). Cl of vineyards is 3.61 t C ha^{-1}, Cl of low-stem orchards is 12.25 t C ha^{-1}. For tree nurseries no stand densities are available. The weighted mean[10] carbon stock of this combination category is 3.74 t C ha^{-1}.

Orchards (CC35)

Orchards are loosely planted larger fruit trees ('Hochstammobst') with grass understory. Swiss values for the biomass stock of orchards were applied (FOEN 2015). The total biomass stock of this combination category (including the biomass of the grassland) is assumed to be 24.32 t C ha^{-1}.

Stony Grassland (CC36)

Stony grassland is categorized as unmanaged grassland. Swiss values for carbon stock of stony grassland were applied (FOEN 2015). Approximately 35% of the surface of CC36 (herbs and shrubs on stony surfaces) is covered by vegetation. No accurate data were available for this category. Therefore, the carbon content of brush forest (20.45 t C ha^{-1}; Düggelin and Abegg 2011) was multiplied by 0.35 to account for the 35% vegetation coverage. This results in a carbon content of 7.16 t C ha^{-1}.

Unproductive Grassland (CC37)

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.

For none of these land-use types, biomass data are currently available. Therefore, the mean value of permanent grasslands in all altitude zones, 7.01 t C ha^{-1} (cf. Table 6-14), is arbitrarily chosen as the preliminary biomass value for CC37 (FOEN 2015).

b) Carbon in soils

Permanent Grassland (CC31)

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

Swiss values for carbon stocks in mineral and organic soils are applied (FOEN 2015). They are based on Leifeld et al. (2003) and Leifeld et al. (2005). The approach correlates measured soil organic carbon stocks (t ha^{-1}) for permanent grasslands with soil texture and elevation after correction for soil depth and stone content.

The mean carbon stock values for mineral soils are displayed in Table 6-15.

[10] Weighted by the area of orchards and vineyards

Table 6-15 Mean carbon stocks under permanent grassland on mineral soils, ± represents the standard deviation.

Altitude [m]	C_s [t C ha^{-1}, 0-30 cm]
≤ 600	62.02 ± 13
601-1200	67.50 ± 12
>1200	75.18 ± 9
Simple mean carbon stock value over altitude classes	*68.23*

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

Shrub Vegetation (CC32)

Due to lack of data, the values of carbon stocks under permanent grassland on mineral soils (CC31) were used (see Table 6-15).

Vineyards, Low-stem Orchards and Tree Nurseries (CC33)

The category includes carbon stocks in soils of vineyards, low-stem orchards and tree nurseries. In accordance to carbon stocks in biomass, only vineyards and low-stem orchards are considered. Both land-use types are assumed to have grass undercover in general. Therefore, the soil carbon content could be between the values for grassland and cropland. As a conservative assumption, the soil carbon content values of cropland, i.e. 53.40 t C ha^{-1} (mineral soils, 0-30 cm) are taken for CC33 (see FOEN 2015).

Copse (CC34)

Due to lack of data, the values of CC31 (Table 6-15) were used as the mineral soil carbon stocks for this category (0-30 cm).

Orchards (CC35)

No specific values for orchards are available, and the mean value of grassland mineral soil carbon stocks from the two lower altitudinal zones (i.e. 64.76 t C ha^{-1}; cf. Table 6-15) was taken for mineral soils (0-30 cm).

Stony Grassland (CC36)

Soil organic carbon stocks under herbs and shrubs on stony surfaces were calculated according to the procedure used for biomass, i.e. it is assumed that not more than 35% of the area of CC36 is covered with vegetation and thus only 35% of the area bears a mineral soil while the remainder is bare rock. These grasslands are mainly located at altitudes > 1200m a.s.l. Thus, using the respective value from Table 6-15, the carbon stock Cs of CC36 is calculated as:

Cs(CC36) = 0.35 * Cs(permanent grassland > 1200 m) = 26.31 t C ha^{-1}

Unproductive Grassland (CC37)

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. For none of these land-use types, Cs data are currently available. Soil carbon stocks of CC37 'unproductive grassland' were arbitrarily set as the mean value of carbon stocks under permanent grassland on mineral soils (Table 6-15) in accordance to the procedure followed for biomass. Cs of CC37 is thus 68.23 t C ha^{-1}.

c) Changes in carbon stocks

The annual net carbon stock change in organic soils on managed grassland (CC31-CC35) was estimated to -9.52 t C ha^{-1} according to measurements in Europe including Switzerland as compiled by Leifeld et al. (2003, 2005) and rechecked by ART (2009b).

Changes of carbon stocks in mineral soils are assumed to be zero for grassland remaining grassland.

6.6.2.2 Land converted to Grassland (4C2)

The activity data collection follows the methods described in chapter 6.2.2.

a) Carbon in biomass

When a conversion of a land to cropland occurs, the stock-difference approach is applied for living and dead biomass. The carbon stocks in living biomass and in soil are reported in detail under "Grassland remaining grassland" and are summarized in Table 6-16).

b) Carbon in soils

When a conversion of a land to cropland occurs, the stock-difference approach is applied for soil carbon.

c) N_2O emissions from Grassland

N_2O emissions from drainage of organic soils on grassland are reported in the agriculture sector.

The calculation of emissions for categories 4III and 4IV (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

Table 6-16 Summary table of carbon stocks in grassland (CC31-37)

Combination category	Carbon in living biomass	Carbon in soils	
		Mineral soils	Organic soils
Permanent grassland (CC31)	6.00-7.95 t C ha^{-1}	62.02-75.18 t C ha^{-1}	240 t C ha^{-1}
Shrub vegetation (CC32)	20.45 t C ha^{-1}	62.02-75.18 t C ha^{-1}	
Vineyards, low-stem Orchards and Tree Nurseries (CC33)	3.74 t C ha^{-1}	53.4 t C ha^{-1}	240 t C ha^{-1}
Copse (CC34)	20.45 t C ha^{-1}	62.02-75.18 t C ha^{-1}	
Orchards (CC35)	24.32 t C ha^{-1}	64.76 t C ha^{-1}	240 t C ha^{-1}
Stony Grassland (CC36)	7.16 t C ha^{-1}	26.31 t C ha^{-1}	
Unproductive Grassland (CC37)	7.01 t C ha^{-1}	68.23 t C ha^{-1}	

6.6.3 Uncertainties and time-series consistency

The AD uncertainty for the Key Category 4C1 is 5% and for the Key Category 4C2 20%. For the EF (CO_2) it is 50% according to the Swiss National Inventory Report (FOEN 2011), see also chapter 1.6 for uncertainty evaluation.

The relative uncertainty in yield determination has been estimated at 13% for biomass carbon from agricultural land (Leifeld et. al. 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.

The time-series are consistent.

6.6.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 8). No additional category-specific QA/QC activities have been carried out.

6.6.5 Category-specific recalculations

No category-specific recalculations were carried out.

6.6.6 Category-specific planned improvements

No further category-specific improvements are planned.

6.7 Source Category 4D – Wetlands

6.7.1 Source category description

Source categories 4D1 “Wetlands remaining Wetlands” and 4D2 “Land converted to Wetlands” are not key categories.

2.3% 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 (CC41) and unproductive wet areas such as shore vegetation and fens (CC42) (Table 6-3). Both types of wetland are categorized as unmanaged.

6.7.2 Methodological issues

6.7.2.1 Wetlands remaining Wetlands (4D1)

The activity data collection follows the methods described in chapter 6.3. Carbon stocks are taken from Switzerland (FOEN 2015). Details are described in the following paragraphs.

a) Carbon in living biomass

Surface Waters (CC41)

Surface waters have no carbon stocks by definition.

Unproductive Wetland (CC42)

CC42 consists of unmanaged or weakly managed grassland, bushes or tree groups. The pool of living biomass was estimated to 6.50 t C ha^{-1} (Mathys and Thürig 2010).

b) Carbon in soils

The soil carbon stock for surface waters (CC41) is zero.

Land cover in CC42 includes bogs and fens as well as reed. Currently, no specific soil data are available for CC42. As a first guess, it is suggested that the soil carbon stock of unproductive wetlands is similar to unproductive grassland (CC37) on mineral soils (mean value: 68.23 t C ha^{-1}; 0-30 cm) as proposed in FOEN 2015.

c) N_2O emissions from drainage of soils

Drainage of intact wetlands is very unlikely. Therefore, no N_2O emissions are reported in CRF Table 4(II).

6.7.2.2 Land converted to Wetlands (4D2)

The activity data collection follows the methods described in chapter 6.2. In the case of land-use change, the net changes in biomass and soil of both surface waters (CC41) and unproductive wetland (CC42) are calculated by the stock-difference approach as described in chapter 6.1.3.

The calculation of emissions for categories 4III and 4IV (N_2O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.7.3 Uncertainties and time-series consistency

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four “rest” categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. Since 4D is not a key category, emissions of 4D are part of the “rest” categories with mean uncertainty.

Time series for Wetlands are all considered consistent; they are calculated based on consistent methods and homogenous databases.

6.7.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 8). No additional category-specific QA/QC activities have been carried out.

6.7.5 Category-specific recalculations

No category-specific recalculations were carried out.

6.7.6 Category-specific planned improvements

No category-specific improvements are planned.

6.8 Source Category 4E – Settlements

6.8.1 Source category description

Key category 4E2
CO_2 emissions from 4E2 "Land converted to Settlements" are a key category by level. Category 4E1 "Settlements remaining Settlements" is not a key category.

11.2% of Liechtenstein's total surface are settlements. Between 1990 and 2014, 433 hectares were converted to settlements, which is an increase of 31.7%. Settlements consist of buildings/constructions (CC51), herbaceous biomass in settlements (CC52), shrubs in settlements (CC53) and trees in settlements (CC54) as shown in Table 6-3.

6.8.2 Methodological issues

6.8.2.1 Settlements remaining Settlements (4E1)

The activity data collection follows the methods described in chapter 6.2.2. Carbon stocks are taken from Switzerland. As structure and density of Liechtenstein's settlements are very similar to the settlements in Switzerland (FOEN 2015), there is no need to collect Liechtenstein specific data on trees in settlements and the Swiss data for CC52, 53 and 54 can be used as they are sufficiently accurate. Details are described in the following paragraphs.

a) Carbon in living biomass

Buildings and Constructions (CC51)

Buildings/constructions contain no carbon by default.

Herbaceous Biomass, Shrubs and Trees in Settlements (CC 52, 53, 54)

Carbon stocks in living biomass are: 9.54 t C ha^{-1} for CC52, 15.43 t C ha^{-1} for CC53, and 20.72 t C ha^{-1} for CC54 (Mathys and Thürig 2010: Table 7).

b) Carbon in soils

The carbon stock in soil for the combination category "Buildings and Construction" (CC51) was set to zero. However, a weighting factor of 0.5 (Leifeld et. al. 2003) was applied to soil carbon changes due to land-use changes involving CC51 (see Chapter 6.1.3). 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).

6.8.2.2 Land converted to Settlements (4E2)

The activity data collection follows the methods described in chapter 6.2.2.

When a conversion of a land to settlements occurs, the stock-difference approach is applied for living biomass, dead biomass and soil carbon as described in Chapter 6.1.3. Carbon stocks are summarized in Table 6-4.

The calculation of emissions for categories 4III and 4IV (N_2O from Nitrogen Mineralization in mineral soils) is described in chp. 6.10.

6.8.3 Uncertainties and time-series consistency

The uncertainties for the Key Category 4E2 are 20% for AD. For the EF (CO_2) it is 50% according to the Swiss National Inventory Report (FOEN 2011), see also chp. 1.6 for uncertainty evaluation.

Since 4E1 is not a key category, its emissions are accounted in the “rest” category CO_2 with mean uncertainty.

The time series are consistent.

6.8.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 8). No additional category-specific QA/QC activities have been carried out.

6.8.5 Category-specific recalculations

No category-specific recalculations were carried out.

6.8.6 Category-specific planned improvements

No category-specific improvements are planned.

6.9 Source Category 4F – Other Land

6.9.1 Source category description

Category 4F1 “Other Land remaining Other Land” is not a key category. Category 4F2 “Land converted to Other Land” CO_2 is a key category by trend.

6.3% of Liechtenstein’s total surface are summarized in “Other Land”. Between 1990 and 2014 the area of “Other Land” has remained rather stable (-1.0%). As shown in Table 6-3 other land (CC61) covers non-vegetated areas such as glaciers, rocks and shores.

6.9.2 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 by the stock-difference approach as described in chapter 6.1.3.

6.9.3 Uncertainties and time-series consistency

The uncertainties for the Key Category 4F2 are 20% for the Activity Data. For the EF (CO_2) it is 50% according to the Swiss National Inventory Report (FOEN 2011), see also chapter 1.6 for uncertainty evaluation.

The time series are consistent.

6.9.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

The LULUCF expert, the NIC and the NIR author report their QC activities in a checklist (see Annex 8). No additional category-specific QA/QC activities have been carried out.

6.9.5 Category-specific recalculations

No category-specific recalculations were carried out.

6.9.6 Category-specific planned improvements

No category-specific improvements are planned.

6.10 Categories 4III, 4IV – N_2O from nitrogen mineralization

6.10.1 Description

This chapter presents the methods for calculating direct (4III) and indirect (4IV) N_2O emissions from nitrogen (N) mineralization in mineral soils. The source of nitrogen is N mineralization associated with loss of soil organic matter resulting from land-use change.

- In category 4III, direct N2O emissions on land converted to forest land, cropland, grassland, wetlands, settlements or other land are reported.
- In category 4IV2, indirect emissions of N2O due to nitrogen leaching and run-off are reported.

The following N_2O emissions were included in the agriculture sector:

- N_2O emissions associated with inputs from N fertilizers (CRF table 4(I).
- N_2O emissions on cropland remaining cropland and on grassland remaining grassland (CRF table 4(III)). In Liechtenstein, managed grassland also belongs to the agricultural area.
- Indirect N_2O emissions due to atmospheric deposition (CRF table 4(IV1)).

6.10.2 Methodological issues

Direct N_2O emissions (4III) as a result of the disturbance of mineral soils associated with land-use change are calculated according to IPCC (2006, Chapter 4_11):

Emission(N_2O) = – deltaCs * 1 / (C:N) * EF1 * 44 / 28, if deltaCs < 0 [kt N_2O]

where:

deltaCs: soil carbon change induced by land-use change [kt C]

C:N: C to N ratio of the soil before the land-use change

EF1: default emission factor = 0.01 kg N_2O-N (kg N)$^{-1}$, IPCC 2006 (Table 4_11.1)

deltaCs is calculated according to the methodology described in chp. 6.1.3.2. If deltaCs is zero or positive (carbon gain) there are no N_2O emissions provoked by a land-use change.

The value of the C:N ratio is related to the land-use category before the change. For cropland and grassland the ratio is 9.8 according to Leifeld et al. (2007). This value was also used for the mineral soils in wetlands (CC42) and unsealed settlement areas (CC 52, 53, 54). For forest land, the default value of C:N=15 was used (IPCC 2006, Equation 4_11.8).

The indirect N_2O emissions (4(IV)) as a result of N leaching and run-off are calculated as follows using default emission factors (IPCC 2006, Table 4_11.3):

Emission(N_2O) = – deltaCs * Frac / (C:N) * EF5 * 44 / 28, if deltaCs < 0 [kt N_2O]

where:

Frac: fraction of mineralized N lost by leaching or run-off, Frac=30%

EF5: default emission factor = 0.0075 kg N_2O-N (kg N)$^{-1}$, IPCC 2006 (Table 4_11.3)

If deltaCs is zero or positive (carbon gain) there are no N_2O emissions provoked by a land-use change. As the approach applied is not tier 3, no N_2O immobilization is reported.

For calculating deltaCs, all land-use changes and conversions between land-use subcategories were taken into account. Cropland remaining cropland is reported in the agriculture sector as prescribed in

CRF table 4(III) in footnote 1. For Liechtenstein, also the N_2O emissions for grassland remaining grassland are reported in the agriculture sector as grassland is part of the agricultural land.

6.10.3 Uncertainties and time-series consistency

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four “rest” categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. Since 4III and 4IV are no key categories their uncertainties are accounted in the “rest” categories with mean uncertainty of N_2O.

Consistency: Time series for Nitrogen Mineralization are all considered consistent; they are calculated based on consistent methods and homogenous databases.

6.10.4 Category-specific QA/QC and verification

The general QA/QC measures are described in Chapter 1.2.3.

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

6.10.5 Category-specific recalculations

No category-specific recalculations were carried out.

6.10.6 Category-specific planned improvements

No category-specific improvements are planned.

6.11 Source Category 4G – Harvested Wood Products (HWP)

6.11.1 Description

Key category 4G

Category 4G Harvested Wood Products (HWP) CO_2 is a key category by level and trend.

The data presented in this chapter are estimates of net emissions and removals from HWP due to changes in the HWP carbon pool.

The applied approach to HWP accounting could be characterized as a production approach as described in chp. 12, Volume 4 of IPCC (2006). The changes in the wood products pool contains only products made from wood harvested in Liechtenstein. The wood products pool also includes products made from domestic harvest that are exported and stored in other countries.

The estimate uses the product categories, half-lives, and methodologies as described in IPCC (2006) and IPCC (2014).

6.11.2 Methodological issues

The same methodology is used for reporting under UNFCCC and accounting under KP for HWPs in Liechtenstein and is based on Decision 2/CMP.7, paragraph 29, namely, that "transparent and verifiable activity data for harvested wood products categories are available, and accounting is based on the change in the harvested wood products pool of the second commitment period, estimated using the first-order decay function".

For the estimation of carbon stocks and carbon stock change, the equations described in IPCC (2014) were used.

In Liechtenstein, there is no domestic production of paper or wood panels. For the product category 'sawnwood' a Tier 2 approach (first order decay) was applied according to equation 2.8.5 in IPCC (2014).

- Emissions occurring during the second commitment period from HWPs removed from forests prior to the start of the second commitment period were also accounted for. The starting year used to estimate the delayed emissions from the existing pool is 1900.
- The feedstock from domestic harvest is calculated on the basis of the feedstock for Switzerland (FOEN 2015) and of FAO-data for Liechtenstein (see below).
- The change in carbon stocks was estimated only for HWPs originating from Forest Management, as there is no harvest in Afforestations in Liechtenstein (here KP-definitions are referred to as defined in Chapter11). Instantaneous oxidation was assumed to HWPs originating from deforestations.

For Liechtenstein, there are no country-specific data available for calculating the feedstock from domestic harvest according to equation 2.8.1 in IPCC (2014). Therefore, feedstock data from Switzerland (FOEN 2015) related to sawnwood for the period 1961-2013 were adopted for Liechtenstein. The Swiss data were calculated with equation 2.8.1 and 2.8.4 in IPCC (2014) on the basis of national statistics, FAO-data and default conversion factors from IPCC (2014; table 2.8.1). Emission factors were calculated with the default half-live of 35 years for sawn wood.

The Swiss feedstock data were adapted to the number of inhabitants of Liechtenstein with the factor 1/200, approximating the ratio of inhabitants in Liechtenstein and Switzerland (0.035 mio. and 7.0 mio. respectively). This is in line with the method that was applied for calculating HWP carbon stock changes included in the Forest Management Reference Level (FMRL) (OEP 2011d).

Any deviation from FAO figures is due to the fact that **Liechtenstein is not a FAO member** and has no obligation to report feedstock numbers to FAO. Consequently, the feedstock numbers are updated only partially or FAO makes its own estimates.

In the FAO forest product statistics (Food and Agriculture Organization of the United Nations: forest product statistics, http://faostat3.fao.org/download/F/FO/E) there are only data for Liechtenstein on sawnwood production from 2006 to 2012; other years or data on export/import are not available. The sawnwood production in these seven years is between 4'000 and 10'000 m^3 yr^{-1} with an average of 7'715 m^3 yr^{-1}. The quality of those data is not quite clear, but the average is close to the average of the adapted Swiss data for 2006-2012 (7'198 m^3 yr^{-1}). Therefore, the FAO-data 2006-2012 were used in the HWP calculation – in order to ensure a consistent time-series after normalization to the average of the adopted Swiss data.

Liechtenstein's sawnwood production between 1900 and 1960 was estimated assuming a development that is proportional to the development of the number of inhabitants in Liechtenstein (increase from 10'500 inhabitants in 1900 to 16'500 inhabitants in 1960).

Production, gains and losses from sawnwood are listed in Table 6-17 and Figure 6-6 shows the resulting net emissions and removals. Fluctuations in the HWP-pool can mainly be attributed to annual changes in the production of sawnwood, which is strongly linked with the domestic harvesting rate.

Table 6-17 Emissions (positive sign) and removals (negative sign) from HWP from land under Forest Management (4G under UNFCCC; Art. 3.4 under KP) between 2000 and 2014, in kt CO_2. HWPs originating from wood harvested at land converted from forest land to non forest land (UNFCCC) or from Deforestations (KP) are not taken into account.

