



OFFICE OF ENVIRONMENT
PRINCIPALITY OF LIECHTENSTEIN

Liechtenstein's Greenhouse Gas Inventory 1990 - 2015

National Inventory Report 2017

Submission of 13 April 2017
under the United Nations Framework Convention on Climate Change
and under the Kyoto Protocol



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Liechtenstein's Greenhouse Gas Inventory 1990-2015

National Inventory Report 2017

Submission of 13.4.2017 under the United Nations Framework Convention on Climate Change (UNFCCC) and the second commitment period (CP2) under the Kyoto Protocol

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Glossary

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| 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) |
| CP | Commitment Period |
| 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 ₂ O | 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 world-wide 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, 2016 and in May 2016 the further GHG inventories 1990–2006, 1990–2007, 1990–2008, 1990–2009, 1990–2010, 1990–2011, 1990–2012, 1990–2013 and 1990–2014 were submitted together with the National Inventory Report (OEP 2008, OEP 2009, OEP 2010, OEP 2011, OEP 2012b, OE 2013, OE 2014, OE 2016a, OE 2016c). The present report is Liechtenstein's 12th National Inventory Report, NIR 2017, prepared under the UNFCCC and under the Kyoto Protocol. It includes, as a separate document, Liechtenstein's 1990–2015 Inventory in the CRF. Furthermore, the Standard Electronic Format application (SEF) is submitted along with the NIR 2017, 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 kt CO₂ equivalents.

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

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).

Another centralized review took place in 2014, addressing the inventory and NIR of 2014 (FCC/ARR 2014). In September 2016, the latest review for the two submissions 2015 and 2016 took place.

The latest recommendations concerning submission 2016 are published in the Report on the individual review of the annual submission of Liechtenstein submitted in 2016 (FCCC/ERT 2016). The current IDP shows the status of implementation for the preliminary findings of the review in 2016 (see also Annex A8.3, Table A - 6).

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 (IPCC 2006) 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 37’623 inhabitants (2015) and with an area of 160 km². 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 has chosen 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, 2014 and 2015, 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 2015 amount to 199.4 kt CO₂ equivalent excluding LULUCF sources or sinks. This refers to 5.3 t CO₂ equivalent per capita. Total emissions excluding LULUCF have declined by 13.0% compared to 1990 and by 1.2% compared to 2014. This decrease is less pronounced when including LULUCF (10.7% for 1990-2015).

Key category analysis (KCA)

In 2015, 11 among 196 categories were identified as key categories in level and trend analysis for Liechtenstein (excluding LULUCF), covering 96.1% of total greenhouse gas (GHG) emissions (CO₂ equivalent). There are three major sources, all from category 1A Fuel combustion within the energy sector, summing up to a contribution of 65.2% of the national total emissions:

- 1A3b Road transportation, CO₂,
- 1A4 Other sectors, liquid fuels, CO₂,
- 1A4 Other sectors, gaseous fuels, CO₂.

When including LULUCF categories in the analysis, 22 among 223 categories are key. Eight of the key categories are from the LULUCF sector. The largest category is 4B1 Cropland remaining cropland.

Uncertainties

An uncertainty analysis with Approach 1 is carried out and presented in chp. 1.6.1.3. In 2014, it estimates a level uncertainty of total CO₂ equivalent emissions excluding the LULUCF sector of 5.49% (level uncertainty) and the trend uncertainty 1990-2014 of 5.58%. Including the LULUCF categories, the level and trend uncertainties are both 5.54%.

Recalculations

Some emissions have been recalculated due to updates in respective sectors. The results are discussed in Chapter 10. For the base year 1990, the recalculations carried out in submission 2017 lead to an increase of 0.01% in the national total emissions (excluding LULUCF categories). In contrary, the national total emissions of the year 2014 decreased by 1.3% due to the recalculations (excluding LULUCF categories).

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 shows the result for

the KP-LULUCF Inventory in year 2015. The net CO₂eq emissions add up to 2.48 kt. The corrected forest management reference level 2013-2020 is 0.36 kt CO₂eq. The level uncertainty (Approach 1) is estimated at ± 2.24 kt CO₂eq.

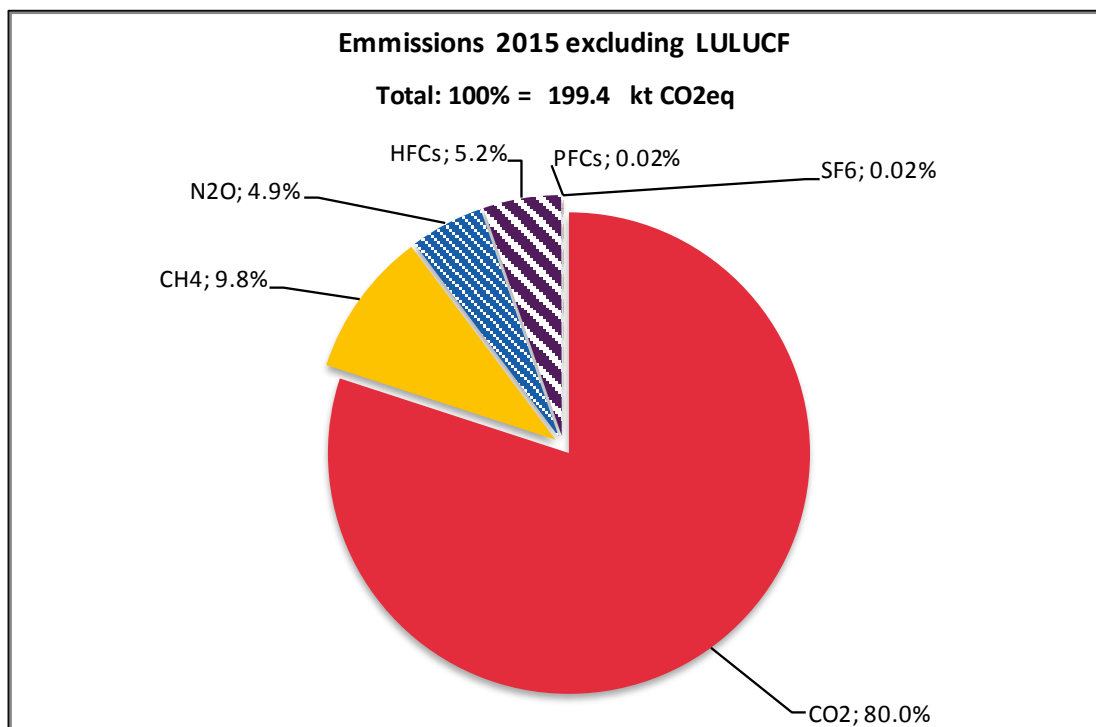
ES Table 1 Summary table afforestation and reforestation, deforestation, forest management and HWP. FMRL: Forest Management Reference Level, incl. technical corrections.

| Activity, year 2015 | Area kha | Net CO ₂ emission/removal kt CO ₂ | N ₂ O emission kt N ₂ O | Net CO ₂ eq emission/removal kt CO ₂ eq |
|----------------------------|-------------|---|--|---|
| A.1 Afforestation | 0.034 | -0.26 | NO | -0.26 |
| A.2 Deforestation | 0.188 | 4.51 | 0.00021 | 4.57 |
| B.1 Forest management (FM) | 6.176 | -0.46 | NO | -0.46 |
| 4.C HWP from FM | --- | -1.37 | NO | -1.37 |
| Total emission/removal | | 2.42 | 0.00021 | 2.48 |
| B.1.1 FMRL 2013-2020 | --- | | | 0.36 |

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

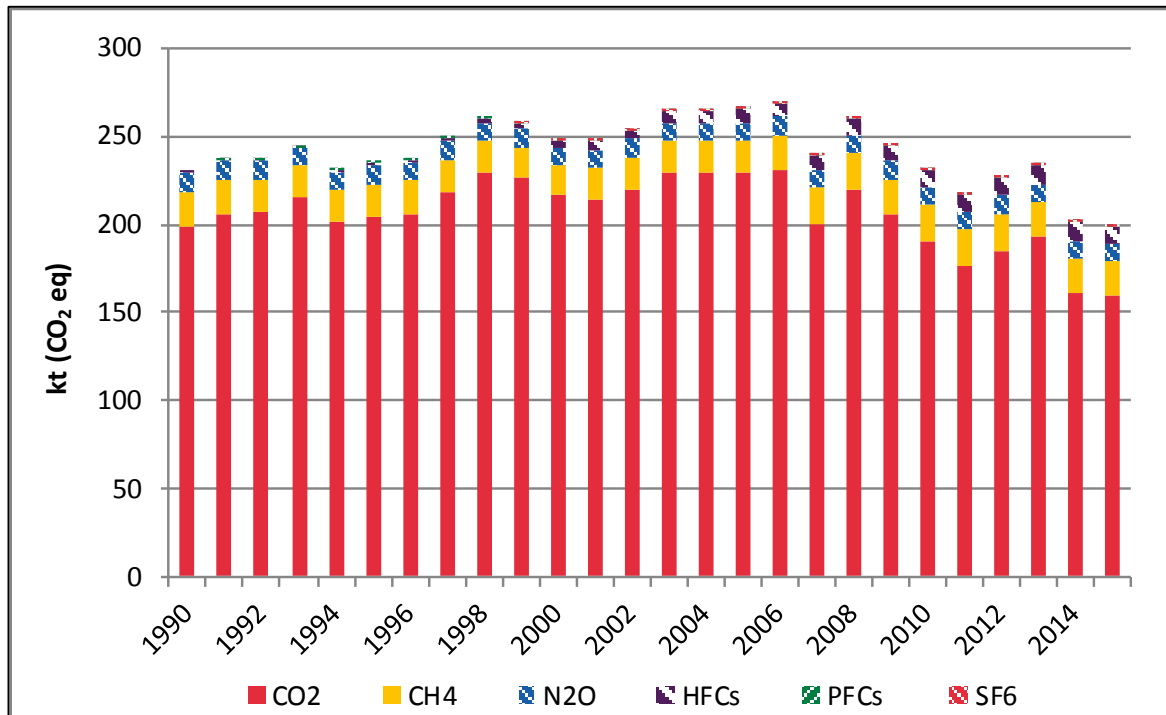
ES.3.1 GHG inventory

ES Figure 1 shows the emissions in 2015 by GHG. The main GHG is CO₂ with a share of 80.0%. CH₄ and N₂O contribute with 9.8% and 4.9%, F-gases with about 5.3%, respectively.



ES Figure 1 Liechtenstein's GHG emissions by gas (excluding LULUCF) in 2015.

ES Figure 2 illustrates that the 2015 shares are typical for the period 1990-2015. 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 2015, emissions reach an all-time low.



ES Figure 2 Trend of Liechtenstein's GHG emissions by gases 1990–2015. CO₂, CH₄ and N₂O correspond to the respective total emissions excluding LULUCF.

Over the period 1990-2015, the share of CO₂ fluctuated between 88.0% (1993) and 79.9% (2014). The share of CH₄ increased from 8.5% in 1990 to 9.8% in 2015. Simultaneously, the share of N₂O slightly increased from 4.8% (1990) to 4.9% (2015) and the share of F-gases clearly increased from 0.0% (1990) to 5.3% (2015). See ES Table 2 for further information.

ES Table 2 Summary of Liechtenstein's GHG emissions in CO₂ equivalent (kt) by gas, 1990-2015. The last column shows the percentage change in emissions in 2015 as compared to the base year 1990. The percentage change of HFCs amounts to 9'974'954%.

| Greenhouse Gas Emissions | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| CO ₂ emissions incl. net CO ₂ from LULUCF | 202.0 | 196.0 | 207.5 | 212.5 | 218.4 | 206.9 | 200.6 | 224.8 | 227.1 | 222.7 |
| CO ₂ emissions excl. net CO ₂ from LULUCF | 198.8 | 206.2 | 206.8 | 214.9 | 201.0 | 204.1 | 205.8 | 218.2 | 229.1 | 226.4 |
| CH ₄ emissions incl. CH ₄ from LULUCF | 19.5 | 19.4 | 19.0 | 18.2 | 18.4 | 18.3 | 18.7 | 18.4 | 18.2 | 17.6 |
| CH ₄ emissions excl. CH ₄ from LULUCF | 19.5 | 19.4 | 19.0 | 18.2 | 18.4 | 18.3 | 18.7 | 18.4 | 18.2 | 17.6 |
| N ₂ O emissions incl. N ₂ O from LULUCF | 11.2 | 11.4 | 11.3 | 11.1 | 11.0 | 10.9 | 10.9 | 10.9 | 10.6 | 10.3 |
| N ₂ O emissions excl. N ₂ O from LULUCF | 10.9 | 11.1 | 11.0 | 10.8 | 10.7 | 10.6 | 10.6 | 10.6 | 10.2 | 10.0 |
| 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) | 232.7 | 226.8 | 237.9 | 242.0 | 248.4 | 237.5 | 231.9 | 256.2 | 258.6 | 254.0 |
| Total (excluding LULUCF) | 229.2 | 236.7 | 236.9 | 244.0 | 230.6 | 234.3 | 236.8 | 249.3 | 260.3 | 257.4 |

| Greenhouse Gas Emissions | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| CO ₂ emissions incl. net CO ₂ from LULUCF | 238.4 | 213.6 | 219.7 | 233.3 | 234.8 | 234.1 | 239.9 | 218.9 | 239.8 | 227.6 |
| CO ₂ emissions excl. net CO ₂ from LULUCF | 216.7 | 214.5 | 219.9 | 229.2 | 229.2 | 228.9 | 231.1 | 200.7 | 219.5 | 205.3 |
| CH ₄ emissions incl. CH ₄ from LULUCF | 17.4 | 18.0 | 18.3 | 18.5 | 18.6 | 19.2 | 19.9 | 20.4 | 20.7 | 20.4 |
| CH ₄ emissions excl. CH ₄ from LULUCF | 17.4 | 18.0 | 18.3 | 18.5 | 18.6 | 19.2 | 19.9 | 20.4 | 20.7 | 20.4 |
| N ₂ O emissions incl. N ₂ O from LULUCF | 10.2 | 10.3 | 10.4 | 10.4 | 10.1 | 10.2 | 10.4 | 10.5 | 10.7 | 10.5 |
| N ₂ O emissions excl. N ₂ O from LULUCF | 9.8 | 9.9 | 10.0 | 10.0 | 9.7 | 9.9 | 10.0 | 10.1 | 10.3 | 10.1 |
| HFCs | 4.1 | 4.9 | 5.5 | 6.1 | 7.0 | 7.4 | 7.8 | 8.5 | 9.1 | 9.1 |
| 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) | 270.2 | 247.0 | 254.2 | 268.7 | 270.8 | 271.3 | 278.2 | 258.4 | 280.7 | 267.9 |
| Total (excluding LULUCF) | 248.1 | 247.6 | 254.0 | 264.2 | 264.8 | 265.7 | 269.0 | 239.9 | 260.0 | 245.2 |

| Greenhouse Gas Emissions | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|---|---------------------------------|--------------|--------------|--------------|--------------|--------------|---------------|
| | CO ₂ equivalent (kt) | | | | | | % |
| CO ₂ emissions incl. net CO ₂ from LULUCF | 211.5 | 197.8 | 206.7 | 206.1 | 174.7 | 167.5 | -17.1% |
| CO ₂ emissions excl. net CO ₂ from LULUCF | 190.8 | 176.8 | 185.4 | 192.6 | 161.3 | 159.6 | -19.7% |
| CH ₄ emissions incl. CH ₄ from LULUCF | 19.8 | 20.3 | 20.7 | 19.8 | 19.8 | 19.5 | -0.2% |
| CH ₄ emissions excl. CH ₄ from LULUCF | 19.8 | 20.3 | 20.7 | 19.8 | 19.8 | 19.5 | -0.2% |
| N ₂ O emissions incl. N ₂ O from LULUCF | 10.3 | 10.7 | 10.6 | 10.4 | 10.3 | 10.3 | -8.5% |
| N ₂ O emissions excl. N ₂ O from LULUCF | 9.9 | 10.3 | 10.2 | 10.0 | 9.9 | 9.8 | -9.7% |
| HFCs | 9.7 | 10.0 | 10.4 | 10.6 | 10.6 | 10.4 | see caption |
| PFCs | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | --- |
| SF ₆ | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.0 | --- |
| Total (including LULUCF) | 251.4 | 238.9 | 248.5 | 247.1 | 215.6 | 207.7 | -10.7% |
| Total (excluding LULUCF) | 230.3 | 217.4 | 226.8 | 233.3 | 201.8 | 199.4 | -13.0% |

ES Table 3 represents the GHG emissions and removals by categories. Sector 1 Energy is the largest source of national emissions, contributing to 81.4% of the emissions (excluding LULUCF) in 2015. Emissions caused within the energy sector decreased by 19.3% over the period 1990-2015. The emissions from sector 2 Industrial processes and product use increased by a factor of about 23 (2'265%) 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 (-5.6%). Emissions and removals in the sector 4 LULUCF form a net source in 2015 and show an increase of 137.2% 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 3 Summary of Liechtenstein's GHG emissions by source and sink categories in CO₂ equivalent (kt), 1990–2015. The last column indicates the percent change in emissions in 2015 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 | 221.1 | 232.0 | 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 & constr. | 36.3 | 36.0 | 36.4 | 37.6 | 35.7 | 35.7 | 35.8 | 37.6 | 40.4 | 39.9 |
| 1A3 Transport | 76.8 | 90.1 | 89.4 | 87.2 | 79.9 | 81.8 | 83.1 | 86.8 | 86.4 | 90.5 |
| 1A4 Other sectors | 87.5 | 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 | 23.9 | 23.7 | 23.9 | 23.5 | 23.0 | 22.1 |
| 5 Waste | 2.2 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.3 | 2.2 | 2.2 | 2.2 |
| Total (excluding LULUCF) | 229.2 | 236.7 | 236.9 | 244.0 | 230.6 | 234.3 | 236.8 | 249.3 | 260.3 | 257.4 |
| 4 LULUCF | 3.5 | -9.9 | 1.0 | -2.1 | 17.8 | 3.2 | -4.9 | 6.9 | -1.7 | -3.4 |
| Total (including LULUCF) | 232.7 | 226.8 | 237.9 | 242.0 | 248.4 | 237.5 | 231.9 | 256.2 | 258.6 | 254.0 |

| Source and Sink Categories | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|--|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| 1 Energy | 219.8 | 217.5 | 222.8 | 232.1 | 231.9 | 231.6 | 233.8 | 203.6 | 222.4 | 208.3 |
| 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 & constr. | 36.5 | 36.4 | 37.9 | 41.2 | 39.9 | 39.2 | 40.6 | 33.9 | 36.4 | 27.6 |
| 1A3 Transport | 91.3 | 87.9 | 83.8 | 83.6 | 82.3 | 81.9 | 79.3 | 83.5 | 87.9 | 82.0 |
| 1A4 Other sectors | 88.5 | 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 | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 |
| 2 IPPU | 4.5 | 5.4 | 6.0 | 6.7 | 7.5 | 7.9 | 8.2 | 8.9 | 9.8 | 9.5 |
| 3 Agriculture | 21.5 | 22.5 | 22.9 | 23.0 | 23.0 | 23.6 | 24.6 | 24.9 | 25.1 | 25.0 |
| 5 Waste | 2.4 | 2.2 | 2.4 | 2.4 | 2.4 | 2.6 | 2.4 | 2.5 | 2.6 | 2.4 |
| Total (excluding LULUCF) | 248.1 | 247.6 | 254.0 | 264.2 | 264.8 | 265.7 | 269.0 | 239.9 | 260.0 | 245.2 |
| 4 LULUCF | 22.0 | -0.6 | 0.1 | 4.5 | 6.0 | 5.6 | 9.2 | 18.5 | 20.7 | 22.7 |
| Total (including LULUCF) | 270.2 | 247.0 | 254.2 | 268.7 | 270.8 | 271.3 | 278.2 | 258.4 | 280.7 | 267.9 |

| Source and Sink Categories | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|--|---------------------------------|--------------|--------------|--------------|--------------|--------------|----------------|
| | CO ₂ equivalent (kt) | | | | | | % |
| 1 Energy | 193.8 | 179.8 | 188.4 | 195.5 | 164.1 | 162.3 | -19.3% |
| 1A1 Energy industries | 3.3 | 3.1 | 2.8 | 3.0 | 2.5 | 2.0 | 1062.9% |
| 1A2 Manufacturing industries & constr. | 26.1 | 23.6 | 25.8 | 26.4 | 27.1 | 27.4 | -24.5% |
| 1A3 Transport | 77.8 | 77.1 | 80.1 | 79.8 | 74.2 | 61.9 | -19.4% |
| 1A4 Other sectors | 85.4 | 74.9 | 78.6 | 85.1 | 59.1 | 69.8 | -20.2% |
| 1A5 Other | NO | NO | NO | NO | NO | NO | - |
| 1B Fugitive emissions from fuels | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.2 | 215.2% |
| 2 IPPU | 10.0 | 10.2 | 10.6 | 11.1 | 11.0 | 10.7 | 2264.5% |
| 3 Agriculture | 24.2 | 24.9 | 25.1 | 24.0 | 24.4 | 24.1 | -5.6% |
| 5 Waste | 2.4 | 2.6 | 2.6 | 2.6 | 2.4 | 2.3 | 4.6% |
| Total (excluding LULUCF) | 230.3 | 217.4 | 226.8 | 233.3 | 201.8 | 199.4 | -13.0% |
| 4 LULUCF | 21.1 | 21.4 | 21.7 | 13.9 | 13.8 | 8.3 | 137.2% |
| Total (including LULUCF) | 251.4 | 238.9 | 248.5 | 247.1 | 215.6 | 207.7 | -10.7% |

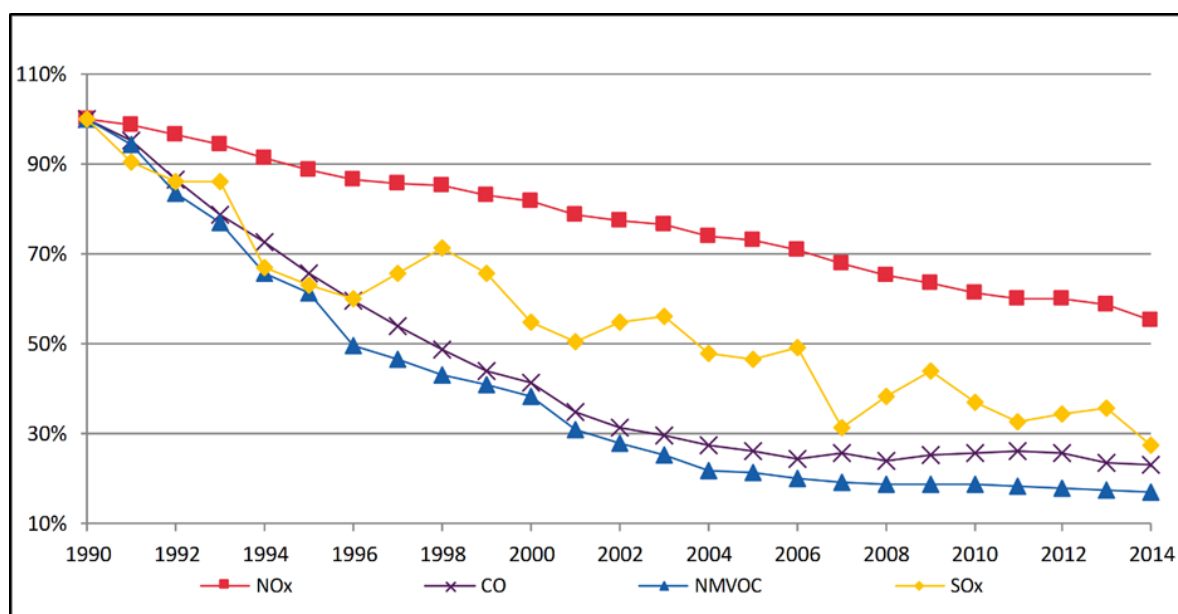
ES.3.2 KP-LULUCF activities

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. The submission in 2017 will take place at the end of April 2017, and **the overview and results provided below are those from the submission to the CLRTAP in 2016.**

For the substances NO_x, CO and NMVOC as well as for the gas SO₂, the emissions are shown in ES Figure 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.



ES Figure 3 Trend of emissions of precursor gases NO_x, CO, NMVOC and SO₂ 1990-2014 (Submission 2016).

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 2017.

PART 1: Annual inventory submission under the UNFCCC

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), the CH2011 (CH2011 2011) report and the Swiss Academies Report no. 11 (SCNAT 2016), which document 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 (see publication "Facts and figures about the climate in Liechtenstein", OE 2016i). 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 to the Swiss Alps. The results can therefore give valuable insights about climate change related future risks.

1.1.1.1 Impacts

The Office of Environment (OE) Liechtenstein published a booklet with facts and figures about climate change in 2018 (OE 2016i). 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 this century. Figure 1-1 illustrates the past and expected 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 scenario.

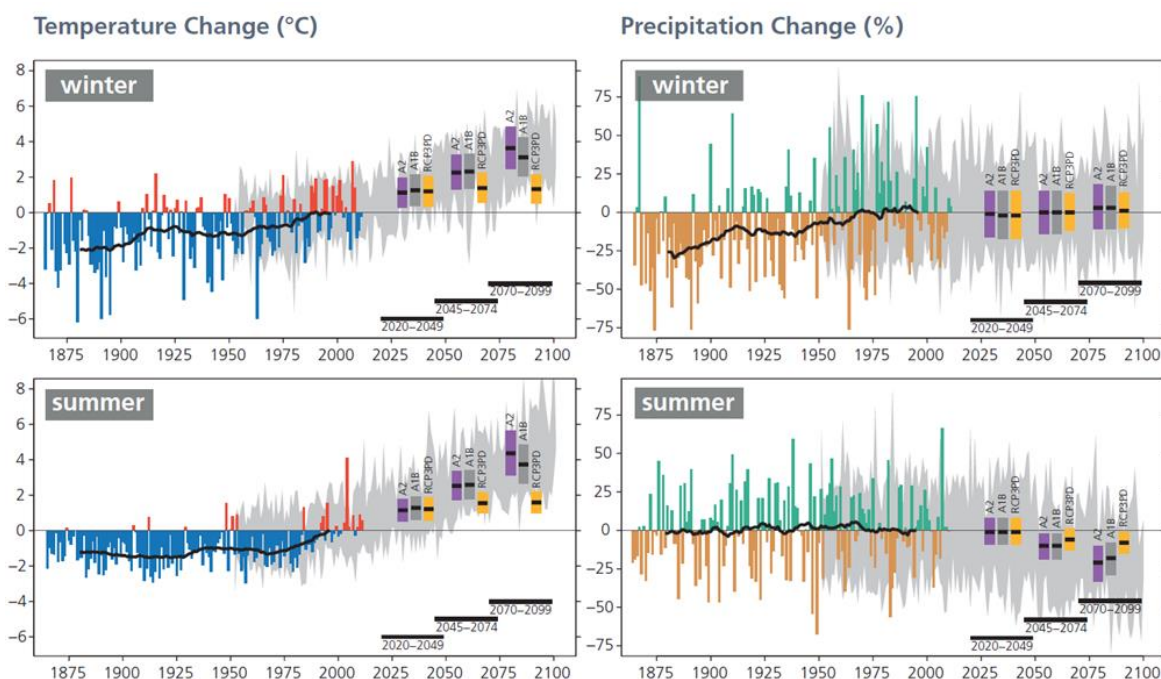


Figure 1-1 Past and expected future changes in seasonal temperature (°C) and precipitation (%) over northeastern Switzerland. The changes are depicted relative to the reference period 1980-2009. The thin coloured bars display the year-to-year differences with respect to the average of observations within 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-year intervals 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 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 increase in intensity of storms and reduction of snowfall and snow cover duration are particularly important for alpine areas. Tourism, infrastructure and forestry are particularly affected due to more frequent floods, landslides and debris flows and an increased risk of 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 Engineering 2015). The climate-related risks for Liechtenstein are expected to be similar but are not yet studied in detail.

1.1.1.2 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 km²). The available climate models are not yet able to predict detailed regional impacts. Overall, the following general effects can be expected as a consequence of further increasing CO₂ 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 human health (see INFRAS/Egli Engineering 2015). Another important health risk of climate change is the occurrence of vector-borne diseases. There is still high uncertainty about how future climate change will trigger further health issues.

Ecosystems: a temperature increase changes the composition of forest and grassland vegetation and biodiversity in general. For instance, deciduous trees may become more important than today. Also natural hazards (e.g. storms, avalanches, and debris flows) may have negative effects on forest and vegetation. The invasive, non-native species are an additional risk for ecosystems.

Water cycles and soil: changes in weather patterns may lead to an increased risk of floods in winter and droughts in summer time. A high flood risk exists particularly 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, such as the economically important recreation resorts in Malbun and Steg, will have to deal with great challenges caused by climate change related developments in Liechtenstein's ecosystems. Especially winter tourism will be affected by higher temperatures, which cause a rise of the freezing level and will lead to a shift of the snow line towards higher altitudes.

Other economic sectors: global warming will also affect other economic sectors in Liechtenstein. A rise in temperature may have a negative effects on the productivity of

grain cultivation in the long term (e.g. increased risk of draughts) but could also bring positive effects (e.g. longer vegetation period). The international engagement of the insurance sector will likely suffer the most severe negative consequences from an increase in the probability of losses.

1.1.1.3 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 2012a), Emissions Trading Act (Government 2012), Energy Efficiency Act (Government 2008), CO₂-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, rockfall and landslides and flooding.

Agriculture: identified adaptation measures are the selection of plant breeds that are suitable under expected future climatic conditions and selecting suitable plant breeds. 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 and subsequent damages caused by insects, pathogens (viruses, bacteria, fungus), fire or storms will lead to a decrease of the protective functions of forests in Liechtenstein. Adaptation measures 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

1.1.2.1 Framework

In 1995, the Principality of Liechtenstein ratified the United Nations Framework Convention on Climate Change (UNFCCC). Furthermore, Liechtenstein ratified the Kyoto Protocol to the UNFCCC in 2004. 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.

1.1.2.2 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 (UNFCCC 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.
- 2016: Submission of the Greenhouse Gas Inventory 1990-2013 together with the National Inventory Report 2016 prepared under the UNFCCC and under the Kyoto Protocol on 15 April 2016 (OE 2016a). Additionally, the Standard Electronic Format application (SEF) was submitted.
- 2016: Submission of the Greenhouse Gas Inventory 1990-2014 together with the National Inventory Report 2016 prepared under the UNFCCC and under the Kyoto Protocol on 27 May 2016 (OE 2016c). Additionally, the Standard Electronic Format application (SEF) was submitted.

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

Liechtenstein's greenhouse gas inventory was subject to in-country reviews in the years 2007 and 2013. Furthermore, centralized reviews took place in 2008, 2009, 2010, 2011, 2012 and 2014. Find further information under chp. 1.2.3.2.

1.1.2.4 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).
- 2016: Submission of the Greenhouse Gas Inventory 1990-2014 together with the National Inventory Report 2016 prepared under the UNFCCC and under the Kyoto Protocol on 27 May 2016 (OE 2016c).

- The present report is Liechtenstein's 12th National Inventory Report, NIR 2017, prepared under the UNFCCC and under the Kyoto Protocol. The present report includes, as separate files, Liechtenstein's 1990–2015 Inventory in the CRF Reporter format and the updated Standard Electronic Format application (SEF).

Note: No CP2 transactions were conducted so far. As requested by the UNFCCC secretariat, the empty SEF reports and tables for Liechtenstein had to be submitted in August 2016. Liechtenstein does not understand why this was necessary.

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

The review for the GHG inventories and National Inventory Reports 2015 and 2016 took place simultaneously in September 2016 due to the postponed submission 2015. Find further information under chp. 1.2.3.2.

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).

Liechtenstein has chosen 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, 2014 and 2015, 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 37'623 inhabitants (2015) and with an area of 160 km². With its neighbouring country Switzerland, Liechtenstein forms 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

Inventory planning, preparation, and management are well-established in Liechtenstein and 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 manager, 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 A8.3, Table A - 6). 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).

Due to the transition to the new UNFCCC and IPCC guidelines, the inventory cycles for submissions 2015 and 2016 deviated uniquely. From 2017 on, the cycle corresponds to the description above again.

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.

| 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. Please note that Liechtenstein's QA/QC system accounts for the **specific circumstances of the Principality of Liechtenstein**: Due to the small size 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 Ryttec (2010). The share of fossil matter in municipal waste has been determined in an extended measuring campaign during 2011 (Mohn 2011). 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, April for the years 2009-2014 and April and May 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 was 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. In addition to these 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.
 - 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) and also contribute to further quality control.
 - 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 2015 were compared with those of the year 2014 within the current Reporting Table Summary2.
 - The emissions of the year 2014 were compared between the current Reporting Table Summary2 of submission 2017 and the Reporting Table Summary2 of submission 2016.
 - The emissions of the base year 1990 were compared between the current Reporting Table Summary2 of submission 2017 and the Reporting Table Summary2 of the submission 2016.
 - 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 within more detailed CRF tables (e.g. Table1.A(a)s1) and explanations for those were sought. This procedure usually leads to the identification of errors in data, which are subsequently corrected before the 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 feedback 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 that 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 (see Annexes A8.3 and A8.4).

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). 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). After this correction, Liechtenstein's assigned amount has been fixed to 1055.623 kt CO₂ equivalents.

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). Important recommendations were integrated in former versions of Liechtenstein's IDP.

Between 2nd and 6th September 2013 the second in-country review was conducted 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 resulted and no resubmission of the inventory 2011 was requested for the submission 2014.

Another 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.

The latest centralized review for the GHG inventories and National Inventory Reports 2015 and 2016 took place simultaneously in September 2016 due to the postponed submission 2015. The ERT found potential methodical issues concerning land use changes from forest to non-forest as well as solid waste disposal and wastewater treatment (FCCC/ERT 2016). Liechtenstein recalculated the emissions in the waste sector in a resubmission of 14 November 2016 (OE 2016d), taking into account the specific recommendations by the ERT. The potential problems with forest land use changes are addressed and corrected in the present National Inventory Report, as recommended by the ERT.

Inventory development plan (IDP)

In the NIR 2016, IDP tables depicted recommendations and encouragements from the ERT and other improvements concerning the NIR which

- had been incorporated into the NIR 2016, see pp. 35-36 of OE 2016c,
- planned improvements for future submissions, improvements that will not be implemented and improvements that are already implemented p. 274 - 276 of NIR 2014 (OE 2016c).

From the planned improvements mentioned above the following have been realised for the current submission 2017:

- Sector Energy: An error in biomass emission factors (CO₂, CH₄, N₂O) was corrected for Submission 2017.

- Sector LULUCF: Data from a new areal survey were implemented as a new basis for estimating emissions from sector 4 LULUCF.
- Sector LULUCF: It is not possible to compare wood-fuel with deforestation. A reference to the wood harvesting statistics (OE 2016f) was added in the energy chapter (3.2.8).
- Data will be implemented in the estimation of emissions from sector 4 LULUCF
- Sector LULUCF: annual values of carbon loss by harvesting for productive forest (CC12) as for the reporting under the Kyoto Protocol (see chp. 11).
- Sector LULUCF: Uncertainties for the LULUCF sector were estimated based on the sample size of the new areal survey.
- Sector Waste: The landfill IPCC 2006 model was implemented in submission 2017.
- Sector Waste: Methane emissions from sewage gas processing are included in submission 2017.
- Sector Waste: The IPCC 2006 model for Wastewater treatment and discharge was implemented based on the parameters used in Switzerland.
- Sector Waste: Errors in activity data (waste and backyard composting) were corrected.

Planned improvements see sector chapters and a summary in chp. 10.4 of this NIR. Improvements that are already implemented and improvements that will not be implemented are documented in Annex A8.3, Table A - 6.

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 CO₂ 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 reached 0.422% in 2014. 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 NO₂, O₃ 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. 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 consolidated during the current

submission. Therefore the inventory preparation cycle, which deviated uniquely in 2015 and 2016, followed again the schedule of Table 1-1 for the current submission.

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 1-2 gives a schematic overview of the institutional setting of the process of inventory preparation within the NIS.

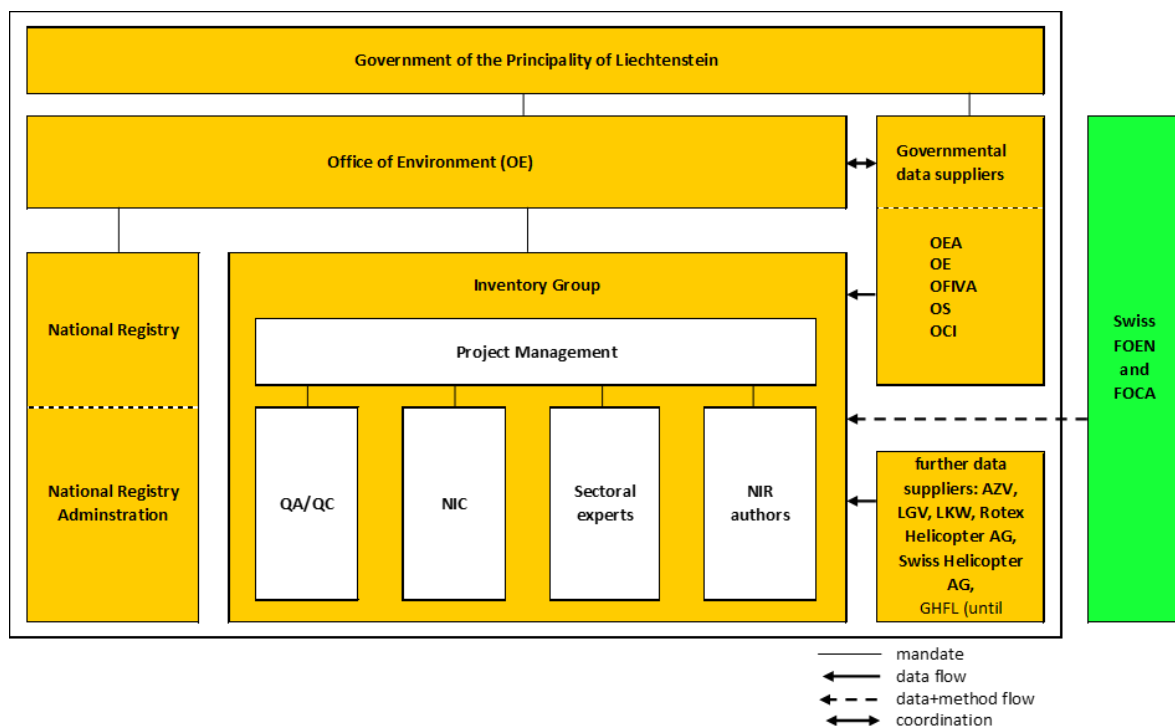


Figure 1-2 National Inventory System: Institutional setting and data suppliers. OE: Office of Environment; OEA: Office of Economic Affairs; OFIVA: Office of Food Inspections and Veterinary Affairs; OS: Office of Statistics; OCI: Office of Construction and Infrastructure; AZV: Liechtenstein's wastewater administration union; GHFL: Corporate 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 2016) also includes the fossil fuel consumption of the Principality of Liechtenstein, except for gas consumption of Liechtenstein, which is excluded from SFOE (2016). 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 extent 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 1-3 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 1-2.

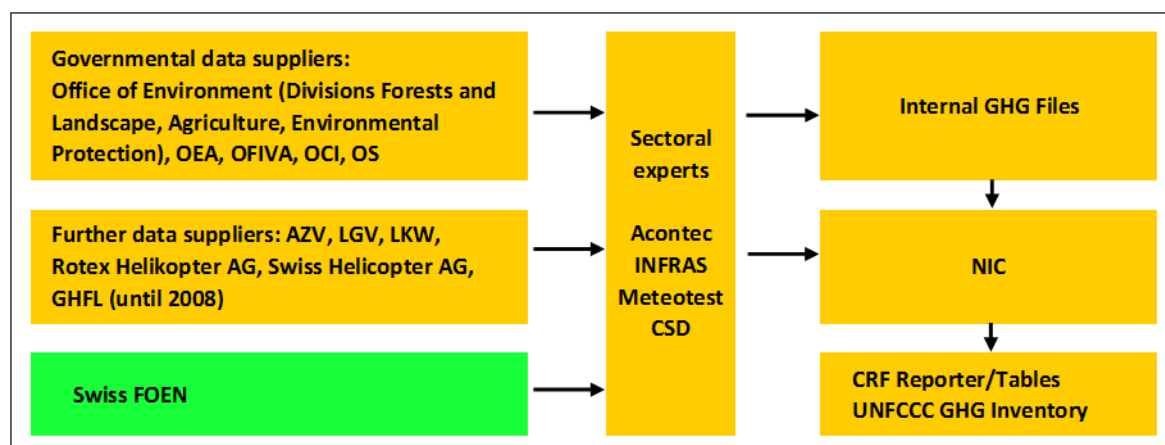


Figure 1-3 Data suppliers and data collection for setting up the UNFCCC GHG Inventory (see Glossary for abbreviations).

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 administrative 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 archived 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 chp. 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 and standards for exhaust gases of combustion and motor vehicles,
- the emission of F-gases due to similar product and consumer's attitude,
- agricultural emissions due to similar stock farming and cultivation of land,
- the sector LULUCF due to – again – similar geographic, meteorological and climatic circumstances for forestry, cropland, grassland and wetlands.

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).

- SF₆ emissions from 2G1 Electrical equipment are reported based on country-specific data.
- N₂O 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 (CO₂, CH₄, N₂O) 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 country-specific data from Liechtenstein's National Forest Inventory are used .

5 Waste

- Emissions for 5A Solid waste disposal, 5B Biological treatment of solid waste and 5D Wastewater treatment and discharge are estimated according to IPCC (2006) with country-specific activity data.
- Emissions for 5C Incineration and open burning of waste a country-specific method is used, based on CORINAIR, adapted from the Swiss NIR (FOEN 2016).