Harvested wood products	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sawnwood production, m^3	8'125	7'000	7'100	6'725	7'525	7'955	9'331	9'331	9'331	3'732
Gains sawnwood, kt C	2.03	1.75	1.78	1.68	1.88	1.99	2.33	2.33	2.33	0.93
Losses sawnwood, kt C	-1.46	-1.47	-1.47	-1.48	-1.48	-1.49	-1.51	-1.52	-1.54	-1.54
Net emissions/removals, kt CO_2	**-2.10**	**-1.03**	**-1.11**	**-0.74**	**-1.45**	**-1.82**	**-3.03**	**-2.97**	**-2.91**	**2.23**

Harvested wood products	2010	2011	2012	2013	2014
Sawnwood production, m^3	3'732	7'465	7'465	7'714	7'714
Gains sawnwood, kt C	0.93	1.87	1.87	1.93	1.93
Losses sawnwood, kt C	-1.53	-1.53	-1.53	-1.54	-1.55
Net emissions/removals, kt CO_2	**2.18**	**-1.25**	**-1.22**	**-1.43**	**-1.40**

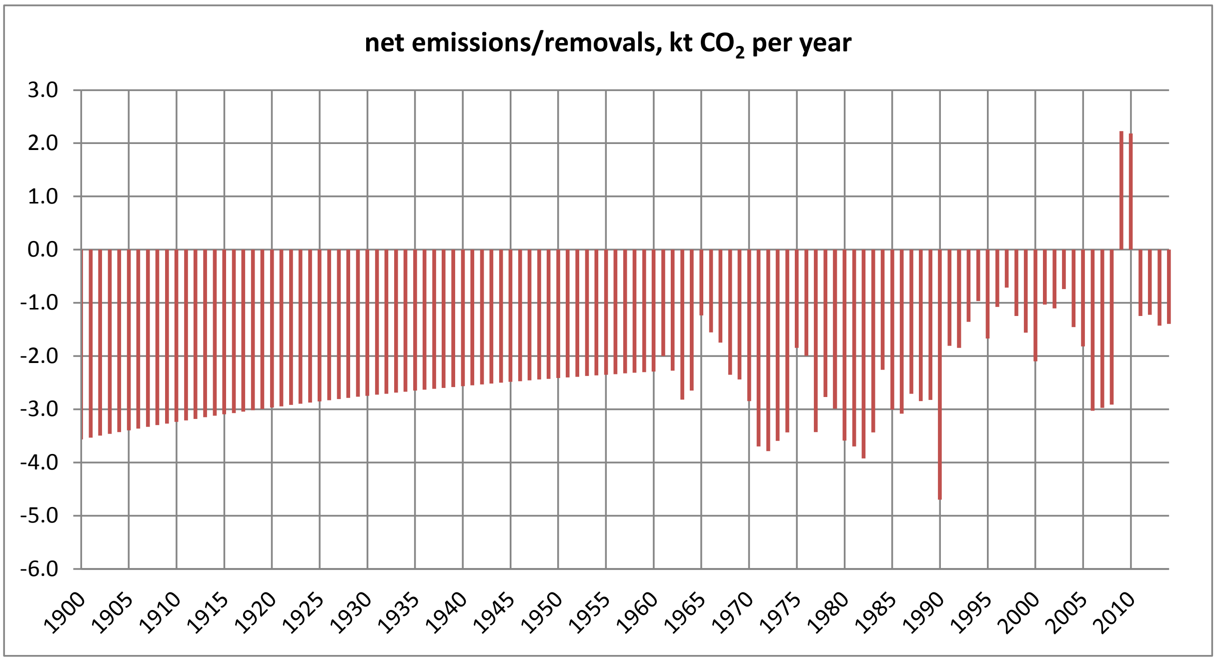

Figure 6-6 Liechtenstein's greenhouse gas net emissions (positive sign) and removals (negative sign) from Harvested Wood Products between 1900 and 2014 originating from forest land (UNFCCC) or land under Forest Management (KP), in kt CO_2 eq.

6.11.3 Uncertainties and time-series consistency

For category 4G HWP, the following information on relative uncertainty was used:

Activity data

Sawnwood production: 20%
(Switzerland has 3% for activity data since 1990, but the adaptation to Liechtenstein using the number of inhabitants induces additional uncertainty.)

Emission factor, including conversion factors:

Wood density: 25% (default from IPCC 2006)

Carbon contents in wood products: 10% (Lamlom and Savidge 2003, assessment of carbon content in wood)

Emission factors (half-life estimates): 50% (default from IPCC 2006)

The total relative uncertainty of carbon losses and gains in HWP can be calculated as:

$$U_{HWP}\text{EmissionFactor} = \sqrt{25\%^2 + 10\%^2 + 50\%^2} = 57\%$$

Consistency: Time series for HWP are considered consistent.

6.11.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

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

6.11.5 Category-specific recalculations

There were no recalculations since category 4G HWP was not reported previously. HWP-specific improvements leading to technical correction of the FMRL are described in chp. 11.7.

6.11.6 Category-specific planned improvements

No category-specific improvements are planned.

7 Waste

7.1 Overview GHG Emissions

Within the waste sector, emissions from four source categories are considered:

- 5A Solid waste disposal
- 5B Biological treatment of solid waste
- 5C Incineration and open burning of waste
- 5D Wastewater treatment and discharge

Source category 5E Other is not occurring in Liechtenstein.

Figure 7-1 depicts Liechtenstein's greenhouse gas emissions in the sector 5 Waste between 1990 and 2014 according to the four source categories 5A-5D. Additionally Table 7-1 lists the GHG emissions of this sector by gas in CO_2 equivalent (kt) for the years 1990 - 2014.

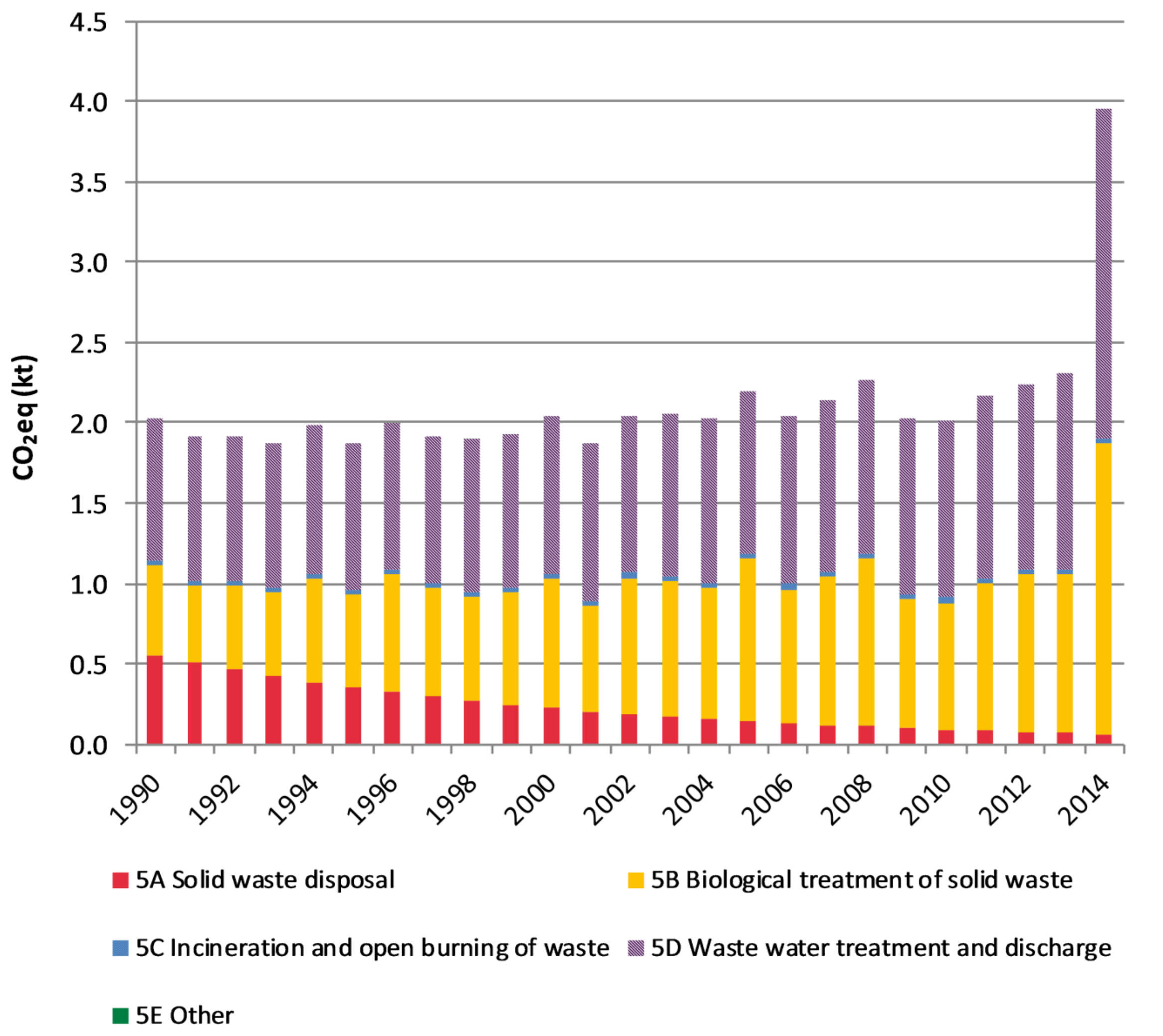

Figure 7-1 Liechtenstein's greenhouse gas emissions in the sector 7 Waste between 1990 - 2014.

Table 7-1 GHG emissions of source category 5 Waste by gas in CO_2 equivalent (kt), 1990 - 2014.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO_2 equivalent (kt)									
CO_2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CH_4	1.10	0.99	0.97	0.93	1.01	0.92	1.02	0.94	0.90	0.92
N_2O	0.91	0.91	0.93	0.92	0.95	0.94	0.96	0.96	0.98	0.98
Sum	**2.02**	**1.92**	**1.92**	**1.88**	**1.98**	**1.88**	**2.00**	**1.92**	**1.90**	**1.92**

Gas	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
CO_2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CH_4	1.00	0.85	0.99	0.98	0.94	1.09	0.93	1.00	1.10	0.88
N_2O	1.03	1.00	1.03	1.05	1.06	1.09	1.09	1.12	1.14	1.12
Sum	**2.05**	**1.87**	**2.04**	**2.05**	**2.03**	**2.20**	**2.04**	**2.13**	**2.26**	**2.03**

Gas	2010	2011	2012	2013	2014	1990-2014
	CO_2 equivalent (kt)					%
CO_2	0.02	0.02	0.02	0.02	0.02	7.3%
CH_4	0.85	0.95	1.01	1.07	2.59	136.1%
N_2O	1.14	1.19	1.21	1.22	1.34	47.7%
Sum	**2.02**	**2.16**	**2.24**	**2.31**	**3.95**	**95.2%**

In the sector 5 Waste a total of 3.95 kt CO_2 equivalents of greenhouse gases were emitted in 2014. 31.62 % of the total emissions origin from 5A Solid waste disposal, 45.70% from 5B Biological treatment of solid waste, 0.77% from 5C Incineration and open burning of waste and 51.91% from the source category 5D Waste water treatment and discharge. Emissions from 5E Other are not occurring in Liechtenstein.

Note that by error the activity data of backyard composting have been overestimated, i.e. 105% share of centralised composting quantity instead of 5%. This is the reason that GHG emissions in source category 5B in the year 2014 are reported to be almost twice than the previous year. The error will be corrected for the next submission.

The total greenhouse gas emissions show an increase from 1990 to 2014 by 95.2%.

Methodological remark for sector 5 Waste: As regulatory frameworks, technical standards and legal principles (threshold values, etc.) in the waste sector of Liechtenstein correspond to Swiss standards, Switzerland's country-specific methodology and/or emission factors are usually adopted.

7.2 Source Category 5A – Solid waste disposal

7.2.1 Source Category Description: Solid waste disposal (5A)

Source category 5A "Solid Waste Disposal " is **not a key category.**

The source category 5A "Solid Waste Disposal" comprises all emissions from handling of solid waste on landfill sites.

5A1. Managed waste disposal sites

There are no managed *waste disposal sites* in Liechtenstein. There are three *landfills* which are managed (e.g. sealing, control of water quality), but they operate exclusively for *inert* materials and do therefore not cause any greenhouse gas emissions. Thus, emissions from the source category 5A1 "Managed Waste Disposal Sites" are not occurring.

5A2. Unmanaged waste disposal sites

100% of the collected municipal solid waste (and the combustible industrial waste) is being exported to Switzerland for incineration to a Swiss municipal solid waste incinerator nearby (MSWIP Buchs). Incineration plants in Switzerland co-generate heat and electricity in a highly efficient manner. Heat is generally fed in a district heating system, which allows replacing large amounts of fossils fuels such as oil and gas. The heat imported by Liechtenstein from the incineration plant is described in the section Energy.

The transition from "landfilling in the country" to "exporting MSW and industrial waste" to Switzerland for incineration started during the 1960ies and was concluded in 1974, when the last municipality in the country stopped landfilling. Before 1974, some waste (municipal and other) were landfilled along the river Rhine in sandy soils which were not suitable for agriculture. In the year 1998, those sites were recorded in a 'contaminated site register'. About 20 of all registered contaminated sites are from the dumping of waste. They are not managed (they are not really "landfills" but rather "contaminated sites") [11]. No landfill gas was collected for flaring or energy recovery. The emissions from these 20 sites are reported under 5A2. Unmanaged waste disposal sites.

5A3. Uncategorized waste disposal sites

Category 5A3 "Uncategorized waste disposal sites" does not occur in Liechtenstein.

Table 7-2 Specification of source category 5A "Solid Waste Disposal".

5A	Source	Specification
5A1	Managed Waste Disposal on Land	Not occurring in Liechtenstein
5A2	Unmanaged Waste Disposal Sites	Emissions from handling of solid waste on unmanaged landfill sites
5A3	Uncategorized waste disposal sites	Not occurring in Liechtenstein

7.2.2 Methodological Issues: Solid Waste Disposal (5A)

Emissions from solid waste disposal are exclusively occurring from category 5A2 Unmanaged Waste Disposal Sites (Table 7-2).

[11] Source: Personal communication with Mr. Theo Banzer (Office of Environment) on 30.08.2013

7.2.2.1 Solid Waste Disposal on Unmanaged Waste Disposal Sites (5A2)

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 1997). It is assumed that the model is still accepted for the reporting under the 2006 IPCC Guidelines. The following equation is applied to calculate the CH_4 generation in the year t:

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

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) • DOC(x) • DOC_F • F • 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 1997)

DOC_F = 0.6 (default value according to IPCC 1997)

F = 0.5 (default value according to IPCC 1997)

The degradable organic carbon (DOC) is calculated based on the default values from IPCC (1997) and based on country-specific data on waste composition for MSW in Switzerland for 1993 (source EMIS 2013 1A1a & 6A1 Kehrichtdeponien according to 1996 IPCC Guidelines (IPCC 1997)). The Swiss MSW composition is representative for the situation in Liechtenstein (CSD 2002).

Table 7-3 Calculation of DOC for Liechtenstein (Source DOC: IPCC (1997), source waste fractions: EMIS 2016/1A1a & 5A1, Quantities of 1993). The resulting DOC_F is calculated by multiplying the waste fraction with specific DOC_F per waste fraction.

Fraction	DOCF	SA 1993	DOC (IPCC 1997c)
Paper and Textile and Cardboard	0.40	28%	0.40
Garden waste and non-food organic putrescible	0.17	5%	0.17
Food waste	0.15	22%	0.15
Wood and Straw	0.30	0%	0.30
Other materials (glass, metals, minerals etc. with no contribution tp methan generation)	0.00	45%	0.00
Sum / Resulting DOC			**0.154**

k-Factor

The ERT recommended Liechtenstein during the centralized review 2013 to modify the value of the k-factor to avoid a potential underestimation of the CH_4 emissions from this category in the time series 1990–2012. This issue was included in the list of potential problems and further questions raised by the ERT during the review. In response to this list, Liechtenstein submitted revised estimates for the times series 1990–2012 using a k value of 0.09/year (default value for bulk waste for wet conditions in boreal and temperate climate from table 3.3 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, volume 5 (IPCC 2006). For 2013 and 2014, the same k value of 0.09/year is applied.

Emission Factors

The emissions are directly calculated in the FOD-model as described above. No country-specific emission factor was used.

Activity data

Activity data for unmanaged MSW Disposal on Land (5A2) have been estimated by OEP (OEP 2007c). The estimates are based on internal (unpublished) research done at OEP 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 MSW quantities are assumed to have been landfilled from 1930 until the closure of the last landfill in 1974 (Table 7-4)

Table 7-4 Amount of MSW landfilled in Liechtenstein (OEP 2007c)

Year	**MSW/cap** [kg/a]	**Inhabitants** (average)	**MSW** [t/a]
1930-1939	150	10500	1575
1940-1949	100	12300	1230
1950-1959	200	15200	3040
1960-1969	300	18500	5550
1970-1975	MSW declines linearly to zero		

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.

Emissions

The following Table 7-5 provides the results of the emission calculation based on the FOD-modeling as well as the waste quantities that have been annually disposed of.

Table 7-5 CH_4 emissions from MSW landfilled in Liechtenstein 1930 – 2014 (Result of FOD model calculation)

Year	Deposition t MSW	Emission t CH_4	Emission t CO_2 eq
1930	1575	3.3	83.2
1931	1575	6.4	159.3
1932	1575	9.2	228.8
1933	1575	11.7	292.4
1934	1575	14.0	350.4
1935	1575	16.1	403.5
1936	1575	18.1	452.0
1937	1575	19.9	496.3
1938	1575	21.5	536.9
1939	1575	23.0	573.9
1940	1230	23.6	589.5
1941	1230	24.1	603.7
1942	1230	24.7	616.8
1943	1230	25.1	628.7
1944	1230	25.6	639.6
1945	1230	26.0	649.5
1946	1230	26.3	658.6
1947	1230	26.7	667.0
1948	1230	27.0	674.5
1949	1230	27.3	681.5
1950	3040	31.3	783.5
1951	3040	35.1	876.7
1952	3040	38.5	961.9
1953	3040	41.6	1039.8
1954	3040	44.4	1110.9
1955	3040	47.0	1176.0
1956	3040	49.4	1235.4
1957	3040	51.6	1289.7
1958	3040	53.6	1339.4
1959	3040	55.4	1384.7
1960	5550	62.4	1558.9
1961	5550	68.7	1718.0
1962	5550	74.5	1863.4
1963	5550	79.9	1996.3
1964	5550	84.7	2117.8
1965	5550	89.2	2228.8
1966	5550	93.2	2330.3
1967	5550	96.9	2423.0
1968	5550	100.3	2507.8
1969	5550	103.4	2585.2
1970	5550	106.2	2656.0
1971	4440	106.5	2662.1
1972	3330	104.4	2608.9
1973	2220	100.1	2501.7
1974	1110	93.8	2345.0
1975	0	85.7	2143.2
1976	0	78.3	1958.7
1977	0	71.6	1790.1
1978	0	65.4	1636.1
1979	0	59.8	1495.3
1980	0	54.7	1366.6
1981	0	50.0	1248.9
1982	0	45.7	1141.4
1983	0	41.7	1043.2
1984	0	38.1	953.4
1985	0	34.9	871.4
1986	0	31.9	796.4
1987	0	29.1	727.8
1988	0	26.6	665.2
1989	0	24.3	607.9
1990	0	22.2	555.6
1991	0	20.3	507.8
1992	0	18.6	464.1
1993	0	17.0	424.1
1994	0	15.5	387.6
1995	0	14.2	354.3
1996	0	13.0	323.8
1997	0	11.8	295.9
1998	0	10.8	270.4
1999	0	9.9	247.2
2000	0	9.0	225.9
2001	0	8.3	206.4
2002	0	7.5	188.7
2003	0	6.9	172.4
2004	0	6.3	157.6
2005	0	5.8	144.0
2006	0	5.3	131.6
2007	0	4.8	120.3
2008	0	4.4	110.0
2009	0	4.0	100.5
2010	0	3.7	91.8
2011	0	3.4	83.9
2012	0	3.1	76.7
2013	0	2.8	70.1
2014	0	2.6	64.1

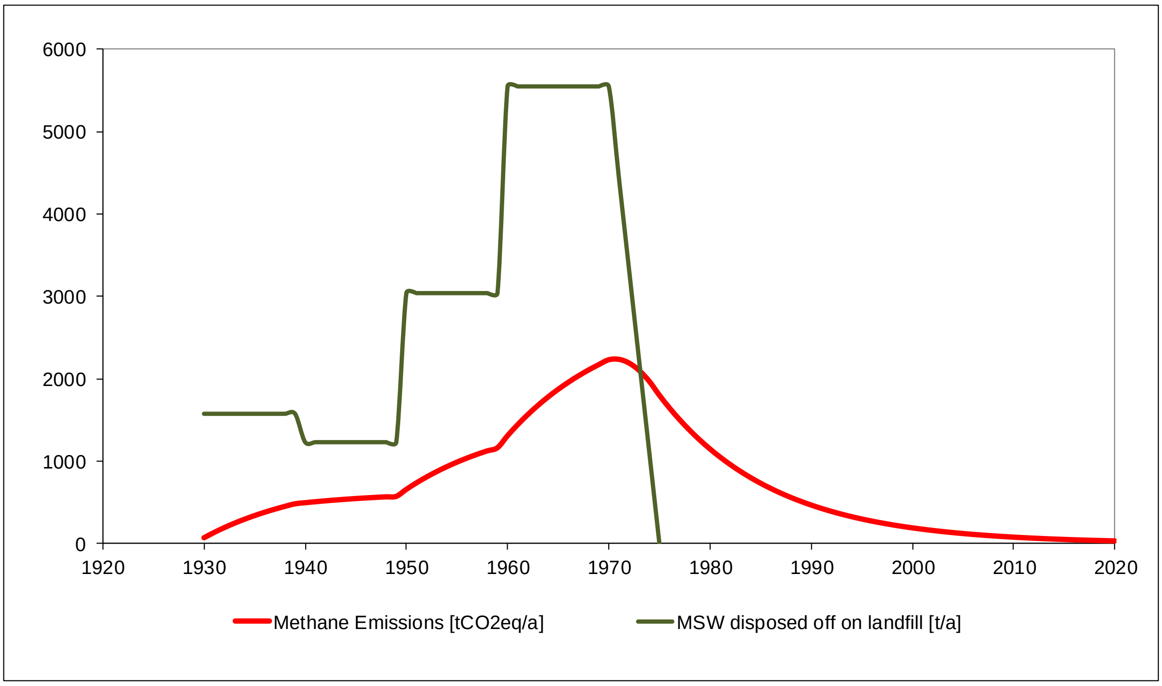

Figure 7-2 MSW disposed of on landfill sites and corresponding emissions of CH_4 in Gg CO_2 equivalents.