1.4.1.2 Specific assumptions for the year 2015

For the modelling of its emissions, Liechtenstein uses several emission factors originating from the Swiss GHG inventory. At the time of inventory preparation, 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 , and N ₂ O) | CO ₂ | | CH ₄ | | N ₂ O | |
|---|-----------------|-----------------|-----------------|-----------------|------------------|-----------------|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| 1. Energy | T1,T2 | CS,D | T1,T2,T3 | CS,D | T1,T2,T3 | CS,D |
| A. Fuel combustion | T1,T2 | CS,D | T1,T2,T3 | CS,D | T1,T2,T3 | CS,D |
| 1. Energy industries | T2 | CS,D | T2 | CS | T2 | CS,D |
| 2. Manufacturing industries and construction | T1,T2 | CS,D | T1,T2 | CS | T1,T2 | CS,D |
| 3. Transport | T1,T2 | CS,D | T2,T3 | CS,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 |
| 2. Oil and natural gas | NA | NA | T3 | CS | NA | NA |
| 2. Industrial processes and product use | NA | NA | NA | NA | CS | CS |
| A. Mineral industry | NA | NA | | | | |
| G. Other product manufacture and use | NA | NA | NA | NA | CS | CS |
| 3. Agriculture | T1b | D | T2 | CS,D | T1b,T2 | D |
| A. Enteric fermentation | | | T2 | CS,D | | |
| B. Manure management | | | T2 | D | T2 | D |
| D. Agricultural soils ⁽³⁾ | | | | | T1b | D |
| H. Urea application | T1b | D | | | | |
| 4. Land use, land-use change and forestry | T2 | CS,D | NA | NA | T2 | CS |
| A. Forest land | T2 | CS,D | NA | NA | NA | NA |
| B. Cropland | T2 | CS | NA | NA | T2 | CS |
| C. Grassland | T2 | CS | NA | NA | T2 | CS |
| D. Wetlands | T2 | CS | NA | NA | T2 | CS |
| E. Settlements | T2 | CS | NA | NA | T2 | CS |
| F. Other land | T2 | CS | NA | NA | T2 | CS |
| G. Harvested wood products | T2 | D | | | | |
| 5. Waste | T2 | CS | T2 | CS,D | T2 | CS,D |
| A. Solid waste disposal | NA | NA | T2 | D | | |
| B. Biological treatment of solid waste | | | T2 | CS | T2 | CS |
| C. Incineration and open burning of waste | T2 | CS | T2 | CS | T2 | D |
| D. Waste water treatment and discharge | | | T2 | CS,D | T2 | CS,D |
| 6. Other (as specified in summary 1.A) | NA | NA | NA | NA | NA | NA |

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES (F-GASES) | HFCs | | PFCs | | SF ₆ | |
|--|----------------|-----------------|----------------|-----------------|-----------------|-----------------|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| 2. Industrial processes and product use | CS | CS | CS | CS | CS | CS |
| F. Product uses as ODS substitutes | CS | CS | CS | CS | NA | NA |
| G. Other product manufacture and use | NA | NA | NA | NA | CS | CS |
| 6. Other (as specified in summary 1.A) | NA | NA | NA | NA | NA | NA |

Note: The CRF Tables Summary3s1 and 3s2 do not always display the correct notation keys for the applied methods and emission factors, which is the reason why the information above has been adapted manually where necessary and may therefore deviate in some positions from information given in the CRF Tables.

1.4.1.3 Reference approach for the energy sector

Liechtenstein carried out the reference approach to estimate energy consumption and CO₂ emissions for the energy sector. The results are shown in chp. 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, resubmitted on December 19 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 chose 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 was built up identically to Switzerland (same method and data structures, same realisation).

The following forest definition is used (OEP 2007b):

- minimum area of land: 0.0625 hectares (with a minimum width of 25 m)
- minimum crown cover: 20 percent
- 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 (CRF Table7). 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 analyses lead to four results:

- Base year 1990 level assessment without LULUCF categories
- Base year 1990 level assessment with LULUCF categories
- Reporting year 2015 level and trend assessment without LULUCF categories
- Reporting year 2015 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 is 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 for category being key as well as possible needs for improvement.

1.5.1 GHG Inventory

1.5.1.1 KCA excluding LULUCF categories

For 2015, among a total of 196 categories, 11 have been identified as Approach 1 key categories by the CRF Reporter Software (see CRF Table7 of the reporting tables) with an aggregated contribution of 96.1% of the national total emissions (see Table 1-3). 10 categories are key categories according to level assessment and 9 according to trend assessment.

Within those 11 key categories, 7 stem from the energy sector, contributing 80.5% to total CO₂ equivalent emissions in 2015. The other key categories are from the sectors Agriculture (3 categories, contribution 10.4%) and Industrial Processes and Product Use IPPU (1 category, contribution 5.1%).

The three major sources, all from the energy sector, sum up to a contribution of 65.2% of the national total emissions:

- 1A3b Road transportation, CO₂,
- 1A4 Other sectors, liquid fuels, CO₂,
- 1A4 Other sectors, gaseous fuels, CO₂.

Compared to the previous submission for the reporting year 2014, two categories are not key anymore in 2015:

- 3D2 Indirect N₂O emissions from managed soils, N₂O
- 5D Wastewater treatment and discharge, CH₄.

On the other hand, one additional category is key in 2015:

- 1B2b Fugitive emissions from fuels, Oil and natural gas and other emissions from energy production, CH₄.

Further details are shown in Table 1-3 below.

Table 1-3 List of Liechtenstein's Approach 1 key categories 2015 excluding LULUCF. Sorted by share of total emissions.

| Key Category Analysis 2015 (excluding LULUCF) IPCC Source Categories (and fuels if applicable) | GHG | Emissions 2015 [kt CO ₂ eq] | Share of Total Emissions | Cumulative Total | Result of Assessment |
|---|------------------|---|-----------------------------|---------------------|----------------------|
| 1.A.3.b Road Transportation | CO ₂ | 61.32 | 30.8% | 30.8% | KC Level & KC Trend |
| 1.A.4 Other Sectors - Liquid Fuels | CO ₂ | 35.02 | 17.6% | 48.3% | KC Level & KC Trend |
| 1.A.4 Other Sectors - Gaseous Fuels | CO ₂ | 33.75 | 16.9% | 65.2% | KC Level & KC Trend |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO ₂ | 14.51 | 7.3% | 72.5% | KC Level & KC Trend |
| 3.A Enteric Fermentation | CH ₄ | 13.25 | 6.6% | 79.2% | KC Level & KC Trend |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO ₂ | 12.80 | 6.4% | 85.6% | KC Level & KC Trend |
| 2.F.1 Refrigeration and Air conditioning | F-gases | 10.25 | 5.1% | 90.7% | KC Level & KC Trend |
| 3.D.1 Direct N ₂ O Emissions From Managed Soils | N ₂ O | 4.87 | 2.4% | 93.2% | KC Level |
| 3.B Manure Management | CH ₄ | 2.67 | 1.3% | 94.5% | KC Level |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | CO ₂ | 2.02 | 1.0% | 95.5% | KC Level & KC Trend |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | CH ₄ | 1.16 | 0.6% | 96.1% | KC Trend |

For the base year 1990, the level key category analysis is given in Table 1-4 below. There are 8 level key categories. There are no changes compared to the KCA of the previous submission.

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 ₂ eq] | Share of Total Emissions | Cumulative Total | Result of Assessment |
|---|------------------|---|-----------------------------|---------------------|----------------------|
| 1.A.4 Other Sectors - Liquid Fuels | CO ₂ | 76.71 | 33.5% | 33.5% | KC Level |
| 1.A.3.b Road Transportation | CO ₂ | 75.29 | 32.8% | 66.3% | KC Level |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO ₂ | 20.99 | 9.2% | 75.5% | KC Level |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO ₂ | 15.20 | 6.6% | 82.1% | KC Level |
| 3.A Enteric Fermentation | CH ₄ | 13.66 | 6.0% | 88.1% | KC Level |
| 1.A.4 Other Sectors - Gaseous Fuels | CO ₂ | 10.21 | 4.5% | 92.5% | KC Level |
| 3.D.1 Direct N ₂ O Emissions From Managed Soils | N ₂ O | 5.20 | 2.3% | 94.8% | KC Level |
| 3.B Manure Management | CH ₄ | 3.06 | 1.3% | 96.1% | KC Level |

1.5.1.2 KCA including LULUCF categories

According to the 2006 IPCC Guidelines (IPCC 2006), the key category analysis including LULUCF categories is conducted on the full GHG inventory in order to identify additional key categories. 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. Eight categories are identified key from the LULUCF sector and contribute with a total of 8.0% to total emissions:

- 4A1 Forest land remaining forest land, CO₂,
- 4A2 Land converted to forest land, CO₂,
- 4B1 Cropland remaining cropland, CO₂,
- 4C1 Grassland remaining grassland, CO₂,
- 4C2 Land converted to grassland, CO₂,
- 4E2 Land converted to settlements, CO₂,
- 4F2 Land converted to Other Land, CO₂,
- 4G Harvested wood products, CO₂.

Additionally, two categories from the sector energy and one from the sector agriculture are key when performing the KCA for the full inventory:

- 1A3b Road Transportation, CH₄,
- 1A4 Other Sectors – Biomass, CH₄,
- 3D2 Indirect N₂O emissions from managed soils, N₂O.

Compared to the KCA in the previous submission 2016 for the reporting year 2014, one additional LULUCF category is key:

- 4A1 Forest land remaining forest land, CO₂.

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, CO₂,
- 4E2 Land converted to settlements, CO₂,
- 4G Harvested wood products, CO₂.

Table 1-5 List of Liechtenstein's Approach 1 key categories 2015 including LULUCF. Sorted by share of total emissions.

| Key Category Analysis 2015 (including LULUCF) IPCC Source Categories (and fuels if applicable) | GHG | Emissions 2015 (absolute value) [kt CO ₂ eq] | Share of Total Emissions | Cumulative Total | Result of Assessment |
|---|------------------|---|-----------------------------|---------------------|----------------------|
| 1.A.3.b Road Transportation | CO ₂ | 61.32 | 28.1% | 28.1% | KC Level & KC Trend |
| 1.A.4 Other Sectors - Liquid Fuels | CO ₂ | 35.02 | 16.0% | 44.1% | KC Level & KC Trend |
| 1.A.4 Other Sectors - Gaseous Fuels | CO ₂ | 33.75 | 15.5% | 59.6% | KC Level & KC Trend |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO ₂ | 14.51 | 6.6% | 66.2% | KC Level & KC Trend |
| 3.A Enteric Fermentation | CH ₄ | 13.25 | 6.1% | 72.3% | KC Level & KC Trend |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO ₂ | 12.80 | 5.9% | 78.2% | KC Level & KC Trend |
| 2.F.1 Refrigeration and Air conditioning | F-gases | 10.25 | 4.7% | 82.9% | KC Level & KC Trend |
| 3.D.1 Direct N ₂ O Emissions From Managed Soils | N ₂ O | 4.87 | 2.2% | 85.1% | KC Level |
| 4.B.1 Cropland Remaining Cropland | CO ₂ | 4.01 | 1.8% | 86.9% | KC Level |
| 4.E.2 Land Converted to Settlements | CO ₂ | 3.04 | 1.4% | 88.3% | KC Level |
| 3.B Manure Management | CH ₄ | 2.67 | 1.2% | 89.5% | KC Level |
| 4.A.1 Forest Land Remaining Forest Land | CO ₂ | 2.43 | 1.1% | 90.7% | KC Level & KC Trend |
| 4.C.2 Land Converted to Grassland | CO ₂ | 2.38 | 1.1% | 91.7% | KC Level & KC Trend |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | CO ₂ | 2.02 | 0.9% | 92.7% | KC Level & KC Trend |
| 3.D.2 Indirect N ₂ O Emissions From Managed Soils | N ₂ O | 1.90 | 0.9% | 93.5% | KC Level |
| 4.A.2 Land Converted to Forest Land | CO ₂ | 1.51 | 0.7% | 94.2% | KC Level |
| 4.C.1 Grassland Remaining Grassland | CO ₂ | 1.48 | 0.7% | 94.9% | KC Level |
| 4.G Harvested Wood Products | CO ₂ | 1.37 | 0.6% | 95.5% | KC Level & KC Trend |
| 4.F.2 Land Converted to Other Land | CO ₂ | 1.18 | 0.5% | 96.1% | KC Trend |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | CH ₄ | 1.16 | 0.5% | 96.6% | KC Trend |
| 1.A.4 Other Sectors - Biomass | CH ₄ | 0.66 | 0.3% | 96.9% | KC Trend |
| 1.A.3.b Road Transportation | CH ₄ | 0.10 | 0.0% | 97.0% | 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 ₂ eq] | Share of Total Emissions | Cumulative Total | Result of Assessment |
|---|------------------|---|-----------------------------|---------------------|----------------------|
| 1.A.4 Other Sectors - Liquid Fuels | CO ₂ | 76.71 | 31.1% | 31.1% | KC Level |
| 1.A.3.b Road Transportation | CO ₂ | 75.29 | 30.5% | 61.6% | KC Level |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO ₂ | 20.99 | 8.5% | 70.1% | KC Level |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO ₂ | 15.20 | 6.2% | 76.3% | KC Level |
| 3.A Enteric Fermentation | CH ₄ | 13.66 | 5.5% | 81.9% | KC Level |
| 1.A.4 Other Sectors - Gaseous Fuels | CO ₂ | 10.21 | 4.1% | 86.0% | KC Level |
| 3.D.1 Direct N ₂ O Emissions From Managed Soils | N ₂ O | 5.20 | 2.1% | 88.1% | KC Level |
| 4.G Harvested Wood Products | CO ₂ | 4.70 | 1.9% | 90.0% | KC Level |
| 4.B.1 Cropland Remaining Cropland | CO ₂ | 4.18 | 1.7% | 91.7% | KC Level |
| 3.B Manure Management | CH ₄ | 3.06 | 1.2% | 92.9% | KC Level |
| 4.E.2 Land Converted to Settlements | CO ₂ | 2.94 | 1.2% | 94.1% | KC Level |
| 3.D.2 Indirect N ₂ O Emissions From Managed Soils | N ₂ O | 2.37 | 1.0% | 95.1% | KC Level |

1.5.2 KP-LULUCF inventory

Liechtenstein identified four key categories for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (Afforestation, Deforestation, Forest Management 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 chp. 11.6 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 (2015) and trend (1990-2015) analyses.

A simplified uncertainty analysis has been carried out for the current submission. The simplification means that uncertainty analysis individually accounts for the key categories, whereas the rest of the categories were aggregated by gas and treated as four “rest” categories CO₂, CH₄, N₂O 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 (see Annex A7.1 for further information).

1.6.1.2 Uncertainty estimates

Data on uncertainties is not provided explicitly for most emission sources and sinks 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 2016). 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 NF₃, 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 ₂ O | 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 (2015) in the national total annual CO₂ equivalent emissions **excluding LULUCF** is estimated to be 5.49%, trend uncertainty (1990-2015) is 5.58%.

The Approach 1 level uncertainty (2015) in the national total annual CO₂ equivalent emissions **including LULUCF** is estimated to be 5.54%, trend uncertainty (1990-2015) is 5.54% as well.

Compared to the **previous submission 2016 (reporting year 2014)**, the results of Approach 1 analyses show a slight increase of level and trend uncertainties:

- Level uncertainty 2014: 5.46% (excluding LULUCF) and 5.38% (including LULUCF)
- Trend uncertainty 1990-2014: 5.49% (excluding LULUCF) and 5.43% (including LULUCF)

The slight increase of the uncertainty values is due to the shift in key categories and non-key rest categories, which leads to a change in the respective emissions that are used to weight the uncertainties of the (sub-)categories in the analyses. In addition, uncertainties of in the energy sector were updated based on data from a measurement campaign in

Switzerland in which the CO₂ emission factors of the dominant liquid fuels were analyzed (SFOE/FOEN 2014).

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 (2015) and trend (1990-2015) 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 2015 emissions or removals | AD unc. | EF unc. | Comb. unc. | Contr. to variance by Category in 2015 | 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 | CO ₂ | 0.12 | 2.02 | 5.0 | 1.1 | 5.1 | 0.003 | 0.01 | 0.01 | 0.01 | 0.06 | 0.004 |
| | | | 2. Manufacturing industries & construction | CO ₂ | 20.99 | 12.80 | 20.0 | 0.1 | 20.0 | 1.649 | 0.02 | 0.06 | 0.00 | 1.58 | 2.496 |
| 1A2 | 1. Energy | A. Fuel combustion activities | 3. Transport; Road Transp. | CO ₂ | 15.20 | 14.51 | 5.0 | 1.1 | 5.1 | 0.139 | 0.01 | 0.06 | 0.01 | 0.45 | 0.200 |
| 1A3b | | | 4. Other Sectors | CO ₂ | 75.29 | 61.32 | 9.0 | 0.1 | 9.0 | 7.679 | 0.02 | 0.27 | 0.00 | 3.41 | 11.621 |
| 1A4 | 1. Energy | A. Fuel combustion activities | 1. Energy industries | CO ₂ | 76.71 | 35.02 | 15.8 | 0.1 | 15.8 | 7.733 | 0.14 | 0.15 | 0.01 | 3.42 | 11.703 |
| 1A4 | | | 2. Manufacturing industries & construction | CO ₂ | 10.21 | 33.75 | 3.9 | 0.9 | 3.9 | 0.446 | 0.11 | 0.15 | 0.09 | 0.80 | 0.652 |
| 1B2 | 2. IPPU | B. Fugitive Em. from Fuels | 2. Oil & Natural Gas | CH ₄ | 0.37 | 1.16 | 35.4 | 35.4 | 50.0 | 0.084 | 0.00 | 0.01 | 0.13 | 0.25 | 0.080 |
| 2F1 | 2. IPPU | F. Product uses as substitutes for ODS | 1. Refrigeration and air conditioning | F-gases | 0.00 | 10.25 | 10.6 | 10.6 | 15.0 | 0.593 | 0.04 | 0.04 | 0.47 | 0.67 | 0.674 |
| 3A | 3. Agriculture | A. Enteric Ferment. | | CH ₄ | 13.66 | 13.25 | 6.4 | 16.9 | 18.1 | 1.451 | 0.01 | 0.06 | 0.10 | 0.53 | 0.288 |
| 3B | | | B. Manure Management | CH ₄ | 3.06 | 2.67 | 6.4 | 54.0 | 54.4 | 0.531 | 0.00 | 0.01 | 0.00 | 0.11 | 0.011 |
| 3D1 | 3. Agriculture | D. Agricultural Soils | 1. Direct Soil Emissions | N ₂ O | 5.20 | 4.87 | 16.6 | 96.9 | 98.3 | 5.761 | 0.00 | 0.02 | 0.15 | 0.50 | 0.269 |
| non-key rest | | | | | CO ₂ | 0.26 | 0.13 | 7.1 | 7.1 | 10.0 | 0.000 | 0.00 | 0.00 | 0.00 | 0.01 |
| | | | | CH ₄ | 2.44 | 2.42 | 21.2 | 21.2 | 30.0 | 0.132 | 0.00 | 0.01 | 0.03 | 0.32 | 0.101 |
| | | | | N ₂ O | 5.70 | 4.98 | 56.6 | 56.6 | 80.0 | 3.990 | 0.00 | 0.02 | 0.00 | 1.74 | 3.019 |
| | | | | F-gases | - | 0.25 | 14.1 | 14.1 | 20.0 | 0.001 | 0.00 | 0.00 | 0.02 | 0.02 | 0.001 |
| Total | | | | | 229.21 | 199.39 | | | | 30.19 | | | | | 31.12 |
| | | | | | | | | | Percentage uncertainty in total inventory: | | 5.49 | | Trend uncertainty: | | 5.58 |

Table 1-9 Approach 1 level (2015) and trend (1990-2015) 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 2015 emissions or removals | AD unc. | EF unc. | Comb. unc. | Contr. to variance by Category in 2015 | 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 trend in total national emissions | | | | |
| (categories including LULUCF) | | | kt CO ₂ eq | kt CO ₂ eq | % | % | % | - | % | % | % | % | - | | | | |
| 1. Energy | A. Fuel combustion activities | 1. Energy industries | Gaseous F. | CO ₂ | 0.12 | 2.02 | 5.0 | 1.1 | 5.1 | 0.002 | 0.01 | 0.01 | 0.01 | 0.06 | 0.004 | | |
| | | | Liquid F. | CO ₂ | 20.99 | 12.80 | 20.0 | 0.1 | 20.0 | 1.520 | 0.03 | 0.06 | 0.00 | 1.56 | 2.421 | | |
| | | 2. Manufacturing ind. & constr. | Gaseous F. | CO ₂ | 15.20 | 14.51 | 5.0 | 1.1 | 5.1 | 0.128 | 0.00 | 0.06 | 0.00 | 0.44 | 0.194 | | |
| | | | Liquid F. | CO ₂ | 75.29 | 61.32 | 9.0 | 0.1 | 9.0 | 7.076 | 0.03 | 0.26 | 0.00 | 3.36 | 11.273 | | |
| | | 3. Transp. | b. Road Transp. | Gaseous F. | CH ₄ | 0.63 | 0.10 | 9.7 | 57.2 | 58.0 | 0.001 | 0.00 | 0.00 | 0.11 | 0.01 | 0.013 | |
| | | | | Liquid F. | CO ₂ | 76.71 | 35.02 | 15.8 | 0.1 | 15.8 | 7.125 | 0.14 | 0.15 | 0.01 | 3.37 | 11.353 | |
| | | 4. Other Sectors | Biomass | Gaseous F. | CO ₂ | 10.21 | 33.75 | 3.9 | 0.9 | 3.9 | 0.411 | 0.11 | 0.15 | 0.09 | 0.79 | 0.632 | |
| | | | | Liquid F. | CH ₄ | 0.13 | 0.66 | 19.2 | 21.5 | 28.8 | 0.008 | 0.00 | 0.00 | 0.05 | 0.08 | 0.008 | |
| | | 2. IPPU | B. Fugitive Emissions from Fuels | 2. Oil, nat. gas, other em. from energy prod. | Gaseous F. | CH ₄ | 0.37 | 1.16 | 35.4 | 35.4 | 50.0 | 0.078 | 0.00 | 0.00 | 0.13 | 0.25 | 0.078 |
| | | | | | Liquid F. | F-gases | 0.00 | 10.25 | 10.6 | 10.6 | 15.0 | 0.547 | 0.04 | 0.04 | 0.47 | 0.66 | 0.653 |
| 3. Agriculture | A. Enteric Ferment. | A. Cattle | Gaseous F. | CH ₄ | 13.66 | 13.25 | 6.4 | 16.9 | 18.1 | 1.337 | 0.00 | 0.06 | 0.08 | 0.52 | 0.275 | | |
| | | | Liquid F. | CH ₄ | 3.06 | 2.67 | 6.4 | 54.0 | 54.4 | 0.489 | 0.00 | 0.01 | 0.01 | 0.10 | 0.011 | | |
| | D. Agricultural Soils | 1. Dir. Indi. Em. | 1. Dir. Indi. Em. | Gaseous F. | N ₂ O | 5.20 | 4.87 | 16.6 | 96.9 | 98.3 | 5.309 | 0.00 | 0.02 | 0.09 | 0.49 | 0.249 | |
| | | | | Liquid F. | N ₂ O | 2.37 | 1.90 | 27.7 | 171.2 | 173.5 | 2.527 | 0.00 | 0.01 | 0.15 | 0.32 | 0.127 | |
| 4. LULUCF | A. Forest Land | 1. Forest land remaining forest land | Gaseous F. | CO ₂ | -0.60 | -2.43 | 2.7 | 47.9 | 48.0 | 0.316 | 0.01 | 0.01 | 0.39 | 0.04 | 0.154 | | |
| | | | Liquid F. | CO ₂ | -1.64 | -1.51 | 17.2 | 40.3 | 43.8 | 0.101 | 0.00 | 0.01 | 0.01 | 0.16 | 0.025 | | |
| | B. Cropland | 1. Cropland remaining cropland | Gaseous F. | CO ₂ | 4.18 | 4.01 | 30.8 | 23.0 | 38.4 | 0.551 | 0.00 | 0.02 | 0.03 | 0.75 | 0.564 | | |
| | | | Liquid F. | CO ₂ | 1.49 | 1.48 | 30.6 | 23.0 | 38.3 | 0.074 | 0.00 | 0.01 | 0.01 | 0.27 | 0.075 | | |
| | C. Grassland | 1. Grassland remaining grassland | Gaseous F. | CO ₂ | 0.33 | 2.38 | 13.6 | 40.3 | 42.5 | 0.237 | 0.01 | 0.01 | 0.36 | 0.20 | 0.169 | | |
| | | | Liquid F. | CO ₂ | 2.94 | 3.04 | 19.4 | 50.0 | 53.6 | 0.618 | 0.00 | 0.01 | 0.09 | 0.36 | 0.137 | | |
| | E. Settlements | 1. Land converted to settlements | Gaseous F. | CO ₂ | 0.44 | 1.18 | 40.9 | 50.0 | 64.6 | 0.136 | 0.00 | 0.01 | 0.17 | 0.29 | 0.115 | | |
| | | | Liquid F. | CO ₂ | -4.70 | -1.37 | 50.0 | 57.0 | 75.8 | 0.250 | 0.01 | 0.01 | 0.69 | 0.42 | 0.652 | | |
| | non-key rest | G. HWP | 2. Land converted to other land | Gaseous F. | CO ₂ | 1.02 | 1.25 | 7.1 | 7.1 | 10.0 | 0.004 | 0.00 | 0.01 | 0.01 | 0.05 | 0.003 | |
| | | | | Liquid F. | CH ₄ | 1.67 | 1.66 | 21.2 | 21.2 | 30.0 | 0.058 | 0.00 | 0.01 | 0.02 | 0.21 | 0.046 | |
| Gaseous F. | | | | N ₂ O | 3.65 | 3.49 | 56.6 | 56.6 | 80.0 | 1.810 | 0.00 | 0.02 | 0.06 | 1.20 | 1.445 | | |
| Liquid F. | | | | F-gases | - | 0.25 | 14.1 | 14.1 | 20.0 | 0.001 | 0.00 | 0.00 | 0.02 | 0.02 | 0.001 | | |
| Total | | | | 232.72 | 207.71 | | | | 30.71 | | | | | 30.68 | | | |
| | | | | | | | | Percentage uncertainty in total inventory: | | 5.54 | | Trend uncertainty: | | 5.54 | | | |

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 2015 for the total national emissions excluding LULUCF.

| Gas | Emmissions 2015 (excluding LULUCF) kt CO₂ eq | Mean absolute uncertainty kt CO₂ eq | Mean relative uncertainty |
|--------------|--|---|--------------------------------------|
| CO2 | 159.6 | 8.4 | 5% |
| CH4 | 19.5 | 3.0 | 15% |
| N2O | 9.8 | 6.2 | 63% |
| F-gases | 10.5 | 1.5 | 15% |
| Total | 199.4 | 11.0 | 5.49% |

Please note that the current results of the Approach 1 uncertainty analysis for GHG emissions from key categories 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 2015 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 CO₂ 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 CO₂ 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 net CO₂ emissions in 2015 are 2.48 kt CO₂eq ± 2.24 kt CO₂eq (see chp. 11.3.2 for details of the calculation).

1.7 Assessment of completeness

1.7.1 GHG inventory

Liechtenstein's current GHG inventory is complete for all gases 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 1990–2015.

2.1 Aggregated greenhouse gas emissions 2015

Liechtenstein's greenhouse gas emissions in the year 2015 amount to 199.4 kt CO₂ equivalent excluding LULUCF sources or sinks (including LULUCF: 207.7 kt CO₂). This refers to 5.3 t CO₂ equivalent per capita. Total emissions (excl. LULUCF) have declined by 13.0% compared to 1990 and by 1.2% compared to 2014.

Among the different greenhouse gases, CO₂ accounts for the largest share of total emissions. Table 2-1 shows the emissions for individual gases and sectors in Liechtenstein for the year 2015. The most important emission sources are fuel combustion activities in the Energy sector. Emissions of CH₄ and N₂O mainly originate 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 2015 by gas and sector in CO₂ equivalent (kt). Numbers may not add to totals due to rounding.

| Emissions 2015 | CO ₂ | CH ₄ | N ₂ O | HFCs | PFCs | SF ₆ | Total |
|---------------------------------|---------------------------------|-----------------|------------------|-------------|-------------|-----------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | |
| 1 Energy | 159.5 | 2.08 | 0.8 | - | - | - | 162.3 |
| 2 IPPU | NO | NO | 0.2 | 10.4 | 0.04 | 0.04 | 10.7 |
| 3 Agriculture | 0.05 | 15.92 | 8.1 | - | - | - | 24.1 |
| 5 Waste | 0.02 | 1.50 | 0.8 | - | - | - | 2.3 |
| Total (excluding LULUCF) | 159.6 | 19.5 | 9.8 | 10.4 | 0.04 | 0.04 | 199.4 |
| 4 LULUCF | 7.9 | NO | 0.4 | - | - | - | 8.3 |
| Total (including LULUCF) | 167.5 | 19.5 | 10.3 | 10.4 | 0.04 | 0.04 | 207.7 |
| <i>International Bunkers</i> | <i>1.2</i> | <i>0.0002</i> | <i>0.01</i> | - | - | - | <i>1.2</i> |

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

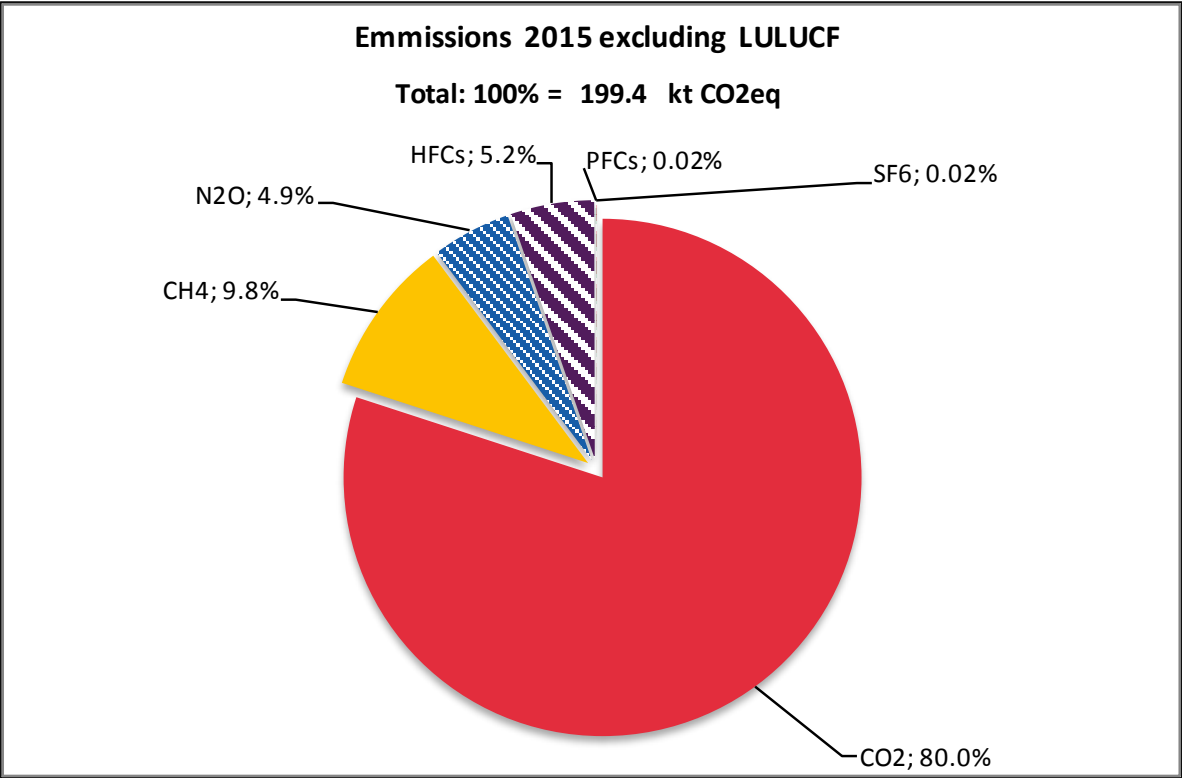


Figure 2-1 Liechtenstein's GHG emissions by gases excluding LULUCF emissions in 2015.

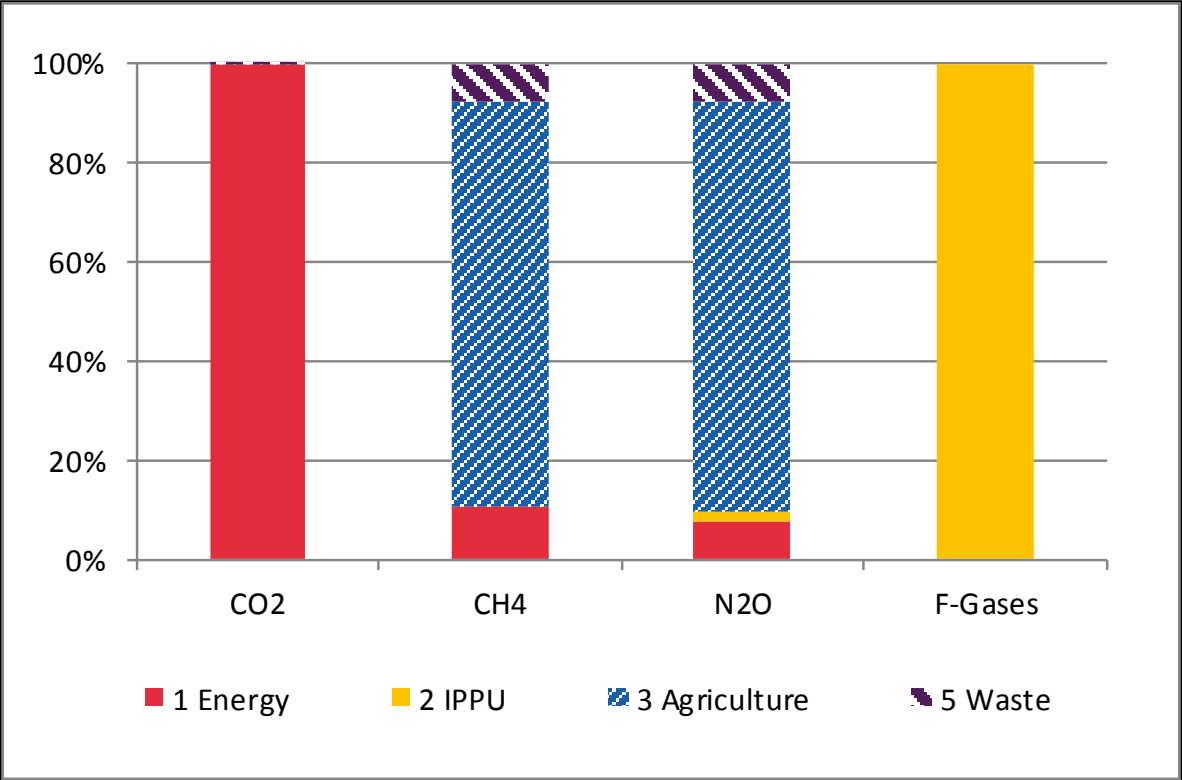


Figure 2-2 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions in 2015.

2.2 Emission trends by gas

Emission trends 1990–2015 by gas are summarised in Table 2-2 and in Figure 2-3.

Table 2-2 Summary of Liechtenstein's GHG emissions in CO₂ equivalent (kt) by gas, 1990-2015. The last column shows the percentage change in emissions in 2015 as compared to the base year 1990. The percentage change of HFCs amounts to 9'974'954%.

| Greenhouse Gas Emissions | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| CO ₂ emissions incl. net CO ₂ from LULUCF | 202.0 | 196.0 | 207.5 | 212.5 | 218.4 | 206.9 | 200.6 | 224.8 | 227.1 | 222.7 |
| CO ₂ emissions excl. net CO ₂ from LULUCF | 198.8 | 206.2 | 206.8 | 214.9 | 201.0 | 204.1 | 205.8 | 218.2 | 229.1 | 226.4 |
| CH ₄ emissions incl. CH ₄ from LULUCF | 19.5 | 19.4 | 19.0 | 18.2 | 18.4 | 18.3 | 18.7 | 18.4 | 18.2 | 17.6 |
| CH ₄ emissions excl. CH ₄ from LULUCF | 19.5 | 19.4 | 19.0 | 18.2 | 18.4 | 18.3 | 18.7 | 18.4 | 18.2 | 17.6 |
| N ₂ O emissions incl. N ₂ O from LULUCF | 11.2 | 11.4 | 11.3 | 11.1 | 11.0 | 10.9 | 10.9 | 10.9 | 10.6 | 10.3 |
| N ₂ O emissions excl. N ₂ O from LULUCF | 10.9 | 11.1 | 11.0 | 10.8 | 10.7 | 10.6 | 10.6 | 10.6 | 10.2 | 10.0 |
| 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) | 232.7 | 226.8 | 237.9 | 242.0 | 248.4 | 237.5 | 231.9 | 256.2 | 258.6 | 254.0 |
| Total (excluding LULUCF) | 229.2 | 236.7 | 236.9 | 244.0 | 230.6 | 234.3 | 236.8 | 249.3 | 260.3 | 257.4 |

| Greenhouse Gas Emissions | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| CO ₂ emissions incl. net CO ₂ from LULUCF | 238.4 | 213.6 | 219.7 | 233.3 | 234.8 | 234.1 | 239.9 | 218.9 | 239.8 | 227.6 |
| CO ₂ emissions excl. net CO ₂ from LULUCF | 216.7 | 214.5 | 219.9 | 229.2 | 229.2 | 228.9 | 231.1 | 200.7 | 219.5 | 205.3 |
| CH ₄ emissions incl. CH ₄ from LULUCF | 17.4 | 18.0 | 18.3 | 18.5 | 18.6 | 19.2 | 19.9 | 20.4 | 20.7 | 20.4 |
| CH ₄ emissions excl. CH ₄ from LULUCF | 17.4 | 18.0 | 18.3 | 18.5 | 18.6 | 19.2 | 19.9 | 20.4 | 20.7 | 20.4 |
| N ₂ O emissions incl. N ₂ O from LULUCF | 10.2 | 10.3 | 10.4 | 10.4 | 10.1 | 10.2 | 10.4 | 10.5 | 10.7 | 10.5 |
| N ₂ O emissions excl. N ₂ O from LULUCF | 9.8 | 9.9 | 10.0 | 10.0 | 9.7 | 9.9 | 10.0 | 10.1 | 10.3 | 10.1 |
| HFCs | 4.1 | 4.9 | 5.5 | 6.1 | 7.0 | 7.4 | 7.8 | 8.5 | 9.1 | 9.1 |
| 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) | 270.2 | 247.0 | 254.2 | 268.7 | 270.8 | 271.3 | 278.2 | 258.4 | 280.7 | 267.9 |
| Total (excluding LULUCF) | 248.1 | 247.6 | 254.0 | 264.2 | 264.8 | 265.7 | 269.0 | 239.9 | 260.0 | 245.2 |

| Greenhouse Gas Emissions | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|---|---------------------------------|--------------|--------------|--------------|--------------|--------------|---------------|
| | CO ₂ equivalent (kt) | | | | | | % |
| CO ₂ emissions incl. net CO ₂ from LULUCF | 211.5 | 197.8 | 206.7 | 206.1 | 174.7 | 167.5 | -17.1% |
| CO ₂ emissions excl. net CO ₂ from LULUCF | 190.8 | 176.8 | 185.4 | 192.6 | 161.3 | 159.6 | -19.7% |
| CH ₄ emissions incl. CH ₄ from LULUCF | 19.8 | 20.3 | 20.7 | 19.8 | 19.8 | 19.5 | -0.2% |
| CH ₄ emissions excl. CH ₄ from LULUCF | 19.8 | 20.3 | 20.7 | 19.8 | 19.8 | 19.5 | -0.2% |
| N ₂ O emissions incl. N ₂ O from LULUCF | 10.3 | 10.7 | 10.6 | 10.4 | 10.3 | 10.3 | -8.5% |
| N ₂ O emissions excl. N ₂ O from LULUCF | 9.9 | 10.3 | 10.2 | 10.0 | 9.9 | 9.8 | -9.7% |
| HFCs | 9.7 | 10.0 | 10.4 | 10.6 | 10.6 | 10.4 | see caption |
| PFCs | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | --- |
| SF ₆ | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.0 | --- |
| Total (including LULUCF) | 251.4 | 238.9 | 248.5 | 247.1 | 215.6 | 207.7 | -10.7% |
| Total (excluding LULUCF) | 230.3 | 217.4 | 226.8 | 233.3 | 201.8 | 199.4 | -13.0% |

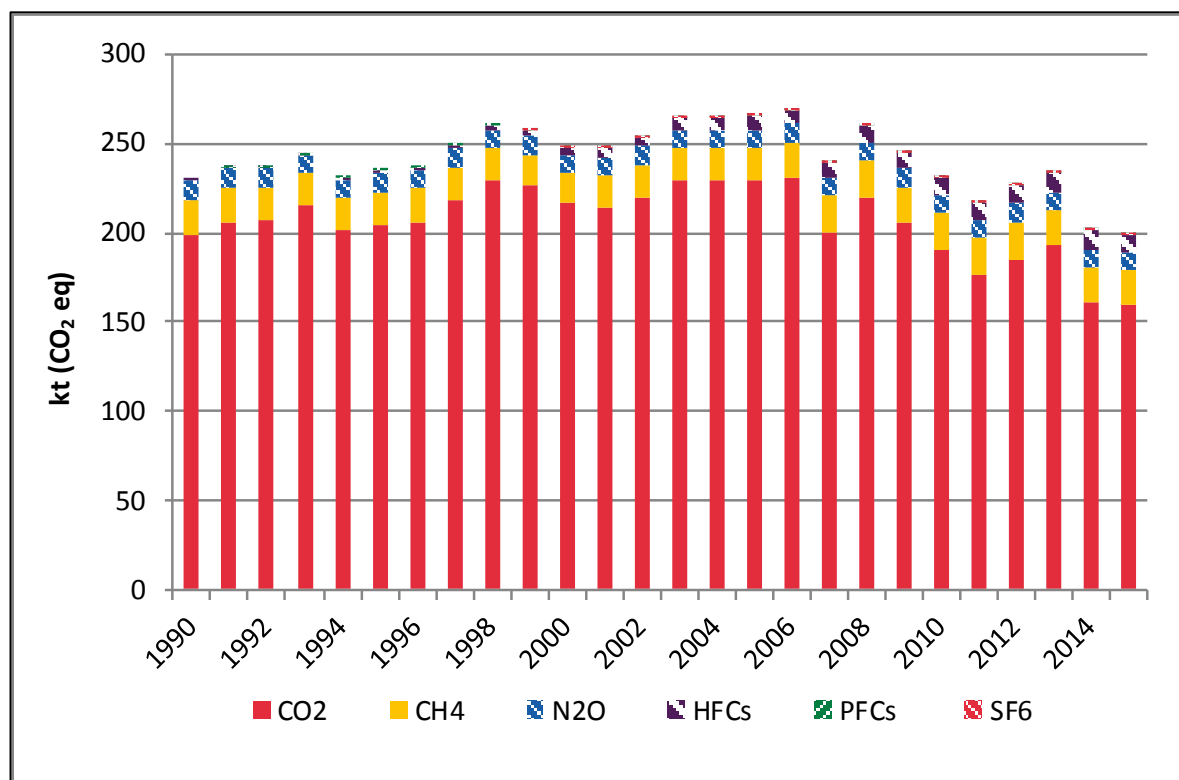


Figure 2-3 Trend of Liechtenstein's greenhouse gas emissions by gases 1990–2015. CO₂, CH₄ and N₂O correspond to the respective total emissions excluding LULUCF.

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

- Total emissions (in CO₂ equivalent) excluding LULUCF sources or sinks decreased by 13.0% from 1990 to 2015.
- Total emissions (in CO₂ equivalent) including LULUCF show a decrease of 10.7% in 2015 compared to 1990 levels.
- Accounting for 80.0% of the total emissions, CO₂ is the most dominant greenhouse gas emitted in Liechtenstein. CH₄ emissions represent 9.8% and N₂O emissions 4.9% of the total emissions.
- CO₂ emissions (excluding net CO₂ from LULUCF) have declined by 19.7% between 1990 and 2015. In comparison to the previous reporting year 2014, CO₂ emissions (excluding net CO₂ from LULUCF) decreased by 1.1% in 2015. The most important drivers of net CO₂ emissions are fuel prices and winter temperatures (heating degree days).
- CH₄ emissions (excluding CH₄ from LULUCF) have slightly decreased by 0.2% since 1990. Compared to 2014, CH₄ emissions (excluding LULUCF) show a decrease by 1.7% in 2015.
- N₂O emissions (excluding N₂O from LULUCF) have declined by 9.7% in 2015 compared to 1990. Regarding 2014, N₂O emissions (without LULUCF) in 2015 slightly decreased by 0.2%.

- HFC emissions increased due to their role as substitutes for CFCs. SF6 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 (within total emissions excl. LULUCF) increased from 0.00005% (1990) to 5.3% (2015).

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 it in more detail (1A1-1A5, 1B).

Table 2-3 Summary of Liechtenstein's GHG emissions by source and sink categories in CO₂ equivalent (kt), 1990–2015. The last column shows the percent change in emissions in 2015 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 | 221.1 | 232.0 | 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 & constr. | 36.3 | 36.0 | 36.4 | 37.6 | 35.7 | 35.7 | 35.8 | 37.6 | 40.4 | 39.9 |
| 1A3 Transport | 76.8 | 90.1 | 89.4 | 87.2 | 79.9 | 81.8 | 83.1 | 86.8 | 86.4 | 90.5 |
| 1A4 Other sectors | 87.5 | 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 | 23.9 | 23.7 | 23.9 | 23.5 | 23.0 | 22.1 |
| 5 Waste | 2.2 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.3 | 2.2 | 2.2 | 2.2 |
| Total (excluding LULUCF) | 229.2 | 236.7 | 236.9 | 244.0 | 230.6 | 234.3 | 236.8 | 249.3 | 260.3 | 257.4 |
| 4 LULUCF | 3.5 | -9.9 | 1.0 | -2.1 | 17.8 | 3.2 | -4.9 | 6.9 | -1.7 | -3.4 |
| Total (including LULUCF) | 232.7 | 226.8 | 237.9 | 242.0 | 248.4 | 237.5 | 231.9 | 256.2 | 258.6 | 254.0 |

| Source and Sink Categories | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|--|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| 1 Energy | 219.8 | 217.5 | 222.8 | 232.1 | 231.9 | 231.6 | 233.8 | 203.6 | 222.4 | 208.3 |
| 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 & constr. | 36.5 | 36.4 | 37.9 | 41.2 | 39.9 | 39.2 | 40.6 | 33.9 | 36.4 | 27.6 |
| 1A3 Transport | 91.3 | 87.9 | 83.8 | 83.6 | 82.3 | 81.9 | 79.3 | 83.5 | 87.9 | 82.0 |
| 1A4 Other sectors | 88.5 | 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 | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 |
| 2 IPPU | 4.5 | 5.4 | 6.0 | 6.7 | 7.5 | 7.9 | 8.2 | 8.9 | 9.8 | 9.5 |
| 3 Agriculture | 21.5 | 22.5 | 22.9 | 23.0 | 23.0 | 23.6 | 24.6 | 24.9 | 25.1 | 25.0 |
| 5 Waste | 2.4 | 2.2 | 2.4 | 2.4 | 2.4 | 2.6 | 2.4 | 2.5 | 2.6 | 2.4 |
| Total (excluding LULUCF) | 248.1 | 247.6 | 254.0 | 264.2 | 264.8 | 265.7 | 269.0 | 239.9 | 260.0 | 245.2 |
| 4 LULUCF | 22.0 | -0.6 | 0.1 | 4.5 | 6.0 | 5.6 | 9.2 | 18.5 | 20.7 | 22.7 |
| Total (including LULUCF) | 270.2 | 247.0 | 254.2 | 268.7 | 270.8 | 271.3 | 278.2 | 258.4 | 280.7 | 267.9 |

| Source and Sink Categories | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|--|---------------------------------|--------------|--------------|--------------|--------------|--------------|----------------|
| | CO ₂ equivalent (kt) | | | | | | % |
| 1 Energy | 193.8 | 179.8 | 188.4 | 195.5 | 164.1 | 162.3 | -19.3% |
| 1A1 Energy industries | 3.3 | 3.1 | 2.8 | 3.0 | 2.5 | 2.0 | 1062.9% |
| 1A2 Manufacturing industries & constr. | 26.1 | 23.6 | 25.8 | 26.4 | 27.1 | 27.4 | -24.5% |
| 1A3 Transport | 77.8 | 77.1 | 80.1 | 79.8 | 74.2 | 61.9 | -19.4% |
| 1A4 Other sectors | 85.4 | 74.9 | 78.6 | 85.1 | 59.1 | 69.8 | -20.2% |
| 1A5 Other | NO | NO | NO | NO | NO | NO | - |
| 1B Fugitive emissions from fuels | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.2 | 215.2% |
| 2 IPPU | 10.0 | 10.2 | 10.6 | 11.1 | 11.0 | 10.7 | 2264.5% |
| 3 Agriculture | 24.2 | 24.9 | 25.1 | 24.0 | 24.4 | 24.1 | -5.6% |
| 5 Waste | 2.4 | 2.6 | 2.6 | 2.6 | 2.4 | 2.3 | 4.6% |
| Total (excluding LULUCF) | 230.3 | 217.4 | 226.8 | 233.3 | 201.8 | 199.4 | -13.0% |
| 4 LULUCF | 21.1 | 21.4 | 21.7 | 13.9 | 13.8 | 8.3 | 137.2% |
| Total (including LULUCF) | 251.4 | 238.9 | 248.5 | 247.1 | 215.6 | 207.7 | -10.7% |

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

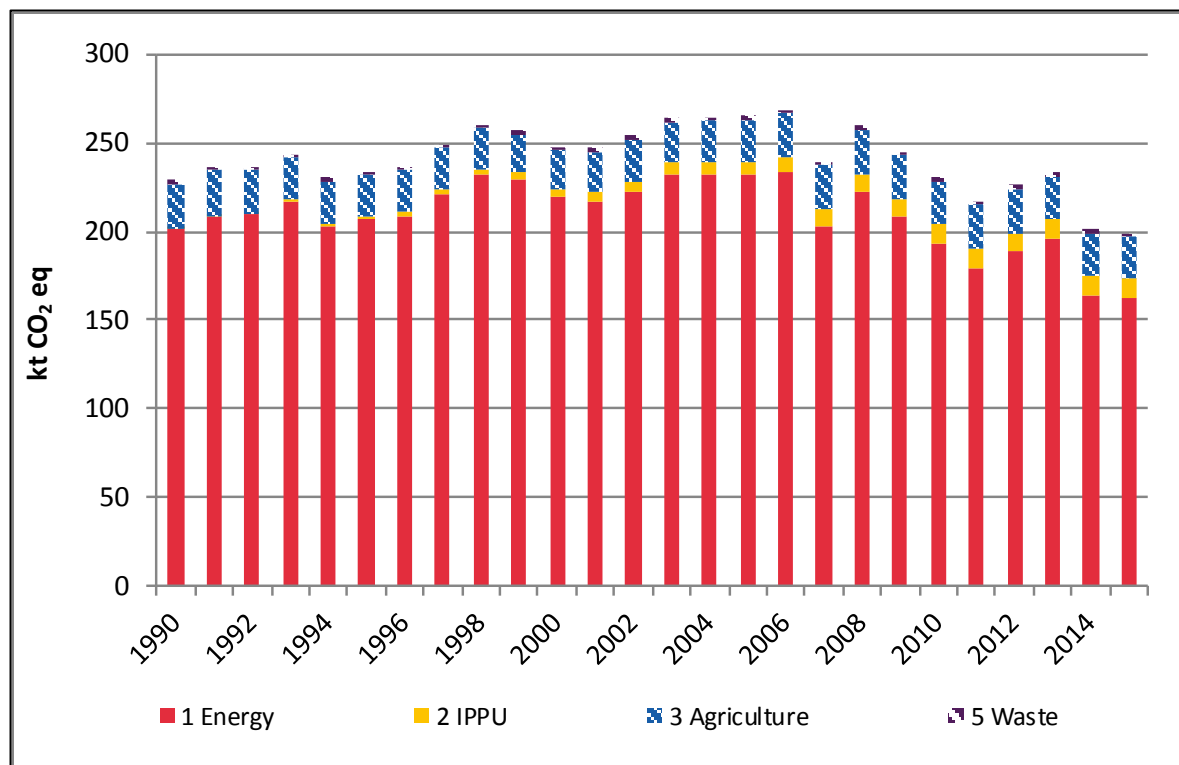


Figure 2-4 Trend of Liechtenstein's greenhouse gas emissions by main source categories in CO₂ equivalent (kt), 1990–2015 (excl. net CO₂ from LULUCF).

The following emission trends are characteristic within the sectors:

Sector 1 Energy: In 2015, 81.4% of Liechtenstein's GHG emissions (excluding LULUCF) originate from sector 1 Energy, which is 1.3 percentage points more than in 2014. The share of sector 1 Energy in the total emissions declined by 6.3 percentage points since 1990. Also the total emissions of the sector 1 Energy clearly decreased in comparison to 1990 levels (19.3%). The source categories within sector 1 Energy show the following trends between 1990 and 2015:

- 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. Total emissions have increased by about 1'060% since 1990.
- 1A2 Manufacturing industries and construction: Total emissions from this source category have declined by 24.5% since 1990. Gaseous fuels are the more important energy carrier in Liechtenstein, although emissions from gaseous fuels decreased by 4.5% and emissions from liquid fuels increased by 11.2% compared to 1990. Compared to 2014, the consumption of gaseous fuels has decreased by 6.5%.

- 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, total emissions have started decreasing since 2014. In 2015, they declined by 16.6% compared to the previous year and the overall trend shows a decrease of 19.4% between 1990 and 2015. This reduction is mainly provoked by a shift in the fuel prices, which have decreased in Austria and increased in Liechtenstein between 2013 and 2015 (MK Consulting 2015).
- 1A4 Other sectors: GHG emissions in source category 1A4 have increased by 18.1% compared to the previous reporting year 2014. The main reason for this increase are the climatic conditions, i.e. the increase in number of heating degree days in 2015. Figure 2-5 shows the substantial correlation of heating degree days and fuel consumption in Liechtenstein (correlation coefficient during the period 1990-2015 is 0.61). Furthermore, various emission reduction measures in Liechtenstein are influencing the fuel consumption, such as the increase of the CO₂-tax in 2010 or the installation of a district heating pipeline, which is suggested by the stronger declining trend of the CO₂ emissions than the trend of the heating degree days. This is also an indication of an increasing decoupling between heating activities and CO₂ emissions.

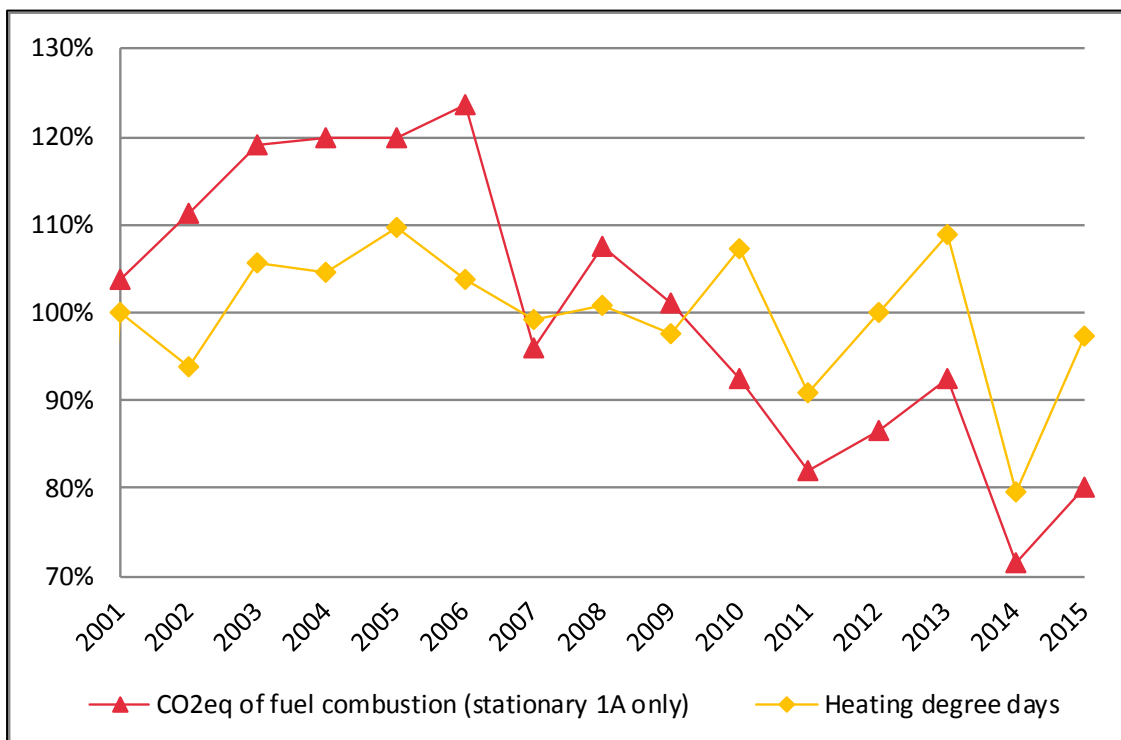


Figure 2-5 Relative trend for CO₂ emissions from 1A Fuel Combustion compared with the number of heating degree days. The drop of emissions in 2007 is driven by high oil and gas prices.

- 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 1990-2015 (215.2%).

Sector 2 Industrial processes and product use: Due to the lack of heavy industry within the borders of Liechtenstein, there are only small sources of F-gases and emissions are on a low level. Still, the use of F-gases has increased throughout the period 1990-2015, which leads to rising emissions in sector 2 by almost a factor of 23 (2'265%).

Sector Agriculture: In 2015, emissions are below the 1990 level by 5.6%. The main parameter influencing emissions in agriculture are animal numbers.

Sector 4 LULUCF: Figure 2-6 shows CO₂ emissions or removals by sources and sinks from LULUCF categories in Liechtenstein. The dominant categories when looking at the changes in CO₂ emissions are gain and loss of living biomass in forests. There is a considerable annual variation of loss of living biomass in forests dependent on the wood harvesting rate. In 1994 and 2000 as well as 2006-2014 the loss of living biomass in forests was larger than the gain. The total net emissions increased by 137.2% between 1990 and 2015.

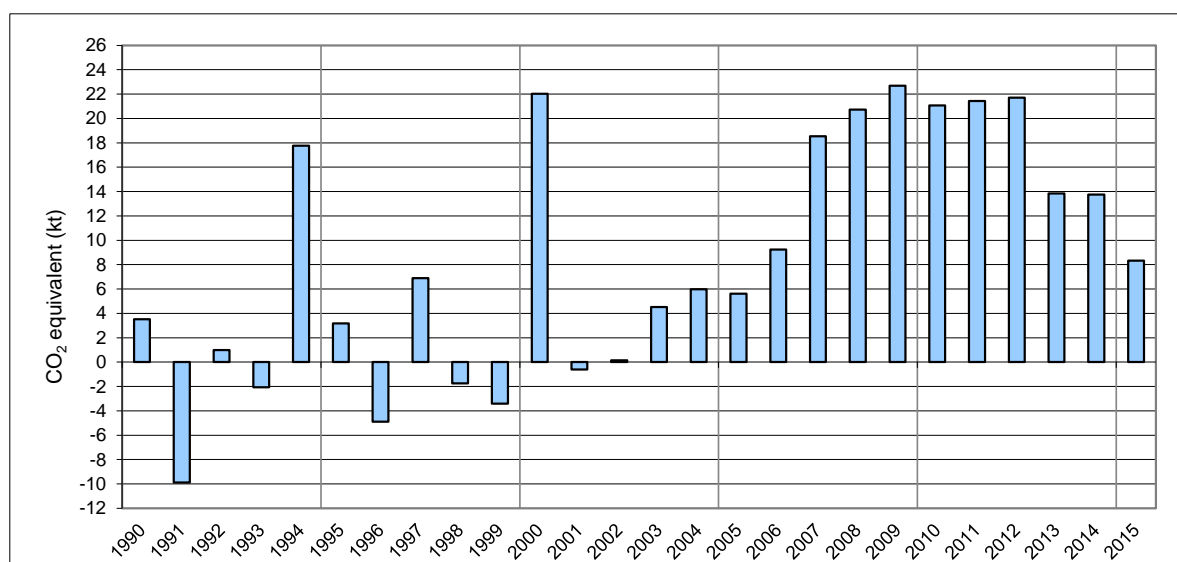


Figure 2-6 Liechtenstein's CO₂ emissions/removals of source category 4 LULUCF 1990–2015 in kt CO₂ equivalent.

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 waste sector shows a slightly increasing trend between 1990 and 2015 (plus 4.6%).

2.4 Emission trends for precursor greenhouse gases and SO₂

Liechtenstein is member to the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) and submits data on air pollutants including indirect GHG. The

submission in 2017 will take place at the end of April 2017, and **the overview and results provided below are from the submission the the CLRTAP in 2016.**

For the precursor substances NO_x, CO and NMVOC as well as for the gas SO₂, data from the current state of knowledge in air pollution reporting is shown in Table 2-4 (Acontec 2016). 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 as of submission 2016 (OE 2016c).

| 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% |

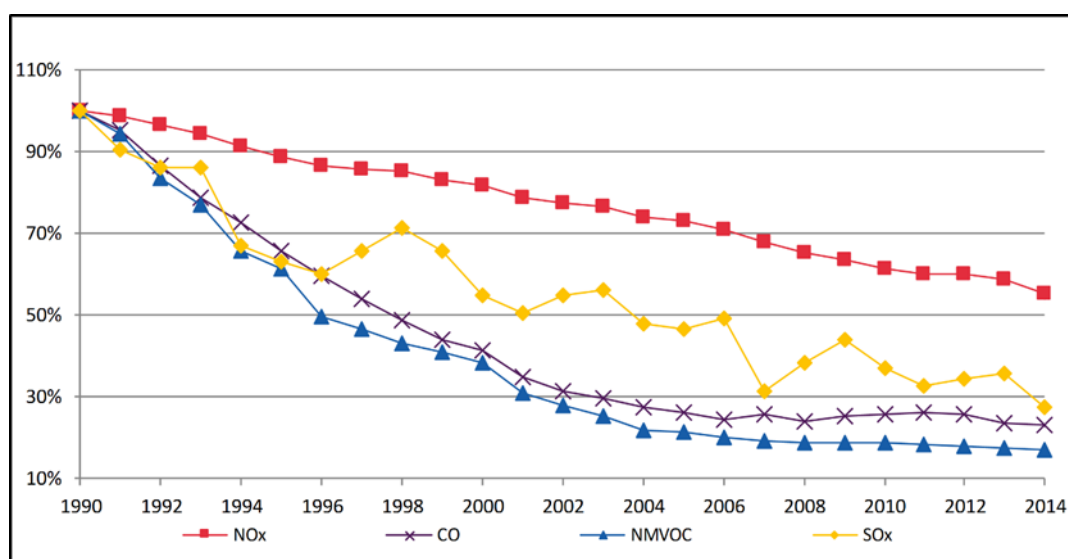


Figure 2-7 Trend of emissions of precursor gases NO_x, CO, NMVOC and SO_x 1990-2014 as of submission 2016 (OE 2016c).

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 and Figure 2-8 illustrates the total net emissions occurring from activities under KP-LULUCF. Deforestation is an emission source, while afforestation and reforestation as well as forest management activities are sinks.

Table 2-5 Development of net CO₂ equivalent emissions of afforestation and reforestation, deforestation and forest management in Liechtenstein.

| KP-LULUCF | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|------------------|---------------------------------|-------|-------|-------|-------|-------|-------|-------|
| | CO ₂ equivalent (kt) | | | | | | | |
| Afforestation | -0.18 | -0.19 | -0.20 | -0.21 | -0.23 | -0.24 | -0.25 | -0.26 |
| Deforestation | 4.17 | 4.26 | 4.34 | 4.42 | 4.51 | 4.59 | 4.51 | 4.51 |
| Forest Mangement | 13.72 | 10.51 | 8.91 | 12.82 | 13.11 | 5.22 | 5.14 | -0.46 |

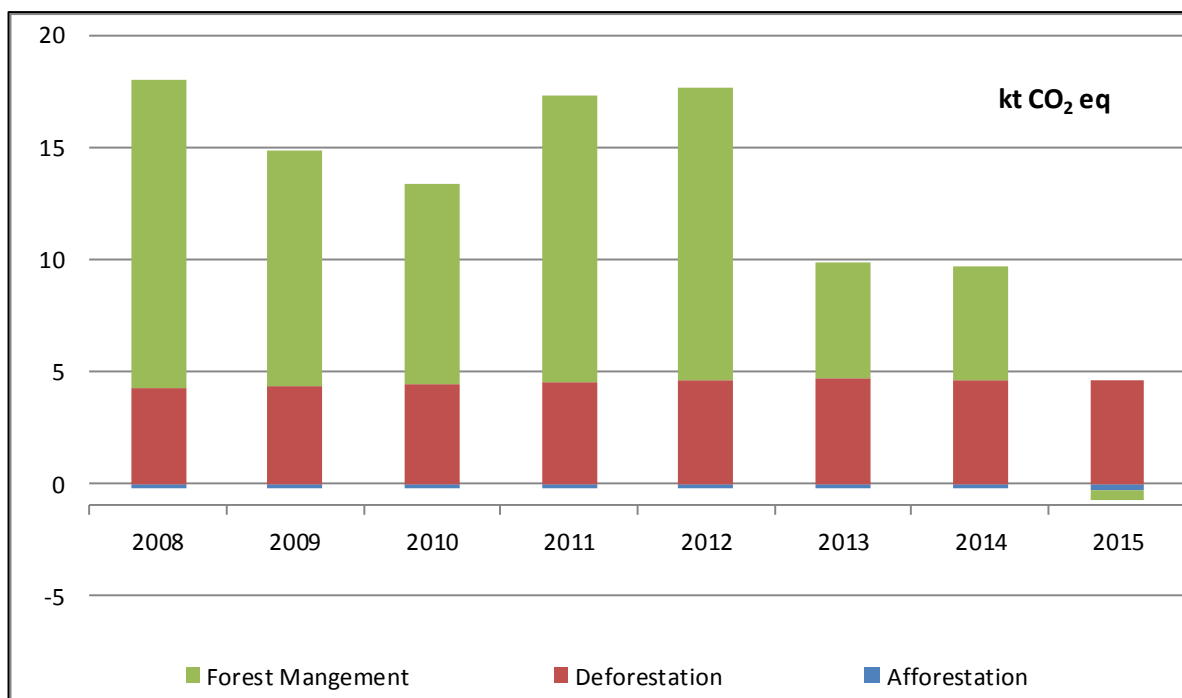


Figure 2-8 Trend of emissions of afforestation and reforestation, deforestation and forest management in Liechtenstein.

3. Energy

3.1 Overview

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. 162.3 kt CO₂ equivalents were emitted within this sector, which corresponds to 81.4% of total emissions (199.4 kt CO₂ equivalent, excluding LULUCF). The emissions of the time period 1990–2015 are depicted in Figure 3-1.

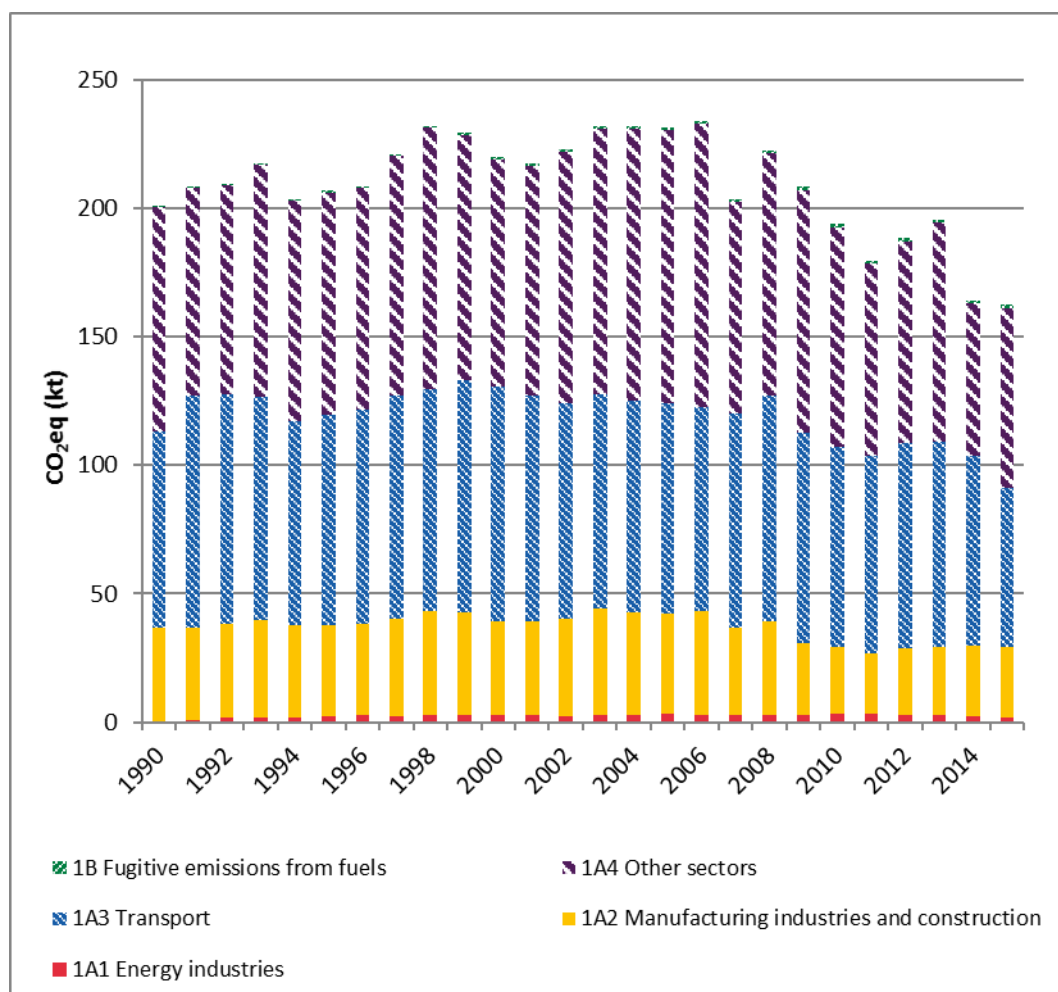


Figure 3-1 Liechtenstein's GHG emissions of the sector 1 Energy from 1990 to 2015 by sub-sectors. Note that there are no emissions in sub-sector 1A5.

Table 3-1 summarises the emissions from sector 1 Energy by individual gases 1990–2015. The numbers do neither include emissions from international bunkers (aviation) nor CO₂ emissions from biomass burning since none of those are accounted for in the UNFCCC and the Kyoto Protocol.

Table 3-1 GHG emissions of sector 1 Energy by gas in CO₂ equivalent (kt), 1990–2015 and the relative increase 1990–2015 (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 | 1.2 | 1.3 | 1.4 | 1.3 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 1.5 |
| N ₂ O | 1.1 | 1.3 | 1.4 | 1.4 | 1.4 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 |
| Sum | 201.1 | 208.6 | 209.4 | 217.6 | 203.6 | 206.8 | 208.6 | 221.1 | 232.0 | 229.4 |

| Gas | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|------------------|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| CO ₂ | 216.7 | 214.5 | 219.8 | 229.1 | 229.2 | 228.8 | 231.0 | 200.7 | 219.4 | 205.3 |
| CH ₄ | 1.6 | 1.6 | 1.6 | 1.7 | 1.8 | 1.9 | 1.9 | 2.0 | 2.1 | 2.0 |
| N ₂ O | 1.5 | 1.4 | 1.3 | 1.3 | 1.0 | 1.0 | 0.9 | 0.9 | 1.0 | 1.0 |
| Sum | 219.8 | 217.5 | 222.8 | 232.1 | 231.9 | 231.6 | 233.8 | 203.6 | 222.4 | 208.3 |

| Gas | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|------------------|---------------------------------|--------------|--------------|--------------|--------------|--------------|---------------|
| | CO ₂ equivalent (kt) | | | | | | % |
| CO ₂ | 190.7 | 176.8 | 185.4 | 192.6 | 161.3 | 159.5 | -19.7% |
| CH ₄ | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.1 | 66.7% |
| N ₂ O | 0.9 | 0.9 | 0.9 | 1.0 | 0.8 | 0.8 | -32.4% |
| Sum | 193.8 | 179.8 | 188.4 | 195.5 | 164.1 | 162.3 | -19.3% |

Table 3-2 shows more details of the emissions of sector 1 Energy in 2015. 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 2015 in kt CO₂ equivalent (rounded values).

| Emissions 2015 | CO ₂ | CH ₄ | N ₂ O | Total | |
|---|---------------------------------|-----------------|------------------|--------------|---------------|
| Sources | CO ₂ equivalent (kt) | | | | % |
| 1 Energy | 159.5 | 2.1 | 0.8 | 162.3 | 100.0% |
| 1A Fuel Combustion | 159.5 | 0.9 | 0.8 | 161.2 | 99.3% |
| 1A1 Energy industries | 2.0 | 0.0 | 0.0 | 2.0 | 1.3% |
| 1A2 Manufacturing industries and construction | 27.3 | 0.0 | 0.1 | 27.4 | 16.9% |
| 1A3 Transport | 61.4 | 0.1 | 0.4 | 61.9 | 38.1% |
| 1A4 Other sectors | 68.8 | 0.8 | 0.3 | 69.8 | 43.0% |
| 1A5 Other | NO | NO | NO | NO | - |
| 1B Fugitive emissions from fuels | NA,NO | 1.2 | NA,NO | 1.2 | 0.7% |
| International Bunkers | 1.2 | 0.0 | 0.0 | 1.2 | - |
| CO₂ Emissions from Biomass | 20.6 | - | - | 20.6 | - |

Emissions from sector 1 Energy may be characterised as follows:

- Concerning the total emissions (CO₂ eq) from sector 1 Energy, a trend of -19.3% can be observed between 1990 and 2015. The trend between 2014 and 2015 shows that emissions declined by 1.1%, which is mainly caused by the decline in fuel tourism (see chp. 3.2.7.2 Road transportation). The reduction in emissions from 1A3b road transportation is however to some extent compensated by the increasing number of heating degree days in 2015, which leads to an increase in emissions from 1A4 Other sectors. The emissions of the sector 1 Energy reached a minimum 2015.
- The three source categories 1A2, 1A3 and 1A4 dominate the emissions of sector 1 Energy and cover altogether 98% (159.1 kt CO₂ eq) of total emissions of sector 1.
 - 1A3 Transport accounts for 38.1% of the emissions in 2015.
 - 1A4 Other sectors (commercial/institutional, residential) contributes to 43.0% of the total energy-related emissions.
 - 1A2 Manufacturing industries and construction contributes to 16.9% of the emissions.
 - 1A1 Energy industries and 1B Fugitive emissions only play a minor role. In 2015, they cover 1.3% 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 CO₂ eq.
- CO₂ emissions from biomass add up to 20.6 kt. They originate from 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 CO₂. It accounts for 98.8% of the category in 1990 and for 98.2% in 2015.

- In 2015, CH₄ emissions accounted for 1.3% of total emissions in the sector 1 Energy. The increasing trend since 1990 (+66.7%) is the result of the increase in consumption of natural gas and the subsequent increase of fugitive emissions of methane (increase by 315%). Additionally, the CH₄ emissions of source category 1A4 have increased by 385% in the same period. The CH₄ emissions from road transportation show a reduction of 84.8%, mainly due to the growing number of gasoline passenger cars with catalytic converters.
- N₂O emissions accounted for 0.6% and 0.5% of the total sector 1 Energy emissions in 1990 and 2015 respectively. The changes in N₂O emissions may be explained by changes in the emissions 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 2015 of these categories are depicted in Figure 3-2. In 2015, CO₂ emissions from 1A3b Road Transportation are most dominant.

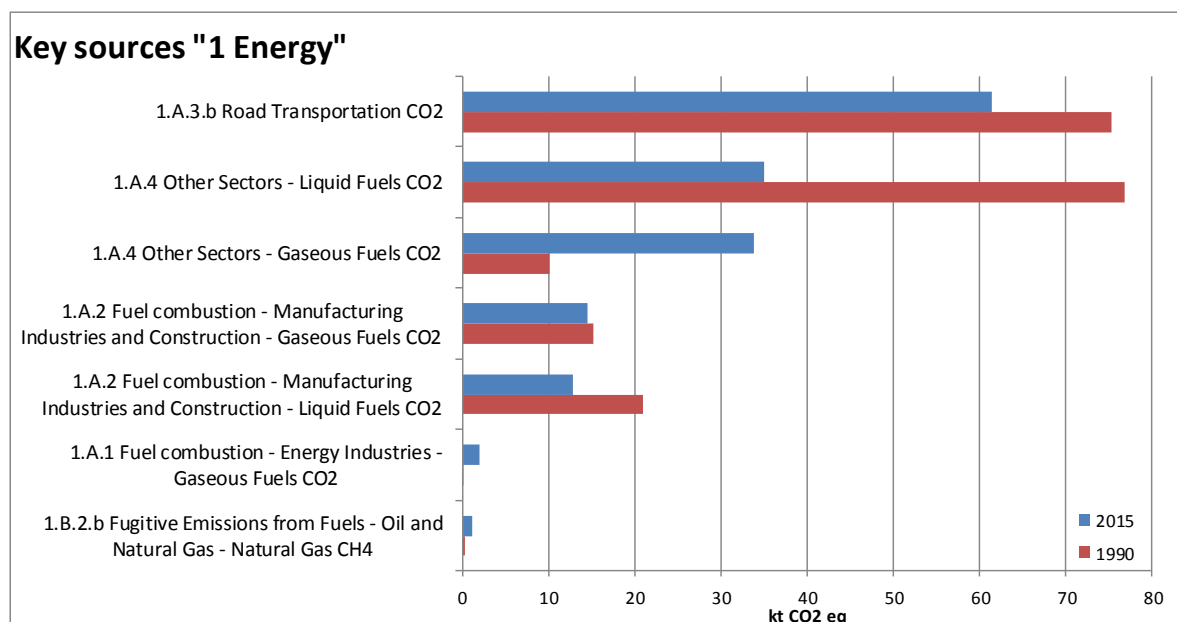


Figure 3-2 Key sources in the energy sector. Emissions in CO₂ equivalents (kt) per key source category in 2015 and in the base year 1990.

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, Liechtenstein is characterized by similar economic structures, the same quality of liquid/gaseous fuels and a similar vehicle fleet composition. Therefore, a large number of emission factors, especially for CO₂, 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 CO₂ 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 greenhouse gas inventory.

Conversion factors (TJ/unit) and carbon emission factors (t C/TJ) for submission 2017 have been taken from Table 3-5 (see reporting table CRF Table 1.A(b)) and are therefore identical to the ones used for the sectoral approach.

The apparent consumption, the net carbon emissions and the effective CO₂ 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 CO₂ 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 1990–2015. Energy consumption differs by around 0.11%, whereas CO₂ emissions show a maximum difference of 0.09%.

The difference of the energy consumption between the reference and the sectoral approach can be explained by different measurement methods of the two 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 CO₂ 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 accounts for 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 CO₂ 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 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 |
| 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 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 |
| 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 | 2015 |
|---------------------------|-------------|------|------|------|------|------|
| | percent (%) | | | | | |
| Energy consumption | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.11 |
| CO ₂ emissions | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.09 |

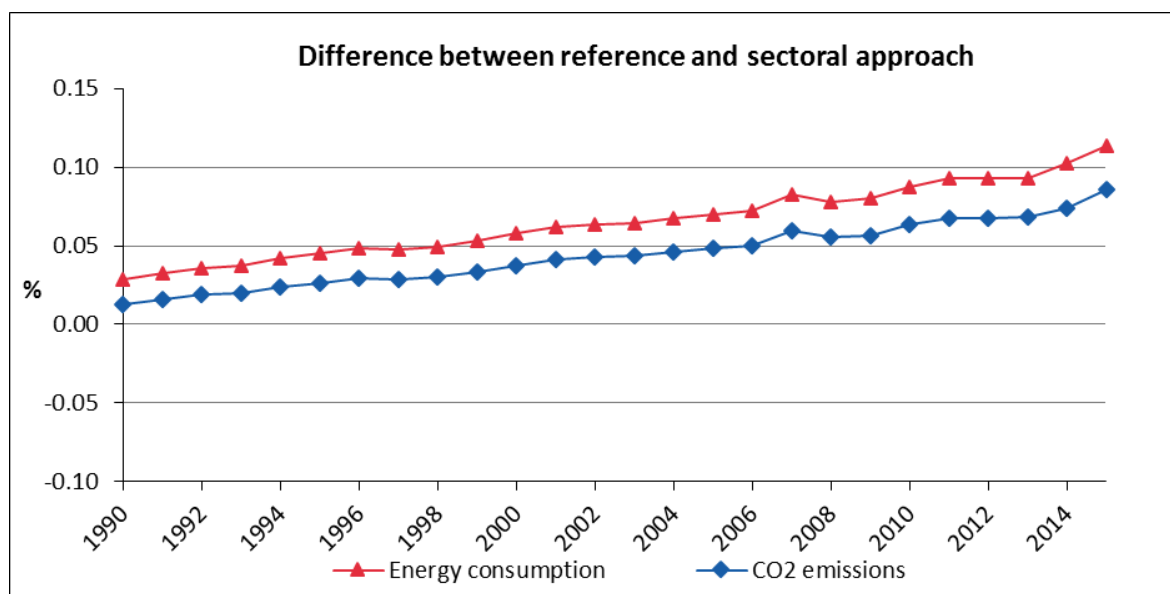


Figure 3-3 Time series for the differences between reference and sectoral approach. Numbers are taken from the table above.

Recalculation in the reference approach

- CO₂ emission factors of diesel, kerosene and gasoline are changed to the ones used in Switzerland (SFOE/FOEN 2014). This leads to a recalculation of CO₂ emissions from 1999-2014.

- Instead of assuming a constant share, the share of kerosene consumed in Liechtenstein is linearly interpolated for years with missing data. This leads to a recalculation for CO₂, CH₄ and N₂O emissions from 2003 to 2011 (FCCC/ERT 2016: 1.A.3.a Domestic aviation).
- A mistake in the share of alkylate gasoline was corrected, which leads to a recalculation of CO₂ emissions in 2014.

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 2015, 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, since 2012), 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 also a linear interpolation was applied. Since 2012, effective consumption data is available for each year.

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 | 6.82 | 4.60 | 6.62 | 11.31 | 11.20 | 10.98 | 13.29 |
| 1A3a Domestic aviation | 1.08 | 1.09 | 1.14 | 1.11 | 1.08 | 1.04 | 1.01 | 0.98 | 0.95 | 0.92 |
| 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 | 2015 |
|------------------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | TJ | | | | | |
| international (bunker) | 11.57 | 12.48 | 15.28 | 14.44 | 16.20 | 16.36 |
| domestic (1A3a) | 0.89 | 0.86 | 0.83 | 0.74 | 0.85 | 0.81 |
| Total | 12.46 | 13.34 | 16.10 | 15.18 | 17.05 | 17.16 |

3.2.3 Feedstocks and non-energy use of fuels

Energy data are taken from Liechtenstein's energy statistics (OS 2016a). These statistics account for production, imports, exports, transformation and stock changes. Hence all figures for energy consumption in Liechtenstein correspond to apparent consumption figures.

No bitumen and lubricants are produced in Liechtenstein. Bitumen is imported for road paving and NMVOC emissions from bituminous materials are related to road paving and to asphalt roofing. 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. The data are not yet taken into account for the national inventory.

It is planned to implement the use of bitumen and lubricants. The ERT recommended this issue in the ARR 2013 paragraphs 26 and 27 (FCCC/ARR 2013, see Annex A8.3, Table A - 6, IDP No 25&26).

3.2.4 Country-specific issues

3.2.4.1 CO₂ emission factors and net calorific values (NCV)

The CO₂ emission factors and the net calorific values (NCV) used for the calculation of the emissions 2015 of sector 1 Energy are shown in Table 3-5. Except for gasoline, diesel and kerosene, emission factors are assumed constant for the entire time series. The time series of gasoline and diesel is shown in Table 3-6.

Table 3-5 CO₂ emission factors and net calorific values (NCV) for fuels in 2015. Except for gasoline, diesel and kerosene emission factors are assumed constant for the entire time series. The time series of gasoline and diesel is shown in Table 3-6.

| Fuel | CO ₂ Emission Factor 2015 | | 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 | 73.8 | 3.14 | 0.0426 |
| Diesel oil | 73.3 | 3.15 | 0.0430 |
| Propane/Butane (LPG) | 65.5 | 3.01 | 0.0460 |
| Jet kerosene | 72.8 | 3.13 | 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 |

Table 3-6 CO₂ emission factors of gasoline, diesel and kerosene 1990-2015.

| Fuel | unit | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|----------|-----------------------|------|------|------|------|------|------|------|------|------|------|
| Gasoline | t CO ₂ /TJ | 73.9 | 73.9 | 73.9 | 73.9 | 73.9 | 73.9 | 73.9 | 73.9 | 73.9 | 73.9 |
| Diesel | t CO ₂ /TJ | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 | 73.6 |
| Kerosene | t CO ₂ /TJ | 73.2 | 73.2 | 73.2 | 73.2 | 73.2 | 73.2 | 73.2 | 73.2 | 73.2 | 73.2 |

| Fuel | unit | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|----------|-----------------------|------|------|------|------|------|------|------|------|------|------|
| Gasoline | t CO ₂ /TJ | 73.9 | 73.9 | 73.9 | 73.9 | 73.9 | 73.9 | 73.8 | 73.8 | 73.8 | 73.8 |
| Diesel | t CO ₂ /TJ | 73.6 | 73.5 | 73.5 | 73.5 | 73.5 | 73.5 | 73.4 | 73.4 | 73.4 | 73.4 |
| Kerosene | t CO ₂ /TJ | 73.1 | 73.1 | 73.1 | 73.1 | 73.0 | 73.0 | 73.0 | 73.0 | 72.9 | 72.9 |

| Fuel | unit | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|----------|-----------------------|------|------|------|------|------|------|
| Gasoline | t CO ₂ /TJ | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 |
| Diesel | t CO ₂ /TJ | 73.4 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| Kerosene | t CO ₂ /TJ | 72.9 | 72.9 | 72.8 | 72.8 | 72.8 | 72.8 |

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 2016a).