7.2.3 Uncertainties and Time-Series Consistency: Solid Waste Disposal (5A)

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

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four “rest” categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. Since 5A is not a key category, its emissions are part of the “rest” categories with mean uncertainty of CH_4.

The time series are consistent.

7.2.4 Category-specific QA/QC and Verification: Solid Waste Disposal (5A)

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

7.2.5 Category-specific recalculations: Solid Waste Disposal (5A)

The CH_4 emission value for the year 2013 was wrong in the CRF Table5 and Table5.A (0.00307 kt instead of 0.00280 kt). This mistake has been corrected. No other recalculations have been carried out.

7.2.6 Category-specific Planned Improvements: Solid Waste Disposal (5A)

No category-specific improvements are planned.

7.3 Source Category 5B – Biological treatment of solid waste

7.3.1 Source category description: Biological treatment of solid waste (5B)

Source category 5B Biological treatment of solid waste is **not a key category.**

Source category 5B – Biological treatment of solid waste 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. Yard waste is mainly composed of residues from tree pruning and hedge trimming as well as of garden waste Backyard composting is carried out on-site. The composition of composted waste is considered to be very similar to the one in Switzerland.

Separately collected organic waste of households (generally food waste) is brought to a composting plant in Switzerland[12].

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

Table 7-6 Specification of source category5B Biological treatment of solid waste.

5B	Source	Specification
	Composting	Emissions from composting of organic waste

7.3.2 Methodological Issues: Biological Treatment of Solid Waste (5B)

Methodology

For the CH_4 and N_2O emissions from composting a country-specific method is used, based on the Swiss NIR (FOEN 2016). The GHG emissions are calculated by multiplying the quantity of composted waste fractions 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 3Da2c.

Emission Factors

Emission factors for composting have been adopted from the Swiss NIR (FOEN 2016): 5.0 kg CH_4/t of composted waste and 0.07 kg N_2O/t of composted waste. They are based on measurements and expert estimates, documented in the Swiss EMIS database (EMIS 2016/5B Kompostierung Industrie).

Activity data

The Office of Environment 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[13]: The amount of composting in small

[12] Mail Mr. Sven Bürzle (Office of Environment) on 29.08.2013

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

compost sites is estimated as a proportion of the amount of composting in centralized compost plants. The proportion is 8 per cent in 1990 and 5 per cent in 2005 and following years compared to the waste composted in centralized compost plants (in the years in between, the factor is linearly interpolated). The expert judgement has been re-confirmed by OEP 2012a.

Table 7-7 Activity data of 5B Biological treatment of solid waste.

Waste composting		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Composted centrally	t/a	3'567	3'078	3'287	3'311	4'143	3'734	4'686	4'316	4'167	4'460
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	3'537	3'556	4'441	3'995	5'005	4'601	4'433	4'737

Waste composting		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Composted centrally	t/a	5'210	4'247	5'501	5'508	5'345	6'614	5'442	5'981	6'859	5'258
Additionally in backyard		6.0%	5.8%	5.6%	5.4%	5.2%	5.0%	5.0%	5.0%	5.0%	5.0%
Composted total	t/a	5'522	4'494	5'809	5'806	5'623	6'945	5'714	6'280	7'202	5'521

Waste composting		2010	2011	2012	2013	2014
Composted centrally	t/a	5'154	5'975	6'426	6'455	6'041
Additionally in backyard		5.0%	5.0%	5.0%	5.0%	5.0%
Composted total	t/a	5'411	6'274	6'748	6'778	6'343

In 2008, there was a significant increase of composted waste quantities. The peak can be related to the clearing of a forest area in the community of Eschen for environmental restoration[14]. Already in 2009, the total amount of composted material falls back to similar levels as previous years. The peak is also the reason for the sudden decrease in CH_4 and N_2O emission in 2009 compared to 2008.

7.3.3 Uncertainties and Time-Series Consistency: Biological treatment of solid waste (5B)

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted for individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four “rest” categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. 5B is not a key category and therefore its uncertainties are part of the “rest” categories with mean uncertainty for CH_4 and N_2O.

The time series are consistent.

7.3.4 Category-specific QA/QC and Verification: Biological treatment of solid waste (5B)

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2014 and for the changing rates 2013/2014).

7.3.5 Category-specific recalculations: Biological treatment of solid waste (5B)

No category-specific recalculations were carried out.

[14] Source: Mr. Bürzle, OEP, oral communication to J. Beckbissinger, Acontec, of November 23, 2010

7.3.6 Category-specific Planned Improvements: Biological treatment of solid waste (5B)

The activity data of backyard composting have been overestimated by error, i.e. 105% share of centralised composting quantity instead of 5%. This error will be corrected for submission 2017.

7.4 Source Category 5C – Incineration and open burning of waste

7.4.1 Source Category Description: Incineration and open burning of waste (5C)

Source category 5C Incineration and open burning of waste 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. However, there are emissions from some illegal waste incineration household wastes and of wastes on construction sites. They are reported under 5C2 Open burning of waste.

Table 7-8 Specification of source category5C Incineration and open burning of waste.

5C	Source	Specification
5C2	Open burning of waste	Emissions from illegal incineration of municipal solid wastes at home. Emissions from waste incneration at construction sites (open burning)

7.4.2 Methodological Issues: Incineration and open burning of waste (5C)

Methodology

For the calculation of the greenhouse gas emissions from illegal incineration of waste, a country-specific Tier 2 method is used, based on CORINAIR, adapted from the Swiss NIR (FOEN 2016).

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

Emission Factors

A constant share of fossil matter of 40% is assumed in the waste mix. The main sources of fossil CO_2 emissions are plastics.

Country-specific emission factors for CO_2, N_2O and CH_4 are adopted from the Swiss NIR (FOEN 2016, EMIS 2016/5C1 Abfallverbrennung illegal). The following table presents the emission factors used in source category 5C2.

Table 7-9 Emission Factors for 5C “Incineration and open burning of waste” (FOEN 2016).

Source	CO_2 biogen (kg/t)	CO_2 fossil (kg/t)	CH_4 (kg/t)	N_2O (kg/t)
Illegal waste incineration	510	510	6.0	0.150

Activity Data

The activity data for waste incineration 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[15]. The MSW generated (t/a) represents the amount of incinerated municipal solid waste which is exported for the purpose of incineration to Switzerland. The recycled fraction and the composted fraction are not included (OS 2016c).

Table 7-10 Activity data for source category 5C Incineration and open burning of waste[16].

5C Open burning of waste	unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
MSW generated	kt	8.00	8.02	8.04	8.06	8.08	8.10	8.12	8.14	8.16	8.18
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	kt	0.040	0.040	0.040	0.040	0.040	0.041	0.041	0.041	0.041	0.041

5C Open burning of waste	unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
MSW generated	kt	8.20	8.22	8.24	8.26	8.28	8.04	8.27	8.34	8.46	8.56
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	kt	0.041	0.041	0.041	0.041	0.041	0.040	0.041	0.042	0.042	0.043

5C Open burning of waste	unit	2010	2011	2012	2013	2014
MSW generated	kt	8.66	8.73	8.78	8.67	8.58
Fraction incinerated illegally		0.5%	0.5%	0.5%	0.5%	0.5%
Waste incinerated illegally	kt	0.043	0.044	0.044	0.043	0.043

7.4.3 Uncertainties and time-series consistency: Incineration and open burning of waste (5C)

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6.1. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four “rest” categories (CO_2, CH_4, N_2O, F-gases) with mean uncertainties according to Table 1-7. 5C is not a key category and therefore its uncertainties are part of the “rest” categories with mean uncertainty for CO_2, CH_4 and N_2O.

The time series are consistent.

7.4.4 Category-specific QA/QC and Verification: Incineration and Open Burning of Waste (5C)

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

[15] 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.

16 Source of amount of municipal solid waste (MSW) generated: Personal communication with Mrs. Heike Summer (Office of Environment) on 04.02.2016.

7.4.5 Category-specific recalculations: Incineration and open burning of waste (5C)

The N_2O emission factor has been adjusted to the IPCC default value (from 0.2 kg N_2O/t waste to 0.15 kg N_2O/t waste). The whole time serie has been recalculated.

The CO_2 non-bigenic emission factor has been adjusted to 510 kg CO_2. This adjustment is based on the assumption that open burned waste is similar in its composition to municipal solid waste. The whole time serie has been recalculated.

No other recalculations have been carried out.

7.4.6 Category-specific Planned Improvements: Incineration and open burning of waste (5C)

No category-specific improvements are planned.

7.5 Source Category 5D – Wastewater treatment and discharge

7.5.1 Source Category Description: Wastewater treatment and discharge (5D)

Key category 5D
Category 5D Wastewater treatment and discharge CH_4 is a key category regarding trend.

Source category 5D1 Domestic wastewater comprises all emissions from handling of liquid wastes and sludge from housing and commercial sources (including gray water and night soil).

Source category 5D2 Industrial wastewater comprises all emissions from the handling of liquid wastes and sludge from industrial processes such as food processing and metal processing industry. Effluents from the food industry have a high content of organic compounds. In order to reduce the load of organically polluted wastewater (and to meet the regulatory standards as well as to reduce discharge fee) the effluent is pre-treated on-site. This pre-treatment includes only a mechanical treatment (separation of solid particles). Effluents are further treated in one centralized Municipal Waste Water Treatment Plant (MWWTP) in Bendern. Two metal processors have toxic waste water which is pretreated by a mechanical and a chemical process; those effluents are then further processed in the MWWTP in Bendern as well. Toxic wastewater is disposed of in Switzerland[17]. As all industrial waste water is processed in the MWWTP in Bendern after a pre-treatment, emissions from source category 5D2 Industrial wastewater are included in 5D1 Domestic wastewater.

Wastewaters deriving from public sewer systems are treated in the MWWTP in Bendern. The cleaned water is discharged into the river Rhine. 98% of the population is connected to the MWWTP[17]. In the MWWTP in Bendern, wastewater is treated in three steps: 1. Mechanical treatment, 2. Biological treatment, and 3. Chemical treatment. The MWWTP in Bendern also produces biogas. After the anaerobic digestion, digested sewage sludge is dewatered and dried. Pellets are transported and incinerated in Switzerland (AZV 2016).

[17] Egon Hilbe, Office of Environment [personal communication 28.8.2013]

Table 7-11 Specification of source category 5D “Wastewater treatment and discharge”.

5D	Source	Specification
5D1	Domestic wastewater	Emissions from handling of liquid wastes and sludge from housing and commercial sources
5D2	Industrial wastewater	Emissions from handling of liquid wastes and sludge from industrial processes (included in 5B1)
5D3	Other	Not occurring in Liechtenstein

7.5.2 Methodological Issues: Wastewater treatment and discharge (5D)

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 wastewater treatment (5D), a country-specific method is used, in line with the former method used in the Switzerland until submission 2014 (FOEN 2014). 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 1997).

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

Emission Factors

For CH_4 it is assumed that 0.75% of the biogas (volume) is emitted as leakage (SFOE 2002). Based on measurements in wastewater treatment plants in Switzerland, a methane content of the biogas by volume of 65% is assumed. With this a country-specific emission factor of 0.0049m^3 CH_4 per m^3 of biogas results.

N_2O is derived based on the former IPCC-default method (IPCC 1997). Specific numbers for protein consumption were adopted from Switzerland. It is assumed that similar conditions prevail in Liechtenstein. Total protein consumption in Switzerland fluctuates around 37 kg/inhabitant and year. The values 1990-2014 are taken from Switzerland (FOEN 2016) According to previous submissions, an N fraction of 0.16 kg N per kg protein (FracNPR; IPCC default value) was used. Emission factors differ from year to year, and range around 93 g N_2O per inhabitant[18].

Activity Data

Activity data for CH_4 emissions is 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 the MWWTP in Bendern.

[18] Calculation: 37.12 (average protein consumption factor 1990-2011 per inhabitant and year) * 0.16 (kg N per kg protein) * 0.01 (Emission factor kgN_2O-N/kg sewage-N produced, IPCC default value) * 44/28 (According to the molecular weight of N_2O) = 0.093 kg N_2O per inhabitant.

Table 7-12 Activity data in 5D Waste water treatment and discharge: Amount of waste water treatment gas produced by the three treatment plants in Liechtenstein (OEP 2009d, AZV 2016).

Gas production		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total gas production	m^3	675'944	708'444	750'015	749'887	813'691	736'949	786'301	800'429	866'294	932'935
Balzers	m^3	44'256	44'785	42'284	46'055	42'709	43'540	48'964	50'090	48'538	49'206
Vaduz	m^3	66'024	55'745	58'464	64'464	64'436	57'713	47'703	0	0	0
Bendern	m^3	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	2007	2008	2009
Total gas production	m^3	941'707	905'828	868'172	899'829	939'399	903'804	978'237	1'053'052	1'086'338	1'026'834
Balzers	m^3	54'321	53'834	51'144	45'723	5'715	0	0	0	0	0
Vaduz	m^3	0	0	0	0	0	0	0	0	0	0
Bendern	m^3	887'386	851'994	817'028	854'106	933'684	903'804	978'237	1'053'052	1'086'338	1'026'834

Gas production		2010	2011	2012	2013	2014
Total gas production	m^3	965'254	976'295	989'242	1'056'079	1'089'363
Balzers	m^3	0	0	0	0	0
Vaduz	m^3	0	0	0	0	0
Bendern	m^3	965'254	976'295	989'242	1'056'079	1'089'363

Activity data for N_2O emissions from wastewater handling are the number of inhabitants (total, i.e. connected and non-connected) in Liechtenstein (provided in Table 4-10 in chp. 4.8.2).

7.5.3 Uncertainties and Time-Series Consistency: Wastewater treatment and discharge (5D)

The uncertainty ranges are expert estimates. The combined uncertainty is estimated to be 60%. with equal uncertainties of EF and AD, i.e. the uncertainty of the EF is 42.4% as well as the uncertainty of AD is 42.4%.

The time series are consistent.

7.5.4 Category-specific QA/QC and Verification: Wastewater treatment and discharge (5D)

The category-specific QA/QC activities have been carried out as mentioned in sections 1.2.3 including also the triple check of the CRF table Summary2 (detailed comparison of latest with previous data for the base year, for 2013 and for the changing rates 2013/2014).

7.5.5 Category-specific recalculations: Wastewater treatment and discharge (5D)

No category-specific recalculations were carried out.

7.5.6 Category-specific Planned Improvements: Wastewater treatment and discharge (5D)

No category-specific improvements are planned.

7.6 Source Category 5E – Other

No emissions are occurring in Liechtenstein under this source category

Memo items

No emissions are occurring in Liechtenstein under memo items.

8 Other

No other sources or sinks are occurring in Liechtenstein.

9 Indirect CO_2 and N_2O emissions

Based on the new IPCC 2006 Guidelines (IPCC 2006) it is not mandatory to take into account indirect CO_2 emissions. Liechtenstein decided not to report indirect CO_2 and nitrous oxide emissions. The emissions are therefore not estimated – NE. For that reason precursor substances such as NMVOC are only reported under 2D3 Other (Solvent use, road paving and asphalt roofing).

10 Recalculations

10.1 Explanations and justifications for recalculations

10.1.1 Recalculations GHG inventory

1 Energy

Recalculation in the Reference Approach

- For this submission, the lower heating values of Gasoil, Natural gas, Hard coal, LPG, Diesel oil and gasoline are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series. The time series for energy consumption and CO_2 emissions has been recalculated for 1990-2013.
- Data on consumption of natural gas are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, which leads to a recalculation for 1990-2012 (CO2).
- Gaseous fuels/Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore, in the consumption of Natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of Natural gas and Biomass for 2013 (CO2).

Recalculation in 1A1

- 1A1a Gaseous fuels, Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore in the consumption of natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of natural gas and biomass for 2013 (CO_2, CH_4, N_2O).

Recalculation in 1A2

- 1A2e Gaseous fuels: Data on consumption of natural gas are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, leading to a recalculation for 1990-2012 (CO_2, CH_4, N_2O).
- 1A2e NCV Gas oil, Natural gas: Data on net calorific values are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series (CO_2, CH_4, N_2O).
- 1A2e Gaseous fuels, Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore in the consumption of Natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of Natural gas and Biomass for 2013 (CO_2, CH_4, N_2O).

Recalculation in 1A3

- 1A3b Gaseous fuels, Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore in the consumption of natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of natural gas and biomass for 2013.
- 1A3bi Gaseous fuels: The emission factor for N_2O has been changed to 3.0 kg/TJ according to the default value for mobile combustion in the IPCC 2006 Guidelines, leading to a recalculations for the years between 1990 and 2013.

Recalculation in 1A4

- 1A4a / 1A4b Gaseous fuels: Data on consumption of natural gas are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, which leads to a recalculation for 1990-2012 (CO_2, CH_4, N_2O).
- 1A4b Biomass: The CH_4 emission factor for wood combustion was adapted from 350 to 300 kg/TJ based on IPCC 2006 Guidelines. The conversion from gas volumes to energy units is now based on the lower heating value (instead of the upper heating value) (CH_4).
- 1A4b Biomass: Activity data for wood combustion are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, which leads to a recalculation for 1990-2012 (CH_4, N_2O).
- 1A4b Gaseous fuels/Biomass: Due to new information from Liechtenstein's gas utility (LGV) regarding the partitioning of gaseous fuels and biomass to different sectors, the entire time series 1990-2013 were recalculated (CO_2, CH_4, N_2O).
- 1A4a/1A4b Gaseous fuels/Biomass: Since November 2013, biogas is produced from sewage gas and fed into the general gas network. Therefore in the consumption of natural gas the biogenic share has to be accounted for, thus leading to a recalculation of the activity data of Natural gas and Biomass for 2013 (CO_2, CH_4, N_2O).
- 1A4a / 1A4b NCV Gasoil, natural gas, hard coal, LPG: Data on net calorific values are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series (CO_2, CH_4, N_2O).

Recalculation in 1B2

- 1B2 Gaseous fuels: Data on consumption of natural gas are taken from the energy statistics of Liechtenstein (OS 2015a) for the entire time series, leading to a recalculation for 1990-2012 (CH_4).

2 IPPU

- 2F1 Refrigeration and air conditioning: The number of households in 2010 was updated based on the population census data from 2010, which results in updated interpolated values since 2001 (chp. 4.7.5).

For Switzerland, the following recalculations have been carried out, which also influence Liechtenstein's emission time series:

- 2F1 Refrigeration and air conditioning: Optimizations of model calculations including number of vehicles in the model of mobile air conditioning of van, extrapolation of emission factor for stationary air conditioning equipment, changes of refrigerant blend applied in transport refrigeration of trains (chp. 4.7.5).

3 Agriculture

- 3D/3H: The nitrogen-flows from commercial fertilisers were adapted according to the Swiss agriculture model (Swiss NIR 2015), leading to an increase in the years 1990-2013.
- 3D/3H: A slight adaptation of the area of agricultural land in the Swiss agriculture model (Swiss NIR 2015) is adopted in Liechtenstein's NIR 2016.

4 LULUCF

- 4A: For the year 2013 a minor calculation error was corrected.

5 Waste

- 5A: The CH_4 emission value for the year 2013 was wrong in the CRF Table5 and Table5.A (0.00307 kt instead of 0.00280 kt). This mistake has been corrected.
- 5B: No category-specific recalculations were carried out.
- 5C: The N_2O emission factor has been adjusted to the IPCC default value (from 0.2 kg N_2O/t waste to 0.15 kg N_2O/t waste). The whole time serie has been recalculated.
- 5C: The CO_2 non-bigenic emission factor has been adjusted to 510 kg CO_2. This adjustment is based on the assumption that open burned waste is similar in its composition to municipal solid waste. The whole time serie has been recalculated.

10.1.2 Recalculations KP-LULUCF

- Forest Management: As shown in chp. 11.3.1.1 the loss in living biomass is calculated annually based on harvesting statistics. In former submissions, constant mean values were used for all years. Please note, that for the LULUCF reporting (CRF Table 4A) the constant values are still used in this submission.
- The forest management cap is now calculated with a factor of 8. In the former submission the factor was 1.
- Forest Management Reference Level (FMRL): a new correction was made related to the carbon stock change in living biomass (correction of forest area), see chp. 11.7.