The CO₂ emission factors of fossil fuels are taken from the Swiss overall energy statistics of the year 2000 (SFOE 2001) with the following exceptions:

The emission factor of LPG is based on FOEN 2015a and natural gas, which is taken from the IPCC 2006 Guidelines.

The emission factors of gasoline, diesel oil and kerosene are based on SFOE/FOEN (2014).

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.

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 CO₂ and 65% CH₄.

Note that the emissions factors for CH₄ and N₂O 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 2016a). 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 3-7.

Table 3-7 Time series of Liechtenstein's fuel consumption based on the sales principle, including bunker fuel consumption (kerosene only) and biomass. Data sources: OS (2016a), 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% |
| <i>Kerosene (bunker)</i> | 5.84 | 5.84 | 5.84 | 5.84 | 5.84 | 5.84 | 6.00 | 6.16 | 6.33 | 6.49 |
| Biomass | | | | | | | | | | |
| <i>Wood</i> | 42.9 | 29.7 | 42.8 | 38.9 | 49.1 | 36.2 | 33.6 | 40.8 | 45.7 | 50.1 |
| <i>Sewage gas</i> | 15.6 | 16.3 | 17.3 | 17.3 | 18.7 | 17.0 | 18.1 | 18.4 | 20.0 | 21.5 |
| <i>Biofuel</i> | 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 | 1.11 | 1.08 | 1.04 | 1.01 | 0.98 | 0.95 | 0.92 |
| Sum | 3'168 | 3'163 | 3'242 | 3'387 | 3'403 | 3'411 | 3'447 | 3'024 | 3'288 | 3'031 |
| 1990=100% | 113% | 113% | 116% | 121% | 121% | 122% | 123% | 108% | 117% | 108% |
| <i>Kerosene (bunker)</i> | 6.66 | 6.82 | 6.12 | 6.82 | 4.60 | 6.62 | 11.31 | 11.20 | 10.98 | 13.29 |
| Biomass | | | | | | | | | | |
| <i>Wood</i> | 87.9 | 53.8 | 56.3 | 74.4 | 81.4 | 90.1 | 102.9 | 137.1 | 138.4 | 169.9 |
| <i>Sewage gas</i> | 21.7 | 20.9 | 20.0 | 20.7 | 21.6 | 20.8 | 22.5 | 24.3 | 25.0 | 23.7 |
| <i>Biofuel</i> | 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 | 2015 | 1990-2015 |
|--------------------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|
| | TJ | | | | | | % |
| Gasoline | 594 | 565 | 583 | 563 | 512 | 410 | -50% |
| Diesel | 475 | 498 | 556 | 578 | 552 | 488 | 95% |
| Gas Oil | 693 | 606 | 634 | 686 | 470 | 569 | -55% |
| Natural Gas | 1'079 | 954 | 971 | 1'030 | 856 | 914 | 101% |
| LPG | 5.3 | 4.2 | 4.1 | 3.9 | 3.6 | 3.7 | -72% |
| Hard Coal | 0.06 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | -100% |
| Kerosene (domestic) | 0.89 | 0.86 | 0.83 | 0.74 | 0.85 | 0.81 | -22% |
| Sum | 2'848 | 2'628 | 2'749 | 2'862 | 2'395 | 2'385 | -15% |
| 1990=100% | 102% | 94% | 98% | 102% | 85% | 85% | |
| <i>Kerosene (bunker)</i> | 11.57 | 12.48 | 15.28 | 14.44 | 16.20 | 16.36 | 180% |
| Biomass | | | | | | | |
| <i>Wood</i> | 182.9 | 198.9 | 202.8 | 172.5 | 185.7 | 209.4 | 388% |
| <i>Sewage gas</i> | 22.2 | 22.5 | 22.8 | 24.3 | 1.0 | 0.5 | -97% |
| <i>Biofuel</i> | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - |
| Sum biomass | 205.2 | 221.4 | 225.6 | 196.8 | 186.8 | 209.9 | 259% |

The following modifications on the original energy statistics data have been carried out for the submission 2017:

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 end 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 end consumers.

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 subtracting 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 3-8).

Table 3-8 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 |
| 2015 | 13'263 | 0 | 13'263 | 0.840 | 15'789 | 0.845 | 13'342 | 572 |

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, m³) and later reported to the Office of Environment in mass units (t). This conversion is made with a (rounded) density of 0.840 t/m³, whereas the more correct density is 0.845 t/m³ (FOEN 2011). Therefore, the Consumption 1 is corrected accordingly, resulting in Consumption 2, as is shown in Table 3-8. Using country-specific net calorific values provided by the Energy statistics of Liechtenstein (OS 2016a), 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 2016a) 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 annually report the amount of gasoline and diesel provided to domestic gasoline stations. Since not all distributors are known (they may originate from any Swiss gasoline station and may differ every year), the census may not provide a complete statistic. 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 survey of all gasoline and diesel oil sold to passenger cars (including "fuel tourism") for the years 2000-2015. 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 was carried out as described in 2006 IPCC Guidelines. Both checks revealed that the time series 1990-2015 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 2016e). The resulting time series is shown in Table 3-7 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 2016e).
- Finally, consumption from the agriculture sector is calculated based on the following 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 from the former method practised by the General Directorate of Swiss Customs. This allowed a quality control check. Since the difference was only 1% (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 2015, 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 3-7 in row "diesel".

Kerosene

The effective kerosene consumption of the only helicopter base at Balzers is reported in detail for the years 2001-2015 (see Rotex Helicopter AG 2006-2016) and separated in domestic and international/bunker consumption using the method described in section 3.2.2. Less detailed information is available for 1995. For all other years in the reporting period, adequate assumptions were made (see section 3.2.7.2).

Bunker

Bunker kerosene consumption see section 3.2.2.

Biomass

A description of the methodology for calculating CO₂ 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).

CO₂ 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 estimated based on expert judgement for all years from 1990 to 2015: The Energy Statistics of Liechtenstein (e.g. OS 2016a) 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 2015. 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 construction

companies (1A2) and the remaining 20% to residential sources (1A4b). As there has not been any 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 2015.

Table 3-9 Estimated share of source categories in total consumption of gas oil in 1A Fuel combustion.

| Source category | | Share in consumption of gas oil (1990-2015) |
|-----------------|---|--|
| 1A2 | Manufacturing industries and construction | 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 2016) and published in the national energy statistics (OS 2016a).

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. Therefore, the following attribution is applied:

Table 3-10 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) was 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 time series. 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 the first year (1995), 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 based on the following assumptions.

Table 3-11 Data sources for the diesel consumption and its attribution to IPCC source categories for the period 1990-2015 (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 3-12 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.

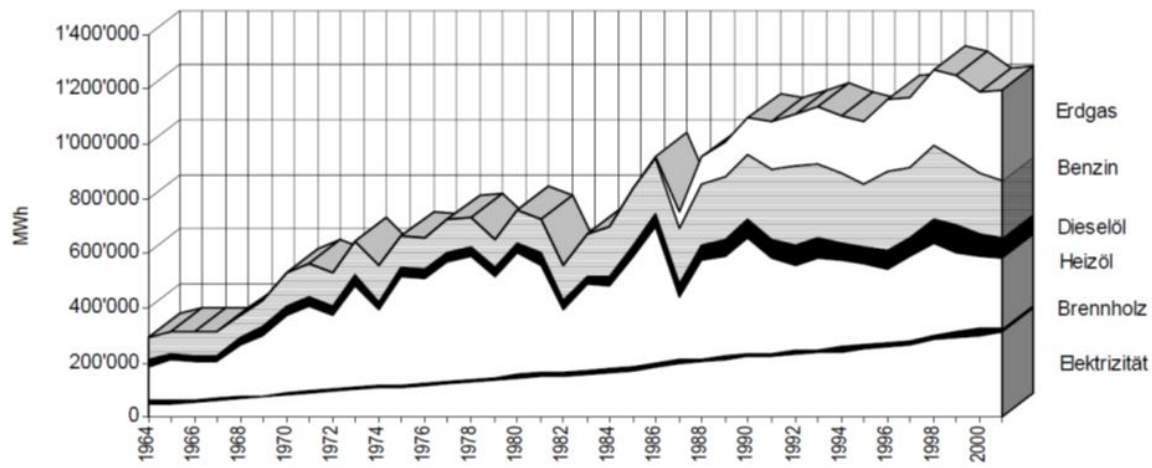


Figure 3-4 Liechtenstein's energy consumption and fuel shares 1964-2001 (OS 2001) in MWh. The fuels are descending: natural gas (Erdgas), gasoline (Benzin), diesel (Dieselöl), gas oil (Heizöl), wood (Brennholz), electricity (Elektrizität).

The electricity production 1990-2001 is given in Table 3-15 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 3-12 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 3-13 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 | | | | |
| 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 category information 1A1

CO₂ 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 3-14).

Table 3-14 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 2015, 17% of Liechtenstein's electricity consumption was produced domestically and 83% was imported (see Table 3-15). In absolute values, the electricity consumption 2015 amounts to 394 GWh. This corresponds to a slight decrease of 0.4% since 2014. Domestic electricity generation increased by 69% since the hydropower plant that was out of operation in 2014 due to maintenance work restarted again in 2015. As a consequence, the electricity imports decreased by 8.4% compared to 2014.

Table 3-15 Electricity consumption, generation and imports in Liechtenstein in 2015. Data source: Energy Statistics 2015 (OS 2016a).

| Electricity consumption, generation and imports in Liechtenstein 2015 | MWh | Share |
|--|------------|--------------|
| Total electricity consumption in Liechtenstein | 393'590 | 100% |
| Electricity generation in Liechtenstein 2015 | 68'431 | 17% |
| Hydro power | 48'838 | 12% |
| Natural gas co-generation | 2'188 | 0.6% |
| Biogas co-generation | 17 | 0.0% |
| Photovoltaic | 17'388 | 4.4% |
| Electricity imports in Liechtenstein 2015 | 325'159 | 83% |

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 fuelled combined heat and power generation plants.

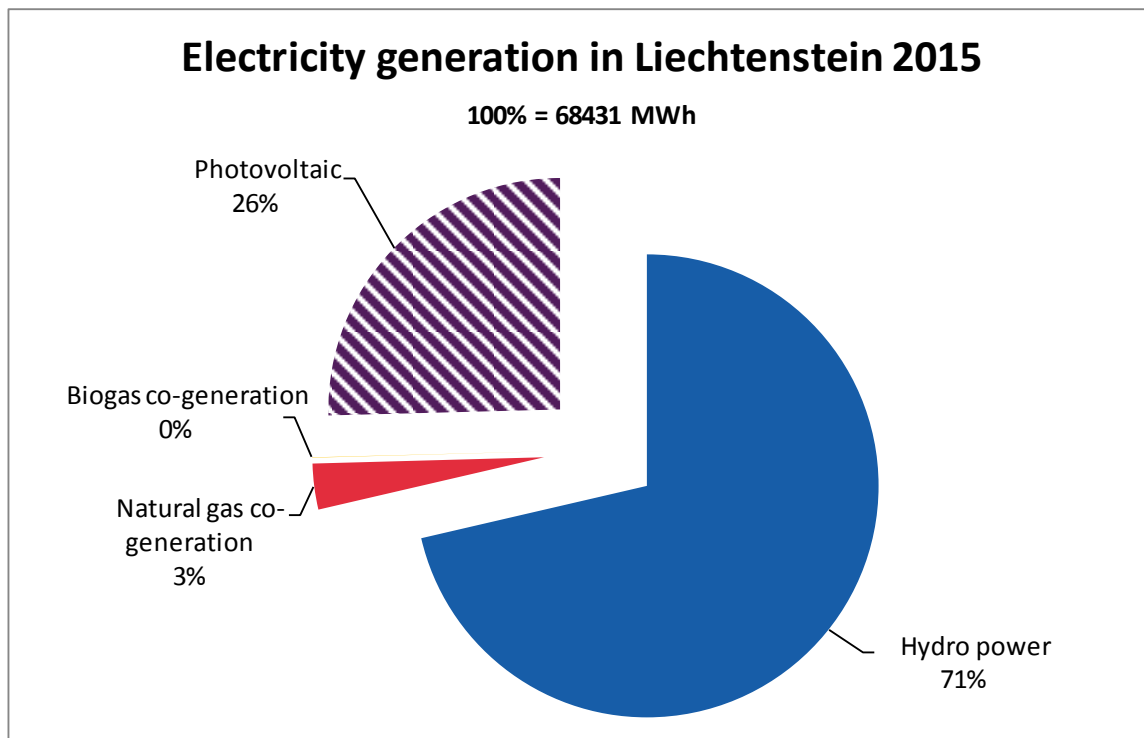


Figure 3-5 Structure of electricity generation in Liechtenstein 2015. Data source: Energy Statistics 2015 (OS 2016a).

Renewable sources account for 96.8% of domestic electricity generation in Liechtenstein. Compared to 2014, the electricity produced by photovoltaic plants has increased by 12% from 15'564 MWh to 17'388 MWh. Photovoltaic is thus representing 25% of the total domestic electricity production in 2015.

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 2016a) is used to calculate emissions. As mentioned above, only natural gas and biomass (sewage gas) are occurring within this source category 1A1a. The waste water treatment plant uses only biogas for electricity generation and no additional fuels are used to combust the biogas. In addition, the WWTP applies lubricants. Corresponding emissions are however not estimated.

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 CO₂ emission factor of natural gas corresponds to the IPCC default value (IPCC 2006). The CH₄ 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, see the assumptions below. The N₂O 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 CO₂ has been adapted to take into account CO₂ being present in the biogas as a product of fermentation already prior to combustion. The following table presents the emission factors used in 1A1a.

Table 3-16 Emission factors for 1A1a Public electricity and heat production in energy industries for 2015 (public co-generation).

| Source/fuel | CO ₂ [t/TJ] | CO ₂ biogenic [t/TJ] | CH ₄ [kg/TJ] | N ₂ O [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 |

Activity data

Activity data on natural gas consumption (in TJ) for Public electricity and heat production (1A1a) is extracted from the energy statistics (OS 2016a). Activity data on sewage gas consumption from waste water treatment plants is provided by plant operators (for data see section 7.5.2). In 2015, natural gas accounts for 86% of energy consumption in source category public electricity and heat fuel consumption. Table 3-17 documents the activity data of heat fuel consumption in Liechtenstein for fossil fuels (natural gas) and biomass (sewage gas). Natural gas consumption increased by a factor of about 16 from 1990 to 2015. 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 2014. 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 and only 4% in 2015.

Table 3-17 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 | 2015 | 1990-2015 |
|---|-------|-------|-------|-------|-------|-------|-----------|
| 1A1a Public electricity and heat production | TJ | | | | | | % |
| Natural gas | 56.16 | 52.56 | 48.24 | 52.13 | 44.24 | 36.02 | 1567% |
| Biomass | 22.24 | 22.49 | 22.79 | 24.40 | 2.13 | 1.39 | -91% |

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

There are no category-specific recalculations

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 category information 1A2

CO₂ 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.

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 2015 only 0.29 kt CO₂eq, representing approximately 1.1% of source category 1A2.

Table 3-18 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 2016a) 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)

A 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 3-11). Emission factors are taken from the Swiss non-road study (INFRAS 2015).

Emission factors

CO₂ 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 N₂O emissions the default emission factors from IPCC 2006 have been used.

CO₂ 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 CH₄ 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 3-19 shows the emission factors used for the sources in category 1A2.

Table 3-19 Emission factors for sources in 1A2 in 2015.

| Source/fuel | CO ₂ [t/TJ] | CO ₂ biogenic [t/TJ] | CH ₄ [kg/TJ] | N ₂ O [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 | 73.3 | | 0.7 | 3.3 |

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 2016a). 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 1990-2015 is given in the table below.

Table 3-20 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 from 1990 to 2015.

| 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 | 2015 | 1990-2015 |
|--|-------|-------|-------|-------|-------|-------|-----------|
| | TJ | | | | | | % |
| 1A2e Food processing, beverages and tobacco | | | | | | | |
| Gas oil | 138.6 | 121.3 | 126.8 | 137.2 | 94.0 | 113.8 | -55% |
| Natural gas | 218.8 | 188.7 | 208.2 | 206.7 | 276.5 | 258.6 | -5% |
| Biomass (Biogas from WWTP) | NO | NO | NO | 0.3 | 6.8 | 6.3 | - |
| 1A2g Other off-road vehicles and machinery | | | | | | | |
| Diesel | 47.8 | 54.0 | 62.9 | 62.8 | 62.4 | 60.2 | 88% |

Table 3-20 documents the decrease of gas oil consumption by 55% from 1990 to 2015. 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.

Between 1990 and 2015 consumption of gaseous fuels decreased by 4.5% 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 CO₂ emissions from gaseous and liquid fuels in category 1A2 being key categories with regards to the trend 1990-2015. 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

- 1A2g: The CO₂ emission factor of diesel is changed to the one used in Switzerland's GHG inventory (SFOE/FOEN 2014). This leads to a recalculation of CO₂ emissions from 1999-2014. In 2014, this leads to a reduction in CO₂ emissions from 1A2 of 0.02 kt CO₂.
- 1A2g: The N₂O and CH₄ emission factors of diesel is changed to the one used in Switzerland's GHG inventory (FOEN 2016). This leads to a recalculation of N₂O and CH₄ emissions from 1990-2014.

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 category information 1A3b

CO₂ and CH₄ 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 3-21 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). Liechtenstein'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 3-22).

Activity data is available as measured consumption of the two helicopter companies Rotex Helicopter AG and Swiss Helicopter AG (see Rotex Helicopter AG 2016) for the years 2012-2015. 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 CO₂ emission factors are derived from the carbon content of fuels (see Table 3-5 and Table 3-6). For CH₄ and N₂O, the country-specific implied emission factors of the Swiss GHG 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.

Note that a large number of Austrian and German citizens are working in Liechtenstein (2015: 36'755 registered employees, 19'652 commuters, whereof 46% are non-Swiss citizens) and buying their gasoline in Liechtenstein (OS 2016b). 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. This statement only holds up to 2014 as long as prices were higher in Austria as compared to Liechtenstein and Switzerland (which both have the same price due to the Customs Union Treaty). The discontinuation of Switzerland's minimum exchange rate on January 15, 2015, resulted in a strong appreciation of the Swiss franc, which led to a switch in the direction of fuel tourism (MK Consulting 2015).

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 GHG emissions occurring.

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.

Other Transportation (1A3e)

Fuel consumption by equipment supporting pipeline transportation activities of natural gas and ground activities in airports do not occur in Liechtenstein.

Emissions factors

Domestic aviation (1A3a)

The emission factors used for emission calculations of 1A3a Domestic aviation are illustrated in Table 3-22. The CO₂ emission factor for kerosene is taken from Table 3-5 (SFOE/FOEN 2014). The CH₄ and N₂O emission factors are default values given by IPCC (2006).

Table 3-22 Emission factors used for estimating emissions of helicopters. The values are used for the entire time series 1990-2015.

| Source/fuel | CO ₂ [t/TJ] | CH ₄ [kg/TJ] | N ₂ O [kg/TJ] |
|--|------------------------|-------------------------|--------------------------|
| 1A3a Domestic aviation (helicopters only) | | | |
| Kerosene | 72.8 | 0.5 | 2.3 |

Road transportation (1A3b)

CO₂

- CO₂ emission factors of for fossil gasoline, diesel oil and natural gas: The emission factors are adopted from Switzerland (see Table 3-5 and Table 3-6 in chp.3.2.4.1).
- CO₂ emission factor of for natural gas: emission factor corresponds to the IPCC default value (IPCC 2006).
- CO₂ emission factors of 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 (see Annex A8.3, Table A - 6, IDP No 27, ARR 2013/34). The emission factor is taken from Switzerland’s GHG inventory (FOEN 2016). In 2010 the imports ceased and thus in Liechtenstein no sale of biofuels occurred anymore since 2011.

CH₄, N₂O

- CH₄, N₂O for gasoline and diesel oil: the implied emission factors of Switzerland's GHG inventory are used for the whole period 1990-2015 (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 CO₂ 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 CO₂ 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 fuel tourism, but in Liechtenstein, the increase would be stronger since fuel tourism was more pronounced in Liechtenstein than in Switzerland. It can therefore be expected that if fuel 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 the deviation of the emission total of source category 1A3b is very small.
- CH₄, N₂O emission factors of natural gas: For CH₄ the lower default emission factor from 2006 IPCC Guidelines is used, for N₂O: the default emission factor from 2006 IPCC Guidelines for mobile combustion is used.
- CH₄, N₂O emission factors of biogas: For biogas from sewage gas treatment, implied emission factors 1A3b for natural gas are used (see Table 3-23).
- Liquid biofuel occurred only from 2007 to 2009. For this period, CH₄, N₂O emission factors for biofuel were taken as identical to those of fossil diesel. (Note that due to revision of the CO₂ emission factor of diesel it was lowered from 73.6 t/TJ to 73.4 t/TJ resulting in a recalculation of the time series. This was carried out for fossil diesel not carried out for biodiesel by error, see Table 3-23. It will be corrected for submission 2018.)

Annex A3.1 provides explanations on the origin of the Swiss emission factors for road transportation.

Table 3-23 Emission factors for road transport. The values for gasoline, diesel oil and biofuels are adopted from the Swiss GHG inventory (FOEN 2016). 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 CO₂ emission factor refers to biogenic emissions.

| 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 | 30.3 | 27.1 | 24.4 | 22.4 | 20.3 | 18.7 | 17.4 | 16.2 | 15.0 | 14.0 |
| N ₂ O | kg/TJ | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 | 4.1 | 4.0 | 4.0 | 3.8 |
| 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 | 1.9 | 1.9 | 1.8 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.4 | 1.3 |
| N ₂ O | kg/TJ | 0.53 | 0.55 | 0.58 | 0.60 | 0.64 | 0.67 | 0.72 | 0.78 | 0.84 | 0.91 |
| Gaseous fuels | | | | | | | | | | | |
| CO ₂ | t/TJ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| CH ₄ | kg/TJ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| N ₂ O | kg/TJ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Biofuel / Biogas | | | | | | | | | | | |
| CO ₂ | t/TJ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| CH ₄ | kg/TJ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| N ₂ O | kg/TJ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

| 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 | 73.8 | 73.8 | 73.8 | 73.8 |
| CH ₄ | kg/TJ | 13.1 | 12.4 | 11.5 | 10.8 | 10.2 | 9.7 | 9.1 | 8.8 | 8.4 | 8.0 |
| N ₂ O | kg/TJ | 3.6 | 3.4 | 3.1 | 2.8 | 1.7 | 1.6 | 1.4 | 1.3 | 1.1 | 1.0 |
| Diesel | | | | | | | | | | | |
| CO ₂ | t/TJ | 73.6 | 73.5 | 73.5 | 73.5 | 73.5 | 73.5 | 73.4 | 73.4 | 73.4 | 73.4 |
| CH ₄ | kg/TJ | 1.2 | 1.1 | 0.95 | 0.87 | 0.76 | 0.70 | 0.61 | 0.54 | 0.45 | 0.38 |
| N ₂ O | kg/TJ | 1.0 | 1.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.3 | 1.47 | 1.69 | 1.92 |
| Gaseous fuels | | | | | | | | | | | |
| CO ₂ | t/TJ | NA | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 |
| CH ₄ | kg/TJ | NA | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |
| N ₂ O | kg/TJ | NA | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Biofuel / Biogas | | | | | | | | | | | |
| CO ₂ | t/TJ | NA | NA | NA | NA | NA | NA | NA | 73.6 | 73.6 | 73.6 |
| CH ₄ | kg/TJ | NA | NA | NA | NA | NA | NA | NA | 0.54 | 0.45 | 0.38 |
| N ₂ O | kg/TJ | NA | NA | NA | NA | NA | NA | NA | 1.47 | 1.69 | 1.92 |

| Gas | unit | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|-------------------------|-------|------|------|------|------|------|------|
| Gasoline | | | | | | | |
| CO ₂ | t/TJ | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 |
| CH ₄ | kg/TJ | 7.7 | 7.5 | 7.4 | 7.2 | 7.1 | 6.9 |
| N ₂ O | kg/TJ | 0.9 | 0.8 | 0.73 | 0.66 | 0.59 | 0.54 |
| Diesel | | | | | | | |
| CO ₂ | t/TJ | 73.4 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| CH ₄ | kg/TJ | 0.34 | 0.31 | 0.29 | 0.27 | 0.26 | 0.25 |
| N ₂ O | kg/TJ | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.5 |
| Gaseous fuels | | | | | | | |
| CO ₂ | t/TJ | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 |
| CH ₄ | kg/TJ | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |
| N ₂ O | kg/TJ | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Biofuel / Biogas | | | | | | | |
| CO ₂ | t/TJ | NA | NA | NA | 56.1 | 56.1 | 56.1 |
| CH ₄ | kg/TJ | NA | NA | NA | 50.0 | 50.0 | 50.0 |
| N ₂ O | kg/TJ | NA | NA | NA | 3.0 | 3.0 | 3.0 |

Activity data

Domestic aviation (1A3a)

The two operating companies of the helicopter base provided data on fuel consumption for 1995, 2001–2015 as well as detailed flying hours, shares of domestic and international flights as well as specific consumption of the helicopter fleet for 2001–2015 (Rotex Helicopter AG 2006-2016). 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 2015 is based on numbers provided by the two operative helicopter companies Rotex Helicopter AG and Swiss Helicopter AG (see Rotex Helicopter AG 2016). 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, the share is linearly interpolated .

Table 3-24 Activity data for 1A3a Domestic aviation: kerosene consumption 1990-2015 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 (domestic) | 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 (domestic) | 1.08 | 1.09 | 1.14 | 1.11 | 1.08 | 1.04 | 1.01 | 0.98 | 0.95 | 0.92 |

| Source/fuel | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990–2015 |
|---|------|------|------|------|------|------|-----------|
| 1A3a Domestic aviation (helicopters only) | TJ | | | | | | % |
| Kerosene (domestic) | 0.89 | 0.86 | 0.83 | 0.74 | 0.85 | 0.81 | -22% |

Road transportation (1A3b)

The amount of gasoline and diesel fuel sold in Liechtenstein serve as activity data for the calculation of the CO₂ emissions (see Table 3-25). For gaseous fuels, the amount reported by gasoline stations is used. The biofuel consumption of imported vegetable oil in Liechtenstein occurred 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 3-25 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 | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Biofuel / Biogas | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 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 | 14 | 31 | 32 | 31 | 32 | 36 | 49 | 54 | 55 |
| Biofuel / Biogas | NO | NO | NO | NO | NO | NO | NO | 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 | 2015 | 1990-2015 |
|------------------|-------|-------|-------|-------|-------|------|-----------|
| | TJ | | | | | | % |
| Gasoline | 593 | 564 | 583 | 563 | 512 | 409 | -50% |
| Diesel | 409 | 430 | 479 | 495 | 473 | 411 | 105% |
| Natural Gas | 59 | 57 | 23 | 23 | 19 | 17 | - |
| Biofuel / Biogas | NO | NO | NO | 0.03 | 0.48 | 0.43 | - |
| Sum | 1'061 | 1'051 | 1'085 | 1'081 | 1'005 | 838 | -18% |
| | 104% | 103% | 106% | 106% | 99% | 82% | |

The share of gasoline decreased from 80% in 1990 to 49% in 2015, while diesel oil increased from 20% to 49%. Natural gas reaches a share of 2% (2015). 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 2015).

The Office of Environmental Protection (OEP) conducted a study in the year 2002 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 CO₂ 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 (as mentioned above in this chapter, the fuel tourism decreased significantly in 2015 due changing of the exchange rate between Swiss francs (Liechtenstein's currency) and Euros (Austria's currency)).

Note that the 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

- 1A3a: The share of kerosene consumed in Liechtenstein is linearly interpolated for years with missing data. This leads to a recalculation for CO₂, CH₄ and N₂O emissions from 2003 to 2011 (FCCC/ERT 2016).
- 1A3a: The CO₂ emission factor of kerosene is changed to the one used in Switzerland's GHG inventory (SFOE/FOEN 2014). This leads to a recalculation of CO₂ emissions from 1999-2014.
- 1A3b The N₂O and CH₄ emission factors of gasoline and diesel are changed to the ones used in Switzerland's GHG inventory (FOEN 2016). This leads to a recalculation of N₂O and CH₄ emissions from 1990-2014.
- 1A3b The CO₂ emission factors of gasoline and diesel are changed to the ones used in Switzerland's GHG inventory (FOEN 2016). This leads to a recalculation of CO₂ emissions from 1999-2014.
- In 2014, these recalculations lead to a reduction of CO₂ emissions from 1A3 by 0.2 kt CO₂. The increase in CH₄ emissions is negligible <10⁻¹¹ kt.

3.2.7.6 Category-specific planned improvements

An error in the CO₂ emission factor of biodiesel 2007-2009 (73.6 t/TJ instead of 73.4 t/TJ) will be corrected for submission 2018 (see Annex 8.3, IDP No 80). According to Liechtenstein's inventory development plan no other improvements are planned under source-category 1A3.

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 information 1A4

CO₂ from the combustion of gaseous and of liquid fuels and biomass 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 3-26 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/forestry/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 2016a) 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 chp. 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)

CO₂ emission factors and NCV values are country-specific (see Table 3-5 and chp. 3.2.4.1 for details).

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 CO₂ 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 CH₄ 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 2emissions from Liquefied Petroleum Gas (LPG) is from UBA 2004. Emission factors for biomass are also country-specific and based on SAEFL 2000 (pp. 26ff).

The emission factor for alkylate gasoline is taken from SFOE 2001 (see Table 3-5). 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 3-27 Emission factors for 1A4a and 1A4b: Commercial/institutional and residential in Other sectors for the year 2015.

| Source/fuel | CO ₂ fossil [t/TJ] | CO ₂ biogenic [t/TJ] | CH ₄ [kg/TJ] | N ₂ O [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 | - | 6.9 | 0.5 |
| 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 3-23).

Table 3-28 Emission factors for 1A4c: Other sectors – Agriculture/forestry for the year 2015.

| Source/fuel | CO ₂ fossil [t/TJ] | CO ₂ biogenic [t/TJ] | CH ₄ [kg/TJ] | N ₂ O [kg/TJ] |
|--|-------------------------------|---------------------------------|-------------------------|--------------------------|
| 1A4c Other sectors - Agriculture/forestry | | | | |
| Diesel | 73.3 | - | 1.6 | 3.0 |
| Alkylate gasoline | 73.9 | - | 6.9 | 0.5 |

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 2016a). 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 2016e). 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 3-29 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 | 665.40 | 642.11 | 709.01 | 653.09 | 635.05 | 589.23 | 670.77 | 720.30 | 632.07 |
| LPG | 13.29 | 8.14 | 15.46 | 12.14 | 9.48 | 8.14 | 9.75 | 6.99 | 7.18 | 5.84 |
| 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 | 2015 | 1990-2015 |
|--------------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|-------------|
| | TJ | | | | | | % |
| 1A4a Commercial/institutional | 799.90 | 728.02 | 768.32 | 792.29 | 528.63 | 645.60 | -31% |
| Gas oil | 415.84 | 363.79 | 380.39 | 411.48 | 282.03 | 341.39 | -55% |
| LPG | 5.34 | 4.23 | 4.14 | 3.86 | 3.63 | 3.68 | -72% |
| Natural gas | 268.97 | 240.66 | 262.08 | 273.12 | 128.39 | 170.73 | 21% |
| Coal | NO | NO | NO | NO | NO | NO | - |
| Biomass | 109.76 | 119.34 | 121.71 | 103.83 | 114.58 | 129.81 | 404% |
| 1A4b Residential | 687.40 | 616.47 | 636.85 | 681.70 | 565.31 | 639.13 | 105% |
| Gas oil | 138.61 | 121.26 | 126.80 | 137.16 | 94.01 | 113.80 | -55% |
| Alkylate gasoline | 0.13 | 0.12 | 0.13 | 0.12 | 0.16 | 0.12 | - |
| Natural gas | 475.43 | 415.47 | 428.78 | 474.83 | 387.37 | 430.90 | 945% |
| Coal | 0.06 | 0.06 | NO | NO | NO | NO | - |
| Biomass | 73.18 | 79.56 | 81.14 | 69.60 | 83.78 | 94.32 | 449% |

Since 1990, gas oil consumption decreased by approximately 55% for both categories 1A4a and 1A4b. 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 CO₂ 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. This shift in fuel mix is the reason for CO₂ emissions from the use of gaseous and liquid fuels in category 1A4a and 1A4b being key categories regarding level and trend.

Among other factors, the increase in consumption of harvested wood as fuel (as documented in the wood harvesting statistics of Liechtenstein, OE 2016f) contributes to the strong increase in biomass consumption between 1990 and 2015.

Agriculture/forestry/fishing (1A4c)

The activity data related non-road machinery is shown in Table 3-30. Besides diesel, the consumption of alkylate gasoline is also accounted for (20% in 1A4b and 80% in 1A4c). The consumption of alkylate fuels in 2015 has been derived from an annual census carried out by the Office of Environment (OE 2016e).

Table 3-30 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 | 0.45 | 0.45 | 0.46 | 0.47 | 0.47 | 0.48 | 0.49 |
| Diesel | 17.92 | 18.62 | 18.69 | 20.73 | 20.73 | 18.70 | 19.51 | 20.17 | 19.41 | 19.45 |

| Source/fuel | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|---|-------|-------|-------|-------|-------|-------|-----------|
| 1A4c Other Sectors - Agriculture/forestry | TJ | | | | | | % |
| Alkylate gasoline | 0.50 | 0.49 | 0.51 | 0.47 | 0.47 | 0.47 | - |
| Diesel | 19.03 | 14.09 | 14.89 | 20.08 | 16.23 | 16.23 | -9% |

Assumptions

Agriculture/forestry (1A4c)

As Liechtenstein is a small neighbouring country of Switzerland with similar agricultural features like topography, climate, machinery (same regulation for Euro classes), 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/1A4d: Revised activity data for biomass based on new statistics for wood consumption result in a recalculation for 2014 (CH₄, N₂O).
- 1A4b/1A4c Alkylate gasoline: an error in the activity data was corrected for years 2012 – 2014 (CO₂, CH₄, N₂O).
- 1A4b emission factor of CH₄ and N₂O for gasoline and diesel were changed to the factors used in the Swiss inventory 2016, leading to a recalculation for the entire time series 1990-2014.
- 1A4c emission factors of CH₄ and N₂O for gasoline and diesel were changed to the factors used in the Swiss inventory 2016, leading to a recalculation for the entire time series 1990-2014.
- 1A4c emission factor of CO₂ diesel were changed to the factor used in the Swiss inventory 2016, leading to a recalculation for the entire time series 1999-2014.
- In 2014, these recalculations lead to an increase of CO₂ emissions from 1A4 by 0.001 kt CO₂ and to an increase of CH₄ emissions by 0.06 kt CO₂eq.

3.2.8.6 Category-specific planned improvements

Liechtenstein is planning to report the share of biofuel mixed in the imported gasoline and diesel in Submission 2018 (see Annex A8.3, Table A - 6, IDP No 27, ARR 2013/34).

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 (CO₂, CH₄, N₂O, 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 CO₂ 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 2016):

In 2013, a large measurement campaign was carried out in Switzerland to determine the CO₂ emission factors of the dominant liquid fuels (SFOE/FOEN 2014). Based on the standard deviation of these measurements relative uncertainties were derived (FOEN 2016). Liechtenstein adopts these uncertainty estimates for the uncertainty analysis. The following uncertainties have been applied for the emission factors (in square bracket, the value of the previous submission is indicated)

- Natural gas (1A1, 1A2, 1A4): $U(\text{EF CO}_2) = 1.1\% [3.1\%]$ – updated based on SFOE/FOEN 2014

- Liquid fuels (1A2, 1A4): $U(\text{EF CO}_2) = 0.08\% [0.51\%]$ - updated based on SFOE/FOEN 2014
- Gasoline (1A3b): $U(\text{EF CO}_2) = 0.13\% [1.36\%]$ - updated based on SFOE/FOEN 2014
- Diesel oil (1A3b): $U(\text{EF CO}_2) = 0.07\% [0.47\%]$ - updated based on SFOE/FOEN 2014

Note that 1A3b/CO₂ 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 (CO₂) 0.13% and 0.07%. Annex 7 shows the procedure for uncertainty aggregation. The results are:

1A3b/CO₂: $U(\text{AD}) = 9.0\%$, $U(\text{EF}) = 0.1\%$.

1A3b/CH₄: $U(\text{AD}) = 9.7\%$, $U(\text{EF}) = 57.2\%$.

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

1A4 liquid/CO₂: $U(\text{AD}) = 15.8\%$, $U(\text{EF}) = 0.1\%$

1A4 gaseous/CO₂: $U(\text{AD}) = 3.9\%$, $U(\text{EF}) = 0.9\%$

1A4 biomass/CH₄: $U(\text{AD}) = 19.2\%$, $U(\text{EF}) = 21.5\%$

All the non-key categories of 1A (1A1a/CH₄, 1A1a/N₂O, 1A2e/CH₄ etc.) are summed up in the rest categories CH₄, N₂O 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 1990-2015. The entire time series are therefore consistent.

Completeness

The emissions for the entire time series 1990–2015 have been calculated and reported. The data on emissions of the Kyoto gases for sector 1 Energy (CO₂, CH₄, N₂O) 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 2016).

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 CH₄ and N₂O 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 CH₄ and N₂O 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 information 1B2b

Source category 1B2b Fugitive emissions of CH₄ from natural gas is a key category regarding trend.

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 in 1B2 covers 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 3-31 shows the sources for which fugitive emissions are accounted for.

Table 3-31 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 CH₄ 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 3-34 and Table 3-35 are considered.

Regarding density, NCV and share of methane within natural gas, the following values are applied for the time series 1990-2015:

- Net calorific value (NCV): 36.3 MJ/m³ (under norm conditions of 0°C and 1013 mbar)
- Density of methane: 0.717 kg/m³ (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 to 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 (see Table 3-33).

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 3-32) and are provided by literature and base mostly on the study of Battelle 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 Battelle (1994). The CH₄ emissions due to gas meters are accounted for by applying an emission factor of 5.11 m³ CH₄ 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 CH₄ emission factors are based on Swiss studies (e.g. Battelle 1994 and Xinmin 2004).

Table 3-32 CH₄ emission factors for 1B2b Fugitive emissions from natural gas in 2015 (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 <i>0.0006</i> | - | - |
| Gas meters | - | - | - | 5.11 |

Table 3-33 provides background information on the natural gas losses at gas meters and at end users, which are provided as shares in terms of natural gas volumes used in industry and “other” (=households and services) respectively as documented in Table 3-35.

Table 3-33 Natural gas losses at end users as additional information (Several years ago, these emission factors for fugitive emission losses were derived for Liechtenstein. The data source are however no longer available).

| Source/fuel | | 1990-2015 |
|--|----------------------------------|-----------|
| 1B2b Fugitive emissions from natural gas | Unit | |
| Losses end user (Gas meters) | m ³ /(gas meter*year) | 5.11 |
| Losses end user (Installations) households, services | % | 0.06 |
| Losses end user (Installations) Industry | % | 0.06 |

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 2016). 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 3-34 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) 1-5 bar | km | 28.5 | 28.5 | 28.3 | 28.5 | 29.2 | 29.5 | 29.8 | 30.0 | 34.1 | 35.8 |
| HDPE (Polyethylene) < 100 mbar | km | 67.0 | 84.3 | 96.5 | 109.0 | 122.4 | 135.9 | 147.6 | 162.7 | 179.3 | 192.0 |
| 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) 1-5 bar | km | 37.3 | 37.4 | 36.0 | 38.9 | 45.3 | 45.6 | 49.3 | 49.7 | 50.1 | 50.8 |
| HDPE (Polyethylene) < 100 mbar | 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 | 2015 | 1990-2015 |
|--|-------------|-------|-------|-------|-------|-------|-------|-----------|
| 1B2b Fugitive emissions from natural gas | Unit | | | | | | | % |
| Steel cath. > 5 bar | km | 26.6 | 26.6 | 26.7 | 26.7 | 26.7 | 26.7 | 1% |
| HDPE (Polyethylene) 1-5 bar | km | 51.0 | 51.5 | 51.6 | 51.9 | 52.1 | 52.1 | 83% |
| HDPE (Polyethylene) < 100 mbar | km | 312.8 | 319.3 | 323.8 | 328.8 | 336.1 | 341.2 | 409% |
| Connections | number | 4'116 | 4'209 | 4'311 | 4'337 | 4'411 | 4'486 | 837% |

Table 3-34 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 2015 compared 1990.

Table 3-35 Natural gas volumes of Liechtenstein's natural gas distribution network as additional information.

| 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 | 2015 | 1990-2015 |
|--|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 1B2b Fugitive emissions from natural gas | Unit | | | | | | | % |
| Natural gas volume industry | Mio. m ³ | 6.0 | 5.2 | 5.8 | 5.7 | 7.6 | 7.1 | -4% |
| Natural gas volume other | Mio. m ³ | 23.7 | 21.1 | 21.1 | 22.7 | 16.0 | 18.1 | 256% |
| Sum natural gas volume | Mio. m ³ | 29.8 | 26.3 | 26.8 | 28.4 | 23.6 | 25.2 | 101% |

3.3.2.3 Uncertainties and time-series consistency

Uncertainty in fugitive CH₄ 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 1.1.3 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 2014/2015).

3.3.2.5 Category-specific recalculations

1B2 Gaseous fuels: By mistake, a methane content of 100% was assumed between 2005 and 2014 in the previous submission. This mistake was corrected for the current submission, leading to a recalculation of CH₄ emissions from 1B2 between 2005 and 2014. In 2014, this recalculation leads to a reduction of CH₄ emissions from 1B2 by 0.08 kt CO₂eq.

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 – CO₂ 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 source 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 from 2F4 Aerosols, as well as from 2G Other product manufacture and use (including N₂O emissions from 2G3a Medical applications and 2G3b Other propellant for pressure and aerosol products), are reported under source category 2 IPPU. In addition, SF₆ emissions from 2G1 Electrical equipment are reported. NF₃ emissions are not occurring.

The emissions of source category 2 Industrial processes and product use have increased from 1990 to 2013 and they have decreased since then, as shown in Table 4-1.