10.2 Implications for emission levels 1990 and 2013

10.2.1 Implications emission levels for GHG inventory

Table 10-1 shows the recalculation results for the base year **1990**. The recalculations have the following effect on the emissions in 1990 in comparison with the submitted emissions of the previous year:

- The difference in the national total emissions amounts to a total decrease of 0.4 kt CO_2eq (0.2%) without emissions/removals from LULUCF.
- Including LULUCF the difference in the national total emissions amounts to a total decrease of 0.4 kt CO_2eq (0.2%).

Table 10-1 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submission in 2015 "Prev." (OE 2015b) and after the recalculation according to the present submission "Latest". The differences "Differ." are defined as latest minus previous submission. Where differences appear, cells are highlighted in grey.

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 (kt)									CO_2 equivalent (kt)		
1 Energy	199.2	198.7	-0.5	1.3	1.3	0.0	1.1	1.1	0.0	201.6	201.1	-0.6
2 IPPU (without F-gases)	NO	NO	NO	NO	NO	NO	0.5	0.5	0.0	0.5	0.5	0.0
3 Agriculture	0.0	0.1	0.0	16.7	16.7	0.0	8.5	8.7	0.2	25.3	25.5	0.2
4 LULUCF	4.3	4.3	0.0	NO	NO	NO	0.3	0.3	0.0	4.6	4.6	0.0
5 Waste	0.0	0.0	0.0	1.1	1.1	0.0	0.9	0.9	0.0	2.0	2.0	0.0
Sum (without F-gases)	203.6	203.0	-0.5	19.1	19.1	0.0	11.3	11.5	0.2	234.0	233.6	-0.4

Recalculation	HFC			PFC			SF_6			Sum (F-gases)		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and sink categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
2 IPPU (F-gases only)	0.0	0.0	0.00	NO	NO	NO	NO	NO	NO	0.0	0.0	0.00

Recalculation		Sum (all gases)		
Emissions for 1990		Prev.	Latest	Differ.
Source and sink categories		CO_2 equivalent (kt)		
Total CO_2 eq Em. with LULUCF		**234.0**	**233.6**	**-0.4**
		100.0%	99.8%	-0.2%
Total CO_2 eq Em. without LULUCF		**229.4**	**229.0**	**-0.4**
		100.0%	99.8%	-0.2%

For **2012**, the recalculations result in a decrease of the total emissions of 2.0 kt CO_2eq (0.8%) without emissions/removals from LULUCF. Including LULUCF the recalculations lead to a decrease of 2.0 kt CO_2eq (0.8%).

Table 10-2 Overview of implications of recalculations on 2013 data. Emissions are shown before the recalculation according to the previous submission in 2015 “Prev.” (OE 2015b) and after the recalculation according to the present submission “Latest”. The differences “Differ.” are defined as latest minus previous submission. Where differences appear, cells are highlighted in grey.

Recalculation	CO_2			CH_4			N_2O			Sum (CO_2, CH_4 and N_2O)		
Emissions for 2013	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and sink categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
1 Energy	194.6	192.8	-1.8	2.2	2.1	-0.1	0.9	0.9	0.0	197.8	195.9	-1.9
2 IPPU (without F-gases)	NO	NO	NO	NO	NO	NO	0.2	0.2	0.0	0.2	0.2	0.0
3 Agriculture	0.0	0.0	0.0	16.0	16.0	0.0	7.9	8.0	0.2	23.9	24.0	0.2
4 LULUCF	11.3	11.3	0.0	NO	NO	NO	0.5	0.5	0.0	11.7	11.7	0.0
5 Waste	0.0	0.0	0.0	1.0	1.1	0.1	1.2	1.2	0.0	2.3	2.3	0.0
Sum (without F-gases)	206.0	204.1	-1.8	19.2	19.2	0.0	10.6	10.8	0.2	235.8	234.1	-1.7

Recalculation	HFC			PFC			SF_6			Sum (F-gases)		
Emissions for 2013	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and sink categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
2 IPPU (F-gases only)	12.2	12.0	-0.3	0.1	0.1	0.0	0.2	0.2	0.0	12.5	12.2	-0.3

Recalculation		Sum (all gases)		
Emissions for 2013		Prev.	Latest	Differ.
Source and sink categories		CO_2 equivalent (kt)		
Total CO_2 eq Em. with LULUCF		**248.3**	**246.3**	**-2.0**
		100.0%	99.2%	-0.8%
Total CO_2 eq Em. without LULUCF		**236.5**	**234.6**	**-2.0**
		100.0%	99.2%	-0.8%

10.2.2 Implications emission levels for KP-LULUCF

Table 10-3 shows the differences in the KP-LULUCF tables on emissions/removals in 2013.

Table 10-3 Overview of implications of recalculations on 2013 data for KP-LULUCF. Emissions are shown according to the previous submission (OE 2016a), and after the recalculation according to the present submission “Latest”.

Source and Sink Categories	**CO_2 equivalent (kt)**		
	Previous	Latest	Difference
Afforestation	-0.261	-0.261	0.000
Deforestation	4.386	4.386	0.000
Forest Management	2.429	5.232	2.804
Harvested Wood Products	-1.426	-1.426	0.000
Total emission/removal	5.127	7.931	2.804

10.3 Implications for emissions trends, including time series consistency

10.3.1 Implications trends GHG inventory

Due to recalculations, the emission trend 1990–2013 reported in the 2015 submission has changed. The 2013 emission trend (national total without emissions/removals from LULUCF) showed an increase of 3.11% before recalculation (previous submission). After recalculation, the trend is slightly lower: 2.42% (latest submission).

Table 10-4 Change of the emission trend 1990–2013 due to recalculations. “Previous” refers to the values from the re-submission 2015 (OE 2015b)

Recalculation	**1990**		**2013**		**change 1990/2013**	
Submission	previous	latest	previous	latest	previous	latest
	CO_2 eq (kt)				%	
Total excl. LULUCF	229.39	229.03	236.53	234.57	3.11%	2.42%

All time series in the present submission are consistent.

10.3.2 Implications trends KP-LULUCF

The recalculations shown in Table 10-3 (year 2013) are relevant for trends in KP-LULUCF as the year 2013 is covered by the 2nd CP. The years 2008-2012 are not mandatory and are only reported to improve transparency. Nevertheless, the years 2008-2014 form consistent time series.

10.4 Recalculations in response to the review process and planned improvements

10.4.1 Recalculations GHG Inventory

The NIR of the previous submission (OE 2016a) contains the history of the recommendations and encouragements of the ERT in the past review processes up to the last review in 2014 (see chp. 1.2.3.2 QA/QC plan on pp. 31-35 in OE 2016a), showing which recommendations had been implemented. Planned improvements for the submission 2017 – partly motivated by the ERT review process – are indicated in the corresponding sectoral chapters of this NIR, and recommendations and encouragements, which are not yet implemented or which will not be implemented, see updated list in Annex 8.3 of this NIR.

10.4.2 Recalculations KP-LULUCF

See Chapter 10.1.2

PART 2
Supplementary Information Required under Article 7, Paragraph 1

11 KP – LULUCF

The information in this chapter is provided in accordance with the Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014) and based on the information given in Liechtenstein’s Initial Report for the second commitment period (OE 2016).

Liechtenstein will choose to account over the entire commitment period for emissions and removals from the KP-LULUCF sector (OE 2016).The decision remains fixed for the entire second commitment period. In addition to the mandatory submission of the inventory years 2013-2014, data for the years 2008-2012 are available and shown in Liechtenstein's NIR. Liechtenstein accounts for the mandatory activity Forest Management under Article 3, paragraph 4 of the Kyoto Protocol.

Table 11-1 (CRF Table NIR-1) shows the activity coverage and the carbon pools reported for the activities under Article 3, paragraph 3 and Forest Management under paragraph 4 of the Kyoto Protocol. The area and area changes between the previous and the current inventory year are shown in Table 11-2 (CRF Table NIR-2). Table 11-3 (NIR-3) presents KP key categories. Table 11-4 is an overview of results related to KP in 2014.

Table 11-1 The table contains information of country-specific activities under Articles 3.3 and 3.4 (KP(LULUCF) NIR 1)

TABLE NIR 1. SUMMARY TABLE

Activity coverage and other information relating to activities under Article 3, paragraph 3, forest management under Article 3.4, and elected activities under Article 3.4

Activity	CHANGE IN CARBON POOL REPORTED[(1)]							GREENHOUSE GAS SOURCES REPORTED[(2)]							
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP[(4)]	Fertilization[(5)]	Drained, rewetted and other soils[(6)]		Nitrogen mineralization in mineral soils[(8)]	Indirect N_2O emissions from managed soil[(5)]	Biomass burning[(9)]		
					Mineral	Organic[(3)]		N_2O	CH4[(7)]	N_2O	N_2O	N_2O	CO_2[(10)]	CH_4	N_2O
Article 3.3 activities															
Afforestation and reforestation	R	R	NR	NR	R	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Deforestation	R	R	R	R	R	NO	IO	NO	NO	NO	R	NO	NO	NO	NO
Article 3.4 activities															
Forest management	R	R	NR	NR	NR	NO	R	NO	NO	NO	NO	NO	NO	NO	NO
Cropland management	NA	NA	NA	NA	NA	NA			NA		NA		NA	NA	NA
Grazing land management	NA	NA	NA	NA	NA	NA			NA		NA		NA	NA	NA
Revegetation	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
Wetland drainage and rewetting	NA	NA	NA	NA		NA		NA	NA	NA		NA	NA	NA	NA

(1) Indicate R (reported), NR (not reported), IE (included elsewhere) or NO (not occurring), for each relevant activity under Article 3.3, forest management or any elected activity under Article 3.4, or instantaneous oxidation (IO) for carbon stock changes in harvest wood products (HWP). With the exception of HWP, if changes in a carbon pool are not reported , verifiable information in the national inventory report (NIR) must be provided that demonstrates that these unaccounted pools were not a net source of anthropogenic greenhouse gas emissions. Indicate NA (not applicable) for each activity that is not elected under Article 3.4. Explanation about the use of notation keys should be provided in the NIR.

(2) Indicate R (reported), NE (not estimated), IE (included elsewhere) or NO (not occurring) for greenhouse gas sources reported, for each relevant activity under Article 3.3, forest management or any elected activity under Article 3.4. Indicate NA (not applicable) for each activity that is not elected under Article 3.4. Explanation about the use of notation keys should be provided in the NIR.

(3) Includes CO_2 emissions/removals from organic soils, including CO_2 emissions from dissolved organic carbon associated with drainage and rewetting. On-site CO_2 emissions/removals from drainage and rewetting from organic soils and off-site CO_2 emissions via water-borne carbon losses from organic soils should be reported here for wetland drainage and rewetting. These emissions could be reported for other activities as appropriate.

(4) HWP from lands reported under deforestation, which originated from the deforestation event at the time of the land-use change shall be accounted for on the basis of instantaneous oxidation (IO).

(5) N_2O emissions from fertilization of afforestation/reforestation, deforestation, forest management, revegetation and wetland drainage and rewetting should be reported here when these emissions are not reported under the agriculture sector.

(6) CH_4 and N_2O emissions from drained and rewetted organic soils should be reported here, as appropriate, when emissions are not reported under the agriculture sector. For wetland drainage and rewetting only emissions from organic soils are included.

(7) CH_4 emissions from drained soils and drainage ditches should be reported here, as appropriate.

(8) N_2O emissions from nitrogen mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils under afforestation/reforestation, deforestation, forest management, cropland management, grazing land management and revegetation should be reported here when these emissions are not reported under the agriculture sector.

(9) Emissions from burning of organic soils should also be included here, as appropriate.

(10) If CO_2 emissions from biomass burning are not already included under changes in carbon stocks, they should be reported under biomass burning. Parties that include CO_2 emissions from biomass burning in their carbon stock change estimates

Table 11-2 KP(LULUCF) NIR 2 - Land Transition Matrix 2014.

Table NIR 2. LAND TRANSITION MATRIX

Areas and changes in areas between the previous and the current inventory year[(1), (2)]

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES						
	Afforestation and reforestation	Deforestation	Forest management[(5)]	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)	Other[(6)]	Total area at the end of the previous inventory year[(7)]
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	0.04	NO							0.04
Deforestation		0.17							0.17
Article 3.4 activities									
Forest management		0.01	6.13						6.13
Cropland management[(3)] (if elected)	NA		NA	NA	NA	NA	NA		NA
Grazing land management[(3)] (if elected)	NA		NA	NA	NA	NA	NA		NA
Revegetation[(3)] (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting[(3)] (if elected)	NA		NA	NA	NA	NA	NA		NA
Other[(4)]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total area at the end of the current inventory year	0.04	0.18	6.13	NA	NA	NA	NA	NA	6.34

(1) This table should be used to report land area and changes in land area subject to the various activities in the inventory year. For each activity it should be used to report area change between the end of the previous inventory year and the end of the current inventory year. For example, the total area of land subject to forest management in the previous inventory year and which was deforested in the current inventory year, should be reported in the

(2) In accordance with relevant decisions. Some of the transitions in the matrix are not possible and the cells concerned have been shaded.

(3) Lands subject to cropland management, grazing land management, revegetation or wetland drainage and rewetting that after 2013 are subject to activities other than those under Article 3.3 and 3.4, should still be tracked and

(4) Other refers to the area that is reported under Article 3.3 or 3.4 in the current inventory for the first time. This footnote does not apply to the cell belonging to the column and the row "other" to "other".

(5) Changes in area from cropland management, grazing land management, revegetation and wetland drainage and rewetting to forest management should be reported only in the case of carbon equivalent forest conversions.

(6) "Other", in this column, is the area of the country that has never been subject to any activity under Article 3.3 or 3.4

(7) The value in the cell of row "Total area at the end of the current inventory year" corresponds to the total land area of a country. The total land area should be the same for the current inventory year and the previous inventory year

Table 11-3 KP(LULUCF) NIR 3 – Key Categories.

FORESTRY
ACTIVITIES UNDER THE KYOTO PROTOCOL

KEY CATEGORIES OF EMISSIONS AND REMOVALS	Gas	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			Comments[(4)]
		Associated category in UNFCCC inventory[(1)] is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory[(2)] (including LULUCF)	Other[(3)]	
Specify key categories according to the national level of disaggregation used[(1)]					
Afforestation	--	--	no		is not key
Deforestation	CO2	4C2, 4E2	yes		is key, level & trend
Forest Management	CO2	--	yes		is key
Harvest Wood Products	CO2	4G	yes		is key, level & trend

(1) See section 2.3.6 of the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol.
(2) If the emissions or removals of the category exceed the emissions of the smallest category identified as key in the UNFCCC inventory (including LULUCF), Parties should indicate YES. If not, Parties should indicate NO.
(3) This should include qualitative assessment as per section 4.3.3 of the 2006 IPCC Guidelines or any other criteria.
(4) Indicate the criteria (level, trend of both) identifying the category as key.

Table 11-4 Overview on net CO_2 equivalent emissions (positive sign) and removals (negative sign) for activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol in 2014.

Activity, year 2014	**Area** kha	**Net CO_2 emission/removal** kt CO_2	**N_2O emission** kt N_2O	**Net CO_2 eq emission/removal** kt CO_2 eq
A.1 Afforestation	0.036	-0.27	NO	-0.27
A.2 Deforestation	0.174	4.32	0.00021	4.38
B.1 Forest managment (FM)	6.127	5.14	NO	5.14
B.1.1 minus FMRL	---	-0.36	NO	-0.36
4.C HWP from FM	---	-1.40	NO	-1.40
Total emission/removal		7.42	0.00021	7.49

11.1 General information

The inventory datasets on which the calculations are based (Land Use Statistics AREA and National Forest Inventory NFI) are described in Chapters 6.2, 6.3 and 6.4.2.1, respectively.

11.1.1 Definition of forest and any other criteria

For activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol, the Marrakech Accords (in the annex to decision 16/CMP.1) list the definitions to be specified by Parties. Liechtenstein's definitions for Forest, Afforestation and Deforestation are specified in the corrigendum to Liechtenstein's Initial Report (OEP 2007b, see there in chp. 4) and is still valid for the second commitment period: Liechtenstein applies the forest definition of the Swiss Land Use Statistics (AREA) of the Swiss Federal Statistical Office. AREA provides an excellent data base to derive accurate, detailed information of not only forest areas, but all types of land use and land cover. Thus, AREA offers a comprehensive, consistent and high quality data set to estimate the surface area of the different land use categories in reporting under the Kyoto Protocol. For Liechtenstein, the Land Use Statistics has been built up identically to Switzerland (same method and data structures, same realisation):

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

In Liechtenstein's Initial Report, the following precisions are stated (OEP 2006a, p.20f.):

The following forest areas are not subject to the criterion of minimum stand height: shrub forest consisting of dwarf pine (Pinus mugo prostrata) and alpine alder (Alnus viridis).

The following forest areas are not subject of the criteria of minimum stand height **and** minimum crown cover, but must have the potential to achieve both criteria:

a) afforested area on land not under forest cover for 50 years (afforestations);
b) regenerated forest, as well as burned, cut or damaged areas situated on land classified as forest.

Although orchards, parks, camping grounds, open tree formations in settlements, gardens, cemeteries, sports and parking fields may fulfil the (quantitative) forest definition, they are not considered as forests.

11.1.2 Elected activities under Article 3, Paragraph 4, of the Kyoto Protocol

Liechtenstein will account for the mandatory activity Forest Management under Article 3, paragraph 4 of the Kyoto Protocol. In accordance with Annex I to Decision 2/CMP.7 (Annex I, Para 13), credits from Forest Management are capped in the second commitment period. For Liechtenstein, the cap amounts to 3.5% of the 1990 emissions (excluding LULUCF).

11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over Time

Liechtenstein's definitions of Afforestation, Deforestation and Forest Management are published in its first Initial Report. These definitions are still valid for the second commitment period.

11.1.3.1 Afforestation

Definition: Afforestation is the conversion to forest of an area not fulfilling the definition of forest for a period of at least 50 years if
(a) the definition of forest in terms of minimum area (625 m^2) is fulfilled, and
(b) the conversion is a direct human-induced activity.

Natural forest regeneration due to abandonment of agricultural land is not considered to be a direct human-induced activity.

The area of forest land reported for Afforestation under the Kyoto Protocol is equal to the area reported for Land use changes to forest type CC11 (see Chapter6.2.1). I.e., afforestation areas in Liechtenstein are identified by aerial photographs which form the basis of Liechtenstein's Land-Use Statistics. In afforestations, the trees are planted in regular patterns, which may easily be recognised in the identification process. Afforestations since 1990 were not subject to harvesting or clear cutting, since there are no forests with such short rotation lengths. For reporting under the Kyoto Protocol, afforested areas always remain in the "afforestation" category. Therefore, the area of afforestation is increasing since 1990.

11.1.3.2 Deforestation

Definition: Deforestation is the permanent conversion of areas fulfilling the definition of forest in terms of minimum forest area (625 m^2) to areas not fulfilling the definition of forest as a consequence of direct human influence.

Deforestation is prohibited by the National Law on Forests with article 6 (Government 1991). Exceptions need governmental authorisation. The authorisation documents are collected by the formerly Office of Forest, Nature and Landscape (OFNLM) now also part of the Office of Environment and are annually reported to the Parliament. To ensure that the total area of forest does not decrease, areas affected by direct human-induced deforestation have to be compensated, mainly by afforestation of the same spatial extent but not at the same location.

However, forested lands are also converted to non-forested land by natural disturbances. According to IPCC (2014) "natural disturbance followed by land-use change will prevent regeneration of forest and is classified as Deforestation". Therefore, the areas converted from Forest Land to Cropland, Grassland, Wetlands or Settlements (LULUCF categories 4B2, 4C2, 4D2 and 4E2) are reported as Deforestation. The areas converted from Forest Land to Other Land (LULUCF category 4F2) are not reported under KP-LULUCF Deforestation because: (1) these conversions are most likely not directly human induced; and (2) there is no human activity in the converted areas that would prevent regeneration (in Liechtenstein, other land consists of unmanaged areas without soil (e.g. rocks, sand, scree and glaciers).

Furthermore, an analysis of Liechtenstein's land-use data from the AREA surveys of 1996, 2002 and 2008 revealed that 6% of the area deforested between 1996 and 2002 was not permanent as it was forest again in 2008. This means that a reduction of crown coverage visible in the aerial photographs in 2002 led to the use of a non-forest code but natural regeneration led to a forest code again in the 2006 survey. Thus, Liechtenstein does not report the areas with these short-term reductions of crown coverage under the KP-LULUCF activities on the grounds that: (1) if the crown cover reduction resulted from natural hazards the land-use change was not directly human induced and the following land use did not prevent regeneration of the forest; and (2) if the crown cover reduction was directly human induced it should be classified as "management interventions" rather than as real land-use change, because the intervention did not lead to a land-use change in the long term.

It must be noted that the estimates for Deforestation based on 4B2, 4C2, 4D2 and 4E2 areas are probably an overestimation, because they include areas that do not meet the criteria for deforestation under the Kyoto Protocol, but which cannot be quantified at the moment, such as: areas with temporarily limited tree loss where natural regeneration (which is a common practice of forest management in Liechtenstein) is expected, but could not yet be recognized in the aerial photographs at the time the AREA survey was conducted; areas smaller than the minimum area of 625 m^2; and areas with a reduction in forest cover on the grid point of the forest inventory but still fulfilling the Kyoto Protocol definition of forest (i.e. having the potential to reach 3 m at maturity in situ).

11.1.3.3 Reforestation

Reforestation does not occur in Liechtenstein (see Sect. 11.4.1).

11.1.3.4 Forest Management

Forest Management includes all activities serving the purpose of fulfilling the National Law on Forests (Landesregierung 1991, Art. 1), i.e. the obligation to conserve forests and to ensure forest functions –

such as wood production, protection against natural hazards, preservation of biodiversity, purification of drinking water and maintenance of recreational value – in a sustainable manner.

Since all forests in Liechtenstein are subject to forest management, the area of managed forest corresponds to the forest area derived from the Liechtenstein's Land Use Statistics AREA (EDI/BFS 2009).

11.1.4 Description of precedence conditions and/or hierarchy among 3.4. activities and how they have been consistently applied in determining how land was classified

Since Liechtenstein only accounts for Forest Management from the activities of Article 3, paragraph 4 of the Kyoto Protocol, the hierarchy among 3.4 activities does not affect the reporting.

11.2 Land-related information

11.2.1 Spatial assessment unit used for determining the area of the units of land

The spatial assessment unit for the submission of the KP LULUCF tables covers the entire territory of Liechtenstein (16.050 kha).

All activity data for reporting the activities under the Kyoto Protocol are retrieved from Liechtenstein's Land Use Statistics AREA (EDI/BFS 2009; see also Chapter 6.3.1). The AREA surveys (SFSO 2006a) use a georeferenced sample grid with a grid size of 100 m by 100 m. To each grid point a specific combination category is assigned.

11.2.2 Methodology used to develop the land transition matrix

The methodology used to develop the land transition matrix is described in detail in Chapter 6.3.

11.2.3 Maps / database to identify the geographical locations and the system of identification codes for the geographical locations

All Afforestations and Deforestations are accounted for under Article 3, paragraph 3 and are not reported under Forest Management under Article 3, paragraph 4. Afforestations older than the conversion period of 20 years, are still reported under Afforestations: CRF-table 4(KP-I)A.1. The calculation of changes in carbon stocks is described in Chapter 11.3.1.1. The changes in areas between the activities under Article 3, paragraph 3 and Article 3, paragraph 4 are listed in KP-Table NIR2 (see Table 11-2).

Forest areas under Forest Management are subdivided into productive forests (CC12) and unproductive forests (CC13; for a description see chp. 6.4.2.3). Productive forests reveal a high heterogeneity in terms of elevation, growth conditions and tree species composition (see chp. 6.2.2). Therefore, Liechtenstein has been stratified into three altitudinal zones (Z1: <601 m, Z2: 601-1200 m, Z3: >1200 m) and two soil types (mineral soils and organic soils; forests are all on mineral soils). Carbon gains and losses are calculated separately in the three altitudinal zones.

11.3 Activity-specific information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

11.3.1.1 Description of the methodologies and the underlying assumptions used

General assumptions

For calculating the shares of above ground biomass and below ground biomass, root-to-shoot ratios given by Brändli (2010, Table 095) for the Swiss NFI-region 3, were used. The average ratio of the three altitude zones is 0.33. This value was used for afforestation, deforestation and forest management.

For calculating carbon stock changes in Afforestation and Deforestation the gains/losses of living biomass and the carbon stock-differences in soils and litter as described in Chapter 6.4.2 are used. Although these carbon values are based on studies and surveys carried out in Switzerland, they are perfectly compatible with the activity data collected in Liechtenstein (AREA, see Chapter 6.2), because (1) the land-use categories are defined in the same way and the same nomenclature (SFSO 2006a) and (2) the topographic, climatic and geological conditions in Liechtenstein are very similar to the Region 3 (Pre-Alps) of the Swiss NFI. Region 3 is situated adjacently along the Western border of Liechtenstein. Data related to dead wood and data related to gain/loss of living biomass in Forest Management were taken from Liechtenstein's own NFI (LWI 2012).

Afforestations

For afforestations ≤20 years old, gross growth of living biomass (carbon stock change in above and below ground biomass) was calculated with the growth rates of land-use category CC11 given in Table 6-4 and chp. 6.4.2.5. For afforestations >20 years old, growth in living biomass from category CC12 was used. Cut and mortality (loss) of living biomass is assumed to be zero in these young forests.

In Liechtenstein, afforestations mostly occur on grasslands by planting young trees. It is assumed that the soil carbon content increases with the developing young forest. The soil carbon stock changes due to afforestation are calculated according to Equation 6.3 (chp. 6.1.3) assuming a land-use change from grassland (CC31) to CC11 with W_s=1.

I.e. for afforestations ≤20 years old the increase in soil carbon is calculated with the stock-difference approach. The soil carbon stocks are different for the three altitude zones z1, z2 and z3 (≤ 600 m, 601-1'200 m, > 1'200 m) (Table 6-4). The resulting increase in soil carbon is evenly distributed over the IPCC default conversion time (CT) of 20 years, giving an evenly distributed yearly increase in soil carbon stock to move from the soil carbon stock level of grasslands to the level of forests.

For afforestations >20 years old, no carbon stock change in soil is assumed.

For all afforestations, it is assumed that there is no change in litter (LFH soil horizons) and no change in dead wood. These are conservative assumptions as the non-forest land-use types do not have any litter or dead wood pools. This is a conservative estimate (in terms of IPCC good practice: IPCC 2006, chp. 4.3.2).

The afforested areas (CC11) were calculated by the methods shown in chp. 6.2. The areas of afforestation are given in the land-use change-matrices (see example in Table 6-7). Table 11-5 summarises all areas per year and the cumulative areas used for calculating carbon fluxes under this activity.

Table 11-5 Area and cumulative area of afforestations (CC11) 1990-2014. The cumulative area is calculated (1) over 20 years since 1990, (2) for afforestation older than 20 years and (3) total cumulated afforestations since 1990. Units: ha.

	altitude zone				cumulated		
Year	z1	z2	z3	total	≤ 20 years	>20 years	total
1990	1.00	0.08	2.08	3.17	3.17		3.17
1991	1.00	0.08	2.08	3.17	6.33		6.33
1992	1.00	0.08	2.08	3.17	9.50		9.50
1993	1.00	0.08	2.08	3.17	12.66		12.66
1994	1.00	0.08	2.08	3.17	15.83		15.83
1995	1.00	0.08	2.08	3.17	19.00		19.00
1996	1.00	0.08	2.08	3.17	22.16		22.16
1997	0.50	0.50	0.50	1.50	23.66		23.66
1998	0.50	0.50	0.50	1.50	25.17		25.17
1999	0.50	0.50	0.50	1.50	26.67		26.67
2000	0.50	0.50	0.50	1.50	28.17		28.17
2001	0.50	0.50	0.50	1.50	29.67		29.67
2002	0.50	0.50	0.50	1.50	31.17		31.17
2003	0.00	0.17	0.33	0.50	31.68		31.68
2004	0.00	0.17	0.33	0.50	32.18		32.18
2005	0.00	0.17	0.33	0.50	32.68		32.68
2006	0.00	0.17	0.33	0.50	33.18		33.18
2007	0.00	0.17	0.33	0.50	33.68		33.68
2008	0.00	0.17	0.33	0.50	34.18		34.18
2009	0.00	0.17	0.17	0.33	34.51		34.51
2010	0.00	0.17	0.17	0.33	31.68	3.17	34.85
2011	0.00	0.17	0.17	0.33	28.85	6.33	35.18
2012	0.00	0.17	0.17	0.33	26.02	9.50	35.52
2013	0.00	0.17	0.17	0.33	23.19	12.66	35.85
2014	0.00	0.17	0.17	0.33	20.35	15.83	36.18

Deforestations

The carbon stock changes due to deforestation are calculated according to Equations 6.1-6.3 (see chp. 6.1.3.2) applying the stock-difference approach with the carbon contents shown in Table 6-4.

The carbon stock changes in living biomass, litter and dead wood are taken from the CRF Tables 4B2, 4C2, 4D2 and 4E2 applying also the correction of minus 6% for non-permanent deforestation (see Chapter 11.1.3.2).

The N_2O emissions arising from nitrogen mineralization on deforested soils are taken from CRF Table 4(III). The method for calculating those emissions is described in chp. 6.10.

Forest Management

Carbon stock changes in living biomass for productive forests (CC12) are calculated with the gain-loss approach. The values for gain (gross growth) were derived from Liechtenstein's National Forest Inventory (NFI, LWI 2012); they represent the average of the period 1998-2010 (see Table 6-4 and chp. 6.4.2). For calculating the loss, annual harvesting statistics (Table 11-6) are used in addition to the NFI results as follows:

- The relative harvesting rates are calculated as the ratio of the yearly harvesting to the average harvesting of the NFI period 1999-2010 (see Table 11-6).
- According to the NFI (period 1999-2010), the average cut is 5.65 m^3 ha^{-1} yr^{-1} and the average mortality is 2.70 m^3 ha^{-1} yr^{-1}. The total loss is 8.35 m^3 ha^{-1} yr^{-1}. With this information the carbon stock losses derived from the NFI (Table 6-4) were split in the two parts cut and mortality as shown in Table 11-7.

- The annual losses per altitude zone were calculated assuming that the annual cut is proportional to the relative harvesting factor (see able 11-6) and that mortality does not depend on the harvesting rate:
  annual loss = (relative harvesting) * (average cut) + (average mortality)

The resulting annual loss is shown in Table 11-7.

Table 11-6 Wood harvesting statistics for Liechtenstein's forest 1986-2014 and the annual harvesting relative to the reference period of the NFI (1999-2010). Source: OE 2015d.

Year	Harvesting m^3	Relative harvesting
1986	18'143	
1987	13'194	
1988	13'843	
1989	13'479	
1990	20'024	
1991	10'333	
1992	16'853	
1993	14'759	
1994	26'315	
1995	18'087	
1996	12'970	
1997	19'527	
1998	14'537	
1999	13'538	
2000	28'683	
2001	14'477	
2002	14'755	
2003	17'016	
2004	18'169	
2005	18'038	
2006	20'776	
2007	26'099	
2008	27'217	1.314
2009	25'364	1.224
2010	24'436	1.180
2011	26'664	1.287
2012	26'813	1.294
2013	22'316	1.077
2014	22'262	1.075
Mean 1999-2010	20'714	

Table 11-7 (a) Splitting total carbon stock loss (NFI, mean 1999-2010) into cut and mortality and (b) calculated annual losses 2008-2014 for the three altitude zones (≤ 600 m, 601-1200 m, > 1200 m). Units: t C ha^{-1} yr^{-1}

(a) Average 1999-2010:

Altitude	Total loss	Mortality	Cut
zone 1	-3.49	-1.13	-2.36
zone 2	-2.96	-0.96	-2.01
zone 3	-2.39	-0.77	-1.62

(b) Annual loss:

Altitude	2008	2009	2010	2011	2012	2013	2014
zone 1	-4.23	-4.02	-3.92	-4.17	-4.19	-3.68	-3.67
zone 2	-3.59	-3.41	-3.33	-3.54	-3.56	-3.12	-3.11
zone 3	-2.90	-2.76	-2.68	-2.86	-2.87	-2.52	-2.51

Carbon stocks in soil, litter and dead wood of productive forests (CC12) are assumed to be constant (see chp. 6.4.2). On unproductive forest land (CC13), all carbon pools are constant (see chp. 6.4.2.3).

11.3.1.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

KP-LULUCF Table NIR 1 (see Table 11-1) summarizes the activity coverage and the pools reported. When using the conservative Tier 1 approach (IPCC 2006 Volume 4, Chapter 1.3) assuming a specific carbon pool to be in carbon balance, the carbon pool is indicated as not reported (NR). This is the case for litter, dead wood and mineral soil in afforestations and under forest management.

For grasslands (the most common land-use type before afforestation) there is no litter and no dead wood and a lower soil carbon stock than in forests. Because an increase of carbon in these pools is expected after a conversion from grasslands to forests by afforestation (compare Table 6-4) a Tier 1 approach has been considered in terms of IPCC good practice (IPCC 2006) and no changes (NR) in the litter, soil and dead wood pools for afforestations has been reported.

For forest management (CC12), no data related to carbon stock changes in litter, mineral soil and dead wood are available for Liechtenstein. Therefore, data from Switzerland's were inspected (FOEN 2015 – Figure 6-5), that were modelled with Yasso07 (Didion 2014). The results show that the changes in mineral soils are close to zero (-0.001 t C ha^{-1} yr^{-1}) and that the changes in litter and dead wood fluctuate approximately between -0.1 and 0.1 t C ha^{-1} yr^{-1}. Overall, these pools together were a sink for every year since 1997 (except in 2008 they were a small source of 0.01 t C ha^{-1} yr^{-1}). On this ground, a Tier 1 approach has been considered in terms of IPCC good practice (IPCC 2006) and no changes (NR) in the litter, soil and dead wood pools for forest management has been reported.

Fertilisation, drainage of soils, and biomass burning are not occurring (NO).

11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

No anthropogenic greenhouse gas emissions and removals resulting from LULUCF activities under Article 3, paragraphs 3 and 4 have been factored out.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

- Forest Management: As shown in chp. 11.3.1.1 the loss in living biomass is calculated annually based on harvesting statistics. In former submissions, constant mean values were used for all years. Please note, that for the LULUCF reporting (CRF Table 4A) the constant values are still used in this submission.
- The forest management cap is now calculated with a factor of 8. In the former submission the factor was 1.
- Forest Management Reference Level (FMRL): a new correction was made related to the carbon stock change in living biomass (correction of forest area), see chp. 11.7.

11.3.1.5 Uncertainty estimates

Afforestation

AD uncertainty is assumed to be 2% and EF uncertainty is 45% in line with the uncertainties applied in the Swiss inventory (FOEN 2015). These uncertainties are assumed to well represented by the LULULCF category 4A2 Land converted to forest land. The combined total uncertainty for afforestation is therefore 45.04% (is highly dominated by the EF uncertainty). Thus the net CO_2 removal by afforestation is –0.27 kt CO_2 ± 0.12 kt CO_2.

Deforestation

AD uncertainty is estimated to be 5% and EF uncertainty of 50% taken from the uncertainty estimate for 4E2 "Land converted to settlements" as this is the main reason for conversion of forest land. The values are the same as applied in the Swiss inventory (FOEN 2015). Therefore, the combined total uncertainty for deforestation is 50.2 % (is also highly dominated by the EF uncertainty). The net CO_2 emissions by deforestations are 4.38 kt CO_2eq ± 2.21 kt CO_2eq.

Forest management

AD uncertainty is estimated to be 5% and emission factor uncertainty 50%. In line with the Swiss inventory, it is assumed that the uncertainties are equal to those of Deforestation. Therefore, the combined uncertainty is 50.2%. The net emissions attributed to forest management are 5.14 kt CO_2 ± 2.57 kt CO_2.

Harvest wood products

AD uncertainty is estimated to be 10% and emission factor uncertainty 57% based on the argumentation of 6.11.3. The corresponding AD uncertainty in the Swiss inventory is 3%, but the data source for Liechtenstein is less reliable, therefore a higher uncertainty is estimated. The EF uncertainty is taken from the Swiss inventory (FOEN 2015). The combined uncertainty is 57.9%. As result the total HWP removals are -1.40 kt CO_2 ± 0.82 kt CO_2.

Total combined uncertainty

The total combined uncertainty of afforestation, deforestation, FM and HWP is 52.8%. The net CO_2 emissions are therefore 7.49 kt CO_2eq ± 3.95 kt CO_2eq.

11.3.1.6 Other methodological Issues

Time series are consistent.

11.3.2 Category-specific QA/QC and verification

In Chapter 6.4.4 category-specific QA/QC and verification items for forest land are described in detail. The general QA/QC measures are described in section 1.2.3.

11.4 Article 3.3.

Figure 11-1 shows removals of CO_2 eq from Afforestations and emissions of CO_2 eq from Deforestations for the years 2008-2014. Removals from Afforestations and emissions from Deforestations differ by one order of magnitude. The area of Deforestation is about 5 times larger than the area of Afforestations.

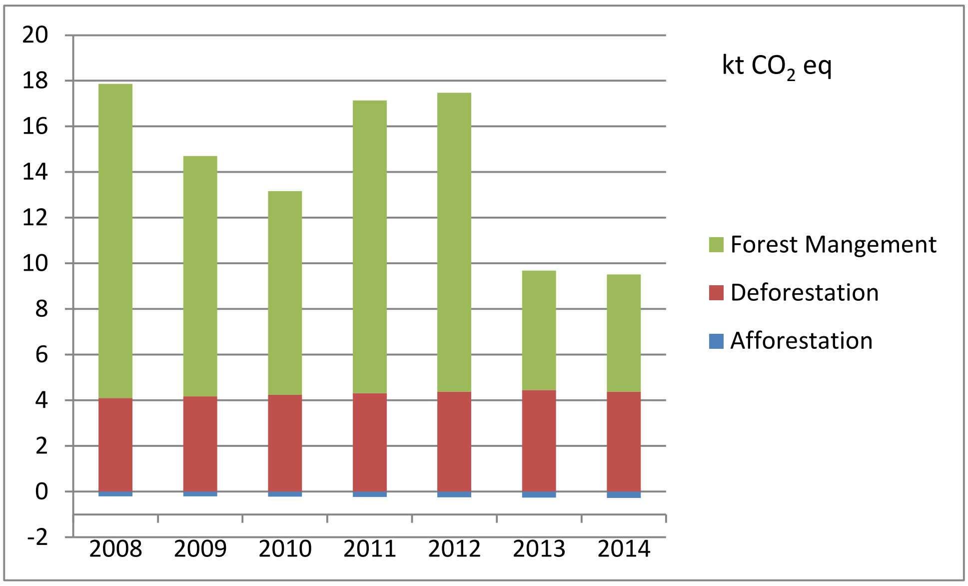

Figure 11-1 The CO_2 removals (negative sign) and emissions (positive sign) from Afforestation, Deforestation and Forest Management, 2008–2014, in kt CO_2 eq.

Since carbon from living biomass is immediately removed after clear-cutting, Deforestations can be considered as a "quick carbon-loosing process" (except for soil carbon). In contrast, due to the slow increase of living biomass, Afforestations are a "more slow process with increasing importance" in terms of carbon accumulation.

11.4.1 Information that demonstrates that activities under Article 3.3. began on or after 1 January 1990 and before December 2020 and are direct human-induced

Reforestation

For more than 100 years, the area of forest in Liechtenstein has been increasing, and a decrease in forest area as a result of deforestation is prohibited by the National Law on Forests with article 6 (Government 1991). Therefore, reforestation of areas not forested for a period of at least 50 years does not occur in Liechtenstein. Liechtenstein therefore, only has to consider afforestation and deforestation under Article 3, paragraph 3.

Afforestation

Liechtenstein is very restrictive in reporting Afforestations under the Kyoto Protocol and only reports planted Afforestations (CC11). The annual rate of Afforestation since 1990 is assessed by AREA (see Chapter 6.3). For reporting under the Kyoto Protocol, afforested areas always remain in the "afforestation" category. Therefore, the area of Afforestations is increasing since 1990.

Afforestations since 1990 were not subject to harvesting or clear cutting, since there are no forests with such short rotation lengths.

Deforestation

Deforestation is prohibited by the National Law on Forests with article 6 (Government 1991) and exceptions need governmental authorisation. In addition to human-induced deforestation processes also natural disturbances followed by a land-use change are included. All areas are assessed by the AREA surveys (see Chapter 6.3). Only deforestations occurring after 1 January 1990 are considered.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from Deforestation

Liechtenstein's definition of Deforestation only covers permanent conversions from forest land into non-forest land. It is assessed by AREA applying the procedure presented in chapter 11.1.3.2 where temporary loss of forest cover by natural disturbance or management is estimated. However, it is probable that the share of temporary loss is underestimated with the presently available data.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

The AREA survey provides a detailed overview of land-use changes with regard to land cover and land use (see Chapter 6.2 and 6.3). Temporal changes of land cover can lead to a reclassification in AREA from a forest category to a non-forest category. In Chapter 11.1.3.2 the criteria are listed which conversions from a forest combination category to a non-forest combination category are not identified as Kyoto Deforestation under the Kyoto Protocol.

11.5 Article 3.4

Net CO_2 emissions from the Kyoto Protocol activity Forest Management for the years 2008 until 2014 are shown in Figure 11-1. Gains were adopted from Liechtenstein's NFI (see Chapter 6.4.2.1) which covers the period 1998-2010. Losses were calculated with NFI-results and harvesting statistics (see chp. 11.3.1.1). In this period, cut and mortality was higher than growth and therefore, Forest Management represents a carbon source.

11.5.1 Information that demonstrates that activities under Article 3.4. have occurred since 1 January 1990 and are human-induced

According to the National Law on Forests, the extent and the spatial distribution of the total forest area in Liechtenstein has to be preserved (Government 1991) and thus, any change of the forested area has to be authorized. All forests are under observation of the communal forest services and monitored by the NFI. Therefore, all forests in Liechtenstein are subject to Forest Management.

11.5.2 Information related to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

Not applicable.

11.5.3 Information relating to Forest Management

There is a long tradition of forest protection in Liechtenstein since the 19th century. The most recent forest law (Government 1991) reaffirms the long-standing tradition of preserving both forest area and forest as a natural ecosystem. It prescribes sustainable Forest Management, prohibits clearing, and bans Deforestation unless it is replaced by an equal area of afforested land or an equivalent measure to improve biodiversity.

11.5.4 Information that demonstrates that emissions and removals resulting from elected Article 3, Paragraph 4, activities are not accounted for under activities under Article 3, Paragraph 3

This information is requested in the Annex to 15/CMP.1 paragraph 9.c. The reporting of Forest Management under article 3, paragraph 4 is clearly separated from the reporting of the activities under article 3, paragraph 3.