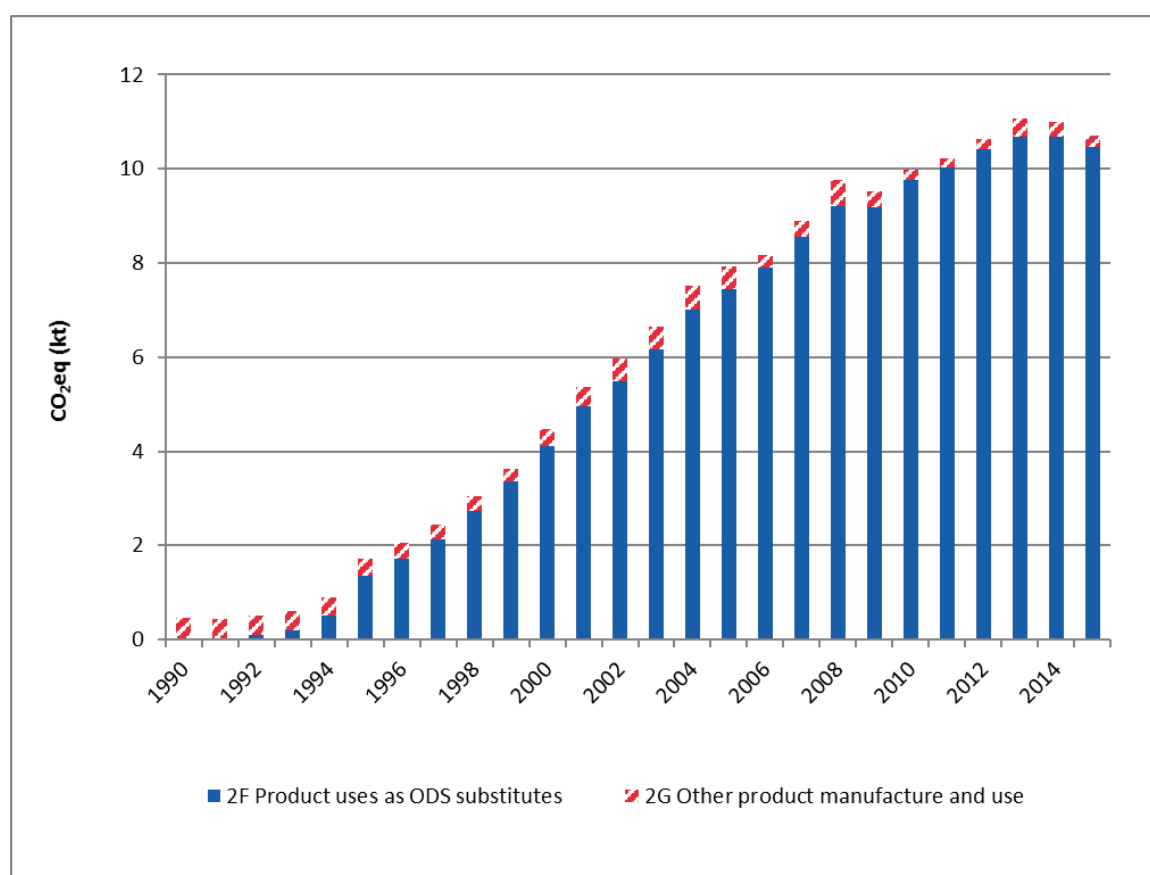


Figure 4-1 Liechtenstein's GHG emissions of sector 2 Industrial processes and product use. Note that there are emissions only in sectors 2F and 2G.

Table 4-1 GHG emissions of source category 2 Industrial processes and product use 1990–2015 by gases in CO₂ equivalent (kt).

| Gas | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|------------------|---------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| N ₂ O | 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 ₂ O | 0.26 | 0.24 | 0.23 | 0.24 | 0.23 | 0.23 | 0.22 | 0.21 | 0.20 | 0.20 |
| F-Gases | 4.21 | 5.12 | 5.74 | 6.42 | 7.28 | 7.69 | 7.95 | 8.68 | 9.55 | 9.33 |
| Sum | 4.46 | 5.36 | 5.97 | 6.65 | 7.51 | 7.92 | 8.17 | 8.89 | 9.75 | 9.53 |

| Gas | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|------------------|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | CO ₂ equivalent (kt) | | | | | | % |
| N ₂ O | 0.20 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | -56% |
| F-Gases | 9.79 | 10.03 | 10.42 | 10.86 | 10.79 | 10.50 | 10047208% |
| Sum | 9.99 | 10.23 | 10.62 | 11.06 | 10.99 | 10.70 | 2265% |

The most relevant emissions are those of HFCs followed by N₂O, SF₆ 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 10.7 kt CO₂ equivalent in 2015. Emissions of the IPPU sector play therefore a minor role in Liechtenstein's inventory and contribute to 5.4% of the total emissions excluding LULUCF. 10.5 kt CO₂ equivalent were emitted in sector 2F Product uses as ODS substitutes and another 0.2 kt CO₂ equivalent in sector 2G Other product manufacture and use. The total emissions increased by a factor of almost 23 (2265%) since 1990. This trend is in particular dominated by the increase in HFC emissions. N₂O emissions even decreased (56%) between 1990 and 2014.

Since 2014, the total F-gas emissions decreased by 3%, HFC emissions decreased by 2% and PFC emissions decreased by 9% and SF₆ emissions by 68%.

Further details on the methodological approach used for the calculation of emissions from source category 2F and 2G are documented in Annex A3.3.

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. Liechtenstein does not report indirect emissions. Therefore, NMVOC emissions from bituminous materials that are related to road paving and to asphalt roofing and NMVOC emissions from solvent use are not reported. Liechtenstein is planning to identify relevant sources of direct emissions and to report them in future submissions (see also Annex A8.3, Table A - 6, IDP No 25 and 26, ARR 2013/26&27).

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 NF₃, which would have to be reported under the revised UNFCCC Guidelines (UNFCCC 2014).

4.7 Source category 2F – Product uses as ODS substitutes

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

Key category information 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 occurring in Liechtenstein. |
| 2F4 | Aerosols | Emissions from use as aerosols, incl. Metered dose inhalers |
| 2F5 | Solvents | Not occurring in Liechtenstein. |
| 2F6 | Other applications | Not occurring in Liechtenstein. |

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

4.7.2.1 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 analysed 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. Further details on the methodological approach used for the calculation of emissions from source category 2F are documented in Annex A3.3.

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 Switzerland's National Inventory Report 2016 (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 and disposal losses 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 manufacturing and 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 Switzerland's National Inventory Report 2016 (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 that are used in Liechtenstein in order to eliminate double counting with the inventory data of Liechtenstein. Under source category 2F1, import data which are 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 risk of 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 foam emissions are only occurring during production, emissions from soft foams are NO.

More details of the underlying data models are documented in Switzerland's National Inventory Report 2016 (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 emission amounts reported under 2F4 is very low (less than 0.1 kt CO₂eq) and therefore, inaccuracies in the estimation model are considered negligible.

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

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

4.7.2.2 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 2016 (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. CO₂ 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 2015 are indicated by the values in brackets. For product life emission factors of some equipment types a dynamic model is applied, which implies that emission decrease linearly between 1995 and 2015 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 2015 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.

4.7.2.3 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 | | 2015 | |
|---|-----------|---|-----------|--|
| Number of households | | | | |
| Liechtenstein | 10'556 | Source: National census 1990 (OEA 2010) | 16'624 | Source: National census 2010 with trend extrapolation (OEA 2010) |
| Switzerland | 2'841'850 | Source: National census 1990 (SFSO 2005) | 3'609'594 | Source: National census 2014 with trend extrapolation (SFSO 2016a) |
| Conversion Factor CH→LIE | 0.371448% | | 0.460550% | |
| Number of employees in industrial and service sector | | | | |
| Liechtenstein | 19'554 | Source: Statistical Yearbook Liechtenstein (OS 2016c) | 36'470 | Source: Statistical Yearbook Liechtenstein (OS 2016c) |
| Switzerland | 3'658'406 | Source: National census of enterprises (SFSO 2016b) | 4'801'268 | Source: National census of enterprises (SFSO 2016b) |
| Conversion Factor CH→LIE | 0.534495% | | 0.759591% | |
| Number of registered passenger cars | | | | |
| Liechtenstein | 16'891 | Source: Statistical Yearbook Liechtenstein (OS 2016c) | 28'802 | Source: Statistical Yearbook Liechtenstein (OS 2016c) |
| Switzerland | 2'985'397 | Source: National motorcar statistics for Switzerland (SFSO 2016c) | 4'458'069 | Source: National motorcar statistics for Switzerland (SFSO 2016c) |
| Conversion factor CH→LIE | 0.565787% | | 0.646064% | |

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 several 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. A more detailed explication would require an in-depth analysis 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 2015 | | |
|-------------------------------|-----------|--------------------|
| Liechtenstein | 37'623 | Source: OS 2016d |
| Switzerland | 8'327'100 | Source: SFSO 2016d |
| Conversion Factor CH→LIE | 0.451814% | |

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 shown 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 is based on a Monte Carlo simulation of the Swiss GHG inventory 2016 for HFC and amounts to 15%. Since 97% of the F-gases emissions are caused by HFC, the value of 15% seems to be justified. 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 1990–2015.

4.7.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in section 1.1.3 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 2014/2015).

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 SF6 in fire extinguishers is prohibited by law in Switzerland. For the 2010 GHG inventory of Liechtenstein (OEP 2012b) 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 SF6. 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 time series of the number of households in Switzerland was revised using updated census data (SFSO 2016a), which leads to a recalculation for HFC-134a between 1990 and 2014.
- 2F1 Refrigeration and air conditioning: Continuous updating of the Swiss EMIS database causes a change in specific emission factors of Liechtenstein and therefore to a recalculation for HFC-143a, HFC-32, HFC-125, HFC134a und HFC 143a between 1990 and 2014.
- 2F1 Refrigeration and air conditioning: A mistake in the time series of households was corrected leading to a recalculation from 1990 to 2014.
- 2F2: Continuous updating of the Swiss EMIS database causes a change in specific emission factors of Liechtenstein and therefore to a recalculation for HFC134a in years 2008, 2009, 2012 and 2013.
- In 2014, these recalculations lead to a reduction of HFC emissions from 2F1 by 1.51 kt CO₂eq.

Since Switzerland's GHG inventory 2017 was not yet available for Liechtenstein's submission 2017. For Switzerland, the following recalculations have been carried out in submission 2016, 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.
- 2F5 Solvents: Revision of import amounts (correction of import declarations of a specific import company).

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 category information 2G

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

According to the IPCC guidelines (IPCC 2006) N₂O 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 N₂O is additive to that of the fluorinated hydrocarbon agents. N₂O is also used as a propellant in aerosol products primarily in food industry. Typical usage is to make whipped cream, where cartridges filled with N₂O 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 | SF ₆ emissions used in electrical equipment and released due to disposal. |
| 2G2 | SF ₆ and PFCs from other product use | Not occurring in Liechtenstein. |
| 2G3 | N ₂ O from product uses | N ₂ O emissions from anaesthesia use in hospitals as well as N ₂ O emissions from the use of aerosol cans. |
| 2G4 | Other | Not occurring in Liechtenstein. |

Source category 2G comprises emissions from SF₆ in electrical equipment as well as N₂O 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)

4.8.2.1 Methodology

Electrical equipment

The only SF₆ 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 SF₆ is occurring.

N₂O from product use

Data availability in Liechtenstein is very limited. In order to estimate 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 approach is that the general characteristics for determining emissions are generally very similar in Liechtenstein and Switzerland (e.g. use of similar products). Further details on the methodological approach used for the calculation of emissions of N₂O from product use are documented in Annex A3.3.

4.8.2.2 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 SF₆ gases. For further information, see Table 4-9.

N₂O from product use

Emission factors for N₂O, which correspond to the specific emissions per inhabitant, are taken from Switzerland's national inventory database EMIS (FOEN 2016a). 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 2016a) are used as a proxy for Liechtenstein.

Table 4-9 Emission factors of Liechtenstein's SF₆ emissions under source category 2G1 and N₂O emissions under 2G3 for the time series 1990-2015.

| 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 ₂ O from product uses - N ₂ O (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 - SF ₆ 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 ₂ O from product uses - N ₂ O (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 | 2015 |
|--|--------|--------|--------|--------|--------|--------|
| 2G1 Electrical equipment - SF ₆ product life factor (% per annum) | 0.0329 | 0.0185 | 0.0005 | 0.2006 | 0.1300 | 0.0413 |
| 2G3 N ₂ O from product uses - N ₂ O (g/inhabitant) | 18.769 | 17.903 | 17.906 | 17.888 | 17.894 | 17.892 |

4.8.2.3 Activity data

Table 4-10 illustrates the numbers of inhabitants of Liechtenstein and Switzerland for the entire time series 1990-2015. 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 | 2015 |
|---|-----------------------|-----------|-----------|-----------|-----------|-----------|
| | Number of inhabitants | | | | | |
| Liechtenstein | 36'149 | 36'475 | 36'838 | 37'129 | 37'366 | 37'623 |
| Switzerland | 7'870'000 | 7'954'700 | 8'039'100 | 8'139'600 | 8'237'700 | 8'327'100 |
| | percentage [%] | | | | | |
| Liechtenstein / Switzerland | 0.46% | 0.46% | 0.46% | 0.46% | 0.45% | 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 ₂ O 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 ₂ O 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 | 2015 |
|--|--------|--------|--------|--------|--------|--------|
| 2G1 Electrical equipment - SF ₆ amount in operating systems (average annual stocks) in kt | 0.0031 | 0.0032 | 0.0037 | 0.0038 | 0.0039 | 0.0040 |
| 2G3 N ₂ O from product uses - number of inhabitants | 36'149 | 36'475 | 36'838 | 37'129 | 37'366 | 37'623 |

Electrical equipment

Activity data is based on industry information. Before 1995/1996 a different technology was applied, which did not use SF₆ (see Table 4-11). SF₆ 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.

N₂O 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 2016d. 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 (CO₂, CH₄, N₂O, 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 SF₆ 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 1.1.3 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 2014/2015).

For the inventory 2010 (OEP 2012b), the sum of SF₆ 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

2G3: Continuous updating of the Swiss EMIS database causes a change in specific N₂O emission factors of Liechtenstein and therefore to a recalculation for N₂O in 2014.

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

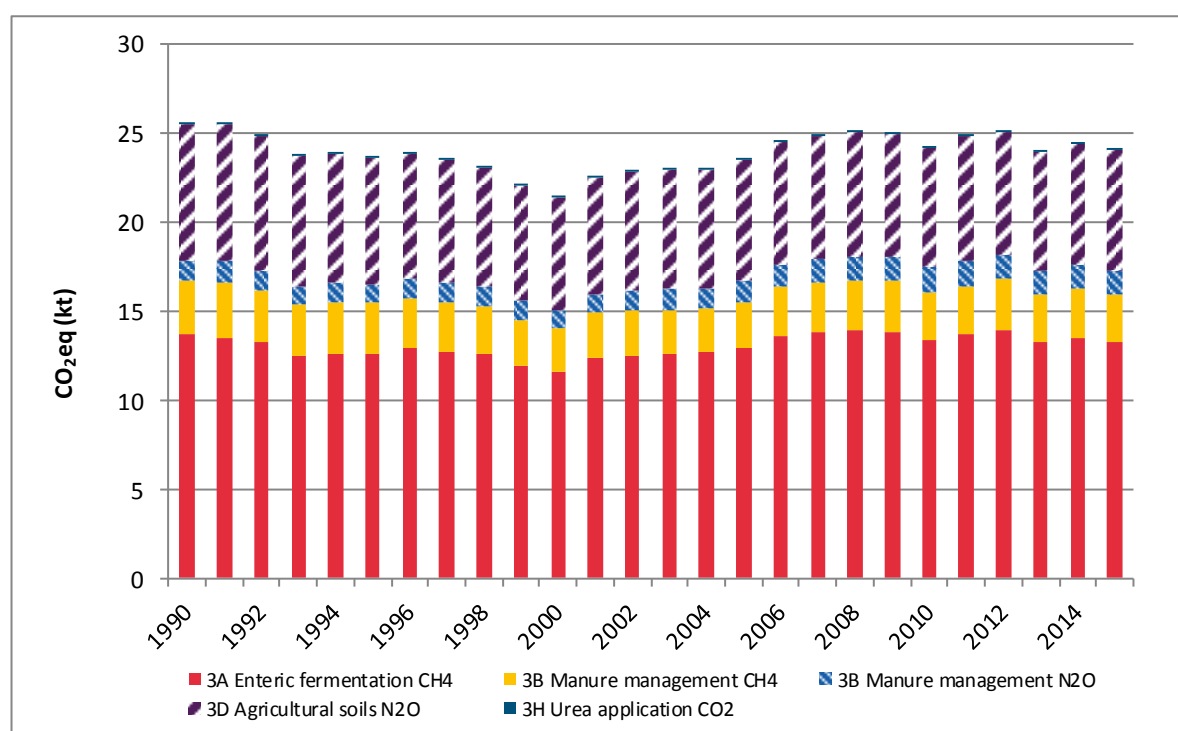
This chapter provides information on the estimation of the greenhouse gas emissions from sector Agriculture. The following source categories are reported:

- Enteric fermentation (3A) – CH₄ emissions from domestic livestock
- Manure management (3B) – CH₄ and N₂O emissions
- Agricultural soils (3D) – N₂O, NO_x, CO, and NMVOC emissions
- Urea application (3H) – CO₂ 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 CO₂ 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 considered this approach as appropriate in its Annual Review Report 2014 (FCCC/ARR 2014) in paragraph 60.** 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 at 5 yearly intervals with latest Swiss values and data. The effort for updating the model at an annual basis 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 planned improvements in Annex A8.3, Table A - 6).

Greenhouse gas emissions from agriculture amount to 24.1 kt CO₂ equivalents in 2015, which is a contribution of 12.1% to the total of Liechtenstein's greenhouse gas emissions (excluding LULUCF). Main agricultural sources of greenhouse gases in 2015 were enteric fermentation emitting 13.3 kt CO₂ equivalents, followed by agricultural soils with 6.8 kt CO₂ equivalents, manure management with 4.0 kt and urea application with 0.05 kt. A decrease of 3.7% can be observed between 1990 and 2015 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. Compared to the previous reporting year 2014, emissions have slightly decreased by around 1.2%.

Figure 5-1 Greenhouse gas emissions in kt CO₂ equivalents of agriculture 1990-2015.Table 5-1 Greenhouse gas emissions in kt CO₂ equivalents of agriculture 1990-2015 (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 ₂ O | 8.73 | 8.84 | 8.63 | 8.36 | 8.33 | 8.18 | 8.10 | 8.05 | 7.77 | 7.54 |
| Sum | 25.51 | 25.53 | 24.85 | 23.76 | 23.86 | 23.68 | 23.89 | 23.54 | 23.04 | 22.09 |

| 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 ₂ O | 7.40 | 7.59 | 7.81 | 7.86 | 7.81 | 7.99 | 8.19 | 8.27 | 8.36 | 8.28 |
| Sum | 21.48 | 22.53 | 22.87 | 23.01 | 22.99 | 23.56 | 24.57 | 24.91 | 25.12 | 25.00 |

| Gas | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|------------------|---------------------------------|--------------|--------------|--------------|--------------|--------------|---------------|
| | CO ₂ equivalent (kt) | | | | | | |
| CO ₂ | 0.04 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | -19.21% |
| CH ₄ | 16.10 | 16.44 | 16.79 | 15.96 | 16.26 | 15.92 | -4.79% |
| N ₂ O | 8.04 | 8.42 | 8.29 | 8.01 | 8.09 | 8.12 | -6.95% |
| Sum | 24.18 | 24.91 | 25.13 | 24.02 | 24.39 | 24.09 | -5.56% |

Figure 5-2 shows the emission trends for CO₂, CH₄ and N₂O within sector 3 Agriculture. Regarding CO₂ emissions, which originate from urea application only, a negative trend of 19.2% between 1990 and 2015 can be observed. The fluctuations in the time series of CO₂ emissions are due to the variability of urea application in the Swiss inventory (see FOEN 2016, chp. 5.1, p. 265). CH₄ emissions are 4.8% below 1990 level, and N₂O emissions also decreased between 1990 and 2015 by 6.9%. Both, CH₄ and N₂O emissions, are highly dependent on animal populations (see also Figure 5-6).

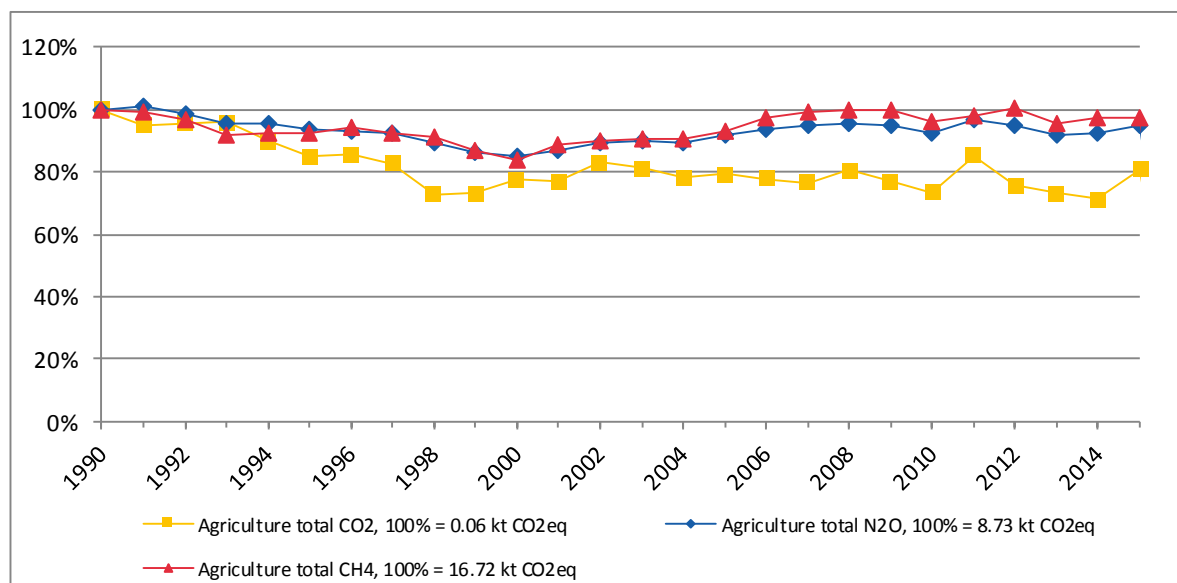


Figure 5-2 Trend of greenhouse gases of the agricultural sector 1990-2015. The base year 1990 represents 100%.

There are three key categories of the inventory out of sector 3 Agriculture. Those categories are displayed in Figure 5-3, including absolute emission numbers for the base year 1990 and the reporting year 2015.

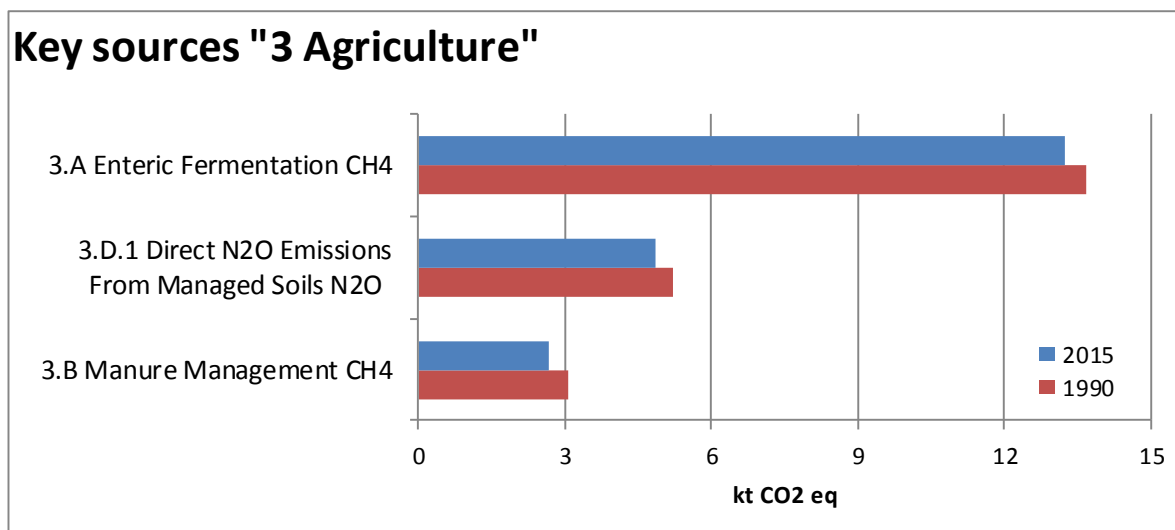


Figure 5-3 Key categories from agriculture. Emissions in CO₂ equivalents (kt) in 2015 and in the base year 1990.

5.2 Source category 3A – Enteric fermentation

5.2.1 Source category description: Enteric fermentation (3A)

Key category information 3A

CH₄ emissions from 3A Enteric fermentation are a key category 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, CH₄ emissions from source category 3A Enteric fermentation have decreased between 1990 and 2000 and then again increased from 2001 to 2015 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 calve, pre-weaned calves, breeding cattle 1 st year, breeding cattle 2 nd year, breeding cattle 3 rd 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 CH₄ 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 CH₄ 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 2016 (FOEN 2016, p. 268). The method is based on the IPCC 2006 Guidelines (IPCC 2006), equation 10.21:

$$EF = \frac{GE * (Y_m \div 100) * 365 \text{ days} / y}{55.65 \text{ MJ} / \text{kg} \text{ CH}_4}$$

where: EF = annual CH₄ 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.

The parameters used for estimating the emission factors are described in the following sections. Find detailed data for the estimation of emission factors in Annex A3.2 (copy of Tables from NIR Switzerland).

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.

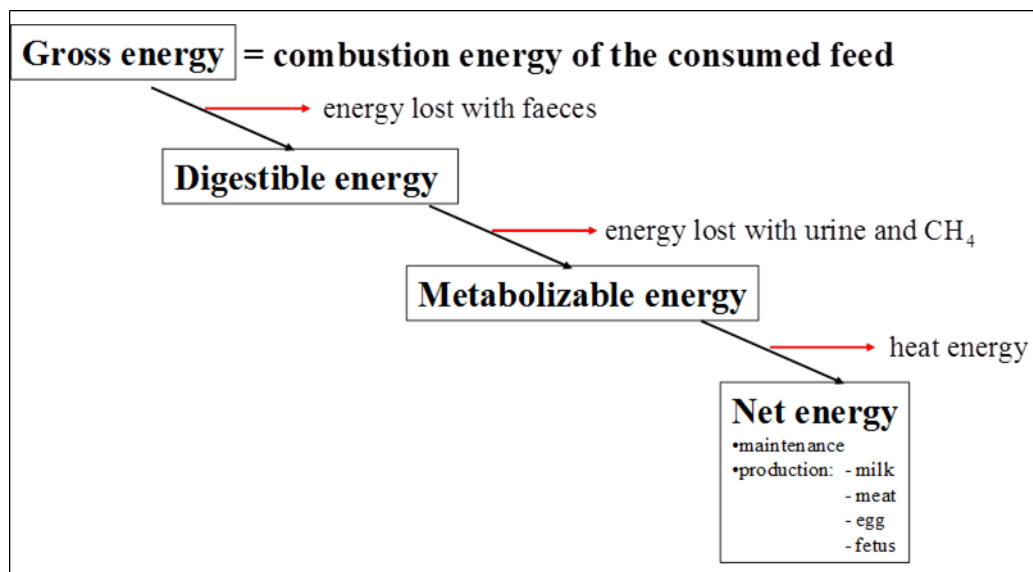


Figure 5-4 Levels of feed energy conversion (Soliva 2006a).

Table 5-3 Conversion factors used for the calculation of energy requirements of individual livestock categories. 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 | <i>Fattening Calves</i> | <i>ME to GE</i> | <i>0.930</i> |
| | <i>Pre-Weaned Calves</i> | <i>NEL to GE</i> | <i>0.291</i> |
| | <i>Breeding Cattle 1st Year</i> | <i>NEL to GE</i> | <i>0.328</i> |
| | <i>Breeding Cattle 2nd Year</i> | <i>NEL to GE</i> | <i>0.313</i> |
| | <i>Breeding Cattle 3rd Year</i> | <i>NEV to GE</i> | <i>0.313</i> |
| | <i>Fattening Cattle</i> | <i>NEV to GE</i> | <i>0.384</i> |
| Sheep | <i>Fattening Sheep</i> | <i>NEV to GE</i> | <i>0.350</i> |
| | <i>Milksheep</i> | <i>NEL to GE</i> | <i>0.287</i> |
| 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: $GE = 0.0151 * Milk + 197.13$

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.

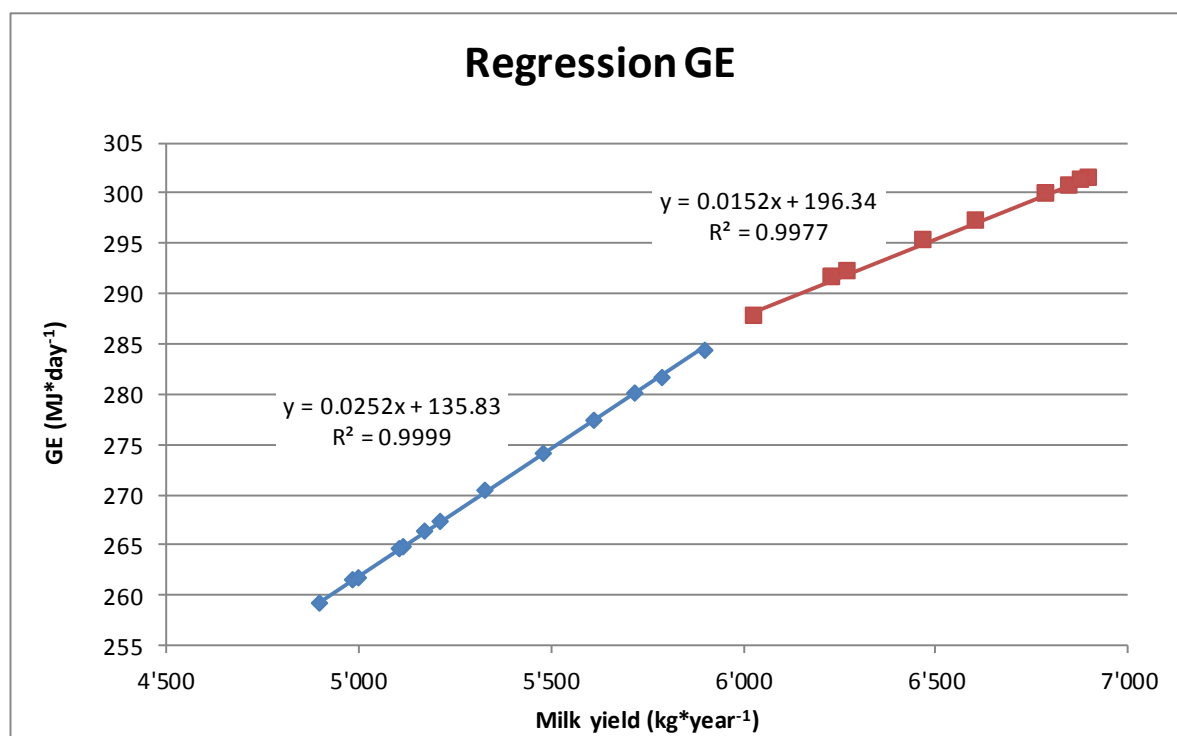


Figure 5-5 Linear regressions relating gross energy intake (GE) to milk yield for mature dairy cattle's (based on FOEN 2016).

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 6'933 kg per head and year in 2015 (22.73 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 1990-2015. 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 | 2015 |
|-------------------------------------|-------------|-------|-------|-------|-------|-------|-------|
| Population Size Mature Dairy Cattle | head | 2'425 | 2'435 | 2'456 | 2'363 | 2'367 | 2'299 |
| Lactation Period | day | 305 | 305 | 305 | 305 | 305 | 305 |
| Milk Yield Mature Dairy Cattle | kg/head/day | 21.87 | 22.09 | 22.40 | 22.19 | 22.16 | 22.73 |
| Milk Yield Other Mature Cattle | kg/head/day | 8.20 | 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) (see

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 2016). 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 1990-2015. 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 |
|-----------------------------------|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 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 |
| Other Mature Cattle | 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 |
| <i>Fattening Calves</i> | 47.6 | 47.6 | 47.6 | 47.6 | 47.6 | 47.6 | 47.6 | 47.6 | 47.6 | 47.6 |
| <i>Pre-Weaned Calves</i> | 55.7 | 55.7 | 55.7 | 55.7 | 55.7 | 55.7 | 55.7 | 55.7 | 55.7 | 55.7 |
| <i>Breeding Cattle 1st Year</i> | 67.6 | 67.6 | 67.6 | 67.6 | 67.6 | 67.6 | 67.6 | 67.6 | 67.6 | 67.6 |
| <i>Breeding Cattle 2nd Year</i> | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 |
| <i>Breeding Cattle 3rd Year</i> | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 | 129.1 |
| <i>Fattening Cattle</i> | 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 |
| Swine | 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 |
| Horses (weighted average) | 107.5 | 107.7 | 108.0 | 108.2 | 108.1 | 108.2 | 108.4 | 108.2 | 108.3 | 108.3 |
| <i>Horses <3 years</i> | 101.4 | 101.4 | 101.4 | 101.4 | 101.4 | 101.4 | 101.4 | 101.4 | 101.4 | 101.4 |
| <i>Horses >3 years</i> | 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 |
| Poultry ¹⁾ | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |

| Gross Energy Intake | 2012 | 2013 | 2014 | 2015 |
|-----------------------------------|-------------|-------|-------|-------|
| | MJ/head/day | | | |
| Cattle | | | | |
| Mature Dairy Cattle | 300.2 | 299.2 | 299.2 | 299.2 |
| Other Mature Cattle | 205.1 | 205.1 | 205.1 | 205.1 |
| Growing Cattle (weighted average) | 95.8 | 96.5 | 97.3 | 96.8 |
| <i>Fattening Calves</i> | 47.6 | 47.6 | 47.6 | 47.6 |
| <i>Pre-Weaned Calves</i> | 55.7 | 55.7 | 55.7 | 55.7 |
| <i>Breeding Cattle 1st Year</i> | 67.6 | 67.6 | 67.6 | 67.6 |
| <i>Breeding Cattle 2nd Year</i> | 129.1 | 129.1 | 129.1 | 129.1 |
| <i>Breeding Cattle 3rd Year</i> | 129.1 | 129.1 | 129.1 | 129.1 |
| <i>Fattening Cattle</i> | 103.6 | 103.6 | 103.6 | 103.6 |
| Sheep | 22.5 | 22.5 | 22.5 | 22.5 |
| Swine | 28.0 | 28.0 | 28.0 | 28.0 |
| Goats | 25.5 | 25.5 | 25.5 | 25.5 |
| Horses (weighted average) | 107.9 | 108.2 | 108.3 | 108.2 |
| <i>Horses <3 years</i> | 101.4 | 101.4 | 101.4 | 101.4 |
| <i>Horses >3 years</i> | 109.0 | 109.0 | 109.0 | 109.0 |
| Mules and Asses | 39.6 | 39.6 | 39.6 | 39.6 |
| Poultry ¹⁾ | 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 5.8%.

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 (population sizes) are provided in Table 5-6.

Table 5-6 Activity data for Liechtenstein (data sources: 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 |
| | <i>Fattening Calves</i> | 0.05 | 0.08 | 0.11 | 0.08 | 0.06 | 0.11 | 0.08 | 0.10 | 0.08 | 0.08 |
| | <i>Pre-Weaned Calves</i> | 0.02 | 0.04 | 0.01 | 0.27 | 0.28 | 0.34 | 0.34 | 0.29 | 0.28 | 0.33 |
| | <i>Breeding Cattle 1st Year</i> | 1.14 | 1.06 | 0.65 | 0.60 | 0.72 | 0.69 | 0.72 | 0.72 | 0.81 | 0.82 |
| | <i>Breeding Cattle 2nd Year</i> | 0.90 | 0.70 | 0.54 | 0.68 | 0.67 | 0.68 | 0.66 | 0.73 | 0.81 | 0.81 |
| | <i>Breeding Cattle 3rd Year</i> | 0.63 | 0.58 | 0.34 | 0.35 | 0.40 | 0.32 | 0.37 | 0.37 | 0.46 | 0.46 |
| | <i>Fattening Cattle</i> | 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 |
| | <i>Horses <3 years</i> | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 |
| | <i>Horses >3 years</i> | 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 | 2015 |
|-----------------------------------|---------------------------------|-----------|-------|-------|-------|
| | | 1000 head | | | |
| Cattle | | 6.29 | 6.01 | 6.21 | 6.03 |
| Mature Dairy Cattle | | 2.46 | 2.36 | 2.37 | 2.30 |
| Other Mature Cattle | | 0.54 | 0.46 | 0.45 | 0.47 |
| Growing Cattle (weighted average) | | 3.29 | 3.18 | 3.40 | 3.27 |
| | <i>Fattening Calves</i> | 0.08 | 0.08 | 0.08 | 0.08 |
| | <i>Pre-Weaned Calves</i> | 0.40 | 0.34 | 0.33 | 0.34 |
| | <i>Breeding Cattle 1st Year</i> | 0.79 | 0.79 | 0.88 | 0.83 |
| | <i>Breeding Cattle 2nd Year</i> | 0.79 | 0.78 | 0.87 | 0.82 |
| | <i>Breeding Cattle 3rd Year</i> | 0.45 | 0.44 | 0.49 | 0.47 |
| | <i>Fattening Cattle</i> | 0.79 | 0.75 | 0.75 | 0.73 |
| Sheep | | 3.80 | 3.52 | 3.58 | 3.89 |
| Swine | | 1.74 | 1.66 | 1.71 | 1.75 |
| Goats | | 0.39 | 0.27 | 0.28 | 0.29 |
| Horses (weighted average) | | 0.33 | 0.30 | 0.31 | 0.30 |
| | <i>Horses <3 years</i> | 0.05 | 0.03 | 0.03 | 0.03 |
| | <i>Horses >3 years</i> | 0.28 | 0.27 | 0.28 | 0.27 |
| Mules and Asses | | 0.18 | 0.17 | 0.18 | 0.16 |
| Poultry | | 12.53 | 13.03 | 12.68 | 12.50 |

Total number of cattle decreased by about a fifth between 1990 and the beginning of the new millennium, grew again between 2000 and 2007 and from then on has stabilised at a slightly lower level than 1990. Other mature cattle have continuously grown in number (from 20 heads in 1990 to 465 heads in 2015), due to an increasing meat demand from extensive livestock production. Swine population has constantly decreased throughout the time period, with one drastic drop between 2003 and 2004 caused by a disease. The extraordinary increase in the poultry population between 1990 and 2007 is a result of two new poultry farms that were established in Liechtenstein. From then on, the poultry population size remained at a similar level.

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

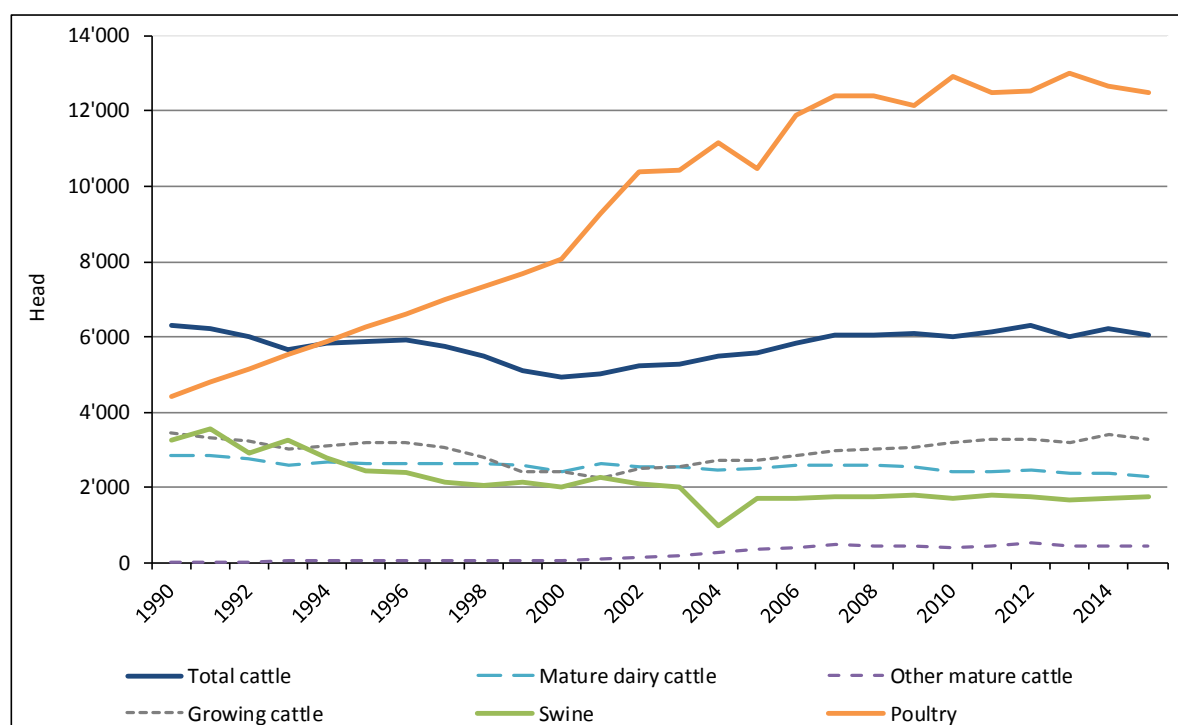


Figure 5-6 Development of population size of main animal categories 1990-2015 (OFIVA/OE 2015, OA 2002).

5.2.3 Uncertainties and time-series consistency

Uncertainties of emission factors and activity data are taken from ART (2008). The uncertainties were determined for the Swiss GHG inventory. However, since the same model is applied for Liechtenstein's GHG inventory, the uncertainties are adopted for Liechtenstein, too. ART (2008) was updated with current activity and emission data of the Swiss inventory and completed with default uncertainties from 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 a later submission as it has already been the case in the last two submissions. 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 1990–2015 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 2014 as well as an analysis of the increase or decrease of emissions between 2014 and 2015 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 CH₄ 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

- 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.

- In the provisional main findings from the review 2016 (FCCC/ERT 2016), the ERT recommended that Liechtenstein conducts a national survey to clarify the feeding situation. Since this parameter is not needed for the calculation of emissions in category 3A and the effort for this survey would be very high and not appropriate (referring to para. 73 in the Annex of the Lima Decision 13/CP.20), this recommendation will not be implemented.

5.3 Source category 3B – Manure management

5.3.1 Source category description: Manure management (3B)

Key category information 3B

CH₄ emissions from 3B Manure Management are a key category 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). Five (CH₄) respectively four (N₂O) different manure management systems are considered including indirect N₂O 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 CH₄ emissions in 2015 are cattle with approximately 86%. Likewise, cattle and sheep contribute significantly to N₂O emissions with 61% and 26%, respectively (direct emissions only). Approximately 73% of the total N₂O emissions attributed to source category 3B Manure management originate from indirect N₂O emissions.

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

| 3B | Source | Specification |
|-----|-----------------|--|
| 3B1 | Cattle | Mature dairy cattle Other mature cattle Growing cattle (fattening calves, Pre-weaned calves, breeding cattle 1 st year, breeding cattle 2 nd year, breeding cattle 3 rd 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 according to manure management system. 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 (CH₄: IPCC 2006 equation 10.23; N₂O: IPCC 2006 equation 10.25).