Units of lands with ARD (Afforestation, Reforestation and Deforestation) activities are reported under Article 3, paragraph 3. These areas always remain under Article 3, paragraph 3. Afforestations older than 20 years are attributed to growth factors of mature forests under forest management. These units of lands are reported in Table 4(KP-I)A.1 and not under forest management. Thus, there is no double counting of units of lands under article 3, paragraph 3 to Article 3, paragraph 4.

11.5.5 Information that indicates to what extent removals from Forest Management offsets the Debit incurred under Article 3, Paragraph 3

This information is shown in the summary KP-CRF-Table "Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol".

11.6 Other Information

11.6.1 Key category analysis for Article 3.3 and 3.4 activities

The results of the approach 1 key category analysis including LULUCF are shown and explained in Chapter 1.5 and are displayed in Table 1-5 for the year 2014. The smallest UNFCCC category, considered key based on an approach 1 assessment is “5.D Wastewater, CH_4” with a contribution of 0.97 kt CO_2 eq (share 0.4%).

The following LULUCF activities under the Kyoto Protocol are listed in Kyoto Table NIR 3 (Table 11-3):

- Afforestation and Reforestation (-0.27 kt CO_2 eq; Table 11-4) is not a key category under the Kyoto Protocol because its absolute contribution is substantially lower than the smallest category considered key in the UNFCCC inventory.
- Deforestation (4.38 kt CO_2 eq; Table 11-4) is a key category under the Kyoto Protocol because its contribution is higher than the smallest UNFCCC category considered key.
- Forest Management (5.14 kt CO_2 eq, Table 11-4) is a key category under the Kyoto Protocol because its absolute contribution is higher than the smallest category considered key in the UNFCCC inventory.
- Harvested Wood Products (-1.40 kt CO_2 eq; 11-4) is a key category under the Kyoto Protocol because its contribution is higher than the smallest UNFCCC category considered key. Exactly the same method is used for calculation of HWP under UNFCCC and KP.

Among the key categories from the LULUCF sector in the UNFCCC inventory, there are several categories which have a relationship to afforestation/reforestation or deforestation, for example:

- 4C2/4E2 Land converted to Grassland/Settlements: related to deforestation
- 4G Harvested Wood Products (HWP): is the same as in KP-LULUCF.

11.7 Technical correction Forest Management Reference Level

Liechtenstein's forest management reference level (FMRL) is documented by OEP (2011d). It is inscribed in the appendix to the annex to Decision 2/CMP.7 and amounts to +0.10 kt CO_2 eq yr^{-1}. OEP (2011d) was subject to a technical assessment. Based on the technical assessment report (UNFCCC 2011) and applying guidance of IPCC (2014), the following technical corrections of Liechtenstein's FMRL have been made (see Table 11-8):

- Wood harvesting; carbon stock changes in living biomass: The calculations by OEP (2011d) were based on a forest areaof 4.413 kha. However, the area in 2013 is 18% higher. The FMRL was corrected accordingly.
- Carbon stock changes in mineral soils: The new model version Yasso07 has been implemented in Switzerland since 2013. The most recent results from Switzerland are adopted.
- Calculation of carbon stock changes in HWP: carbon stock changes in HWP are calculated following the IPCC methodology (IPCC 2014); the historical time series has been updated (see chp. 6.11.2).

Table 11-8 Summary of the technical correction of the FMRL. Values from FMRL as defined in OEP (2011d) and corrected values (this chapter) are listed per pool.

kt CO2/yr	**FMRL submitted 2011**	**FMRL corrected 2015**	**Technical correction**
Wood harvesting, stock change in living biomass	1.30	1.30	--
Stock change of organic soil carbon	1.20	0.00	-1.20
Stock change in HWP	-2.40	-1.18	1.22
FMRL 2013-2020	**0.10**	**0.12**	**0.02**

kt CO_2 yr^{-1}	**FMRL submitted 2011**	**FMRL corrected 2016**	**Technical correction**
Wood harvesting, stock change in living biomass	1.30	1.54	0.24
Stock change in HWP	-2.40	-1.18	1.22
Stock change of organic soil carbon	1.20	0.00	-1.20
FMRL 2013-2020	**0.10**	**0.36**	**0.26**

The calculations of stock change in living biomass by OEP (2011d) were based on a forest area of 4.413 kha. However, the actual area of productive forest (CC12) in 2013 was 18% higher (5.187 kha, see Table 6-6). This leads to a correction of the FMRL for this pool by 0.24 kt CO_2 eq yr^{-1} (see Table 11-8). OEP (2011d) used a mean net decrease in growing stock of -0.232 m^3 ha^{-1} (average of two modelled scenarios). This value was not changed.

The new version of the model Yasso07 has been implemented since Switzerland's GHG inventory 2013 and improvements related to input data, model parameterization and model calibration have been made (see Didion 2014). For the FMRL submitted by OEP (2011d) the results of an older version (2006) of the Swiss Yasso model application was adopted to estimate the carbon stock change in mineral soils for Liechtenstein (1.20 kt CO_2/year). The most recent Yasso07 results do not confirm this emission value but indicate that the carbon stock change in mineral soil is practically zero (FOEN 2015, Figure 6-5). This new result is adopted for Liechtenstein (see Table 11-8).

Carbon stock changes in HWP are calculated following the IPCC methodology (IPCC 2014) which is different from the methodology applied in OEP (2011d). For the recalculation of the FMRL only the in-country production of sawnwood from domestic harvest is included. Further, the historical time series has been updated (Chapter 6.11).

For calculating the carbon stock change in HWP for the FMRL 2013-2020, the annual production of sawnwood 2013-2020 was estimated by the average production from 2000 to 2009. I.e. a business as usual scenario was assumed based on the ten-year average 2000-2009 (7'616 m^3). With this production value the time series of gains and losses shown in Chapter 6.11 were extended until 2020 (Table 11-9). The resulting average CO_2 removal 2013-2020 is -1.18 kt CO_2/year, which was used to correct the FMRL (Table 11-8).

Table 11-9 Calculation of the annual CO_2 removal by HWP for the FMRL in the 2nd Commitment Period 2013-2020.

Harvested wood products	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Mean 2000-2009**
Sawnwood production, m^3	8'125	7'000	7'100	6'725	7'525	7'955	9'331	9'331	9'331	3'732	7'616
Gains sawnwood, kt C	2.03	1.75	1.78	1.68	1.88	1.99	2.33	2.33	2.33	0.93	
Losses sawnwood, kt C	-1.46	-1.47	-1.47	-1.48	-1.48	-1.49	-1.51	-1.52	-1.54	-1.54	
Net emissions/removals, kt CO_2	**-2.10**	**-1.03**	**-1.11**	**-0.74**	**-1.45**	**-1.82**	**-3.03**	**-2.97**	**-2.91**	**2.23**	

Harvested wood products	**2010**	**2011**	**2012**
Sawnwood production, m^3	7'616	7'616	7'616
Gains sawnwood, kt C	1.90	1.90	1.90
Losses sawnwood, kt C	-1.54	-1.55	-1.55
Net emissions/removals, kt CO_2	**-1.34**	**-1.32**	**-1.29**

Harvested wood products	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Mean 2013-2020**
Sawnwood production, m^3	7'616	7'616	7'616	7'616	7'616	7'616	7'616	7'616	7'616
Gains sawnwood, kt C	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Losses sawnwood, kt C	-1.56	-1.57	-1.57	-1.58	-1.59	-1.59	-1.60	-1.60	-1.58
Net emissions/removals, kt CO_2	**-1.26**	**-1.24**	**-1.22**	**-1.19**	**-1.17**	**-1.15**	**-1.12**	**-1.10**	**-1.18**

11.8 Natural disturbances

11.8.1 Application of the provision of natural disturbances

As indicated in Liechtenstein's 2nd Initial Report (OE 2016), Liechtenstein intends to apply, in the case of significant magnitude events, the provision of natural disturbances for units of lands under Forest Management during the second commitment period in accordance with decision 2/CMP.7. In cases or events in which emissions from natural disturbances are higher than the nationally established threshold value and all other requirements defined in 2/CMP.7 and IPCC (2014) are met, Liechtenstein will evaluate and decide whether the effort would be justified to exclude them.

In the inventory year 2014, no natural disturbances causing emissions exceeding the upper confidence interval (background level plus margin) occurred. Thus, no emissions from natural disturbances are excluded for 2014.

11.8.2 Technical correction of the background level and margin

There is no technical correction of the background level and margin for the inventory year 2014.

11.9 Harvested Wood Products

Methodology, estimates and uncertainties of carbon stock changes in the HWP pools are described in Chapter 6.11. The same methodology is applied for reporting HWP from forest land under UNFCCC and accounting for HWP from Forest Management under KP. A time series for changes in the HWP-pool is shown in Chapter 6.11.2. HWPs originating from wood harvested at land converted from forest land to non-forest land (UNFCCC) or from Deforestations (KP) are not taken into account.

11.10 Information relating to Article 6

Liechtenstein currently does not host projects under the Joint Implementation Mechanism.

12 Accounting on Kyoto Units

12.1 Background Information

The standard electronic format (SEF) is part of the submission under Article 7.1 of the Kyoto Protocol in accordance with decisions 11/CP.4, 14/CMP1 and 15/CMP.1. The SEF Tables have been developed to facilitate the reporting and the review of Kyoto Protocol units by Annex-I Parties.

Additionally several reports for the Standard Independent Assessment Report (SIAR) have to be submitted by a Party, matching the requirements of Decision 14/CMP.1 and 15/CMP.1.

12.2 Summary of Information Reported in the SEF Tables

The tables of the Standard Electronic Format (SEF) providing all necessary information on Kyoto units (AAU, CER, ERU, tCER, lCER and RMU) for 2015 were submitted together with this report (NIR 2015). Details are disclosed in the corresponding files ITL_LI_2015_1_1.xml, RREG1_LI_2015.xlsx. No CP2 units were transferred in the reporting period and therefore no SEF reports for CP2 were submitted.

12.3 Discrepancies and Notifications

The following information on Kyoto units are covered by the Annex of Decision 15/CMP.1 Part I.E para 12 to 17:

Para. 12: 2 discrepant transaction occurred in 2015. Therefore, a R-2 report was submitted (SIAR_Report_R-2_2015-LI.xls).

Para. 13/14: No CDM notifications occurred in 2015. Therefore, no R-3 is submitted.

Para. 15: No non-replacements occurred in 2015. Therefore, no R-4 is submitted.

Para. 16: No invalid units exist as at 31 December 2015. Therefore, no R-5 is submitted.

Para. 17: Necessary actions have been undertaken to correct any problem causing a discrepancy in the reporting year 2015. All relevant transactions were terminated.

12.4 Publicly Accessible Information

Pursuant to paragraphs 44 to 48 in section I.E of the annex to decision 13/CMP.1, Liechtenstein makes non-confidential information available to public using Registry Homepage and/or user interface. In Liechtenstein the following information is considered as non-confidental and publicly accessible on website https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml.

13/CMP.1 annex II paragraph 45 Account information	The requested information is publicly available for all accounts. The data of operator holding accounts can be viewed online at: https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml The data of all accounts can be viewed online at: https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml Representative name and contact information is classified as confidential due to Article 83 paragraph 8 and 9 Registry Regulation No. 1193/2011.

13/CMP.1 annex II paragraph 46 Joint implemention project information	This is information is available on the website: http://www.llv.li/#/12414
13/CMP.1 annex II paragraph 47 Unit holding and transaction information	The information requested in (a), (d), (f) and (l) is classified as confidential due to Article 83 paragraph 1 Registry Regulation No. 1193/2011 as well as national data protection law and therefore not publicly available. Transactions of units within the most recent five year period are also classified as confidential, therefore the transactions provided are only those completed more than five years in the past. The information requested in (b), (c), (e), (g), (h), (i), (j) and (k) is publicly available at https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml (b) In 2014 there was no issuance of AAU. (c) In 2014 no ERUs were issued. (e) 165 RMUs were issued for the reporting year 2014 in 2015. For the current reporting year no verified units for issuance RMUs are available at the time of submission. (g) 4'942 RMUs and 13'808 CERs were cancelled on the basis of activities under Article 3, paragraph 3 and 4 in the reported year. (h) No ERU, CER, AAU and RMU were cancelled on the basis of activities under Article 3, paragraph 1 in the reported year. (i) In 2015, no AAU, no ERU and no CER were voluntary cancelled. No RMU was cancelled. (j) In 2015, 5'156 ERUs, 216'768 CERs, 953'020 AAUs, and 165 RMUs, no tCER, no lCER were retired. (k) There was no carry over of ERU, CER, AAU or RMU from the previous commitment period.
13/CMP.1 annex II paragraph 48 Authorized legal entities information	The following legal entities are authorized by the Member State to hold Kyoto units: (see table below) OHA: Operator Holding Account (installation and aircraft) PHA: Person Holding Account TA: Trading Account NHA: National Holding Account

	Legal entities authorised by Liechtenstein to hold units
AAU	Federal Government, TA
ERU	Each account holder of OHA, PHA, TA and NHA
CER	Each account holder of OHA, PHA, TA and NHA
RMU	Federal Government only, TA
tCER	Federal Government only, TA
lCER	Federal Government only, TA

Additionally all required information on Article 6 projects (JI) would be available on the internet website of the Office of Environment (OE) if there would be such a project in Liechtenstein. So far, there are no JI projects in Liechtenstein (http://www.llv.li/#/12414). Those informations comprise name of projects, host counties, available documents and dates.

Personalized data and some information of individual holding accounts are considered as business secrets and the disclosure may prejudice their competiveness. Information on acquiring and transferring accounts of legal entities (companies) is therefore regarded as personal data. According to article 20 of the national Act on Data Protection (Datenschutzgesetz vom 14. März 2002, LGBl Nr.55) enacts that public authorities may disclose personal data if there is a legal basis or if there is an overriding public interest. Neither case is fulfilled and therefore the registry of Liechtenstein can not make the information on acquiring and / or transferring accounts publicly available. All related information is considered as **confidential** and therefore paragraphs 44-40 of the Annex to Decision 13/CMP.1 are not applicable.

12.5 Calculation of the Commitment Period Reserve (CPR)

The commitment period reserve and the assigned amount for the second commitment period will be defined in the Report to facilitate the calculation of the assigned amount pursuant to Article 3, paragraphs 7bis, 8 and 8bis, of the Kyoto Protocol for the second commitment period 2013 - 2020 (Liechtenstein's Initial Report under the Kyoto Protocol, 2nd CP). This report will be submitted on April 15 2016.

According to the annex to Decision 11/CMP.1, paragraph 6, and taking into account Decision 1/CMP.8, paragraph 18, 'each Party included in Annex I shall maintain, in its national registry, a commitment period reserve which should not drop below 90 per cent of the Party's assigned amount calculated pursuant to Article 3, paragraphs 7bis, 8 and 8bis, of the Kyoto Protocol, or 100 per cent of eight times its most recently reviewed inventory, whichever is lowest.

In view of the changes in the reporting guidelines for the second commitment period, Liechtenstein understands the 'most recently reviewed inventory' to be the National Greenhouse Gas Inventory submitted on 15 April 2016 (OE 2016), i.e. the inventory submitted in conjunction with this Second Initial Report under the Kyoto Protocol. The values regarding the two criteria for the commitment period reserve are presented in Table 12-1.

Table 12-1 Liechtenstein's commitment period reserve as presented in its Second Initial Report (Government 2016).

90 per cent of assigned amount (see chapter 5)	Total emissions with LULUCF in 2013 (see Table 2 and Table 3) times eight
[t CO_2 equivalent]	[t CO_2 equivalent]
1'572'251 x 90/100 = 1'415'025	248'252 x 8 = 1'986'018

Accordingly, a commitment period reserve of 1'415'025 t CO_2 equivalent (1'415.025 kt CO_2 equivalent) results for Liechtenstein.

12.6 KP-LULUCF Accounting

Liechtenstein does not account for KP LULUCF. Therefore the inventory is understood to be calculated without LULUCF emissions/removals.

13 Information on Changes in National System

The National System remained unchanged for the inventory cycle leading to the submission 2016. Due to the implementation of the IPCC 2006 Reporting Guidelines (IPCC 2006) the schedule had to be adapted uniquely (see chapter 1.2.2.)

14 Information on Changes in National Registry

Directive 2009/29/EC adopted in 2009, provides for the centralization of the EU ETS operations into a single European Union registry operated by the European Commission as well as for the inclusion of the aviation sector. At the same time, and with a view to increasing efficiency in the operations of their respective national registries, the EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway decided to operate their registries in a consolidated manner in accordance with all relevant decisions applicable to the establishment of Party registries - in particular Decision 13/CMP.1 and decision 24/CP.8.

With a view to complying with the new requirements of Commission Regulation 920/2010 and Commission Regulation 1193/2011, in addition to implementing the platform shared by the consolidating Parties, the registry of EU has undergone a major re-development. The consolidated platform which implements the national registries in a consolidated manner (including the registry of EU) is called Consolidated System of EU registries (CSEUR) and was developed together with the new EU registry on the basis the following modalities:

(1) Each Party retains its organization designated as its registry administrator to maintain the national registry of that Party and remains responsible for all the obligations of Parties that are to be fulfilled through registries;

(2) Each Kyoto unit issued by the Parties in such a consolidated system is issued by one of the constituent Parties and continues to carry the Party of origin identifier in its unique serial number;

(3) Each Party retains its own set of national accounts as required by paragraph 21 of the Annex to Decision 15/CMP.1. Each account within a national registry keeps a unique account number comprising the identifier of the Party and a unique number within the Party where the account is maintained;

(4) Kyoto transactions continue to be forwarded to and checked by the UNFCCC Independent Transaction Log (ITL), which remains responsible for verifying the accuracy and validity of those transactions;

(5) The transaction log and registries continue to reconcile their data with each other in order to ensure data consistency and facilitate the automated checks of the ITL;

(6) The requirements of paragraphs 44 to 48 of the Annex to Decision 13/CMP.1 concerning making non-confidential information accessible to the public would be fulfilled by each Party individually;

(7) All registries reside on a consolidated IT platform sharing the same infrastructure technologies. The chosen architecture implements modalities to ensure that the consolidated national registries are uniquely identifiable, protected and distinguishable from each other, notably:

    (a) With regards to the data exchange, each national registry connects to the ITL directly and establishes a distinct and secure communication link through a consolidated communication channel (VPN tunnel);

    (b) The ITL remains responsible for authenticating the national registries and takes the full and final record of all transactions involving Kyoto units and other administrative processes such that those actions cannot be disputed or repudiated;

(c) With regards to the data storage, the consolidated platform continues to guarantee that data is kept confidential and protected against unauthorized manipulation;

(d) The data storage architecture also ensures that the data pertaining to a national registry are distinguishable and uniquely identifiable from the data pertaining to other consolidated national registries;

(e) In addition, each consolidated national registry keeps a distinct user access entry point (URL) and a distinct set of authorisation and configuration rules.

Following the successful implementation of the CSEUR platform, the 28 national registries concerned were re-certified in June 2012 and switched over to their new national registry on 20 June 2012. During the go-live process, all relevant transaction and holdings data were migrated to the CSEUR platform and the individual connections to and from the ITL were re-established for each Party.

The following changes to the national registry of Liechtenstein have therefore occurred in 2012:

In accordance to the SIAR Reporting Requirements and Guidance for Registries a high level description for each change should be provided as test plans, test reports and readiness documentation. The required documents are confidential and accessible for assessors only (“documentation annexed to this submission”). Therefore the documents which are mentioned in the below table are not available within this document.

The following changes to the national registry of Liechtenstein have therefore occurred in 2015:

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change since the last submission.
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	There was no change to the database structure as it pertains to KP functionality in 2015. Versions of the CSEUR released after 6.3.3.2 (the production version at the time of the last Chapter 14 submission) introduced minor changes in the structure of the database. These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model is provided in Annex A. No change to the capacity of the national registry occurred during the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced since version 6.3.3.2 of the national registry are listed in Annex B. Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). Annex H testing was carried out in February 2016 and the test report is attached. No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No change of security measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced since version 6.3.3.2 of the national registry are listed in Annex B. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as Annex B. Annex H testing was carried out in February 2016 and the test report is attached.

15 Minimization of Adverse Impacts in Accordance with Article 3, Paragraph 14

The Convention (Art. 4 paragraphs 8 and 10) and its Kyoto Protocol (Art. 2 paragraph 3 and Art. 3 paragraph 14) commit Parties to strive to implement climate policies and measures in such a way as to minimize adverse economic, social and environmental impacts on developing countries when respond-ing to climate change. The concrete assessment of potential impacts on developing countries is extremely complex and uncertain, as the effects are often indirect, potentially positive and negative in nature, displaced over time and interacting with other policies, including those applied in developing countries. In addition, it has to beared in mind that Liechtenstein is a very small country (160 km^2) with a respective small share in international trade. It is thus not assumed that Liechtenstein's climate change policies have any significant adverse economic, social and environmental impacts in developing countries.

However, Liechtenstein has implemented different instruments striving at minimizing *potential* adverse impacts of its climate change response measures. Liechtenstein is implementing climate change response measures in all sectors and for different gases. The policies and measures are very much compatible and consistent with those of the European Union in order to avoid trade distortion, non-tariff barriers to trade and to set similar incentives. In accordance with international law, this approach strives at ensuring that Liechtenstein is implementing those climate change response measures, which are least trade distortive and do not create unnecessary barriers to trade.

Tax exemption in Switzerland and consequently also Liechtenstein (tax union) for biofuels is limited to fuels that meet ecological and social criteria. The conditions are set out in such a way that biofuels do not compete with food production and are not causing degradation of rainforests or other valuable ecosystems. The Swiss Centre for Technology Assessment (TA-Swiss) published a study on the assessment of social and environmental impacts of the use of second generation biomass fuels with the following result: "In summary, 2nd generation biofuels allow a more sustainable mobility than both fossil and 1st generation biofuels based on agriculture. Due to the limited availability of both waste feedstocks and cultivation area, however, sustainable bioenergy-based mobility is restricted to clearly less than 8% of individual mobility in Switzerland, if constant mobility and fleet efficiency is assumed. Nevertheless, 2nd generation biofuels may play a relevant complementary part in supplying our future mobility, in particular for long distance transport and aviation where electric mobility is less suitable." (TA-SWISS 2010).

The Swiss Academies of Arts and Sciences have started a project to assess possible conflicts and synergies between the expansion of renewable energy production and land management. Many forms of renewable energy (solar, wind, water, biomass, geothermal) require considerable floor space and lead to changes in land use, ecosystems, and the views of places and landscape. Large-scale use of areas for energy production thus have to be planned considering the maintenance of ecosystem services, protection of biodiversity, or natural sceneries which are important for tourism.

An assessment of conflicts and synergies between policies and measures to mitigate climate change and biodiversity protection has been made by the biodiversity forum and ProClim in 2008 (SCNAT 2008). While there are several synergies in the area of ecosystem management and agriculture, conflicts exist concerning the use of renewable energies, be it the adverse effects of increased hydroelectricity generation on natural water flows or the impacts of other renewable energy systems on natural landscapes and ecosystems. The report gives recommendations on how to take advantage of synergies and how to detect conflicts in an early stage.

The issue of adverse impacts of climate related policies and measures (in Liechtenstein) has been addressed by "The Energy Strategy 2020", adopted by the Government (2012a). The strategy provides future-oriented impulses for the national energy policy. The focus areas of the concept are the promotion of efficient energy use, the use of renewable energies, and energy conservation:

- Increase the share of renewable energy in total energy use from 8% to 20% by 2020,
- Increase the energy efficiency to 20% to stabilize the energy consumption on the level of 2008 by 2020, and
- A 20% reduction of the CO_2 emission by 2020.

The Energy Strategy 2020 also reflects the need to minimize adverse effects of its proposed measures as required by Art. 3 paragraph 14 of the Convention and Art. 2 paragraph 3 of the Kyoto Protocol. The proposed set of measures has been checked against its compatibility with economic as well as social requirements.

16 Other Information

No other information to be reported.

Annexes to the National Inventory Report

Annex 1: Key categories

No supplementary information to KCA to the statements given in Chapter 1.5.

Annex 2: Detailed discussion of methodology and data for estimating CO_2 emissions from fossil fuel combustion

No supplementary information.

Annex 3: Other detailed methodological descriptions for individual source or sink categories

No supplementary information.

Annex 4: CO_2 reference approach and comparison with sectoral approach, and relevant information on the national energy balance

No supplementary information to the statements given in Chapter 3.2.1 Comparison of Sectoral Approach with Reference Approach.

Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

No supplementary information to the statements given in Chapter 1.7 assessment of completeness.

Annex 6: Additional information to be considered as part of the NIR submission (where relevant) or other useful reference information

A6.1 Additional information on sewage sludge prohibition

As described in chapter 5.5 for source category 3D Agricultural soils the use of sewage sludge as fertilizer is prohibited in Liechtenstein. The corresponding regulation (in German only) is given below:

522.1

Liechtensteinisches Landesgesetzblatt

Jahrgang 1998 Nr. 79 ausgegeben am 26. Mai 1998

Verordnung

vom 14. April 1998

zum Störfallgesetz (Störfallverordnung)

V. Klärschlamm[2]

Art. 35a[3]

Düngeverbot

Klärschlamm darf nicht als Dünger verwendet werden.

Art. 36

Klärschlamm-Entsorgungsplan

1) Die Inhaber von Abwasserreinigungsanlagen erstellen einen Klärschlamm-Entsorgungsplan und passen ihn in den fachlich gebotenen Zeitabständen den neuen Erfordernissen an.[4]

2) Der Klärschlamm-Entsorgungsplan legt mindestens fest:

a) wie der Klärschlamm der Abwasserreinigungsanlagen entsorgt werden soll;

b) welche Massnahmen, einschliesslich der Erstellung und Änderung von Anlagen, die der Entsorgung des Klärschlamms dienen, erforderlich sind und bis zu welchem Zeitpunkt diese umgesetzt werden.[5]

Annex 7: Supplementary information to the uncertainty analysis

A7.1 Aggregation of categories for application of uncertainty analyses to key categories

In the automatic KCA of the CRF Reporter the aggregation level of the categories is not identical to the aggregation level as applied so far for the uncertainty analysis. That means that uncertainties that were used for previous uncertainty analyses and which are still valid need to be aggregated to be applied to key categories. This paragraph shows how the aggregation has been carried out. Technically, the Gaussian error propagation is applied for the aggregation used in following analytical form in order aggregate uncertainties of EF and AD:

$$U_{\%,EF} = \sqrt{\sum_i (Em_{\%,i} * U_{\%,EF,i})^2} \quad (1)$$ error propagation for emission factors

$$U_{\%,AD} = \sqrt{\sum_i (Em_{\%,i} * U_{\%,AD,i})^2} \quad (2)$$ error propagation for activity data

where $U_{\%,EF}$ aggregated relative uncertainty in emission factors

$U_{\%,AD}$ aggregated total relative uncertainty in activity data

$Em_{\%,i}$ disaggregated relative emissions of source i compared to total emissions

$U_{\%,EF,i}$ disaggregated relative uncertainty in emission factor of source i

$U_{\%,AD,i}$ disaggregated relative uncertainty in activity data of source i.

The results of the aggregation process are displayed in Table A-1. Aggregated relative uncertainties are derived based on emission data from the previous submission (reporting year 2013). The same relative uncertainties are applied in the uncertainty assessment of in the current submission (reporting year 2014).

Table A - 1 Aggregation with Gaussian error propagation for the three categories affected by the structural change in the new 2006 IPCC Guidelines

1A3b CO_2	Submission 2014 (Sub)Categories		**Submission 2016**
	gasoline	*diesel*	*total/implied*
$U_{\%}$ Emissions	10.1%	15.0%	**8.7%**
$U_{\%}$ Activity Data	10.0%	15.0%	**8.7%**
$U_{\%}$ Emission Factor	1.4%	0.5%	**0.8%**
1A4 Liquid fuels CO_2	Submission 2014 (Sub)Categories		**Submission 2016**
	1A4a	*1A4b*	*total/implied*
$U_{\%}$ Emissions	20.0%	20.0%	**15.8%**
$U_{\%}$ Activity Data	20.0%	20.0%	**15.8%**
$U_{\%}$ Emission Factor	0.5%	0.5%	**0.4%**
1A4 Gaseous fuels CO_2	Submission 2014 (Sub)Categories		**Submission 2016**
	1A4a	*1A4b*	*total/implied*
$U_{\%}$ Emissions	5.9%	5.9%	**4.2%**
$U_{\%}$ Activity Data	5.0%	5.0%	**3.6%**
$U_{\%}$ Emission Factor	3.1%	3.1%	**2.2%**

Annex 8: Supplementary information the QA/QC system

A8.1 Checklists for QC activities

- Checklist for project manager (PM), project manager assistant (PMA), staff member climate unit (SC), sectoral experts (SE)
- Checklist for national inventory compiler (NIC)
- Checklist for NIR authors (NA)

Table A - 2 Checklist for QC activities and for follow-up activities if necessary (table depicted on next page). The general activities are taken from IPCC 2006 Guidelines (IPCC 2006), table 6.1, the country-specific activities are ad-hoc activities. Abbr.: NA NIR authors, NIC national inventory compiler, PM project manager, PMA project manager assistant, DFP designated focal point, SC staff member climate unit, SE sectoral experts. Member codes: AG Andreas Gstoehl, BES Bettina Schäppi, BRI Beat Rihm, FEW Felix Weber, HE Hanspeter Eberle, HK Helmut Kindle, HS Heike Summer, JB Jürgen Beckbissinger, JH Jürg Heldstab, SB Sven Braden.

Quality Control System for Climate Reporting Liechtenstein Submission 2016				
Checklist for sectoral experts and NIR Authors				
Contact person:	Jürg Heldstab (INFRAS)			
Telephone, e-mail:	+41 44 205 95 11, juerg.heldstab@infras.ch			
QC general activities ***(table 6.1 IPCC 2006 Guidelines)***	**Procedure** ***(description of checks that were carried out)***	**Respon-sibles**	**Date**	**Visa**
1. Check that assumptions and criteria for the selection of activity data and emission factors are	Acontec-internal checks, comparison with methods chosen	SE/NIC	31.03.16	JB, HK
	INFRAS-internal checks, comparison with methods chosen	NA	27.11.15	JH
2. Check for transcription errors in data input and reference	plausibility check of the basic input data for Solvent and Ind calculation	SE	17.03.16	JB
	plausibility check of the basic input data from the LWA	SE	09.03.16	JB
	check input Data for SF6 Emission calculation	SE	10.03.16	JB
	check stationary Energy	NA	28.04.16	BES
	check IPPU	NA	28.04.16	BES
	check Waste	NA	02.05.16	MSM
	Agriculture: Plausibility check of data in background tables Acontec. Issues identified and discussed with Acontec	SE	03.05.16	FEW, JB
3. Check that emissions are calculated correctly	Ongoing checks of the calculated emissions in all sectors	SE	16.03.16.-14.04.16	JB
	Clarification of data/figures	PM	28.04.16	BES, JH
	INFRAS-internal control: Plausibility checks, "Delta-Analysis" combined with KCA, INFRAS-internal control of time series	NA	04.05.16	JH
	INFRAS-internal checks during generationof tables/figure in Chapter. 2 Trends (independant control by second person JH)	SE	06.05.16	FEW
4. Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used	check energy-activity-data (reference approach)	SE	12.04.16	JB
	check energy-activity-data (reference approach)	NA	20.04.16	BES
	check Energy	SE	14.04.16	JB
	check Energy	NA	16.04.16	BES
	check IPPU	SE	11.04.16	JB
	check IPPU	NA	13.04.16	BES
	check Agriculture	SE	19.04.16	JB
	check Agriculture	NA	20.04.16	FEW
	check LULUCF	SE	08.04.16	JB
	check LULUCF	NA	30.03.16	BRI
	check Waste	SE	31.03.16	JB
	check Waste	NA	02.04.16	MSM
	check KP-LULUCF	SE	21.03.16	HS
	check KP-LULUCF	NA	11.04.16	BRI

Continued on next page

5. Check the integrity of database	integrity checked	SE	04.04.16	JB
6. Check for consistency in data between source categories	check general data consistency	SE	12.04.16	JB
	check Energy (stationary)	NA	19.04.16	BES
	check Energy (mobile)	NA	18.04.16	BES
	check IPPU	NA	19.04.16	BES
	check Agriculture	NA	19.04.16	JH
	check LULUCF	NA	30.03.16	BRI
	check Waste	NA	19.04.16	MSM
	check KP-LULUCF	NA	11.04.16	BRI
7. Check that the movement of inventory data among processing steps is correct	Processing checked	NIC	13.01.16	HK
	Data transfer from the land-use statistics to the LULUCF tables and clarification of comprehensive questions with JB	SE	02.03.16	HS
	check Agriculture	SE	05.03.16	JB
	plausibility check / control of overall emissions from agriculture in CO2 equivalents, in total and for the source categories for all years	SE	15.04.16	JB
	check LULUCF	SE	06.03.16	HS
8. Check that uncertainties in emissions and removals are estimated or calculated correctly	check Energy	NA	14.05.16	JH, FEW
	check IPPU	NA	16.05.16	JH, FEW
	check Agriculture	NA	16.05.16	JH, FEW
	check Waste	NA	17.05.16	MSM, FEW
	check (KP-)LULUCF	SE	27.04.16	BRI
9. Check time series consistency	check for temporal consistency in time series input data for each category.	NIC	15.04.16	JB
	check in the algorithm/method used for calculations throughout the time series.	NIC	12.04.16	JB
	check methodological and data changes resulting in recalculations.	NA	19.04.16	JH, BES
	check that the effects of mitigation activities have been appropriately reflected in time series calculations.	NIC	13.01.16	HK, HS
10. Check completeness	Completness check for all sectors	SE	18.04.16	JB
	Completness check for all sectors	NA	19.04.16	JH
11. Trend checks	For each category, current inventory estimates should be compared to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain any differences. Significant changes in emissions or removals from previous years may indicate possible input or calculation	NIC/SE/NA	13.04.16	JB, JH, FEW, BES, MSM, BRI
	Check value of implied emission factors across time series.	NIC	13.04.16	HK
	Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series.	NIC/SE	30.04.16	JB, JH, FEW, BES, MSM, BRI
12. Review of internal	Internal QE check of documentation; Clarification of open questions with SE	PM/PMA	06.01.16	HS
Further (country-specific) activities	**Procedure**	**Respon-**	**Date**	**Visa**
13. Compare estimates for key catgories to previous estimates	check of KCA previous/latest key categories	SE	03.05.16	BES
14. Compare CRF tables with previous year	check Energy	NA	09.05.16	JH/BES
	check IPPU	NA	09.05.16	BES
	check Agriculture	NA	09.05.16	FEW
	check Waste	NA	09.05.16	MSM
	check LULUCF	NA	06.05.16	BRI
	check KP-LULUCF	NA	11.04.16	BRI
15. 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	PM/PMA	15.03.16	AG
	check: Energy (stationary)	NA	16.03.16	BES
	check: Solvents	NA	16.03.16	BES
	Clarification of comprehensive questions in different sectors with SE	PM/NA	17.03.16	HS
	Two independent checks of Energy (mobile)	SE	12./13.04.16	BES, JH
	check waste	NA	14.04.16	MSM
	check Agriculture	SE	15.04.16	FEW
	check LULUCF	SE	30.03.16	BRI
16. Where LIE uses Swiss-specific EF: Where changes in the Swiss EFoccur, check whether the changes are also adequate for LIE	Clarify the changes of emission factors in IPPU and Agriculture	SE	06.04.16	BES
17. Check correctness of KCA, comparison with previous results	Plausibility checks of KCA	PM	04.05.16	HS
	cross-check within KCA with/without LULUCF 1990 and 2014: Emissions correct, thresholds correct. Comparison with KCA of Submission Apr 2016. Plausibility checks	NA	05.04.16	JH

Continued on next page

18. Check correctness of uncertainty analysis, comparison with previous results	internal plausibility checks for all sectors	NA	04.12.15	FEW, JH
	internal plausibility checks for KP-LULUCF	NA	11.04.16	BRI, JH
19. Check of transcription errors CRF --> NIR (numbers, tables, figures)	INFRAS internal plausibility checks	NA	18.05.16	MBE/JH
	check waste	NA	23.05.16	MSM
	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), Energy, Agriculture, 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	16.-23.5.16	JH, FEW, BES
20. Check AD in NIR and CRF and compare data with reference data sources	check waste	NA	15.05.16	MSM
21. Check for complete and correct references in NIR	INFRAS-internal checks	NA	23.05.16	JH
22. Check for correctness, completeness, transparency and quality of NIR	Proofread of complete draft NIR	NA	23.5.16	JH
	final proofread Executive Summary, feedback to HS	NFP	23.05.16	HK
	final proofread inventory/NIR, feedback and discussion with HS	QM	23.05.16	AG
	final proofread inventory/NIR, discussion with JH and JB	PM	18.05.16	HS
	final proofread inventory/NIR, feedback to HS	PMA	19.05.16	SB
	final proofread inventory/NIR, feedback to HS	SC	19.05.16	HE
	Internal OE discussions on the inventory/NIR draft with AG,SB, HE and HS	PM/PMA	24.05.16	HS
	Feedback from OE internal discusions	PM/PMA	25.05.16	HS
	Final proofreading inventory/NIR	PM/PMA	26.05.16	HS
23. Check for completeness of submission documents	Final check and Submission	PM/NIC NFP	26.05.16	HK, HS
24. Archiving activities	Archiving: INFRAS, Meteotest, save internally all data individually. NIR in MS-DOC and PDF format are sent to OE. All tables in MS-EXCEL format are sent to OE for separate archiving. Compile all emails related to report and data.	NA	27.05.16	JH, BRI
	Internal Review of documents submitted in May 2016; all relevant documents archived	NIC	27.05.16	JB

A8.2 Checklists for QA activities (internal review)

Table A - 3 Checklists for QA activity internal review.

Reviewer	**Helmut Kindle**
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Chapter(s) reviewed	ES, Ch. 1

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Reviewer's comments yellow und answers of authors (green)	
ES 3.1 Explanation to ES Table 1-3: clarification of the time period necessary ES.4 Clarification of the changes in Figure 1-3 in comparison to former NIRs may be helpful	
done, 24.5.16, JH	
Reviewers comments performed Date / Signum	25.5.16, HK

Taken note of review Date / Signum	25.5.16, JH

If necessary: Additional comments of reviewer (yellow) and author's answers

Datum / Signum	25.05.2016, H. Kindle

Reviewer	**Andreas Gstöhl**
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Reviewer's comments yellow und answers of authors (green)

ES. 1.2 and Ch. 1.1.2: additional information on CP2 (see p. 62).

done, JH 25.5.16

Reviewers comments performed	
Date / Signum	25.05.2016 / Andreas Gstöhl

Taken note of review	
Date / Signum	26.5.16, JH

If necessary: Additional comments of reviewer (yellow) and author's answers

Datum / Signum	26.5.16, Andreas Gstöhl

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Reviewer's comments yellow und answers of authors (green)

Please check consitency between CRF tables and numbers in the text, especially focus on possible rounding errors. Please check if reference to reporting/submission year is correct.

done, 24.5.16, JH

Reviewers comments performed	
Date / Signum	25.05.2016, HS

Taken note of review	
Date / Signum	25.05.2016, JH

If necessary: Additional comments of reviewer (yellow) and author's answers

Datum / Signum	25.5.2016, H. Summer

A8.3 Inventory development plan submission 2015

The Inventory Development Plan (IDP) is a tool within Liechtenstein's National Inventory System (NIS) to improve the Greenhouse Gas Inventory and the National Inventory Report (NIR). It is updated regularly based on the recommendations of the expert review teams of the UNFCCC (ERT). The last recommendations are FCCC/ARR/2006/LIE, FCCC/ARR/2008/LIE, FCCC/ARR/2009/LIE, FCCC/ARR/2010/LIE, FCCC/ARR/2011/LIE, FCCC/ARR/2012/LIE and FCCC/ARR/2013 resulting from the Centralized Reviews in 2007, 2009, 2010, 2011, 2012 and 2013. The most recent recommendations resulting from the in-country review in September 2014 (FCCC/ARR 2014) are already partly addressed.

The IDP summarizes the recommendations and planned improvements. The meaning of the headers are shown on this page. The table below shows which improvements will be checked by the Office of the Environment for eventual improvements.

IDP No.

The first column indicates the internal number of each point of Liechtenstein's IDP.

Recommendations/Planned improvement

The recommendations of the ERT or planned improvements are described in detail in the second column.

Reference (accordig to ARR)

This column in the IDP refers to the relevant paragraph in the report of the individual review of the greenhouse gas inventory of Liechtenstein of the corresponding year, e.g. ARR 2013/59 means paragraph 59 of the report on the inventory submitted in 2013, FCCC/ARR/2013/LIE.

Status

The status provides information about the state of development of each specific point ("not yet implemented" or "will not be implemented").

Comment/Reason

The last column includes a short summary of the issue given or an explanation on what Liechtenstein's has done related to this point.