CH₄ 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).

N₂O 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 N₂O emissions are based on IPCC (2006), corresponding to the third EF (EF₃), whereas the emission factor for indirect emissions from atmospheric deposition is based on Bühlmann et al. (2015) and Bühlmann (2014). Leaching of NO₃⁻ from manure management systems was considered negligible and is thus not included in the estimates. Note that N₂O 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 CH₄ and N₂O 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 CH₄ emissions had to be adapted to data available for energy requirements, while the categorisation for the estimation of N₂O 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 CH₄ and N₂O 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 CH₄ and N₂O emissions from source category 3B Manure management.

| 3B | CH ₄ | N ₂ O |
|-----------------|--------------------------------------|---|
| Cattle | Mature Dairy Cattle | Mature Dairy Cattle |
| | Other Mature Cattle | Other Mature Cattle |
| | Growing Cattle | Fattening Calves Pre-Weaned Calves Breeding Cattle 1 st 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 CH₄

Calculation of CH₄ emissions from manure management is based on methods described in the 2006 IPCC Guidelines (IPCC 2006, equation 10.23):

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

where:

EF_T = annual CH₄ 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 CH₄ producing capacity for manure produced by livestock category T (m³/kg)

0.67 kg/m³ = conversion factor of m³ CH₄ to kilograms CH₄

MCF_S = CH₄ conversion factors for each manure management system S (%)

MST_S = 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):

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

where:

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 chp. 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 72.1% on average, gross energy content (EDF) was 18.27 MJ/kg and ash content was 8.9% 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 CH₄ producing capacity (B₀)

For the methane producing capacity (B₀) default values were used (IPCC 2006).

Methane conversion factor (MCF) (compare FOEN 2016 page 284)

For estimating CH₄ 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 (see 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 14.5% to 13.5% 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 in Liechtenstein's inventory the MCF is kept constant since submission 2015 (i.e. 13.7%) until the agriculture model is updated (5-yearly).

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, Sommer et al. 2007 and 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). 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.

| Manure management system | | Description | MCF (%) | | |
|--------------------------|------------------|----------------------------|--|---|------|
| 3B6a | Direct emissions | Liquid systems | Combined storage of dung and urine under animal confinements for longer than 1 month. | 13.7 | |
| 3B6b | | Solid storage and dry lot | 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 | |
| 3B / 3D | | Pasture, range and paddock | Manure is allowed to lie as it is, and is not managed (distributed, etc.). | 1.0 | |
| 3B6e | | 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 (see 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 |
| <i>Fattening Calves</i> | 14.6 | 0.0 | 0.0 | 85.4 | 15.3 | 0.0 | 0.0 | 84.7 | 22.0 | 0.0 | 0.3 | 77.7 |
| <i>Pre-Weaned Calves</i> | 41.5 | 32.2 | 26.3 | 0.0 | 39.5 | 34.2 | 26.2 | 0.0 | 41.5 | 21.2 | 37.3 | 0.0 |
| <i>Breeding Cattle 1st Year</i> | 37.3 | 48.6 | 14.1 | 0.0 | 38.3 | 47.5 | 14.2 | 0.0 | 34.0 | 38.9 | 27.0 | 0.0 |
| <i>Breeding Cattle 2nd Year</i> | 45.6 | 29.0 | 25.4 | 0.0 | 47.5 | 26.8 | 25.6 | 0.0 | 38.1 | 23.5 | 38.4 | 0.0 |
| <i>Breeding Cattle 3rd Year</i> | 50.8 | 29.2 | 20.0 | 0.0 | 51.7 | 28.0 | 20.3 | 0.0 | 42.5 | 22.6 | 34.8 | 0.0 |
| <i>Fattening Cattle</i> | 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 |
| <i>Fattening Calves</i> | 22.7 | 0.0 | 0.2 | 77.1 | 18.1 | 0.0 | 0.2 | 81.6 |
| <i>Pre-Weaned Calves</i> | 50.9 | 19.0 | 30.1 | 0.0 | 45.9 | 33.3 | 20.9 | 0.0 |
| <i>Breeding Cattle 1st Year</i> | 41.9 | 34.9 | 23.3 | 0.0 | 44.6 | 33.9 | 21.5 | 0.0 |
| <i>Breeding Cattle 2nd Year</i> | 42.3 | 21.1 | 36.5 | 0.0 | 44.5 | 21.2 | 34.3 | 0.0 |
| <i>Breeding Cattle 3rd Year</i> | 46.5 | 21.7 | 31.8 | 0.0 | 47.5 | 21.9 | 30.6 | 0.0 |
| <i>Fattening Cattle</i> | 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 CH₄

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 former 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. Table 5-6 (see chp. 5.2.2.2) illustrates livestock data.

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's livestock numbers.

5.3.2.4 Emission factors N₂O

Estimation of direct N₂O emissions from Manure management relies basically on the same manure management systems as the estimation of CH₄ emissions (see Table 5-8). All emission factors are based on default values given in table 10.21 of the 2006 IPCC Guidelines (see 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 2016). 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 N₂O emission factor that ranges from 0.0000 to 0.0004, respectively.

The emission factor for indirect N₂O emissions after volatilisation of NH₃ 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 average share of volatilised nitrogen that is re-deposited in (semi-)natural habitats is 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 in Liechtenstein's inventory the emission factor for indirect emissions is kept constant since submission 2015 (i.e. 0.026 kg N₂O-N / kg N) until the agriculture model is updated (5-yearly).

Table 5-12 N₂O emission factor for manure management systems in Liechtenstein.

| Animal waste management system | Emission factor |
|--|------------------------------|
| | kg N ₂ O-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 N₂O

Activity data for N₂O emissions from source category 3B Manure management was estimated according to equation 10.25 of the 2006 IPCC Guidelines:

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T (N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)}) \right] \cdot EF_{3(S)} \right] \cdot \frac{44}{28}$$

N₂O_{D(mm)} = direct N₂O emissions from manure management (kg N₂O/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 N₂O emissions from manure management system S (kg N₂O-N/kg N)

44/28 = conversion of (N₂O-N)_(mm) emissions to N₂O_(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 animal population sizes 1990-2015.

| Population sizes Liechtenstein | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|--------------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Fattening Calves | 50 | 81 | 112 | 83 | 81 | 82 | 82 | 79 | 79 | 77 |
| Pre-Weaned Calves | 15 | 35 | 11 | 266 | 281 | 329 | 395 | 341 | 330 | 342 |
| Breeding Cattle 1st Year | 1'136 | 1'057 | 649 | 601 | 814 | 821 | 792 | 789 | 877 | 828 |
| Breeding Cattle 2nd Year | 903 | 699 | 544 | 676 | 808 | 814 | 786 | 782 | 871 | 822 |
| Breeding Cattle 3rd Year | 631 | 575 | 343 | 348 | 459 | 462 | 446 | 444 | 494 | 466 |
| Fattening Cattle | 723 | 725 | 774 | 743 | 743 | 763 | 792 | 748 | 745 | 732 |
| Growing Cattle | 3'458 | 3'172 | 2'433 | 2'717 | 3'186 | 3'271 | 3'293 | 3'183 | 3'396 | 3'267 |
| Mature Dairy Cattle | 2'850 | 2'643 | 2'440 | 2'489 | 2'425 | 2'435 | 2'456 | 2'363 | 2'367 | 2'299 |
| Other Mature Cattle | 20 | 47 | 74 | 362 | 382 | 448 | 538 | 464 | 449 | 465 |
| Total Cattle | 6'328 | 5'862 | 4'947 | 5'568 | 5'993 | 6'154 | 6'287 | 6'010 | 6'212 | 6'031 |
| Fattening Sheep | 1'636 | 1'079 | 1'522 | 2'005 | 2'061 | 2'102 | 2'154 | 2'077 | 2'105 | 2'094 |
| Milksheep | 0 | 0 | 0 | 41 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total Sheep | 2'781 | 2'632 | 2'983 | 3'063 | 3'656 | 3'631 | 3'800 | 3'522 | 3'581 | 3'892 |
| Goat Places | 111 | 100 | 96 | 171 | 253 | 255 | 217 | 187 | 169 | 182 |
| Total Goats | 171 | 145 | 164 | 324 | 434 | 462 | 388 | 269 | 283 | 285 |
| Horses <3 years Agr. | 33 | 27 | 20 | 28 | 31 | 31 | 46 | 29 | 27 | 29 |
| Horses >3 years Agr. | 133 | 135 | 136 | 237 | 304 | 301 | 283 | 271 | 282 | 272 |
| Total Horses Agr. | 166 | 162 | 156 | 265 | 335 | 332 | 329 | 300 | 309 | 301 |
| Total Mules and Asses Agr. | 73 | 133 | 223 | 144 | 154 | 191 | 177 | 166 | 178 | 163 |
| Piglets | 506 | 452 | 398 | 222 | 301 | 143 | 234 | 242 | 114 | 285 |
| Fattening Pig over 25 kg | 1'006 | 1'091 | 1'229 | 1'162 | 1'058 | 1'152 | 1'053 | 1'112 | 1'180 | 1'206 |
| Dry Sows | 207 | 191 | 91 | 96 | 101 | 89 | 76 | 94 | 72 | 87 |
| Nursing Sows | 66 | 62 | 22 | 21 | 18 | 31 | 28 | 14 | 26 | 12 |
| Boars | 5 | 5 | 4 | 3 | 3 | 5 | 4 | 4 | 2 | 10 |
| Total Swine | 3'251 | 2'429 | 1'992 | 1'703 | 1'690 | 1'789 | 1'739 | 1'655 | 1'712 | 1'747 |
| Growers | 105 | 53 | 0 | 0 | 61 | 25 | 15 | 17 | 12 | 246 |
| Layers | 4'145 | 5'506 | 6'866 | 10'112 | 12'175 | 11'862 | 12'216 | 12'544 | 12'509 | 12'056 |
| Broilers | 0 | 500 | 1'000 | 250 | 390 | 362 | 112 | 250 | 5 | 0 |
| Turkey | 22 | 55 | 87 | 52 | 103 | 42 | 0 | 25 | 31 | 43 |
| Other Poultry (Geese, Ducks, Ostriches, Quails) | 163 | 134 | 106 | 39 | 191 | 203 | 182 | 189 | 123 | 153 |
| Total Poultry | 4'435 | 6'248 | 8'059 | 10'453 | 12'920 | 12'494 | 12'525 | 13'025 | 12'680 | 12'498 |

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), see Figure 5-7 below. 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 chp. 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: $\text{NexDC} = 0.00841 * \text{Milk} + 61.5771$
- milk production per year > 6'000 kg: $\text{NexDC} = 0.00298 * \text{Milk} + 94.5031$

where:

NexDC = 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 the increase in nitrogen excretion rate is thus slower than for lower milk yields. Data on milk yield is contained in Table 5-4.

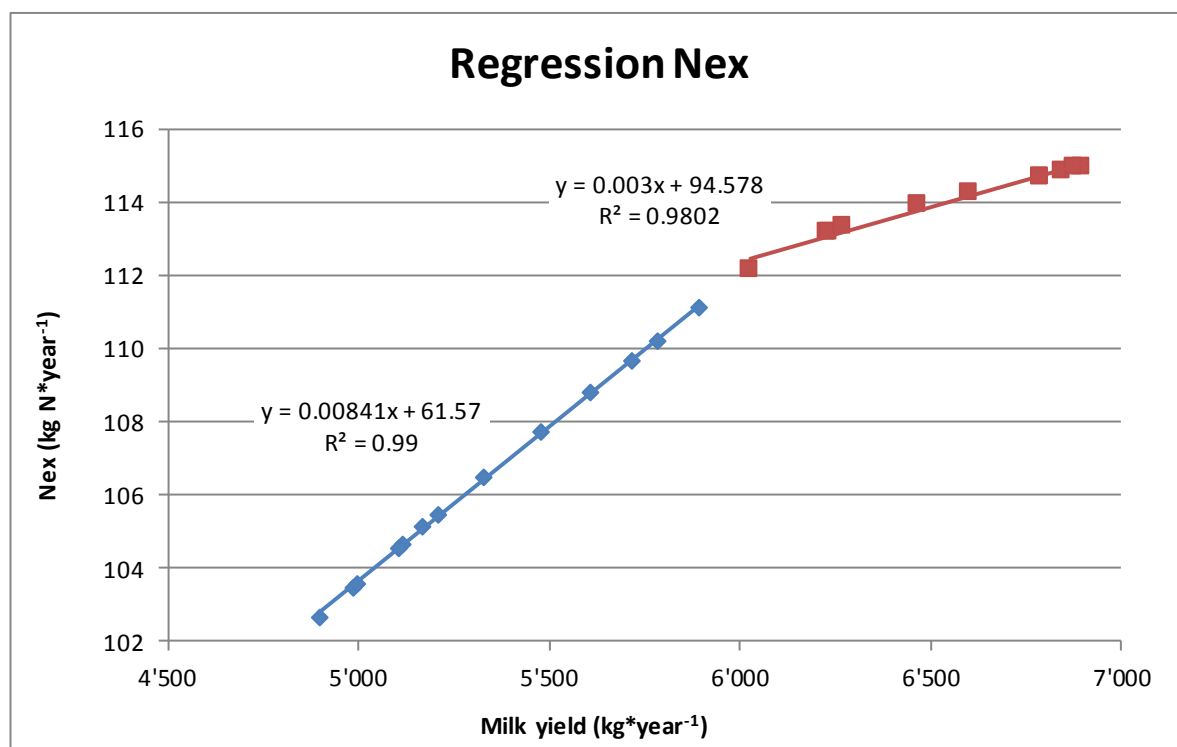


Figure 5-7 Linear regression relating nitrogen excretion (NexDC) of mature dairy cattle to milk yield (based on FOEN 2015).

Table 5-14 Nitrogen excretion rates of Liechtenstein's livestock, 1990-2015.

| 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 |
| Cattle | <i>Fattening Calves</i> | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| | <i>Pre-Weaned Calves</i> | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 |
| | <i>Breeding Cattle 1st Year</i> | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| | <i>Breeding Cattle 2nd Year</i> | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 |
| | <i>Breeding Cattle 3rd Year</i> | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 |
| | <i>Fattening Cattle</i> | 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 | 2015 |
|-----------------------------------|---------------------------------|-------|-------|-------|
| | kg N/head/year | | | |
| Mature Dairy Cattle | 114.9 | 114.7 | 114.7 | 115.2 |
| Other Mature Cattle | 80.0 | 80.0 | 80.0 | 80.0 |
| Growing Cattle (weighted average) | 35.3 | 35.4 | 35.6 | 35.5 |
| Cattle | <i>Fattening Calves</i> | 13.0 | 13.0 | 13.0 |
| | <i>Pre-Weaned Calves</i> | 34.0 | 34.0 | 34.0 |
| | <i>Breeding Cattle 1st Year</i> | 25.0 | 25.0 | 25.0 |
| | <i>Breeding Cattle 2nd Year</i> | 40.0 | 40.0 | 40.0 |
| | <i>Breeding Cattle 3rd Year</i> | 55.0 | 55.0 | 55.0 |
| | <i>Fattening Cattle</i> | 33.0 | 33.0 | 33.0 |
| Sheep (weighted average) | 8.5 | 8.8 | 8.8 | 8.1 |
| Swine (weighted average) | 9.5 | 10.3 | 10.1 | 10.4 |
| Goats | 8.9 | 11.1 | 9.6 | 10.2 |
| Horses (weighted average) | 43.7 | 43.8 | 43.8 | 43.8 |
| Mules and Asses | 15.7 | 15.7 | 15.7 | 15.7 |
| Poultry (weighted average) | 0.8 | 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 CH₄ emissions from Manure management (see chp. 5.3.2.2).

Volatilisation of NH₃ and NO_x from manure management systems (compare FOEN 2016 page 294)

N₂O emissions from the deposition of volatilised nitrogen from manure management are based on NH₃ 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 NH₃ 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 ART (2008). The uncertainties were determined for the Swiss GHG inventory. However, since the same model is applied for Liechtenstein’s GHG inventory, the uncertainties are adopted for Liechtenstein, too. ART (2008) was updated with current activity and emission data of the Swiss inventory and completed with 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 (see Table 3-16).

Table 5-15 Uncertainties for source category 3B Manure management 2015. AD: Activity data; EF: Emission factor; CO: Combined

| Uncertainty 3B | | Approach 1 | | |
|----------------------------|---|------------|-------|-------|
| | | AD | EF | CO |
| | | % | | |
| CH ₄ | | 6.4 | 54.0 | 54.4 |
| N ₂ O direct | Liquid/slurry | 32.0 | 75.0 | 81.5 |
| N ₂ O direct | Solid storage / Deep bedding / Poultry manure | 32.0 | 75.0 | 81.5 |
| N ₂ O indirect | Indirect emissions | 46.5 | 240.0 | 244.5 |
| N ₂ O 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 1990–2015 are consistent, although the following issues should be considered:

- For time series consistency of livestock population data and gross energy intake see chp. 5.2.3.
- The MCF for liquid/slurry systems varies according to the development of the grazing management over the years as described in chp. 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 approximately 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 N₂O emissions after volatilisation of NH₃ 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 2014 as well as an analysis of the increase or decrease of emissions between 2014 and 2015 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 CH₄ 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 category information 3D

Direct N₂O emissions from agricultural soils (3D1) are a key category by level.

The source category 3D includes direct and indirect N₂O emissions from managed soils with a subdivision given in Table 5-16.

The most significant N₂O emission sources in 2015 were animal manure applied to soils (21.9%), nitrogen input from atmospheric deposition (19.0%), nitrogen in crop residues returned to soils (13.3%), Urine and dung deposition by grazing animals and inorganic nitrogen fertilisers (12.7%).

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 ₂ O emissions from managed soils | <ol style="list-style-type: none"> 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 ₂ O emissions from managed soils | <ol style="list-style-type: none"> 1. Atmospheric deposition 2. Nitrogen leaching and run-off |

Direct and indirect N₂O emissions have decreased by 6.4% and 19.6% compared to 1990 levels, respectively. The lowest N₂O emission level was in the year 2000. Since then, total emissions are slightly increasing, reflecting a similar 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 N₂O emissions from source category 3D Agricultural soils a country-specific Tier 2 method used in the Swiss inventory and based on the IULIA model from Schmid et al. (2000) was applied. IULIA is an IPCC-derived method for the calculation of N₂O 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 N₂O 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 N₂O emissions from agricultural soils is consistent with source category 3B N₂O 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.

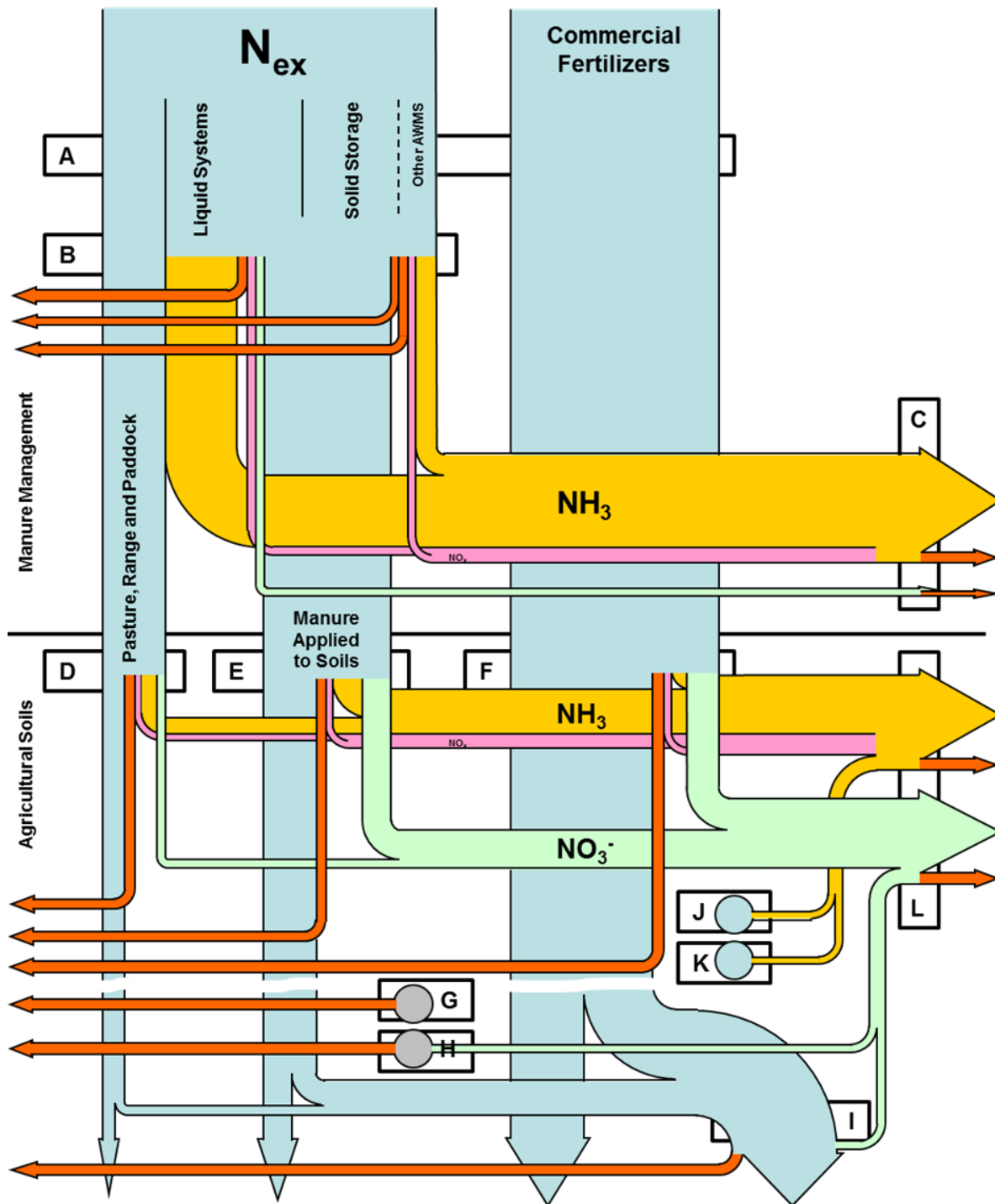


Figure 5-8 Diagram depicting the methodology of the approach to calculate the N₂O emissions in agriculture (red arrows). Black frames and the respective letters refer to the nitrogen flows in Table 5-17. Note that the figure shows explicitly the methodology of the approach and not necessarily the physical 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 | 2015 | |
| | | tN | | |
| A | 1 Pasture, range and paddock | 54.97 | 99.48 | 3.Da3 |
| | 2 Liquid/slurry systems | 291.46 | 272.83 | 3.B(b) |
| | 3 Solid storage | 135.74 | 89.68 | 3.B(b) |
| | 4 Other AWMS | 23.51 | 34.14 | 3.B(b) |
| | 5 Commercial fertiliser | 277.36 | 199.70 | 3.Da1,2,7 |
| B | 1 Pasture, range and paddock | 54.97 | 99.48 | 3.Da3 |
| | 2 NH ₃ volatilisation housing | 30.50 | 50.24 | 3.B(b)5 |
| | 3 N ₂ O 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 | 316.78 | 3.Da2 |
| | 7 N ₂ O emission solid storage | 0.68 | 0.45 | 3.B(b) |
| | 8 N ₂ O emission other AWMS | 0.21 | 0.26 | 3.B(b) |
| | 9 NO _x volatilisation solid storage and deep litter | 0.40 | 0.31 | 3.B(b)5 |
| | 10 NH ₃ volatilisation storage | 33.17 | 28.53 | 3.B(b)5 |
| C | 1 NH ₃ deposition manure management | 63.67 | 78.76 | 3.B(b)5 |
| | 2 NO _x deposition manure management | 0.41 | 0.32 | |
| | 3 Leaching manure management | 0.00 | 0.00 | |
| D | 1 Available N PR&P | 38.04 | 70.32 | |
| | 2 N ₂ O emission PR&P | 1.02 | 1.84 | 3.Da3 |
| | 3 NO _x volatilisation PR&P | 0.30 | 0.55 | |
| | 4 NH ₃ volatilisation PR&P | 2.73 | 5.10 | |
| | 5 Leaching and run-off PR&P | 12.88 | 21.67 | |
| E | 1 Available N animal manure | 183.18 | 166.33 | |
| | 2 N ₂ O emission application animal manure | 3.86 | 3.17 | 3.Da2 |
| | 3 NO _x volatilisation application animal manure | 2.12 | 1.74 | |
| | 4 NH ₃ volatilisation application animal manure | 106.22 | 76.52 | |
| | 5 Leaching and run-off application animal manure | 90.36 | 69.01 | |
| F | 1 Available N com. fertiliser | 192.25 | 145.21 | |
| | 2 N ₂ O emission application com. fertiliser | 2.77 | 2.00 | 3.Da1,2,7 |
| | 3 NO _x volatilisation application com. fertiliser | 1.53 | 1.10 | |
| | 4 NH ₃ volatilisation application com. fertiliser | 15.84 | 7.89 | |
| | 5 Leaching and run-off application com. fertiliser | 64.97 | 43.51 | |
| G | 1 Cultivation of organic soils (ha) | 193.00 | 183.83 | 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 | 163.39 | 3.Da4 |
| | 2 N in crop residues arable crops | 33.24 | 28.47 | |
| 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 | 89.50 | 3.Db1 |
| | 2 NO _x deposition fertiliser appl. and PR&P | 3.95 | 3.39 | |
| | 3 NH ₃ deposition agricultural and alpine area | 10.56 | 10.95 | |
| | 4 Leaching and run-off fertiliser appl. and PR&P | 168.21 | 134.19 | 3.Db2 |
| | 5 Leaching and run-off mineralisation SOM | 0.00 | 0.00 | |
| | 6 Leaching and run-off crop residues | 44.75 | 41.80 | |

5.5.2.2 Direct N₂O emissions from managed soils (3Da)

Calculation of Direct N₂O emissions from managed soils is based on IPCC 2006 equation 11.2 including six terms for activity data and three different emission factors:

$$N_2O_{Direct-N} = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \cdot EF_1 + F_{OS} \cdot EF_2 + F_{PRP} \cdot EF_3$$

where:

N_2O_{Direct} = annual direct N₂O emissions produced from managed soils (kg N₂O–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 N₂O emissions from N inputs (kg N₂O–N/kg N input)

EF_2 = emission factor for N₂O emissions from drained/managed organic soils (kg N₂O–N/ha/year)

EF_3 = emission factor for N₂O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (kg N₂O–N/kg N input)

Emission factors for direct N₂O emissions

Emission factors for calculating direct N₂O emissions from managed soils are all based on default values as provided in the 2006 IPCC Guidelines (see 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 N₂O emissions from managed soils (IPCC 2006).

| Emission Source | Emission factor |
|--|-----------------|
| EF ₁ Inorganic N fertilisers (kg N ₂ O-N/kg) | 0.0100 |
| EF ₁ Organic N fertilisers (kg N ₂ O-N/kg) | 0.0100 |
| EF ₁ Crop residue (kg N ₂ O-N/kg) | 0.0100 |
| EF ₁ Mineralisation/immobilisation soil organic matter (kg N ₂ O-N/kg) | 0.0100 |
| EF ₁ Other (domestic synthetic fertilisers) (kg N ₂ O-N/kg) | 0.0100 |
| EF ₂ Cultivation of organic soils (kg N ₂ O-N/ha) | 8.0000 |
| EF ₃ Urine and dung deposited by grazing animals (kg N ₂ O-N/kg) | 0.0185 |

Activity data for direct N₂O 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 fertilisers (mainly ammonium-nitrate). Data on the application of synthetic fertilisers in Liechtenstein is not available. Consequently, N input was estimated multiplying average inorganic N input per ha in Switzerland (FOEN 2016) with the area fertilized in Liechtenstein which is provided by the Division of Agriculture (OE 2015a). The split of mineral fertilisers in urea and other mineral fertiliser 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 fertilisers. 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 N₂O 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).

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 (see Annex A6.1). From then on, the entire sewage sludge is treated in one centralized Municipal Waste Water Treatment Plant (MWWTP) in Bendern. After the anaerobic digestion, the digested sewage sludge is dewatered and dried. Pellets are transported and incinerated in Switzerland in the cement plant Untervaz (AZV 2016).

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 chp. 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 chp. 5.3.2.5, compare also Figure 5-8 and Table 5-20). FracGASM in reporting table 3.D represents the amount of nitrogen volatilised as NH₃, NO_x and N₂O 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.

Other organic fertilisers contain 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 fertiliser. The rest of the compost amount is reported under sector 5 Waste, categories 5B and 5C.

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 approximately 3000 Swiss farms (2000, 2007, 2010).

N₂O 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):

$$F_{CR,AC} = \sum_T (N_T \cdot A_T)$$

where:

$F_{CR,AC}$ = 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:

$$F_{CR,MP} = \sum_P \left(A_P \cdot \frac{SY_{DM,P}}{10} \cdot N_{DM,P} \div 1000 \cdot R_P \right)$$

where:

$F_{CR,MP}$ = 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 percentage of 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 chp. 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 chp. 6).

Table 5-19 Activity data for calculating direct N₂O emissions from managed soils (1990-2015).

| 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) | | 193 | 193 | 192 | 192 | 191 | 191 | 190 | 190 | 189 | 189 |
| 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) | | 188 | 188 | 187 | 187 | 186 | 186 | 186 | 185 | 185 | 185 |
| 7. Other (domestic inorganic fertilisers) | | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

| Activity Data | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|--|------------------------------|--------|------|------|------|------|------|
| | | t N/yr | | | | | |
| 1. Inorganic N fertilisers | Urea | 27 | 31 | 28 | 27 | 26 | 30 |
| | Other mineral fertilisers | 147 | 170 | 151 | 146 | 142 | 161 |
| 2. Organic N fertilisers | a. Animal manure | 321 | 328 | 333 | 319 | 323 | 317 |
| | b. Sewage sludge | 0 | 0 | 0 | 0 | 0 | 0 |
| | c. Other organic fertilisers | 0 | 0 | 1 | 1 | 0 | 0 |
| 3. Urine and dung deposited by grazing animals | | 99 | 102 | 105 | 99 | 102 | 99 |
| 4. Crop residues | Arable crops | 25 | 25 | 26 | 26 | 29 | 28 |
| | Residues PR&P | 165 | 181 | 165 | 164 | 164 | 163 |
| 5. Min./imm. associated with loss/gain of SOM | | 0 | 0 | 0 | 0 | 0 | 0 |
| 6. Cultivation of organic soils (ha) | | 185 | 185 | 184 | 184 | 184 | 184 |
| 7. Other (domestic inorganic fertilisers) | | 7 | 8 | 7 | 7 | 7 | 8 |

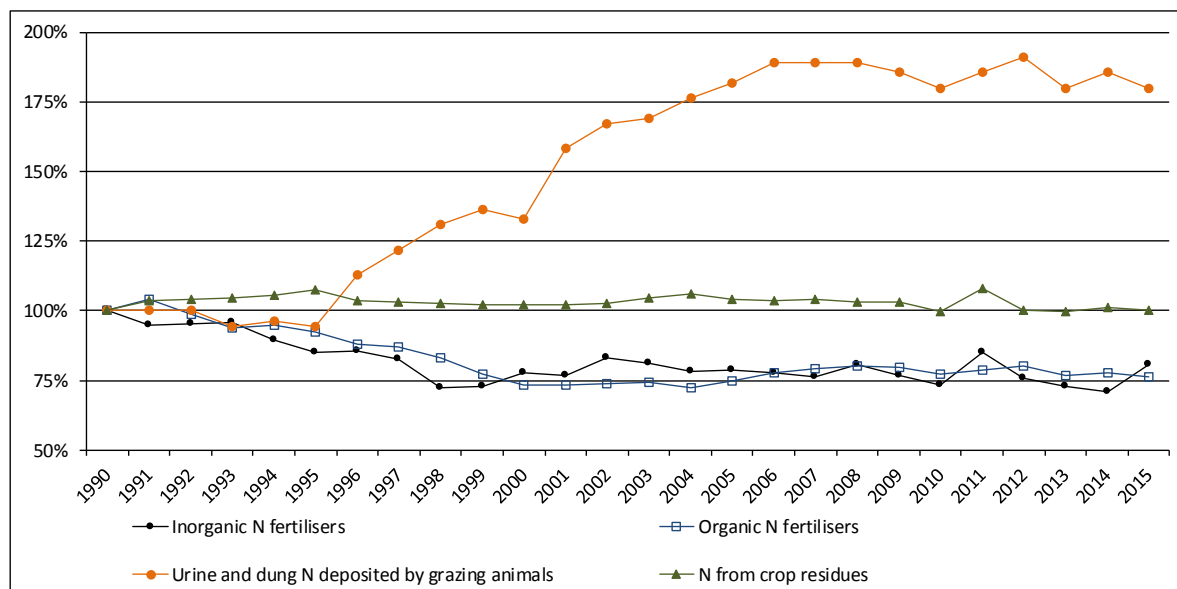


Figure 5-9 Relative development of the most important activity data for source category 3Da direct N₂O emissions from managed soils 1990-2015.

Figure 5-9 depicts the development of the most important activity data for direct N₂O 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 smaller 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 21st century (see also chp. 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.

Due to a recalculation in the Swiss inventory 2014 (see chp. 5.5.5 or FOEN 2016, p. 480), the amount of commercial fertiliser applied on agricultural soils has increased in Switzerland and Liechtenstein. This leads to an increase of NH₃-emissions from the application and leaching and run-off of commercial fertiliser.

5.5.2.3 Indirect N₂O emissions from atmospheric deposition of N volatilised from managed soils (3Db1)

N₂O 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:

$$N_2O_{(ATD)} - N = \left[\begin{array}{l} \sum_i (F_{CN_i} \cdot Frac_{GASF_i}) \\ + \sum_T (F_{AM_T} \cdot Frac_{GASM_T}) \\ + \sum_T (F_{PRP_T} \cdot Frac_{GASP_T}) \end{array} \right] + \left[\begin{array}{l} (F_{CN} + F_{AM}) \cdot Frac_{NOXA} \\ + F_{PRP} \cdot Frac_{NOXP} \end{array} \right] \cdot EF_4$$

where:

$N_2O_{(ATD)} - N$ = annual amount of $N_2O - N$ produced from atmospheric deposition of N volatilised from managed soils (kg $N_2O - N$ /year)

F_{CN_i} = annual amount of commercial fertiliser N of type i applied to soils (kg N/year)

$Frac_{GASF_i}$ = fraction of commercial fertiliser N of type i that volatilises as NH_3 (kg N/kg N)

F_{AM_T} = 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)

NH_{3AS} = 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 chp. 5.3.2.4. For Fra_{CNOXA} and Fra_{CNOXP} , see Stehfest and Bouwman (2006).

Activity data for indirect N₂O 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 (see 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 NH₃ emissions, changes of agricultural structures (e.g. changes to more animal friendly housing systems) and techniques (manure management, measures to reduce NH₃ 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) and is not occurring (NO) from 2004 on. Other organic fertilisers include compost with an ammonia emission factor of 3.4%.

Total Fra_{CGASF} as reported in reporting table 3.D declined considerably from 6.3% in 1990 to 4.5% in 2015 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 NH₃ 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 Fra_{CGASMT} for animal manure applied to soils slightly decreased from 27.5% in the early 1990s to 24.2% in 2015.

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 (Fra_{CGASPT}) 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 NH₃-N/ha are emitted from agricultural land (Schjoerring and Mattsson 2001).

Nitrogen pools and flows for calculating indirect N₂O emissions from managed soils are displayed in Table 5-21.

Table 5-20 Overview of NH₃ and NO_x emission factors used for the assessment of emissions from source category 3Db1 Indirect N₂O emissions from atmospheric deposition (1990-2015).

| 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 | NO | NO | NO | NO | NO | NO | NO |
| | 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 | 2015 |
|--|--|-------|-------|-------|-------|
| | | % | | | |
| NH ₃ from commercial fertiliser N (Frac _{GASFI}) | | 3.95 | 3.95 | 3.95 | 3.95 |
| | Urea | 15.00 | 15.00 | 15.00 | 15.00 |
| | Other Mineral Fertilisers | 2.00 | 2.00 | 2.00 | 2.00 |
| | Recycling Fertilisers (weighted average) | 3.43 | 3.43 | 3.43 | 3.43 |
| | Sewage Sludge | NO | NO | NO | NO |
| | Compost | 3.43 | 3.43 | 3.43 | 3.43 |
| NH ₃ from application of animal manure N (Frac _{GASMT}) | | 24.18 | 24.17 | 24.19 | 24.16 |
| | Mature Dairy Cattle | 26.14 | 26.14 | 26.14 | 26.14 |
| | Other Mature Cattle | 26.22 | 26.22 | 26.22 | 26.22 |
| | Growing Cattle (weighted average) | 25.62 | 25.64 | 25.71 | 25.69 |
| | Sheep (weighted average) | 10.98 | 10.98 | 10.98 | 10.98 |
| | Swine (weighted average) | 19.37 | 19.43 | 19.48 | 19.46 |
| | Other Livestock (weighted average) | 11.59 | 11.76 | 11.74 | 11.70 |
| NH ₃ from urine and dung N deposited on PR&P (Frac _{GASPT}) | | 5.11 | 5.13 | 5.13 | 5.12 |
| | Mature Dairy Cattle | 4.80 | 4.80 | 4.80 | 4.80 |
| | Other Mature Cattle | 4.98 | 4.98 | 4.98 | 4.98 |
| | Growing Cattle (weighted average) | 4.98 | 4.98 | 4.98 | 4.98 |
| | Sheep (weighted average) | 5.00 | 5.00 | 5.00 | 5.00 |
| | Swine (weighted average) | 14.00 | 14.00 | 14.00 | 14.00 |
| | Other Livestock (weighted average) | 9.24 | 9.76 | 9.64 | 9.61 |
| NH ₃ from Agricultural Soils (kg/ha/year) | | 2.00 | 2.00 | 2.00 | 2.00 |
| NO _x from applied fertilisers (Frac _{NOXA}) | | 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 |

Note: The notation key of emission factors for sewage sludge is automatically set "NO" by the CRF reporter.

Table 5-21 Overview of N pools and flows for calculating indirect N₂O emissions from managed soils (1990-2015).

| Nitrogen Pools and Flows | | 1990 | 1995 | 2000 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|--------------------------|---|--------|-------|-------|-------|-------|-------|-------|-------|-------|
| | | t N/yr | | | | | | | | |
| | Animals manure N applied to soils | 385.7 | 352.6 | 293.8 | 310.9 | 323.8 | 329.1 | 331.7 | 331.4 | 321.0 |
| | Commercial fertiliser | 277.4 | 241.2 | 202.5 | 195.8 | 192.0 | 189.2 | 199.6 | 190.2 | 181.6 |
| | Area of agricultural soils (ha) | 5'278 | 5'377 | 5'476 | 5'476 | 5'476 | 5'476 | 5'476 | 5'476 | 5'476 |
| Deposition | Sum volatilised N (NH ₃ and NO _x) | 139.3 | 130.3 | 104.0 | 106.3 | 110.6 | 112.6 | 111.6 | 108.9 | 103.9 |
| | NH ₃ emissions from commercial fertilisers | 15.8 | 15.8 | 10.4 | 7.7 | 7.6 | 7.5 | 7.9 | 7.5 | 7.2 |
| | NH ₃ emissions from applied animal manure | 106.2 | 97.6 | 75.9 | 79.2 | 83.3 | 85.4 | 83.9 | 81.8 | 77.4 |
| | 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 |
| | NH ₃ emissions from agricultural soils | 10.6 | 10.8 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| | NO _x emissions from commercial fertilisers | 1.53 | 1.33 | 1.11 | 1.08 | 1.06 | 1.04 | 1.10 | 1.05 | 1.00 |
| | 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 |
| | NO _x emissions from PR&P | 0.30 | 0.29 | 0.40 | 0.55 | 0.57 | 0.57 | 0.57 | 0.56 | 0.54 |
| Leaching and run-off | Sum leaching and run-off | 213.0 | 191.6 | 166.2 | 175.4 | 178.2 | 179.0 | 181.4 | 178.5 | 172.5 |
| | Leaching and run-off from commercial fertilisers | 65.0 | 54.3 | 44.1 | 42.7 | 41.8 | 41.2 | 43.5 | 41.4 | 39.6 |
| | Leaching and run-off from applied animal manure | 90.4 | 79.4 | 64.0 | 67.7 | 70.6 | 71.7 | 72.3 | 72.2 | 69.9 |
| | Leaching and run-off from pasture, range and paddock | 12.9 | 11.8 | 15.8 | 21.7 | 22.7 | 22.7 | 22.6 | 22.1 | 21.6 |
| | Leaching and run-off from crop residues | 44.8 | 46.1 | 42.3 | 43.2 | 43.1 | 43.3 | 43.1 | 42.8 | 41.5 |
| | Leaching and run-off from mineralisation of SOM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| Nitrogen Pools and Flows | | 2011 | 2012 | 2013 | 2014 | 2015 |
|--------------------------|---|--------|-------|-------|-------|-------|
| | | t N/yr | | | | |
| | Animals manure N applied to soils | 327.6 | 332.9 | 318.7 | 323.2 | 316.8 |
| | Commercial fertiliser | 210.5 | 187.1 | 181.2 | 176.1 | 199.7 |
| | Area of agricultural soils (ha) | 5'476 | 5'476 | 5'476 | 5'476 | 5'476 |
| Deposition | Sum volatilised N (NH ₃ and NO _x) | 107.0 | 107.6 | 103.5 | 104.6 | 103.8 |
| | NH ₃ emissions from commercial fertilisers | 8.31 | 7.39 | 7.16 | 6.95 | 7.89 |
| | NH ₃ emissions from applied animal manure | 79.0 | 80.5 | 77.0 | 78.2 | 76.5 |
| | NH ₃ emissions from pasture, range and paddock | 5.20 | 5.34 | 5.10 | 5.21 | 5.10 |
| | NH ₃ emissions from agricultural soils | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| | NO _x emissions from commercial fertilisers | 1.16 | 1.03 | 1.00 | 0.97 | 1.10 |
| | NO _x emissions from applied animal manure | 1.80 | 1.83 | 1.75 | 1.78 | 1.74 |
| | NO _x emissions from PR&P | 0.56 | 0.57 | 0.55 | 0.56 | 0.55 |
| Leaching and run-off | Sum leaching and run-off | 184.3 | 177.7 | 171.8 | 173.0 | 176.0 |
| | Leaching and run-off from commercial fertilisers | 45.9 | 40.8 | 39.5 | 38.4 | 43.5 |
| | Leaching and run-off from applied animal manure | 71.4 | 72.5 | 69.4 | 70.4 | 69.0 |
| | Leaching and run-off from pasture, range and paddock | 22.2 | 22.8 | 21.6 | 22.2 | 21.7 |
| | Leaching and run-off from crop residues | 45.0 | 41.6 | 41.3 | 42.1 | 41.8 |
| | Leaching and run-off from mineralisation of SOM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Figure 5-10 depicts the development of the most important activity data for indirect N₂O 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 NH₃ (Fra_{CGASMT}) declined slightly and also contributed to the decreasing trend.

Due to a recalculation in the Swiss inventory 2014 (see chp. 5.5.5 or FOEN 2016, p. 480), the amount of commercial fertiliser applied on agricultural soils has increased in Switzerland and Liechtenstein. This leads to an increase of NH₃-emissions from the application and leaching and run-off of commercial fertiliser.

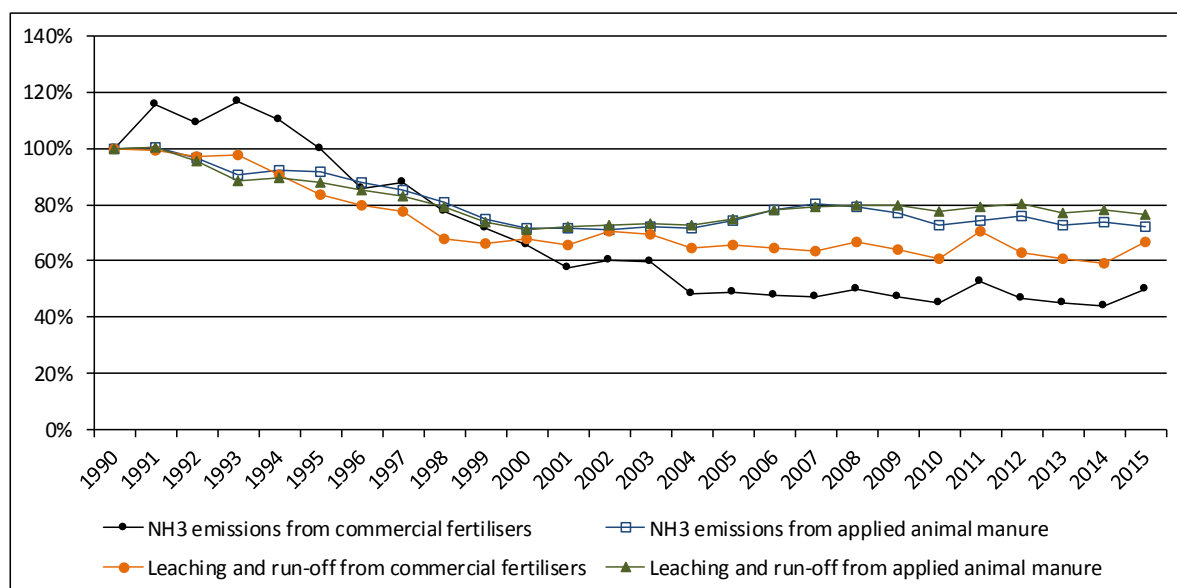


Figure 5-10 Relative development of the most important activity data for source category 3Db indirect N₂O emissions from managed soils 1990-2015.

5.5.2.4 Indirect N₂O emissions from leaching and run-off from managed soils (3Db2)

N₂O emissions from leaching and run-off from managed soils were estimated based on equation 11.10 of the 2006 IPCC Guidelines (IPCC 2006):

$$N_2O_{(L)} - N = (F_{CN} + F_{AM} + F_{PRP} + F_{CR} + F_{SOM}) \cdot \text{Frac}_{LEACH-(H)} \cdot EF_5$$

$N_2O_{(L)} - N$ = annual amount of N₂O–N produced from leaching and run-off of N additions to managed soils (kg N₂O–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)

$\text{Frac}_{LEACH-(H)}$ = fraction of all N added to/mineralised in managed soils that is lost through leaching and runoff (kg N/kg of N additions)

EF₅ = emission factor for N₂O emissions from N leaching and run-off (kg N₂O–N/kg N leached and run-off)

Emission factor for indirect N₂O emissions from nitrogen leaching and run-off

The emission factor for indirect N₂O emissions from leaching and run-off from managed soils is 0.0075 kg N₂O–N/kg N according to the 2006 IPCC guidelines (IPCC 2006).

Activity data for indirect N₂O emissions from nitrogen leaching and run-off (compare FOEN 2016 page 314)

For the calculation of N₂O 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 (FAM), urine and dung N deposited by grazing animals (FPRP) and N in crop residues returned to soils (FCR) 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 chp. 5.5.2.2 and numbers are contained in Table 5-19.

Fra_{CLEACH} 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 Fra_{CLEACH} 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 N₂O 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 (Fra_{CLEACH}). However, due to a recalculation in the Swiss inventory 2014 (see chp. 5.5.5 and FOEN 2016, p. 480), the amount of commercial fertiliser applied on agricultural soils has increased in Switzerland and Liechtenstein.

5.5.3 Uncertainties and time-series consistency

Uncertainties of emission factors and activity data are taken from ART (2008). The uncertainties were determined for the Swiss GHG inventory. Since the same model is applied for Liechtenstein's GHG inventory, the uncertainties are adopted for Liechtenstein, too. ART (2008) was updated with current activity and emission data of the Swiss inventory and completed with default uncertainties from 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 N₂O 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 be considered.

Since there are two aggregate categories 3D direct/N₂O and 3D indirect/N₂O, 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/N₂O 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 2015. 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 | 16.6 | 96.9 | 98.3 |
| 3D2 Indirect soil emissions | Atmospheric deposition | 39.6 | 240.0 | 243.2 |
| | Leaching and run-off | 22.4 | 163.3 | 164.8 |
| | 3D2 aggregate | 27.7 | 171.2 | 173.4 |

For further uncertainty results also consult chp. 1.6.

The time series 1990–2015 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 approximately 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 N₂O emissions following volatilization of NH₃ and NO_x varies according to varying land use as described in chp. 5.3.2.4.
- Considerable fluctuations within the small animal populations due to establishment or cessation of farms or agricultural activities can lead to fluctuations in activity data and emissions (e.g. for animal manure applied to agricultural soils).
- For more details on time-series consistency see chp. 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 2014 as well as an analysis of the increase or decrease of emissions between 2014 and 2015 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

- Switzerland has estimated N-inputs for co-substrates in agricultural biogas plants for the first time in its GHG inventory 2016, which leads to higher activity data of commercial fertilisers applied to agricultural soils (see FOEN 2016, p. 480). In 2014, this recalculation leads to an increase of N₂O emissions by 0.01 kt CO₂eq.

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 category information 3H

There are no key categories under source category 3H Urea application.

Adding urea to soils during fertilisation leads to a loss of CO₂ that was fixed during the industrial production process of the fertiliser. Emissions in Liechtenstein range from 0.04 to 0.06 kt CO₂ per year with a general decreasing trend from 1990 to 2015.

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 applied to Liechtenstein's soils is not known. Based on Swiss fertiliser use data it is assumed that urea amounts to a share of 15% of all synthetic fertilisers. Further information regarding the methods for estimating commercial fertilisers see chp. 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 (CO₂, CH₄, N₂O, 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 chp. 1.2.3.

No further category-specific quality assurance activities were conducted.

5.9.5 Category-specific recalculations

No category-specific recalculations were carried out.

5.9.6 Category-specific planned improvements

There are no further planned improvements in this area.

5.10 Source category 3I – Other carbon-containing fertilisers

Other carbon-containing fertilisers 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 1990-2015 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, 2008 and 2014. They are based on the same methodology as the Swiss land-use statistics (SFSO 2006a).

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 CO₂ equivalent emissions and removals in consequence of carbon losses and gains for the years 1990-2015. The total net emissions of CO₂ equivalent vary between -10.19 kt (1991) and 22.29 kt (2009). Three components of the CO₂ 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 N₂O emissions due to N mineralization in soils (up to 0.42 CO₂ eq) associated with land-conversions (CRF-table 4(III)) and nitrogen leaching and run-off on non-agricultural soils (indirect N₂O emissions; CRF-table 4(IV)).

Table 6-1 Liechtenstein's CO₂ equivalent emissions/removals [kt] of the source category LULUCF 1990-2015. 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 CO ₂ eq | | | | | | | | | |
| Gain of living biomass in forest | -51.10 | -51.17 | -51.24 | -51.31 | -51.38 | -51.45 | -51.52 | -51.61 | -51.71 | -51.80 |
| Loss of living biomass in forest | 50.81 | 34.63 | 45.63 | 42.17 | 61.70 | 47.90 | 39.32 | 50.47 | 42.11 | 40.49 |
| Land-use change, soil and HWP | 3.79 | 6.66 | 6.60 | 7.07 | 7.45 | 6.73 | 7.30 | 8.03 | 7.86 | 7.91 |
| Sector 4 LULUCF (total) | 3.51 | -9.88 | 0.99 | -2.07 | 17.76 | 3.18 | -4.90 | 6.89 | -1.74 | -3.40 |

| LULUCF | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|----------------------------------|-----------------------|--------------|-------------|-------------|-------------|-------------|-------------|--------------|--------------|--------------|
| | kt CO ₂ eq | | | | | | | | | |
| Gain of living biomass in forest | -51.89 | -51.98 | -52.07 | -52.14 | -52.20 | -52.27 | -52.34 | -52.41 | -52.48 | -52.64 |
| Loss of living biomass in forest | 66.16 | 42.21 | 42.75 | 46.65 | 48.68 | 48.53 | 53.25 | 62.37 | 64.35 | 61.33 |
| Land-use change, soil and HWP | 7.74 | 9.16 | 9.46 | 10.02 | 9.51 | 9.35 | 8.33 | 8.59 | 8.85 | 14.01 |
| Sector 4 LULUCF (total) | 22.01 | -0.61 | 0.13 | 4.53 | 5.98 | 5.61 | 9.25 | 18.55 | 20.72 | 22.70 |

| LULUCF | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Mean |
|----------------------------------|-----------------------|--------------|--------------|--------------|--------------|-------------|-------------|
| | kt CO ₂ eq | | | | | | |
| Gain of living biomass in forest | -52.80 | -52.96 | -53.12 | -53.20 | -53.30 | -53.36 | -52.13 |
| Loss of living biomass in forest | 59.88 | 63.81 | 64.20 | 56.60 | 56.61 | 51.24 | 51.69 |
| Land-use change, soil and HWP | 13.99 | 10.59 | 10.64 | 10.46 | 10.45 | 10.45 | 8.88 |
| Sector 4 LULUCF (total) | 21.08 | 21.44 | 21.71 | 13.86 | 13.76 | 8.32 | 8.44 |

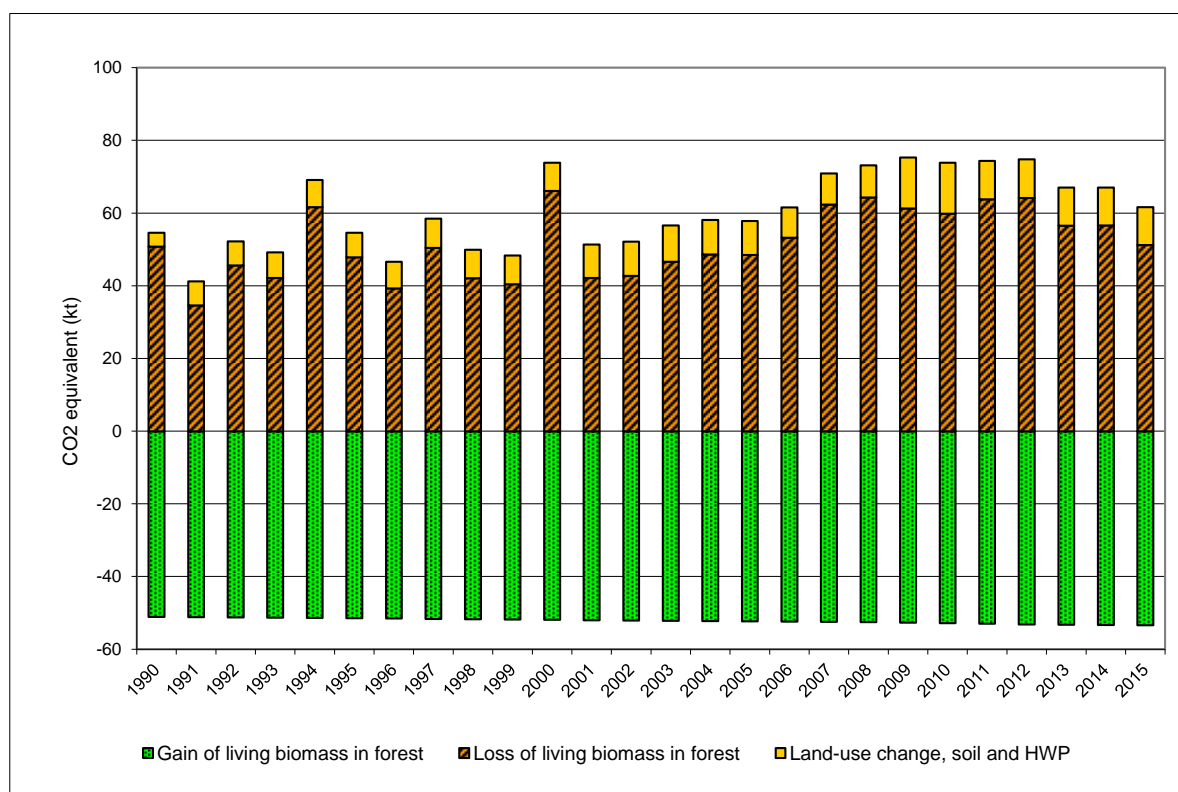


Figure 6-1 The CO₂ removals due to the increase (growth) of living biomass on forest land, the CO₂ emissions due to the decrease (harvest and mortality) of living biomass on forest land and the net CO₂ equivalent emissions due to land-use changes and from use of soils, 1990–2015.

Gain and loss of living biomass in forests are the dominant categories when looking at the CO₂ emissions and removals. There is a considerable annual variation of loss of living biomass in forests dependent on the wood harvesting rate. In 1994 and 2000 as well as 2006–2014 the loss of living biomass in forests was larger than the gain (Table 6-1). The resulting CO₂ emissions are also visible in the total emissions/removals of the LULUCF sector (see Figure 6-2).

Compared to these biomass changes in forests, the net CO₂ equivalent emissions arising from land-use changes, from soils and HWP are relatively small (see Figure 6-1). It can be observed that land-use conversions to grassland increase significantly between 1997 and 2013: higher conversion rates from forest land to grassland leads to increased CO₂ 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.

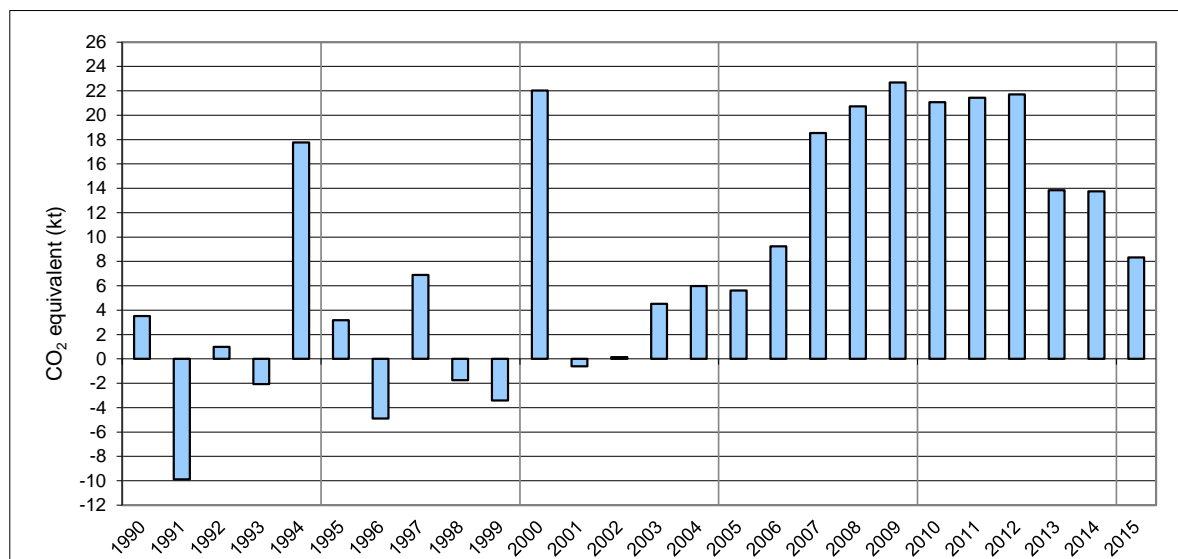


Figure 6-2 Liechtenstein's CO₂ emissions/removals of source category 4 LULUCF 1990–2015 in kt CO₂ equivalent.

Table 6-2 Net CO₂ removals and emissions per land-use category in kt CO₂ equivalent, 1990-2015.

| Net CO ₂ emissions/removals | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|--|--------------|---------------|--------------|---------------|--------------|--------------|---------------|--------------|---------------|---------------|
| Total Land-Use Categories | 3.20 | -10.19 | 0.69 | -2.37 | 17.46 | 2.87 | -5.20 | 6.57 | -2.06 | -3.74 |
| A. Forest Land | -2.25 | -18.51 | -7.58 | -11.11 | 8.35 | -5.52 | -14.17 | -3.10 | -11.55 | -13.25 |
| 1. Forest Land remaining Forest Land | -0.60 | -16.86 | -5.93 | -9.46 | 10.00 | -3.87 | -12.52 | -1.47 | -9.93 | -11.65 |
| 2. Land converted to Forest Land | -1.64 | -1.64 | -1.64 | -1.64 | -1.64 | -1.64 | -1.64 | -1.63 | -1.61 | -1.60 |
| B. Cropland | 4.54 | 4.53 | 4.52 | 4.51 | 4.50 | 4.49 | 4.48 | 4.48 | 4.48 | 4.48 |
| 1. Cropland remaining Cropland | 4.18 | 4.17 | 4.17 | 4.16 | 4.15 | 4.14 | 4.13 | 4.13 | 4.12 | 4.11 |
| 2. Land converted to Cropland | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.36 | 0.36 | 0.37 |
| C. Grassland | 1.82 | 1.81 | 1.80 | 1.79 | 1.79 | 1.78 | 1.77 | 1.97 | 2.17 | 2.37 |
| 1. Grassland remaining Grassland | 1.49 | 1.48 | 1.47 | 1.47 | 1.46 | 1.45 | 1.44 | 1.44 | 1.43 | 1.43 |
| 2. Land converted to Grassland | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.53 | 0.73 | 0.94 |
| 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 | 3.22 | 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 | 2.99 | 3.02 |
| F. Land converted to Other Land | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.53 | 0.61 | 0.70 |
| 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 | 21.66 | -0.97 | -0.24 | 4.15 | 5.60 | 5.22 | 8.85 | 18.14 | 20.31 | 22.29 |
| A. Forest Land | 12.35 | -11.69 | -11.23 | -7.36 | -5.37 | -5.55 | -0.86 | 8.21 | 10.16 | 6.96 |
| 1. Forest Land remaining Forest Land | 13.93 | -10.12 | -9.68 | -5.84 | -3.87 | -4.08 | 0.58 | 9.63 | 11.55 | 8.38 |
| 2. Land converted to Forest Land | -1.58 | -1.57 | -1.55 | -1.53 | -1.50 | -1.47 | -1.45 | -1.42 | -1.39 | -1.42 |
| B. Cropland | 4.48 | 4.48 | 4.48 | 4.45 | 4.43 | 4.41 | 4.39 | 4.36 | 4.34 | 4.34 |
| 1. Cropland remaining Cropland | 4.11 | 4.10 | 4.10 | 4.08 | 4.07 | 4.06 | 4.05 | 4.04 | 4.03 | 4.03 |
| 2. Land converted to Cropland | 0.37 | 0.38 | 0.38 | 0.37 | 0.36 | 0.35 | 0.34 | 0.32 | 0.31 | 0.31 |
| C. Grassland | 2.57 | 2.77 | 2.97 | 3.10 | 3.23 | 3.36 | 3.49 | 3.63 | 3.76 | 3.78 |
| 1. Grassland remaining Grassland | 1.43 | 1.43 | 1.43 | 1.43 | 1.44 | 1.44 | 1.45 | 1.45 | 1.46 | 1.46 |
| 2. Land converted to Grassland | 1.14 | 1.34 | 1.54 | 1.67 | 1.80 | 1.92 | 2.05 | 2.17 | 2.30 | 2.32 |
| D. Wetlands | 0.25 | 0.27 | 0.29 | 0.29 | 0.30 | 0.30 | 0.31 | 0.31 | 0.32 | 0.33 |
| 1. Wetlands remaining Wetlands | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2. Land converted to Wetlands | 0.25 | 0.27 | 0.29 | 0.29 | 0.30 | 0.30 | 0.31 | 0.31 | 0.32 | 0.33 |
| E. Settlements | 3.34 | 3.38 | 3.41 | 3.42 | 3.43 | 3.44 | 3.45 | 3.45 | 3.46 | 3.46 |
| 1. Settlements remaining Settlements | 0.29 | 0.30 | 0.31 | 0.32 | 0.33 | 0.34 | 0.34 | 0.35 | 0.36 | 0.37 |
| 2. Land converted to Settlements | 3.05 | 3.07 | 3.10 | 3.10 | 3.10 | 3.10 | 3.10 | 3.10 | 3.10 | 3.09 |
| F. Land converted to Other Land | 0.78 | 0.87 | 0.95 | 0.99 | 1.03 | 1.07 | 1.11 | 1.15 | 1.19 | 1.19 |
| 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 | 2015 |
|--|--------------|--------------|--------------|--------------|--------------|--------------|
| Total Land-Use Categories | 20.67 | 21.02 | 21.29 | 13.44 | 13.35 | 7.91 |
| A. Forest Land | 5.33 | 9.07 | 9.28 | 1.58 | 1.51 | -3.94 |
| 1. Forest Land remaining Forest Land | 6.77 | 10.54 | 10.76 | 3.09 | 3.00 | -2.43 |
| 2. Land converted to Forest Land | -1.44 | -1.46 | -1.49 | -1.51 | -1.49 | -1.51 |
| B. Cropland | 4.35 | 4.35 | 4.36 | 4.36 | 4.36 | 4.35 |
| 1. Cropland remaining Cropland | 4.03 | 4.03 | 4.03 | 4.03 | 4.03 | 4.01 |
| 2. Land converted to Cropland | 0.32 | 0.33 | 0.33 | 0.34 | 0.33 | 0.34 |
| C. Grassland | 3.81 | 3.84 | 3.87 | 3.89 | 3.86 | 3.85 |
| 1. Grassland remaining Grassland | 1.47 | 1.48 | 1.48 | 1.49 | 1.48 | 1.48 |
| 2. Land converted to Grassland | 2.34 | 2.36 | 2.38 | 2.40 | 2.38 | 2.38 |
| D. Wetlands | 0.35 | 0.37 | 0.38 | 0.40 | 0.38 | 0.38 |
| 1. Wetlands remaining Wetlands | NO | NO | NO | NO | NO | NO |
| 2. Land converted to Wetlands | 0.35 | 0.37 | 0.38 | 0.40 | 0.38 | 0.38 |
| E. Settlements | 3.46 | 3.45 | 3.45 | 3.45 | 3.45 | 3.45 |
| 1. Settlements remaining Settlements | 0.38 | 0.39 | 0.40 | 0.42 | 0.40 | 0.40 |
| 2. Land converted to Settlements | 3.07 | 3.06 | 3.05 | 3.03 | 3.05 | 3.04 |
| F. Land converted to Other Land | 1.19 | 1.19 | 1.18 | 1.18 | 1.18 | 1.18 |
| G. Harvested wood products | 2.18 | -1.25 | -1.22 | -1.43 | -1.40 | -1.37 |

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 (AREA survey, 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 (ΔC_l), in dead organic matter (ΔC_d) and in soil (ΔC_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).

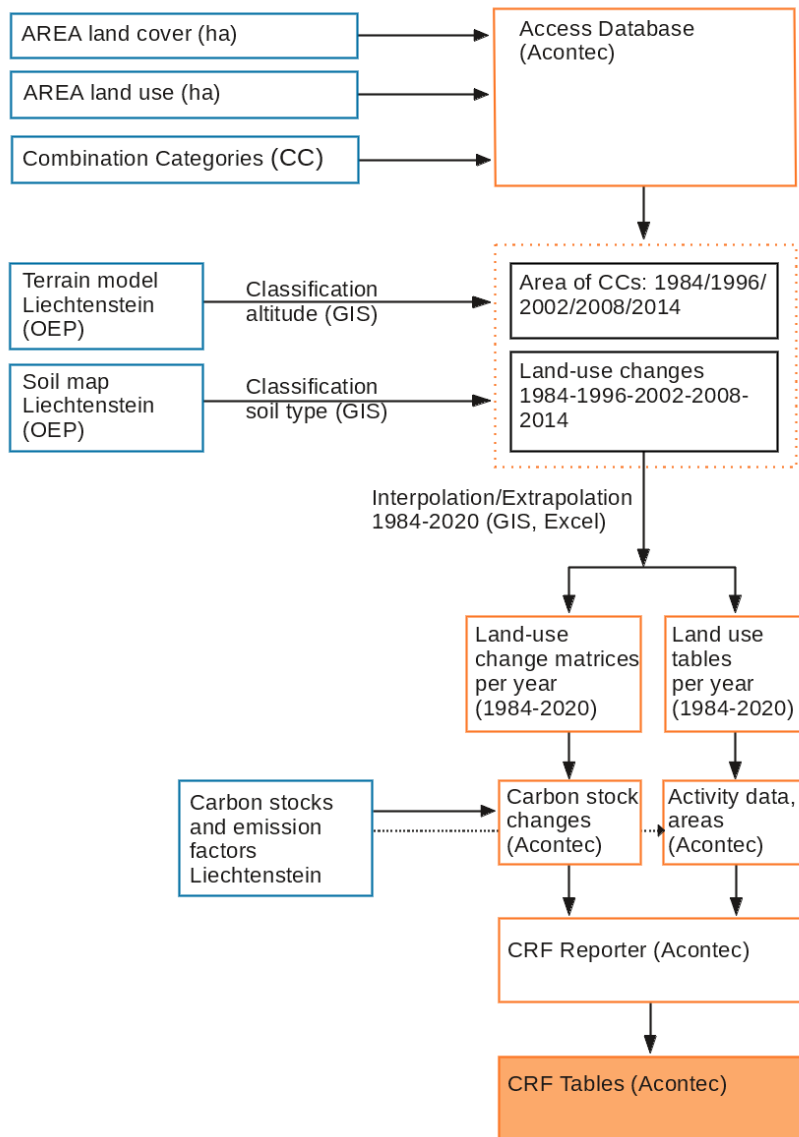


Figure 6-3 Procedure of calculating emissions and removals from LULUCF in Liechtenstein.

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 see chp. 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):

stock_{C_{i,CC}}: carbon stock in living biomass

stock_{C_{d,i,CC}}: carbon stock in dead organic matter (dead wood and litter)

| | |
|-------------------------|--|
| stock $C_{s,i,CC}$: | carbon stock in soil |
| increase $C_{l,i,CC}$: | annual gain (growth) of carbon in living biomass |
| decrease $C_{l,i,CC}$: | annual loss (cut & mortality) of carbon in living biomass |
| change $C_{d,i,CC}$: | annual net carbon stock change in dead organic matter (dead wood and litter) |
| change $C_{s,i,CC}$: | annual net carbon stock change in soil |

On this basis, the carbon stock changes in living biomass (ΔC_l), in dead organic matter (ΔC_d) and in soil (ΔC_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):

$$\Delta C_{l,i,ba} = [\text{increase}C_{l,i,a} - \text{decrease}C_{l,i,a} + W_l * (\text{stock}C_{l,i,a} - \text{stock}C_{l,i,b}) / CT] * A_{i,ba} \quad (6.1)$$

$$\Delta C_{d,i,ba} = [\text{change}C_{d,i,a} + W_d * (\text{stock}C_{d,i,a} - \text{stock}C_{d,i,b}) / CT] * A_{i,ba} \quad (6.2)$$

$$\Delta C_{s,i,ba} = [\text{change}C_{s,i,a} + W_s * (\text{stock}C_{s,i,a} - \text{stock}C_{s,i,b}) / CT] * A_{i,ba} \quad (6.3)$$

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 6-8). 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 1990-2015 except for the loss in living biomass of productive forest (CC12) where annual values are used (see chp. 6.4.2).

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 1990-2015, except the highlighted cells (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) |
|-----------------------------|-----------------|---|---------------------------------------|------------------------------------|--|--|--|-----------------------------------|--------------------------------------|-----------------------------------|---|---|
| | | | | | | | | | | | | |
| 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 Cs 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 orange in 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. The deduction of the individual values is explained in the sector sub-chapters 6.x.2.

6.1.5 Uncertainty estimates, overview

Table 6-5 gives an overview of uncertainty estimates of activity data (AD) and of emission factors (EF). The uncertainty of AD often depends on the uncertainty of the AREA survey data (see chp. 6.3.3); in the Table these values are highlighted in orange. For categories 4B, 4C1, 4(III), 4(IV) and 4G other data sources are relevant; they are presented in detail in the respective chp. (6.x.3) of the LULUCF categories, along with the uncertainty estimates of EF.

Table 6-5 Uncertainty estimates in the LULUCF sector, expressed as half of the 95% confidence intervals. Highlighted values: see main text.

| IPCC category | | Gas | Activity data uncertainty | Emission factor uncertainty |
|---------------|-----------------------------------|------------------|---------------------------|-----------------------------|
| | | | % | % |
| 4A1 | Forest Land remaining Forest Land | CO ₂ | 2.7 | 47.9 |
| 4A2 | Land converted to Forest Land | CO ₂ | 17.2 | 40.3 |
| 4B1 | Cropland remaining Cropland | CO ₂ | 30.8 | 23.0 |
| 4B2 | Land converted to Cropland | CO ₂ | 40.3 | 23.0 |
| 4C1 | Grassland remaining Grassland | CO ₂ | 30.6 | 23.0 |
| 4C2 | Land converted to Grassland | CO ₂ | 13.6 | 40.3 |
| 4D1 | Wetlands remaining Wetlands | CO ₂ | 10.5 | 50.0 |
| 4D2 | Land converted to Wetlands | CO ₂ | 40.9 | 40.3 |
| 4E1 | Settlements remaining Settlements | CO ₂ | 6.5 | 50.0 |
| 4E2 | Land converted to Settlements | CO ₂ | 19.4 | 50.0 |
| 4F1 | Other Land remaining Other Land | CO ₂ | NA | NA |
| 4F2 | Land converted to Other Land | CO ₂ | 40.9 | 50.0 |
| 4III | N Mineralization | N ₂ O | 19.4 | 100.0 |
| 4IV2 | Indirect emissions Leaching | N ₂ O | 20.0 | 100.0 |
| 4G | Harvested Wood Products | CO ₂ | 50.0 | 57.0 |

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. 6.1.3) every hectare of Liechtenstein's territory was assigned to a land-use category (NOLU04) and to a land-cover category (NOLC04) according to the "nomenclature 2004".

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 6-6). 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 6-6. CC definition was strongly influenced by the land cover and land use (NOLC04/NOLU04) classification and "nomenclature 2004" 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 6-6. 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 6-6 Relation between the land-use (NOLU04) and land-cover (NOLC04) categories of the AREA survey and the derived combination categories (CC).

| Land Use (NOLU04) acc. to AREA | | Land Cover (NOLC04) acc. to AREA | | | Combination Categories (CC) | | |
|---|--|---|--|--|--|--|--|
| 18 Combination Categories (CC) | | Land Cover (NOLC04) acc. to AREA 10 Artificial areas 11 Sealed surfaces 12 Buildings 13 Greenhouses 14 Gardens with border and patch structures 15 Lawns 16 Trees in artificial areas 17 Mix of small structures 20 Grass and herb vegetation 21 Grass and herb vegetation 30 Brush vegetation 31 Shrub 32 Brush meadows 33 Short-stem fruit trees 34 Vines 35 Permanent garden plants and brush crops 40 Tree vegetation 41 Closed forest 42 Forest edges 43 Forest strips 44 Open forest 45 Brush forest 46 Linear woods 47 Clusters of trees 50 Bare land 51 Solid rock 52 Granular soil 53 Rocky areas 60 Watery areas 61 Water 62 Glacier, perpetual snow 63 Wetlands 64 Reedy marshes | | | Settlement and urban areas 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 | | |
| | | | | | Agricultural areas 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 Forest areas 301 Forest 302 Afforestation 303 Umbrella areas 304 Damaged forest Unproductive areas 401 Lakes 402 Streams, rivers 403 Flood protection structures 421 Unused 422 Avalanche and rockfall protection structures 423 Alpine sports facilities 424 Landscape intervention Unproductive land 51 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.

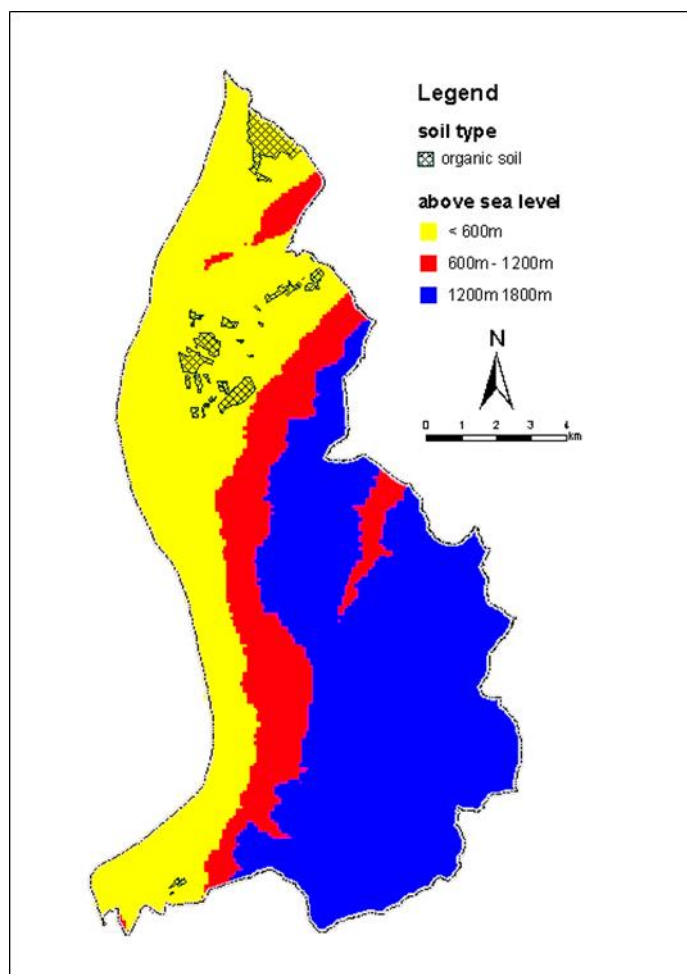


Figure 6-4 Map of Liechtenstein showing the altitude classes and soil types. Reference: OEP 2006d.

6.2.3 The land-use tables and change matrices (activity data)

Table 6-7 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 63% and 100% from 1990 to 2015, while the area of managed forests (CC12) increases by 8% 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 258 ha, mineral and organic soils), grassland CC31-CC37(decrease by 325 ha) and settlements CC51-CC54 (increase by 416 ha).

Table 6-7 Statistics of land use (CC = combination categories) for the period 1990-2015 (in ha) and change between 1990 and 2015. (n.s. = no stratification)

| CC | altitude | soil type | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 | 2015 | Change 1990-2015 (ha) | Change 1990-2015 (%) |
|------------|----------|-----------|-------|-------|-------|-------|-------|-------|-------|-----------------------|----------------------|
| 11 | ≤ 600 | n.s. | 9 | 11 | 7 | 3 | 1 | 1 | 1 | -8 | -88% |
| | 601-1200 | n.s. | 7 | 2 | 2 | 2 | 1 | 0 | 0 | -7 | -100% |
| | > 1200 | n.s. | 26 | 26 | 16 | 13 | 11 | 10 | 10 | -16 | -63% |
| 12 | ≤ 600 | n.s. | 966 | 968 | 967 | 965 | 958 | 950 | 948 | -17 | -2% |
| | 601-1200 | n.s. | 1970 | 1974 | 1967 | 1962 | 1961 | 1963 | 1963 | -7 | 0% |
| | > 1200 | n.s. | 2171 | 2203 | 2220 | 2233 | 2269 | 2326 | 2340 | 170 | 8% |
| 13 | ≤ 600 | n.s. | 1 | 1 | 0 | 0 | 0 | 0 | 0 | -1 | -100% |
| | 601-1200 | n.s. | 9 | 9 | 10 | 11 | 8 | 3 | 3 | -6 | -71% |
| | > 1200 | n.s. | 880 | 906 | 919 | 930 | 943 | 952 | 954 | 75 | 9% |
| 21 | n.s. | mineral | 1826 | 1803 | 1771 | 1707 | 1634 | 1587 | 1575 | -251 | -14% |
| | n.s. | organic | 127 | 125 | 124 | 122 | 120 | 120 | 120 | -7 | -5% |
| 31 | ≤ 600 | mineral | 1131 | 1093 | 1076 | 1090 | 1118 | 1138 | 1143 | 12 | 1% |
| | ≤ 600 | organic | 64 | 62 | 61 | 63 | 64 | 63 | 63 | -1 | -1% |
| | 601-1200 | mineral | 364 | 354 | 347 | 345 | 342 | 338 | 337 | -26 | -7% |
| | 601-1200 | organic | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| | > 1200 | mineral | 1668 | 1650 | 1647 | 1639 | 1629 | 1624 | 1623 | -45 | -3% |
| | > 1200 | organic | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| 32 | ≤ 600 | n.s. | 20 | 21 | 23 | 25 | 27 | 28 | 28 | 8 | 42% |
| | 601-1200 | n.s. | 10 | 8 | 9 | 11 | 12 | 13 | 13 | 4 | 39% |
| | > 1200 | n.s. | 563 | 528 | 514 | 515 | 500 | 465 | 456 | -107 | -19% |
| 33 | n.s. | mineral | 31 | 32 | 33 | 33 | 34 | 36 | 37 | 6 | 20% |
| | n.s. | organic | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| 34 | ≤ 600 | n.s. | 382 | 374 | 347 | 322 | 302 | 289 | 286 | -96 | -25% |
| | 601-1200 | n.s. | 81 | 78 | 74 | 74 | 75 | 76 | 76 | -4 | -5% |
| | > 1200 | n.s. | 255 | 256 | 252 | 246 | 237 | 226 | 223 | -32 | -12% |
| 35 | n.s. | mineral | 1 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | -100% |
| | n.s. | organic | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| 36 | n.s. | n.s. | 347 | 341 | 345 | 344 | 337 | 332 | 331 | -16 | -5% |
| 37 | n.s. | n.s. | 399 | 389 | 382 | 373 | 368 | 369 | 369 | -29 | -7% |
| 41 | n.s. | n.s. | 203 | 186 | 208 | 214 | 207 | 207 | 207 | 5 | 2% |
| 42 | n.s. | n.s. | 160 | 161 | 162 | 163 | 164 | 168 | 169 | 9 | 6% |
| 51 | n.s. | n.s. | 904 | 969 | 1044 | 1118 | 1185 | 1234 | 1246 | 343 | 38% |
| 52 | n.s. | n.s. | 305 | 314 | 327 | 351 | 374 | 381 | 383 | 78 | 26% |
| 53 | n.s. | n.s. | 15 | 12 | 16 | 19 | 19 | 16 | 15 | 0 | 2% |
| 54 | n.s. | n.s. | 144 | 158 | 158 | 148 | 139 | 138 | 138 | -6 | -4% |
| 61 | n.s. | n.s. | 1027 | 1040 | 1026 | 1021 | 1016 | 1001 | 997 | -29 | -3% |
| Sum | | | 16054 | 16054 | 16054 | 16054 | 16054 | 16054 | 16054 | 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 6-8 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, fully stratified land-use change matrices are used for each year (see chp.6.1.3). More aggregated change-matrices are reported in CRF-table 4.1 for each year 1990-2015.

Table 6-8 Land-use change in 2010 (change matrix). Units: ha/year.

| main category | | To | | | | | | | | | | | | | | | | | | | Decrease | |
|---------------|-------------|-------------|-----|-----|--------|-----------|------|------|-----|-----|-----|-----|----------|-----|------------|-----|------|-----|----------|-----|----------|-------|
| | | Forest Land | | | Cropl. | Grassland | | | | | | | Wetlands | | Settlement | | | | Other L. | | | |
| CC | | 11 | 12 | 13 | 21 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 41 | 42 | 51 | 52 | 53 | 54 | 61 | | | |
| From | Forest Land | 11 | 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 | 1.0 | |
| | | 12 | 0.0 | | 1.0 | 0.0 | 1.2 | 0.7 | 0.0 | 1.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.7 | 1.3 | 0.3 | 0.0 | 0.0 | 0.3 | 6.8 | |
| | | 13 | 0.0 | 7.0 | | 0.0 | 1.3 | 0.8 | 0.0 | 0.3 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 9.8 | |
| | | Cropland | 21 | 0.0 | 0.0 | 0.0 | 16.3 | 0.0 | 0.5 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 2.8 | 1.0 | 0.0 | 0.0 | 0.0 | 21.2 | |
| | | Grassland | 31 | 0.0 | 0.7 | 2.2 | 8.3 | 2.5 | 0.0 | 2.5 | 0.0 | 1.0 | 0.2 | 0.0 | 0.5 | 6.3 | 3.0 | 0.2 | 0.2 | 0.2 | 27.7 | |
| | | | 32 | 0.2 | 4.8 | 7.2 | 0.0 | 1.7 | | 0.0 | 2.2 | 0.0 | 0.5 | 0.3 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 17.0 | |
| | | | 33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | |
| | | | 34 | 0.0 | 5.2 | 0.2 | 0.0 | 4.3 | 0.5 | 0.3 | | 0.0 | 0.3 | 0.5 | 0.3 | 0.7 | 1.0 | 0.0 | 0.3 | 0.0 | 13.7 | |
| | | | 35 | 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 | 0.2 | 0.3 | 0.3 | 0.2 | 2.0 | 1.5 | 0.0 | 0.3 | 0.0 | | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 6.0 | |
| | | | 37 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 1.5 | 0.0 | 0.2 | 0.0 | 0.3 | | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 2.5 | |
| | | Wetlands | 41 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 2.5 | 2.7 | |
| | | | 42 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | |
| | | Settlement | 51 | 0.0 | 0.0 | 0.0 | 0.5 | 2.2 | 0.0 | 0.0 | 0.2 | 0.0 | 0.2 | 0.0 | 0.0 | | 1.5 | 0.2 | 0.2 | 0.0 | 4.8 | |
| | | | 52 | 0.0 | 0.0 | 0.0 | 0.2 | 0.7 | 0.2 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 | | 0.5 | 2.5 | 0.0 | 7.8 | |
| | | | 53 | 0.2 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.3 | | 0.0 | 0.0 | 1.5 | |
| | | | 54 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 2.5 | 0.0 | | 0.0 | 3.5 | |
| | | Other Land | 61 | 0.0 | 0.2 | 0.0 | 0.0 | 0.7 | 1.0 | 0.0 | 0.5 | 0.0 | 2.7 | 0.5 | 1.8 | 0.2 | 0.2 | 0.0 | 0.0 | | 7.7 | |
| | | Increase | | 0.5 | 19.5 | 10.8 | 9.2 | 30.7 | 8.7 | 0.8 | 7.8 | 0.0 | 4.8 | 2.8 | 2.7 | 1.3 | 17.2 | 9.7 | 0.8 | 3.2 | 3.8 | 134.3 |

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 for Liechtenstein are collected according to the same method as in Switzerland. This so-called AREA survey is based on sampling points covering the whole territory on a 100x100 m² grid ('hectare raster'). Every sampling point was assigned to one of 46 land-use categories and to one of 27 land-cover categories (NOLU04/NOLC04, see chp. 6.2.1) by means of stereographic interpretation of aerial photos (EDI/BFS 2009).