IDP No.	Recommendations/Planned improvements	Reference (according to ARR)	Status	Comment/Reason NIR	Sector
5	Conduct internal review complemented with systematic external review.	2013_22	Not yet implemented	As the emissions of Liechtenstein are relatively low and partially based on Swiss data that is quality assured and reviewed, we assume that the data is sufficently assured.	Cross-cutting Issues
6	Complete CRF table 2(II)s2	ARR 2013/41	Not yet implemented	This issue will be implemented in future submissions. Due to ist limited resources, an implementation for submission 2015 is not possible. The main focus is on the implentation of the new guidelines. Additionally, Liechtenstein collects new data in industry and car garages. These data must be first analyzed.	Cross-cutting Issues
7	Review and strengthen its QC procedures to eliminate errors and improve the accuracy of its emission estimates.	ARR 2013/21;81;87;89;Table 3	Not yet implemented	Due to the new structure of the CRF tables the quality controls so far implemented will have to be adapted accordingly during preparation of the submission 2015. The party will check how systematic additional quality control proceedures can be implemented for future submissions.	Cross-cutting Issues
8	Implement additional QC procedures to avoid mistakes or discrepancies between the CRF tables and the NIR.	ARR 2013/16c;21;24;35;Table 3	Not yet implemented	Due to the new structure of the CRF tables the quality controls so far implemented will have to be adapted accordingly during preparation of the submission 2015. The party will check how systematic additional quality control proceedures can be implemented for future submissions.	Cross-cutting Issues
9	The ERT reiterates the recommendation that the Party further consider the applicability of Swiss uncertainty estimates to the national circumstances of Liechtenstein and that the Party develop national uncertainty estimates, where appropriate, in its next annual submission.	2013_19 & 2013_27	will not be implemented	This recommendation will not be implemented. The situation of Liechtenstein is highly similar to the situation of Switzerland and therefore, the use of similar uncertainty levels is justified. A respective explication is included in the NIR. Please note that for the most relevant sources such as 1A2, 1A3 and 1A4 country specific uncertainties are applied for liquid fuels.	Cross-cutting Issues
10	Complete CRF table 8(b) for all years by including explanatory information for all recalculations	ARR 2013/Table 3	will not be implemented	Table 8(b) contains already information. The party will not provide any additional information due to its limited resources. The recalculations are already described in NIR.	Cross-cutting Issues
24	Implement additional QC procedures to avoid mistakes or discrepancies between the CRF tables and the NIR.	ARR 2013/21	Not yet implemented	Due to the new structure of the CRF tables/energy the quality controls so far implemented will have to be adapted accordingly during preparation of the submission 2015. The party will check how systematic additional quality control proceedures can be implemented for future submissions.	Energy
25	Report lubricants and bitumen activities in CRF tables 1.A(b) and 1.A(d).	ARR 2013/26;Table 5	Not yet implemented	The party will implement extended information on bitumen and lubricants for the submission 2017.	Energy
26	Report secondary fuels consumed in the country and complete the lubricants and bitumen AD in the CRF tables.	ARR 2013/27	Not yet implemented	The party will implement extended information on bitumen and lubricants for the submission 2017.	Energy
27	Check if biofuel is not already mixed in the imported gasoline and diesel oil fuels and document this in the NIR.	ARR 2013/34	Not yet implemented	This issue is planned to be improved for the submission 2017 due to limited ressources in 2015.	Energy
30	The ERT encourages LIE to check the split between CH_4 and CO_2 emissions from natural gas fugitive losses.	Review 2013	will not be implemented	This will not be implemented beause of the disproportional effortts incurred.	Energy

Continued on next page

IDP No.	Recommendations/Planned improvements	Reference (according to ARR)	Status	Comment/Reason NIR	Sector
32	Investigate the fluctuations in the emissions from foam blowing and provide a clear explanation.	ARR 2013/42	Not yet implemented	Liechtenstein will provide an interpretation as soon as other important issues are solved.	IPPU
34	The ERT recommends that LIE provide information on potential emissions for f-gases in its next annual submission (CRF 2).	2012/50	will not be implemented	According to new reporting guidelines potential emissions need not to be provided anymore.	IPPU
35	Complete CRF table 2(II)s2 for potential emissions data on HFCs and PFCs from consumption of halocarbons and SF6, together with the estimation methods used	ARR 2013/41	will not be implemented	According to new reporting guidelines potential emissions need not to be provided anymore.	IPPU
51	The ERT reecommends to make clear in table 4B(b) that the total N allocated to different types of livestock corresponds only to cattle and not include N excretions of other animals in the next annual submission. This could be done in the documentation box.	ARR 2012/64	will not be implemented	This issue will not be implemented because of Liechtenstein's limited resources.	Agriculture
60	During the in-country review it was identified that wood is used in energy sector, representing around 10% of the fuel used in TJ based. Encourage the Party to use energy data on wood consumption to validate KP-LULUCF deforestation data taking into account also the waste sector as well. The ERT acknowledges that this implies that the origin of wood is known.	Review 2013	Not yet implemented		LULUCF
73	Liechtenstein has made recalculations for the whole time series for CH4 and N2O emissions. CH4 emissions have been recalculated using a new EF owing to a revision of the biogas leakage ratio in Liechtenstein's country-specific methodology. N2O emissions have been recalculated using updated year-specific values for protein consumption according to the numbers provided by the Swiss Farmers' Union. The ERT commends the updating of AD and EFs to improve the accuracy of the emissions estimates.	2013_88	will not be implemented	Emission estimated for N2O correspond to the Swiss standard and are considered to be very accurate. CH4 emissions are country specific and have been updated recently.	Waste

Annex 9: Voluntary supplementary information for article 3 paragraph 3 of the Kyoto Protocol: Kyoto tables

No supplementary information in addition to chp. 11.

Annex 10: Information required under Art. 7 paragraph 2 of the Kyoto Protocol: national registry and commitment period reserve (CPR)

A10.1 Introduction

Under the terms of Art. 7 of the Kyoto Protocol, each Party included in Annex I shall provide the necessary supplementary information in its National Inventory Report (NIR) to demonstrate compliance with Art. 3 of the Kyoto Protocol. Decision 15/CMP.1 is – inter alia – focusing on the reporting requirements for changes in the national registries. Additionally decision 15/CMP.1 refer to Art. 5, para 1, defining the national Guidelines for national systems. Each Party shall describe the changes that have occurred in the system as well as in the registry, compared with the information reported in its last submission. The changes described are in comparison with the NIR submitted in April 2016.

A10.2 Changes in the national system

No changes since the last submission.

A10.3 Registry administrator

The name and contact information of the registry administrator designated by the Party to maintain the national registry:

Registry Administrator

Office of Environment

P.O. Box 684

Dr. Grass-Strasse 12

9490 Vaduz

Principality of Liechtenstein

phone: +423 236 75 96

fax: +423 236 64 11

email: registry@llv.li

website: http://www.llv.li/amtsstellen/llv-au-umweltschutz/llv-au-emissionshandel/llv-au-emissionshandelsregister.htm

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Alternative Contact 2

Helmut Kindle

Email: helmut.kindle@llv.li

A10.4 Consolidated system

The names of the other Parties with which the Party cooperates by maintaining the national registries in a consolidated system:

The consolidation of European national registries (including all EU Member States, Iceland, Liechtenstein and Norway) was a significant change to the system of registries. After certification of the consolidated System of EU registries on 1st June 2012, on 19 June 2012, 29 registries became operational under the Consolidated System of European Union Registries (CSEUR). A detailed describtion is given in the EU Commission Regulation 920/2010. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of the EU and all consolidating national registries. This description includes:

- Readiness questionnaire
- Application logging
- Change management procedure
- Disaster recovery
- Manual Intervention
- Operational Plan
- Roles and responsibilities
- Security Plan
- Time Validation Plan
- Version change Management

The required documents are confidential and accessible for assessors only. Therefore the documents which are mentioned are not available within this document. The documents above will be submitted separately as an appendix to the final NIR 2016 and **MUST NOT** be published in any form.

A10.5 Database structure and capacity

<u>Description of the database structure and capacity of the national registry:</u>

For the purposes of meeting their obligations as KP Parties and under Article 6 of the European Union Decision No 280/2004/EC to ensure the accurate accounting of Kyoto units, each Member State and the Union operate a registry (hereinafter ‘KP registry’) in the form of a standardised electronic database that complies with the UNFCCC's requirements concerning registries, and in particular the functional and technical specifications for data exchange standards for registry systems under the Kyoto Protocol elaborated pursuant to Decision 12/CMP.1 of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol. The Union registry and every other KP registry conform to the functional and technical specifications for data exchange standards for registry systems under the Kyoto Protocol elaborated pursuant to Decision 12/CMP.1 and comply with the hardware, network and software and security requirements set out in the Data Exchange and Technical Specifications provided European Union Transaction Log (EUTL) is used as an independent transaction log that records and checks the issue, transfer and cancellations of allowances in the form of a standardised electronic database. The EUTL also serves to record all information relating to the holdings and transfers of Kyoto units made available.

The standardised and secured system of registries in the form of standardised electronic databases containing common data elements to track the issue, holding, transfer and cancellation of allowances, to provide for public access and confidentiality as appropriate and to ensure that there are no transfers which are incompatible with the obligations resulting from the Kyoto Protocol is drawn up.

The required documents are confidential and accessible for assessors only. Therefore the descriptions are not available within this document. The documents will be submitted separately as an appendix to the final NIR 2016 and **MUST NOT** be published in any form.

A10.6 Conformity with data exchange standards (DES)

Description of how the national registry conforms to the technical standards for data exchange between registry systems for the purpose of ensuring the accurate, transparent and efficient exchange of data between national registries, the clean development mechanism registry and the transaction log (decision 19/CP.7):

In order to ensure that Kyoto units and allowances can be held on the same Union registry accounts, the Union registry must also conform to the functional and technical specifications for data exchange standards for registry systems under the Kyoto Protocol, adopted by Decision 12/CMP.1,
The EUTL is capable of checking and recording all processes referred to under Article 3(2), and is conform to the functional and technical specifications for data exchange standards for registry systems under the Kyoto Protocol elaborated pursuant to Decision 12/CMP.1 and comply with the hardware, network and software requirements set out in the Data Exchange and Technical Specifications. The Union registry and every other KP registry are conform to the functional and technical specifications for data exchange standards for registry systems under the Kyoto Protocol elaborated pursuant to Decision 12/CMP.1 and comply with the hardware, network and software and security requirements set out in the Data Exchange and Technical Specifications.

The required documents are confidential and accessible for assessors only. Therefore the descriptions are not available within this document. The documents will be submitted separately as an appendix to the final NIR 2016 and **MUST NOT** be published in any form.

A10.7 Prevention of discrepancies

Description of the procedures employed in the national registry to minimize discrepancies in the issuance, transfer, acquisition, cancellation and retirement of ERUs, CERs, tCERs, lCERs, AAUs and/or RMUs, and replacement of tCERs and lCERs, and of the steps taken to terminate transactions where a discrepancy is notified and to correct problems in the event of a failure to terminate the transactions:

The Union registry and every other KP registry check input codes and check response codes to ensure the correct interpretation of information exchanged during each process. The check codes shall correspond to those contained in the Data Exchange and Technical Specifications. The consolidated system adopts the Data Exchange and Technical Specifications necessary for exchanging data between registries and transaction logs, including the identification codes, automated checks and response codes, as well as the testing procedures and security requirements necessary for the launching of data exchange. The Data Exchange and Technical Specifications shall be consistent with the functional and technical specifications for data exchange standards for registry systems under the Kyoto Protocol elaborated pursuant to Decision 12/CMP.1. Prior to and during the execution of all processes the Union registry shall conduct appropriate automated checks to ensure that discrepancies are detected and incorrect processes are terminated in advance of automated checks being conducted by the EUTL.In case of processes completed through the direct communication link between the Union registry and the EUTL referred to in Article 5(2) of the previous mentioned regulation, the EUTL terminates any processes where it identifies discrepancies upon conducting the automated checks referred to in Article 66(2) of the mentionend regulation, and informs thereof the Union registry and the administrator of the accounts involved in the terminated transaction by returning an automated check response code. The Union registry immediately informs the relevant account holders that the process has been terminated.

In case of transactions completed through the ITL referred to in Article 5(1) of the mentioned regulation, the ITL terminates any processes where discrepancies are identified either by the ITL or the EUTL upon conducting the automated checks referred to in Article 66(2) of the mentioned regulation. Following a termination by the ITL, the EUTL also terminates the transaction. The ITL informs the administrators of the registries involved of the termination of the transaction by returning an automated check response code. If one of the registries involved is the Union registry, the Union registry also informs the administrator of the Union registry accounts involved in the terminated transaction by returning an automated check response code. The Union registry immediately informs the relevant account holders that the process has been terminated.

The required documents are confidential and accessible for assessors only. Therefore the descriptions are not available within this document. The documents will be submitted separately as an appendix to the final NIR 2016 and **MUST NOT** be published in any form.

A10.8 Determent of unauthorized manipulations

An overview of security measures employed in the national registry to prevent unauthorized manipulations and to prevent operator error and of how these measures are kept up to date:

The identity of the Union registry are authenticated towards the EUTL with digital certificates and usernames and passwords as indicated in the Data Exchange and Technical Specifications.

The Member States and the Union use the digital certificates issued by the Secretariat to the UNFCCC, or an entity designated by it, to authenticate their registries to the ITL for the purposes of establishing the communication. Adequate and harmonised requirements on authentication and access rights are applied to protect the security of information held in the integrated registries system and records concerning all processes, operators and persons in the registries system are kept.

Authentication of registries and the EUTL

1. The identity of the Union registry is authenticated towards the EUTL with digital certificates and usernames and passwords as indicated in the Data Exchange and Technical Specifications provided for in Article 71.

2. The Member States and the Union use the digital certificates issued by the Secretariat to the UNFCCC, or an entity designated by it, to authenticate their registries to the ITL for the purposes of establishing the communication link referred to in Article 5.

Accessing accounts in the Union registry

1. Account holders are able to access their accounts in the Union registry through the secure area of the Union registry. The Central administrator ensures that the secure area of the Union registry website is accessible through the Internet. The website of the Union registry is available in all languages of the European Union.

2. The Central administrator ensures that accounts in the Union registry where access through trading platforms in accordance with Article 19(3) is enabled and one authorised representative is also the authorised representative of a trading platform holding account are accessible to the trading platform operated by the holder of that trading platform holding account.

3. Communications between authorised representatives or trading platforms and the secure area of Union registry are encrypted in accordance with the security requirements set out in the Data Exchange and Technical Specifications provided for in Article 71.

4. The Central administrator takes all necessary steps to ensure that unauthorised access to the secure area of the Union registry website does not occur.

5. If the security of the credentials of an authorised representative or additional authorised representative has been compromised, the authorised representative or additional authorised representative shall immediately inform the administrator of the account thereof and request a replacement.

Authentication and authorisation of authorised representatives in the Union registry

1. The Union registry issues each authorised representative and additional authorised representative with a username and password to authenticate them for the purposes of accessing the registry.

2. An authorised representative or additional authorised representative only have access to the accounts within the Union registry which he is authorised to access and only be able to request the initiation of processes which he is authorised to request pursuant to Article 19. That access or request takes place through a secure area of the website of the Union registry.

3. In addition to the username and password referred to in paragraph 1, national administrators provides secondary authentication to all accounts administered by them. The types of secondary authentication mechanisms that can be used to access the Union registry shall be set out in the Data Exchange and Technical Specifications provided for in Article 71.

4. The administrator of an account may assume that a user who was successfully authenticated by the Union registry is the authorised representative or additional authorised representative registered under the provided authentication credentials, unless the authorised representative or additional authorised representative informs the administrator of the account that the security of his credentials has been compromised and requests a replacement.EN L 270/22 Official Journal of the European Union 14.10.2010.

Suspension of all access by authorised representatives due to a security breach

1. The Central Administrator may suspend access to the Union registry or the EUTL if there is a breach of security of the Union registry or the EUTL which threatens the integrity of the registries system, including the back-up facilities referred to in Article 59.

2. The administrator of a KP registry may suspend access by all users to its KP registry if there is a breach of security of the KP registry which threatens the integrity of the registries system, including the back-up facilities referred to in Article 59.

3. In the event of a breach of security that may lead to suspension of access, the administrator who becomes aware of the breach shall promptly inform the Central Administrator of any risks posed to other parts of the registries system. The Central Administrator shall then inform all other administrators.

4. If an administrator becomes aware of a situation that requires the suspension of all access to its system, it shall inform the Central Administrator and account holders with such prior notice of the suspension as is practicable. The Central Administrator will then inform all other administrators as soon as possible.

5. The notice referred to in paragraph 3 shall include the likely duration of the suspension and shall be clearly displayed on the public area of that KP registry's website or on the public area of the EUTL's website.

The required documents are confidential and accessible for assessors only. Therefore the descriptions are not available within this document. The documents will be submitted separately as an appendix to the final NIR 2016 and **MUST NOT** be published in any form.

In 2012 an additional scurity measure has been implemented. The third account representative has been set to mandatory as of February 2012. This representative fulfils the function to confirm transactions initiated by the first and second representative. This 4-eyes-priciple should restrain the possiblitiy of transactions done by unauthorized persons who have hacked or stolen access data from representatives.

A10.9 Public reports

A list of the information publicly accessible by means of the user interface to the union registry:

Pursuant to paragraphs 44 to 48 in section I.E of the annex to decision 13/CMP.1, Liechtenstein makes non-confidential information available to public using Registry Homepage and/or user interface. In Liechtenstein the following information is considered as non-confidental and publicly accessible on website:

https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml

13/CMP.1 annex II paragraph 45 Account information	The requested information is publicly available for all accounts. The data of operator holding accounts can be viewed online at: https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml The data of all accounts can be viewed online at: https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml Representative name and contact information is classified as confidential due to Article 83 paragraph 8 and 9 Registry Regulation No. 1193/2011.
13/CMP.1 annex II paragraph 46 Joint implemention project information	This is information is available on the website: http://www.llv.li/#/12414
13/CMP.1 annex II paragraph 47 Unit holding and	The information requested in (a), (d), (f) and (l) is classified as confidential due to Article 83 paragraph 1 Registry Regulation No. 1193/2011 as well as national data protection law and therefore not publicly available. Transactions of units within the most recent five year period are also

transaction information	classified as confidential, therefore the transactions provided are only those completed more than five years in the past. The information requested in (b), (c), (e), (g), (h), (i), (j) and (k) is publicly available at https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml b) In 2015 there was no issuance of AAU. (c) In 2015 no ERUs were issued. (e) 165 RMUs were issued for the reporting year 2014 in 2015. For the current reporting year no verified units for issuance RMUs are available at the time of submission. (g) 4'942 RMUs and 13'808 CERs were cancelled on the basis of activities under Article 3, paragraph 3 and 4 in the reported year. (h) No ERU, CER, AAU and RMU were cancelled on the basis of activities under Article 3, paragraph 1 in the reported year. (i) In 2015, no AAU, no ERU and no CER were voluntary cancelled. No RMU was cancelled. (j) In 2015, 5'156 ERUs, 216'768 CERs, 953'020 AAUs, and 165 RMUs, no tCER, no lCER were retired. (k) There was no carry over of ERU, CER, AAU or RMU from the previous commitment period.
13/CMP.1 annex II paragraph 48 Authorized legal entities information	The following legal entities are authorized by the Member State to hold Kyoto units: (see table below) OHA: Operator Holding Account (installation and aircraft) PHA: Person Holding Account TA: Trading Account NHA: National Holding Account

	Legal entities authorised by Liechtenstein to hold units
AAU	Federal Government, TA
ERU	Each account holder of OHA, PHA, TA and NHA
CER	Each account holder of OHA, PHA, TA and NHA
RMU	Federal Government only, TA
tCER	Federal Government only, TA
lCER	Federal Government only, TA

A10.10 Internet address

No changes compared to submission 2015. The URL of the interface for the national registry of Liechtenstein is:

www.emissionshandelsregister.li and alias

www.emissionstradingregistry.li

A10.11 Safeguard and recovery plan

A description of measures taken to safeguard, maintain and recover data in order to ensure the integrity of data storage and the recovery of registry services in the event of a disaster:

The Central Administrator of the CSEUR shall ensure that the Union registry and EUTL incorporate robust systems and procedures for the safeguarding of all data and the prompt recovery of all data and operations in the event of a disaster as stated in the new requirements of Commission Regulation 920/2010.

The required documents are confidential and accessible for assessors only. Therefore the documents which are mentioned are not available within this document. The documents above will be submitted separately as an appendix to the final NIR 2016 and **MUST NOT** be published in any form.

A10.12 Test procedures

The results of any test procedures that might be available or developed with the aim of testing the performance, procedures and security measures of the national registry undertaken pursuant to the provisions of decision 19/CP.7 relating to the technical standards for data exchange between registry systems:

The accounting mechanisms are described in the COMMISSION REGULATION (EU) No 920/2010, Article 52. The described steps below refer to the commission regulation.

Minimum deposited quantity on the ETS AAU deposit account

1. The EUTL shall record a minimum deposited quantity for each Member State. In the case of Member States with KP registries, the EUTL will prevent transfers of Kyoto units from their ETS AAU deposit account that would result in Kyoto unit holdings on the ETS AAU deposit account that are below the minimum deposited quantity. In the case of Member States with no KP registry, the minimum deposited quantity is a value used in the clearing process.

2. The EUTL shall add a quantity to the minimum deposited quantity after an issue of Chapter III allowances has taken place in accordance with Article 39, where the addition shall be equal to the amount of Chapter III allowances issued.

3. The EUTL shall deduct a quantity from the minimum deposited quantity immediately after:

(a) a transfer of Chapter III allowances to the Union allowance deletion account has taken place as a result of downwards correction of Chapter III allowances after their allocation in accordance with Article 37(3), where the deduction shall be equal to the amount of Chapter III allowances transferred;

(b) a set-aside of Kyoto units against surrenders of Chapter III allowances by aircraft operators in accordance with Article 54 has taken place, where the deduction shall be equal to the amount set-aside; (c) a cancellation of Kyoto units against deletions of Chapter III allowances in accordance with Article 55(1) has taken place, where the deduction shall be equal to the quantity cancelled;

(d) a deletion of allowances set out in Article 55(2) took place, where the deduction shall be equal to the quantity deleted.

4. The Central Administrator carries out a deduction of a quantity from the minimum deposited quantity recorded in the EUTL after the clearing transactions in accordance with Article 56 have taken place. The deduction shall equal the total amount of Chapter III allowances surrendered by user accounts administered by the national administrator of the Member State for the 2008-12 period; plus the clearing value calculated in accordance with Article 56(3).

The required documents are confidential and accessible for assessors only. Therefore the documents which are mentioned are not available within this document. The documents above will be submitted separately as an appendix to the final NIR 2016 and **MUST NOT** be published in any form.

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