For the reconstruction of the land use conditions in Liechtenstein for the period 1990-2015 five data sets are used:

- Land-Use Statistics 1984
- Land-Use Statistics 1996
- Land-Use Statistics 2002
- Land-Use Statistics 2008

- Land-Use Statistics 2014

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, 2008 and 2014 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 for AREA are known. 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 to 1996, 1996 to 2002, 2002 to the 2008 and from 2008 to 2014 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. The status after 2014 is estimated by linear extrapolation, assuming that the average trend observed between 2008 and 2014 goes on.

Figure 6-5 shows an example: A certain area was assigned to the land-use category "Cropland" (CC 21) in 1984. A partial land-use change to "Shrubs in Settlements" (CC 53) was discovered in 1996. And another partial change to "Buildings and construction" (CC 51) was discovered in 2002.

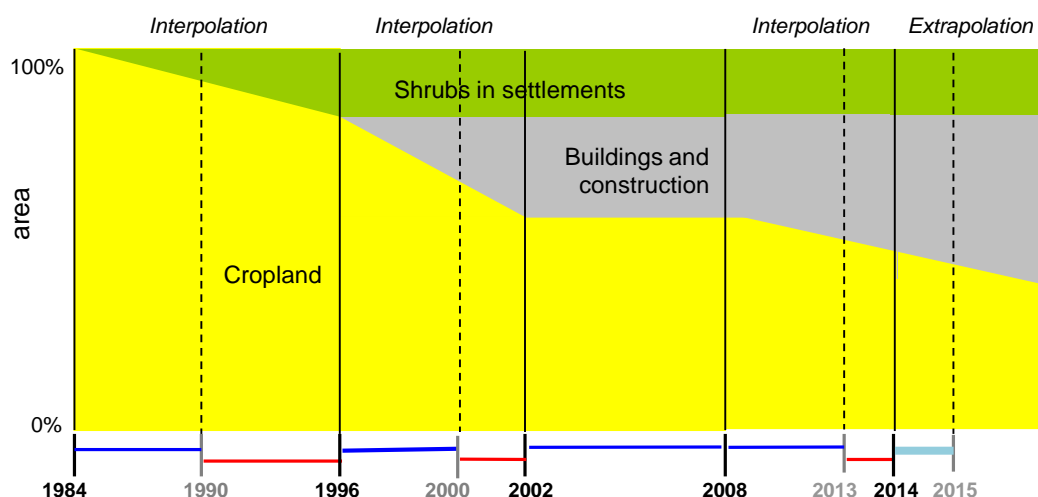


Figure 6-5 Hypothetical linear development of land-use changes between the five Land-usesurveys (1984, 1996, 2002, 2008, 2014) with the example of areas changing 1984-1996 from “cropland” to “shrubs in settlements” and then 1996-2002 and again 2008-2014 to “buildings and constructions”. The dotted lines show how the share of the different land use categories is determined in years between land use statistics and extrapolated after 2014.

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 2000 in Figure 6-5 as example). Extrapolation after 2014 is done by taking the average trend of the time period 2008 to 2014. The ‘status’ for each individual year in the period 1990-2015 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 6-7).

6.3.3 Uncertainties and time-series consistency of activity data

An overview of uncertainty estimates for activity data (AD) and emission factors (or biomass parameters) is shown in Table 6-5. Details related to uncertainties of AREA data are presented in this chp., while uncertainties of other AD (such as consumption of harvested wood products) and emission factors are presented in the respective chp. (6.x.3) of the LULUCF categories.

Uncertainties of the AREA-based activity data are presented in Table 6-9. They have two main sources that were quantified as follows:

1) Interpretation error: In the AREA survey, the first classification of the aerial photos is checked by a second independent interpreter. The portion of sampling points with a mismatch of the first and the second interpretation was supplied by SFSO and used as the uncertainty of the interpretation. This uncertainty integrates all errors related to the manual interpretation of land-use and land-cover classes on aerial photographs. While it is clear that this is rather an estimate of the maximum potential interpretation error than of the actual interpretation error, it is reported hereafter unless more accurate information is available.

2) Statistical sampling error: In the AREA survey, the land-use types are interpreted on points situated on a regular 100x100 m grid. Thus, the uncertainty of the surface area covered by a certain land-use type or land-use change decreases with increasing numbers of sampling points. Assuming a binomial distribution of the errors, this uncertainty was calculated as

$$U_{\text{sampling}} = 100 * 1.96 * (\text{number of points})^{-0.5}$$

The number of sampling points in AREA 2014 lies between 23 (for 4F2) and 6'074 (for 4A1) leading to values of U_{sampling} between 40.9% and 2.5%.

The overall uncertainty is between 2.7% and 40.9%. It was calculated as:

$$U_{\text{overall}} = (U_{\text{interpret}}^2 + U_{\text{sampling}}^2)^{0.5}$$

Table 6-9 Sources of AD uncertainty and overall uncertainties in the area calculations, expressed as half of the 95% confidence intervals. Calculations are based on AREA data from 2014.

| Category | Description | Interpretation uncertainty | Sampling uncertainty | Overall uncertainty |
|----------|-----------------------------------|----------------------------|----------------------|---------------------|
| 4A1 | Forest Land remaining Forest Land | 1.1 | 2.5 | 2.7 |
| 4A2 | Land converted to Forest Land | 1.1 | 17.1 | 17.2 |
| 4B1 | Cropland remaining Cropland | 4.9 | 4.8 | 6.9 |
| 4B2 | Land converted to Cropland | 4.9 | 26.4 | 26.9 |
| 4C1 | Grassland remaining Grassland | 5.2 | 2.8 | 6.0 |
| 4C2 | Land converted to Grassland | 5.2 | 12.6 | 13.6 |
| 4D1 | Wetlands remaining Wetlands | 0.9 | 10.4 | 10.5 |
| 4D2 | Land converted to Wetlands | 0.9 | 40.9 | 40.9 |
| 4E1 | Settlements remaining Settlements | 4.4 | 4.8 | 6.5 |
| 4E2 | Land converted to Settlements | 4.4 | 18.9 | 19.4 |
| 4F1 | Other Land remaining Other Land | 1.4 | 6.3 | 6.4 |
| 4F2 | Land converted to Other Land | 1.4 | 40.9 | 40.9 |

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

4A–4F: The new AREA survey for the year 2014 was integrated in the calculations for interpolation and extrapolation. This led to recalculations of areas for the years 2009–2014, as the former extrapolation was replaced by an interpolation. Very small changes also occurred in the years 1990–2008 as the updated database now covers a total of 16'054 hectares (instead of (16'050) for the whole country.

6.3.6 Planned improvements for activity data

There are no planned improvements.

6.4 Source Category 4A – Forest Land

6.4.1 Source category description

Key category information 4A1 and 4A2

The CO₂ emission from 4A1 Land Converted to Forest Land is key source by level and trend. The CO₂ emission from 4A2 Land Converted to Forest Land is key source by level.

38.7% of the total area of Liechtenstein is forest land. The total forest area increased by 3.0% between 1990 and 2015. The annual net CO₂ emissions/removals are in the range - 18.51 kt CO₂ (1991) to 12.35 kt CO₂ (2000). The source category 4A1 “Forest Land remaining Forest Land” is in some years a net source and in some years a net sink depending on the harvesting amount of the year. The source category 4A2 “Land converted to Forest Land” is a net sink in all years.

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 calculating emissions and removals, 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 chp. 6.2. Carbon stocks and carbon stock changes are taken partly from Switzerland and partly from Liechtenstein's

NFI as well as from Liechtenstein's wood harvesting statistics. Details are described in the following paragraphs.

6.4.2.1 National Forest Inventory (NFI) data for productive forest (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. The NFI is based on 403 terrestrial sampling points situated in accessible forest stands (without brush forest) representing a mesh of 354x354 m². 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 6-10 shows important results of the LWI (2012). The average annual rates were 7.9 m³ ha⁻¹ for growth, 5.7 m³ ha⁻¹ for cut and 2.7 m³ ha⁻¹ for mortality. Overall, the growing stock decreased during this period.

In order to simplify the calculation of annual gains and growing stocks in carbon stocks, it is assumed that gross growth and stocks are constant over the whole time period, i.e. the average rates 1998-2010 are applied for all years between 1990 and 2015.

For calculating cut and mortality annual values of biomass loss by harvesting are used (see chp. 6.4.2.3).

Table 6-10 Results of Liechtenstein's forest inventory 2010 (LWI 2012).

| | Growth [m³ 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 [m³ 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 also chp.6.2.2):

- 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. With this procedure, the values for CC12 shown in Table 6-4 were produced.

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 are 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 ($\text{m}^3 \text{ha}^{-1}$) and the total above- and belowground biomass (t ha^{-1}). Table 6-11 shows the BEFs for coniferous and deciduous species stratified for altitude.

Table 6-11 Biomass expansion factors (BEFs) to convert round-wood over bark ($\text{m}^3 \text{ha}^{-1}$) 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 ($\text{m}^3 \text{ha}^{-1}$) into tons of dry matter ha^{-1} it was multiplied by a species-specific density. Table 6-12 shows the applied densities.

Table 6-12 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 Gain and loss of living biomass for productive forest (CC12)

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 Table 6-14).

For calculating the loss, annual harvesting statistics (Table 6-13) 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 1998-2010 (see Table 6-13).
- According to the NFI (period 1999-2010), the average cut is 5.65 m³ ha⁻¹ yr⁻¹ and the average mortality is 2.70 m³ ha⁻¹ yr⁻¹. The total loss is 8.35 m³ ha⁻¹ yr⁻¹. With this information the carbon stock losses were calculated and split in the two parts cut and mortality as shown in Table 6-14.
- The annual losses per altitude zone were calculated assuming that the annual cut is proportional to the relative harvesting factor (see Table 6-13) 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 6-14.

Table 6-13 Wood harvesting statistics for Liechtenstein's forest 1986-2015 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 | 0.876 |
| 1987 | 13'194 | 0.637 |
| 1988 | 13'843 | 0.668 |
| 1989 | 13'479 | 0.651 |
| 1990 | 20'024 | 0.967 |
| 1991 | 10'333 | 0.499 |
| 1992 | 16'853 | 0.814 |
| 1993 | 14'759 | 0.713 |
| 1994 | 26'315 | 1.270 |
| 1995 | 18'087 | 0.873 |
| 1996 | 12'970 | 0.626 |
| 1997 | 19'527 | 0.943 |
| 1998 | 14'537 | 0.702 |
| 1999 | 13'538 | 0.654 |
| 2000 | 28'683 | 1.385 |
| 2001 | 14'477 | 0.699 |
| 2002 | 14'755 | 0.712 |
| 2003 | 17'016 | 0.821 |
| 2004 | 18'169 | 0.877 |
| 2005 | 18'038 | 0.871 |
| 2006 | 20'776 | 1.003 |
| 2007 | 26'099 | 1.260 |
| 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 |
| 2015 | 19'089 | 0.922 |
| Mean 1999-2010 | 20'714 | |

Table 6-14 (a) Splitting total carbon stock loss of living biomass (NFI, mean 1999-2010) into cut and mortality and (b) calculated annual losses 2008-2015 for the three altitude zones (≤ 600 m, 601-1200 m, > 1200 m). Units: t C ha⁻¹ yr⁻¹

(a) Average 1999-2010:

| Altitude | Gain | Total loss | Mortality | Cut |
|----------|------|------------|-----------|-------|
| zone 1 | 3.21 | -3.49 | -1.13 | -2.36 |
| zone 2 | 2.83 | -2.96 | -0.96 | -2.01 |
| zone 3 | 2.34 | -2.39 | -0.77 | -1.62 |

(b) Annual loss:

| Altitude | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| zone 1 | -3.41 | -2.31 | -3.05 | -2.81 | -4.13 | -3.19 | -2.61 | -3.36 | -2.79 | -2.67 |
| zone 2 | -2.90 | -1.96 | -2.59 | -2.39 | -3.51 | -2.71 | -2.21 | -2.85 | -2.37 | -2.27 |
| zone 3 | -2.34 | -1.58 | -2.09 | -1.93 | -2.83 | -2.19 | -1.79 | -2.30 | -1.91 | -1.83 |

| Altitude | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| zone 1 | -4.40 | -2.78 | -2.81 | -3.07 | -3.20 | -3.19 | -3.50 | -4.11 | -4.23 | -4.02 |
| zone 2 | -3.74 | -2.36 | -2.39 | -2.61 | -2.72 | -2.71 | -2.97 | -3.49 | -3.59 | -3.41 |
| zone 3 | -3.01 | -1.90 | -1.93 | -2.10 | -2.19 | -2.18 | -2.40 | -2.81 | -2.90 | -2.76 |

| Altitude | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|----------|-------|-------|-------|-------|-------|-------|
| zone 1 | -3.92 | -4.17 | -4.19 | -3.68 | -3.67 | -3.31 |
| zone 2 | -3.33 | -3.54 | -3.56 | -3.12 | -3.11 | -2.81 |
| zone 3 | -2.68 | -2.86 | -2.87 | -2.52 | -2.51 | -2.27 |

6.4.2.4 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 6-6).

"Unproductive forests not covered by NFI are mainly associated with extensively pastured land where sparse tree vegetation (land cover 44 and 47 in Table 6-6) is found. As those forests are assumed to grow preferably on bad site conditions, an average growing stock (> 7 cm diameter) of 150 m³ 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 6-15 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 |

6.4.2.5 Dead wood

Data from Liechtenstein's NFI (see Table 6-10) 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.

6.4.2.6 Human-induced conversion to Forest Land (Afforestations)

For the afforestation areas (CC11), the Swiss growing stocks and growth rates per altitude level are applied in Liechtenstein (see Table 6-4). The following paragraph explain the Swiss calculation of carbon stock changes in living biomass (excerpt from FOEN 2015):

"The average growing stock and growth of afforestations were empirically assessed with NFI 1 and NFI 2, 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 m³ ha⁻¹. The growing stock on sites between 600 and 1200 m was assumed to be one-third smaller (60 m³ ha⁻¹) than on sites below 600 m, and two-third smaller on sites above 1200 m (30 m³ 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 $2 \text{ m}^3 \text{ ha}^{-1}$. 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 6-16 shows the simulated growing stock and growth for the three altitudinal levels."

Thereby it is assumed that the growing stocks result from the exponential growth function without harvest and mortality, and that it is very unlikely that the afforested areas (CC11) are harvested before 20 years, as the small trees were planted in order to establish a mature forest (production forest or protective forest) in the long term.

Table 6-16 Estimated average growing stock and annual growth of forest stands in stem wood up to 20 years (CC11) specified for altitude zone.

| Stand age [years] | ≤ 600 m altitude | | 601 - 1200 m altitude | | > 1200 m altitude | |
|----------------------|--|--|--|--|--|--|
| | Growing stock [$\text{m}^3 \text{ha}^{-1}$] | Growth [$\text{m}^3 \text{ha}^{-1} \text{year}^{-1}$] | Growing stock [$\text{m}^3 \text{ha}^{-1}$] | Growth [$\text{m}^3 \text{ha}^{-1} \text{year}^{-1}$] | Growing stock [$\text{m}^3 \text{ha}^{-1}$] | Growth [$\text{m}^3 \text{ha}^{-1} \text{year}^{-1}$] |
| 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 6-17):

$$\begin{aligned} \text{C stock in living biomass} &= \text{Average growing stock} * \text{BCEF} * \text{C content} \\ \text{Growth of living biomass} &= \text{Average growth} * \text{BCEF} * \text{C content} \end{aligned}$$

Table 6-17 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 _{i,i,11}) [t C ha ⁻¹] | Gain of living biomass (gainC _{i,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 |

6.4.2.7 Land converted to Forest Land, not human-induced

According to the land use statistic the areas switching to forest land (CC12 or CC13) are mainly abandoned areas of grassland with woody biomass (CC32 and CC34).

The carbon fluxes of living biomass 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 chp. 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 chp. 6.1.3.2).

6.4.2.8 Soil carbon and litter in all forest categories (CC11, CC12, 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 2015 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 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.
- In the case of land converted to forest land, the stock of soil organic carbon (SOC) is always larger on forest land than on non-forest land (see Table 6-4) and therefore a loss of SOC is improbable. This is also the case for human-induced conversions, as the process of afforestation consists of planting small trees on grasslands; therefore, the conversion itself hardly disturbs the soil structure. In fact, an increase of SOC could be expected, however such sinks are not reported either (see chp. 6.1.3.2, factor W_s) in order to avoid overestimating sinks.

6.4.2.9 N₂O 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).

6.4.2.10 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).

6.4.3 Uncertainties and time-series consistency

An overview of uncertainties in the LULUCF sector is shown in Table 6-5. The uncertainty of the AD (areas) for categories 4A1 and 4A2 are presented in chp. 6.3.3.

The EF uncertainty for category 4A1, Land remaining forest land, was estimated to 47.9%, the Swiss value according to FOEN 2016). This value includes the uncertainties in gain and loss of living biomass (i.e. uncertainties of the NFI results), which are the dominant processes for 4A1.

For category 4A2, land converted to forest land, the dominant process is the stock-difference in living biomass. Therefore, the uncertainty of the carbon stock of forest was used as EF-uncertainty (40.3%). It was calculated by error propagation combining the following uncertainties of input data:

- Growing stock: 26.0%. This value was derived from the Swiss NFI online-results for the Canton Glarus (GL), which is comparable with the topographic situation in Liechtenstein (<http://www.lfi.ch/resultate/anleitung-en.php?lang=en>)
- Carbon content: 2% (FOEN 2016, Chapter 6.4.3)
- Biomass expansion functions: 21.2% (allometric functions, see FOEN 2016, Chapter 6.4.3)
- Sampling uncertainty: 22.2% ((FOEN 2016, Chapter 6.4.3)

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 1.2.3.1 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 2014/2015).

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

- The activity data 1990–2014 were updated (see chp. 6.3.5) causing small modifications in areas.
- 4A1: A major recalculation for 1990-2014 was due to a methodical improvement in calculating loss of living biomass in productive forests (CC12): Instead of using a constant value for the whole period, annual losses are calculated based on annual wood harvesting statistics (see chp. 6.4.2.3). This method was used already in the last submission for the reporting under the Kyoto Protocol and is now applied also for the UNFCCC reporting.
- In 2014, these recalculations lead to an increase of CO₂ emissions from 4A of 2.32 kt CO₂eq. The methodical improvement in calculating loss of living biomass in productive forests is the most important recalculation. The updating of activity data has a much smaller effect.

6.4.6 Category-specific planned improvements

No category-specific improvements are planned.

6.5 Source Category 4B – Cropland

6.5.1 Source category description

Key category information 4B1

CO₂ emissions from 4B1 Cropland remaining Cropland is a key source by level.

10.6% 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 2015 by 13.2%.

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) cover the arable land (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 $-9.52 \text{ t C ha}^{-1}$ with an uncertainty of 23% 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 chapter 6.3. 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) N₂O Emissions from cropland

N₂O emissions from drainage of organic soils on cropland are reported in the agriculture sector.

The calculation of emissions for categories 4III and 4IV (N₂O from Nitrogen Mineralization in mineral soils) is described in Chapter 6.10.

6.5.3 Uncertainties and time-series consistency

The dominant process determining the uncertainty of categories 4B1 and 4B2 is the carbon loss on organic soils.

The uncertainty of the area of organic soils (AD) is determined by the uncertainty of the AREA survey (4B1 6.9%, 4B2 26.9% from Table 6-9) combined with the uncertainty of the soil map used to identify organic soils (chp. 6.2.2), which is assumed to be 30%. As shown in Table 6-5, the resulting AD uncertainties are 30.8% for 4B1 and 40.3% for 4B2.

The uncertainty of the emission factor is 23% according to Leifeld et al. (2003).

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 (CO₂, CH₄, N₂O, F-gases) with mean uncertainties according to Table 1-7.

Emissions and sinks of the category 4B2 are no key category and are therefore part of the "rest" categories with mean uncertainty.

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 1.2.3.1 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 2014/2015).

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

The activity data 1990–2014 were updated (see chp. 6.3.5) causing small modifications in areas. In 2014, this recalculation leads to an increase of CO₂ emissions from 4B of 0.19 kt CO₂eq.

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 category information 4C1 and 4C2

CO₂ emissions from 4C1 "Grassland remaining Grassland" are a key category regarding level. CO₂ emissions from 4C2 "Land converted to Grassland" are a key category concerning level and trend.

31.1% 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 6.1% in 2015 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 6-18.

Table 6-18 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 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 6-18), 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 6-19.

Table 6-19 Mean carbon stocks under permanent grassland on mineral soils, \pm 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 |
| <i>Simple mean carbon stock value over altitude classes</i> | 68.23 |

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

Shrub Vegetation (CC32)

Due to lack of data, the values of carbon stocks under permanent grassland on mineral soils (CC31) were used (see Table 6-19).

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. $53.40 \text{ t C ha}^{-1}$ (mineral soils, 0-30 cm) are taken for CC33 (see FOEN 2015).

Copse (CC34)

Due to lack of data, the values of CC31 (Table 6-19) 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 6-19) 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 6-19, the carbon stock Cs of CC36 is calculated as:

$$Cs(CC36) = 0.35 * Cs(\text{permanent grassland} > 1200 \text{ m}) = 26.31 \text{ t C ha}^{-1}$$

Unproductive Grassland (CC37)

The category CC37, 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 6-19) 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 6-20.

b) Carbon in soils

When a conversion of a land to grassland occurs, the stock-difference approach is applied for soil carbon.

c) N₂O emissions from Grassland

N₂O emissions from drainage of organic soils on grassland are reported in the agriculture sector.

The calculation of emissions for categories 4III and 4IV (N₂O from Nitrogen Mineralization in mineral soils) is described in chp. 6.10.

Table 6-20 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

For category 4C1 the dominant process determining the uncertainty is the carbon loss on organic soils. The uncertainty of the area of organic soils (AD) is determined by the uncertainty of the AREA survey (4C1 6.0%, from Table 6-9) combined with the uncertainty of the soil map used to identify organic soils (chp. 6.2.2), which is assumed to be 30%. As shown in Table 6-5, the resulting AD uncertainty for 4C1 is 30.6%.

For category 4C2, land converted to grassland, the dominant process determining the uncertainty is the carbon loss in (living) biomass calculated by the stock-difference approach for conversions from forest land to grassland. Therefore, the uncertainty of the carbon stock of forest was used as EF-uncertainty (40.3%, see chp. 6.4.3). The AD uncertainty (13.6%) comes from the AREA survey as shown in Table 6-9.

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 1.2.3.1 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 2014/2015).

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

The activity data 1990–2014 were updated (see chp. 6.3.5) causing small modifications in areas.. In 2014, this recalculation leads to a reduction of CO₂ emissions from 4C of 0.15 kt CO₂eq.

6.6.6 Category-specific planned improvements

No further category-specific improvements are planned.

6.7 Source Category 4D – Wetlands

6.7.1.1 Source category description

Key category information 4D

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: $68.23 \text{ t C ha}^{-1}$; 0-30 cm) as proposed in FOEN 2015.

c) N₂O emissions from drainage of soils

Drainage of intact wetlands is very unlikely. Therefore, no N₂O 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 chp. 6.1.3.

The calculation of emissions for categories 4III and 4IV (N₂O from Nitrogen Mineralization in mineral soils) is described in chp. 6.10.

6.7.3 Uncertainties and time-series consistency

Category 4D1 does not have any sinks or emissions. For completeness, Table 6-5 shows the AD uncertainty of the AREA survey (10.5%) and a generic EF uncertainty of 50%.

For category 4D2, land converted to wetlands, the dominant process determining the uncertainty is the carbon loss in (living) biomass calculated by the stock-difference approach for conversions from forest land to grassland. Therefore, the uncertainty of the carbon stock of forest was used as EF-uncertainty (40.3%, see chp. 6.4.3). The AD uncertainty (40.9%) comes from the AREA survey as shown in Table 6-9.

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 (CO₂, CH₄, N₂O, F-gases) with mean uncertainties according to Table 1-7. Emissions and sinks of the category 4D2 are no key category and are therefore 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 1.2.3.1 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 2014/2015).

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

The activity data 1990–2014 were updated (see chp. 6.3.5) causing small modifications in areas..

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 information 4E2

CO₂ emissions from 4E2 “Land converted to Settlements” are a key category by level. Category 4E1 “Settlements remaining Settlements” is not a key category.

11.1% of Liechtenstein’s total surface are settlements. Between 1990 and 2015, 416 hectares were converted to settlements, which is an increase of 30.4%. 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), Liechtenstein adopted the Swiss data on vegetation in settlements for CC52, 53 and 54. 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 chp. 6.1.3. Carbon stocks are summarized in Table 6-4.

The calculation of emissions for categories 4III and 4IV (N₂O from Nitrogen Mineralization in mineral soils) is described in chp. 6.10.

6.8.3 Uncertainties and time-series consistency

The dominant process determining the uncertainty of categories 4E1 and 4E2 is the carbon loss on mineral soils.

Thus, the uncertainty of the area (AD) is determined by the uncertainty of the AREA survey (4E1 6.5%, 4E2 19.4% from Table 6-9).

For the EF (CO₂) it is 50% according to the Swiss National Inventory Report (FOEN 2015).

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 (CO₂, CH₄, N₂O, F-gases) with mean uncertainties according to Table 1-7. Since 4E1 is not a key category, its emissions are accounted in the “rest” category CO₂ 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 1.2.3.1 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 2014/2015).

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

The activity data 1990–2014 were updated (see chp. 6.3.5) causing small modifications in areas. In 2014, this recalculation leads to a reduction of CO₂ emissions from 4E of 0.01 kt CO₂eq.

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

Key category information 4F2

Category 4F2 “Land converted to Other Land” CO₂ is a key category by trend.

6.2% of Liechtenstein’s total surface are summarized in “Other Land”. Between 1990 and 2015 the area of “Other Land” has declined by 2.9%. As shown in Table 6-3 other land

(CC61) covers non-vegetated areas such as glaciers, rocks and shores. For category 4F1 “Other Land remaining Other Land” only areas are reported (no emissions or sinks).

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 chp. 6.1.3.

6.9.3 Uncertainties and time-series consistency

The dominant process determining the uncertainty of category 4F2 is the carbon loss by loss of mineral soils. Thus, the uncertainty of the area (AD) is determined by the uncertainty of the AREA survey (40.9% from Table 6-9). For the EF (CO₂) it is 50% according to the Swiss National Inventory Report (FOEN 2015).

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 1.2.3.1 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 2014/2015).

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

The activity data 1990–2014 were updated (see chp. 6.3.5) causing small modifications in areas. In 2014, this recalculation leads to a reduction of CO₂ emissions from 4E of 0.1 kt CO₂eq.

6.9.6 Category-specific planned improvements

No category-specific improvements are planned.

6.10 Categories 4(III), 4(IV) – N₂O from nitrogen mineralization

6.10.1 Description

This chapter presents the methods for calculating direct and indirect N₂O 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. These N₂O emissions are not key categories.

- In category 4(III), direct N₂O emissions on land converted to forest land, cropland, grassland, wetlands, settlements or other land are reported.
- In category 4(IV2), indirect emissions of N₂O due to nitrogen leaching and run-off are reported.

The following N₂O emissions were included in the agriculture sector:

- N₂O emissions associated with inputs from N fertilisers (CRF table 4(I)).
- N₂O 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 N₂O emissions due to atmospheric deposition (CRF table 4(IV1)).

6.10.2 Methodological issues

Direct N₂O emissions (4(III)) as a result of the disturbance of mineral soils associated with land-use change are calculated according to IPCC (2006, Chapter 4_11):

$$\text{Emission(N}_2\text{O)} = -\text{deltaCs} * 1 / (\text{C:N}) * \text{EF1} * 44 / 28, \text{ if } \text{deltaCs} < 0 \quad [\text{kt N}_2\text{O}]$$

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 N₂O-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 N₂O 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 N₂O 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):

$$\text{Emission(N}_2\text{O)} = -\text{deltaCs} * \text{Frac} / (\text{C:N}) * \text{EF5} * 44 / 28, \text{ if } \text{deltaCs} < 0 \quad [\text{kt N}_2\text{O}]$$

where:

Frac: fraction of mineralized N lost by leaching or run-off, Frac=30%

EF5: default emission factor = 0.0075 kg N₂O-N (kg N)⁻¹, IPCC 2006 (Table 4_11.3)

If deltaCs is zero or positive (carbon gain) there are no N₂O emissions provoked by a land-use change. As the approach applied is not tier 3, no N₂O 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 N₂O 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

The dominant process determining the uncertainty of category 4(III) is the carbon loss on mineral soils arising from land converted to settlements. Thus, the AD uncertainty is determined by the uncertainty of the AREA survey (4E2 19.4% from Table 6-9).

A relative uncertainty for the emission factors of 4(III) and 4(IV2) was estimated as the mean of the upper and the lower limit of the uncertainty ranges listed in IPCC (2006), Vol 4, Tables 11.1 and 11.3.:

Uncertainty (EF1): 135%

Uncertainty (EF5): 162%

According to IPCC (2006, Vol 3, p. 3.32) the final value for EF uncertainty was set to 100% (see Table 6-5) as the EF is a non-negative quantity.

The uncertainty of the activity data (20%) for category 4(IV2) was adopted from ART (2008).

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 (CO₂, CH₄, N₂O, F-gases) with mean uncertainties according to Table 1-7. Since 4(III) and 4(IV) are no key categories their uncertainties are accounted in the “rest” categories with mean uncertainty of N₂O.

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

The activity data 1990–2014 were updated (see chp. 6.3.5) causing small modifications in areas. In 2014, this recalculation leads to a reduction of CO₂ emissions from 4B of 0.15 kt CO₂eq.

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 information 4G

Category 4G Harvested Wood Products (HWP) CO₂ 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 the reporting under UNFCCC and the accounting under KP. It 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 chp. 11). 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-life 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 m³ yr⁻¹ with an average of 7'715 m³ 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 m³ 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 6-21 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 6-21 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 2015, in kt CO₂. 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 CO₂ | -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 | 2015 |
|--|-------------|--------------|--------------|--------------|--------------|--------------|
| Sawnwood production, m ³ | 3'732 | 7'465 | 7'465 | 7'714 | 7'714 | 7'714 |
| Gains sawnwood, kt C | 0.93 | 1.87 | 1.87 | 1.93 | 1.93 | 1.93 |
| Losses sawnwood, kt C | -1.53 | -1.53 | -1.53 | -1.54 | -1.55 | -1.55 |
| Net emissions/removals, kt CO₂ | 2.18 | -1.25 | -1.22 | -1.43 | -1.40 | -1.37 |

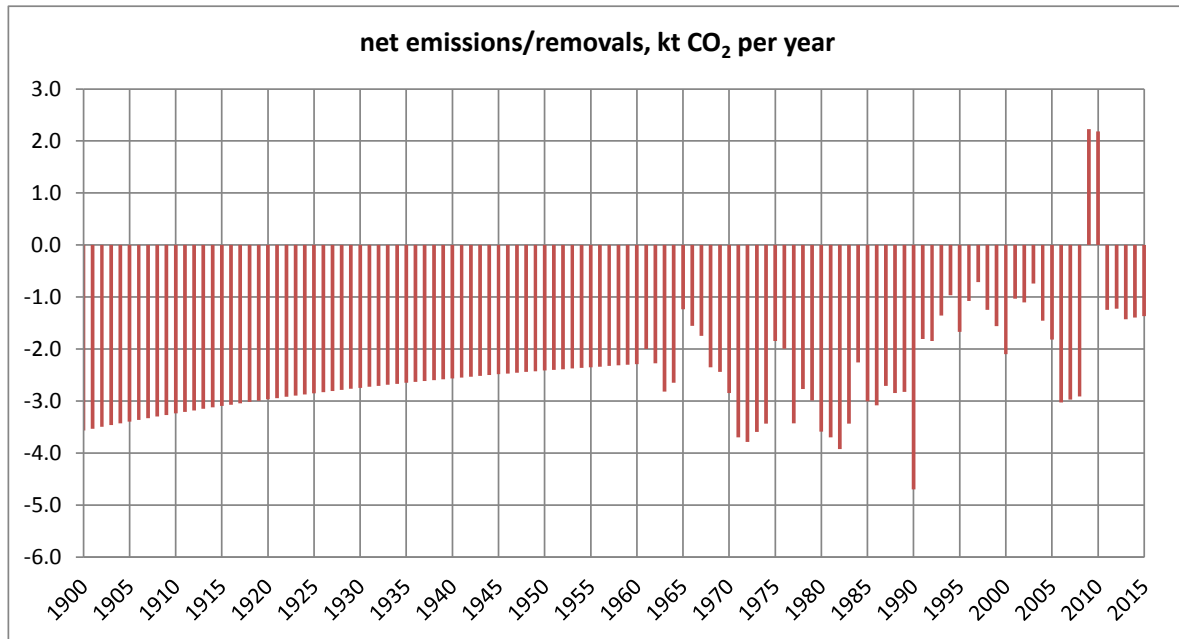


Figure 6-6 Liechtenstein's greenhouse gas net emissions (positive sign) and removals (negative sign) from Harvested Wood Products between 1900 and 2015 originating from forest land (UNFCCC) or land under Forest Management (KP), in kt CO₂ eq.

6.11.3 Uncertainties and time-series consistency

For category 4G HWP, the following information on relative uncertainty was used.

Activity data:

Sawnwood production: 50%

(Switzerland has 3% for activity data since 1990, but the adaptation to Liechtenstein using the number of inhabitants induces additional uncertainty which is estimated by expert judgment.)

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 the EF for carbon losses and gains in HWP can be calculated as:

$$U_{\text{HWP EmissionFactor}} = \sqrt{25\%^2 + 10\%^2 + 50\%^2} = 57\%$$

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 1.2.3.1 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 2014/2015).

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

6.11.5 Category-specific recalculations

No category specific recalculations were carried out. 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 2015 according to the four source categories 5A - 5D. Additionally Table 7-1 lists the GHG emissions of this sector by gas in CO₂ equivalent (kt) for the years 1990 - 2015.

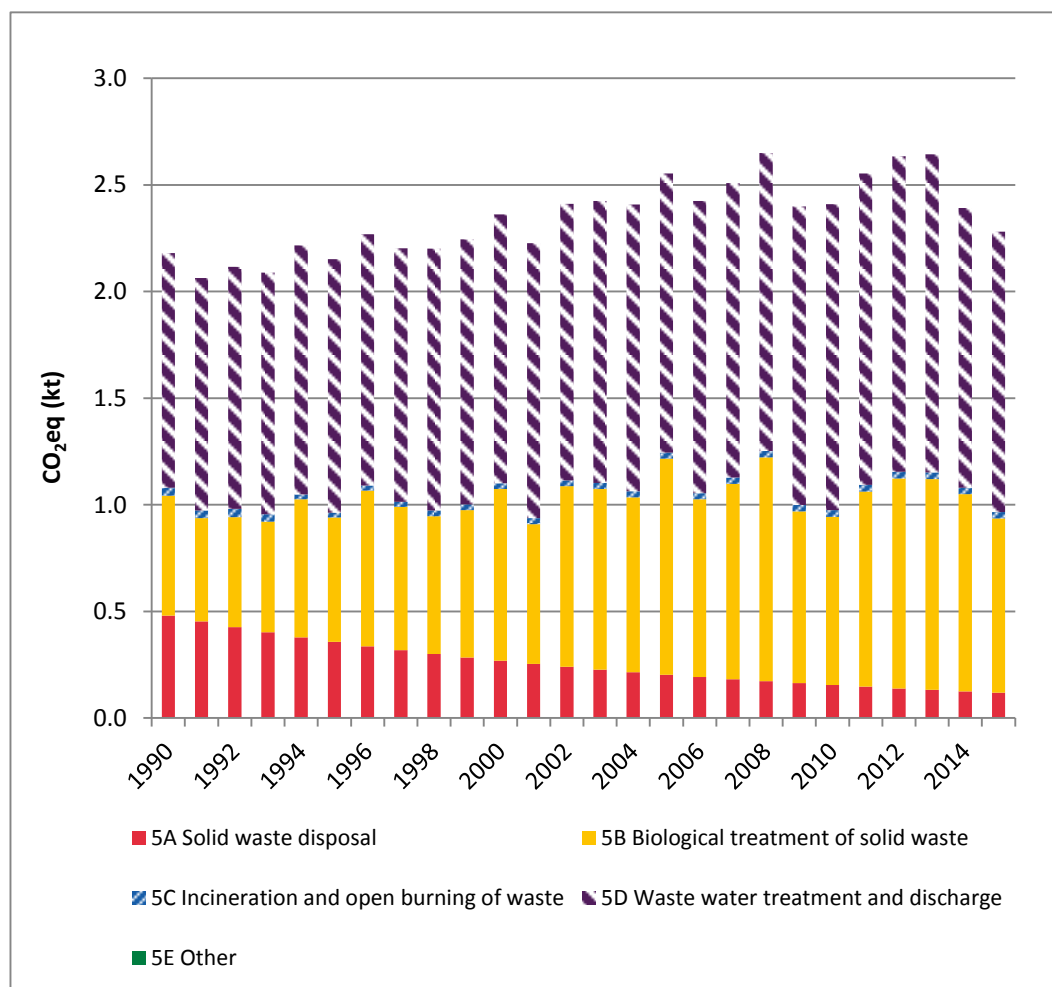


Figure 7-1 Liechtenstein’s greenhouse gas emissions in sector 5 Waste between 1990 - 2015.

Table 7-1 GHG emissions of source category 5 Waste by gas in CO₂ equivalent (kt), 1990 - 2015.

| Gas | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|------------------|---------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| | CO ₂ equivalent (kt) | | | | | | | | | |
| CO ₂ | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| CH ₄ | 1.56 | 1.48 | 1.49 | 1.48 | 1.59 | 1.51 | 1.63 | 1.57 | 1.56 | 1.59 |
| N ₂ O | 0.59 | 0.56 | 0.59 | 0.58 | 0.61 | 0.62 | 0.62 | 0.61 | 0.63 | 0.63 |
| Sum | 2.18 | 2.06 | 2.12 | 2.09 | 2.22 | 2.15 | 2.27 | 2.20 | 2.20 | 2.24 |

| 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 | 1.69 | 1.56 | 1.71 | 1.71 | 1.69 | 1.85 | 1.70 | 1.77 | 1.88 | 1.67 |
| N ₂ O | 0.66 | 0.65 | 0.68 | 0.69 | 0.70 | 0.68 | 0.70 | 0.72 | 0.74 | 0.71 |
| Sum | 2.36 | 2.23 | 2.41 | 2.42 | 2.41 | 2.55 | 2.42 | 2.51 | 2.65 | 2.40 |

| Gas | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 1990-2015 |
|------------------|---------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| | CO ₂ equivalent (kt) | | | | | | % |
| CO ₂ | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | -20.1% |
| CH ₄ | 1.64 | 1.75 | 1.81 | 1.82 | 1.58 | 1.50 | -4.0% |
| N ₂ O | 0.74 | 0.78 | 0.80 | 0.80 | 0.79 | 0.76 | 28.3% |
| Sum | 2.41 | 2.55 | 2.63 | 2.64 | 2.39 | 2.28 | 4.6% |

In sector 5 Waste a total of 2.28 kt CO₂ equivalents of greenhouse gases were emitted in 2015. 5.21% of the total emissions origin from 5A Solid waste disposal, 35.84% from 5B Biological treatment of solid waste, 1.31% from 5C Incineration and open burning of waste and 57.64% from source category 5D Waste water treatment and discharge. Emissions from 5E Other are not occurring in Liechtenstein.

The total greenhouse gas emissions show an increase from 1990 to 2015 by 4.6%.

Methodological remark for sector 5 Waste: As living standards, infrastructure as well 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. Wherever available country specific data have been used, e.g. activity data for unmanaged waste disposal sites or for the estimation of CH₄ from wastewater treatment.

7.2 Source Category 5A – Solid waste disposal

7.2.1 Source Category Description: Solid waste disposal (5A)

Key category information 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 fossil fuels such as oil and gas. The heat imported by Liechtenstein from the incineration plant is reported 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 waste dumping. They are not managed (they are not really “landfills” but rather “contaminated sites”). No landfill gas was collected for flaring or energy recovery. The emissions from these 20 sites are reported under 5A2 Unmanaged waste disposal sites.

The landfills in Liechtenstein were unmanaged (in the definition of IPCC GPG), because municipal solid waste was disposed off on the landfills by users directly (only on 3 landfill sites a temporary control by landfill staff was executed). No mechanical compacting or levelling of waste has been carried out. No collection or treatment of leachate took place which caused environmental pollution. Landfills are all less than 5 m deep (OEP 2007g).

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).

7.2.2.1 Solid waste disposal on unmanaged waste disposal sites (5A2)

Methodology

The CH₄ emissions from solid waste disposal are estimated according to the 2006 IPCC Guideline.

Emissions are calculated by a Tier 2 method based on the decision tree in Fig. 3.1 of chapter 3. Solid waste disposal in 2006 IPCC Guideline. The spreadsheet for the First Order Decay (FOD) model provided by IPCC 2006 has been applied and parametrised for Liechtensteins conditions.

The following equation is applied to calculate the CH₄ generation in the year t:

$$\text{CH}_4 \text{ generated in the year } t \text{ [kt/year]} = \sum x [A \cdot k \cdot M(x) \cdot L0(x) \cdot e^{-k(t-x)}] \cdot (1-OX)$$

where

- t = current year
- x = the year of waste input, $x \leq t$
- A = $(1-k)/k$, norm factor (fraction)
- k = methane generation rate [1/yr]
- M(x) = the amount of waste disposed in year x
- L0(x) = methane generation potential ($MCF(x) \cdot DOC(x) \cdot DOCF \cdot F \cdot 16/12$) [kt CH₄ / kt waste]
- MCF(x) = methane correction factor (fraction)
- DOC(x) = degradable organic carbon [kt C/ kt waste]
- DOCF = fraction of DOC, that is converted to landfill gas (fraction)
- F = fraction of CH₄ in landfill gas (fraction)
- 16/12 = factor to convert C to CH₄.
- OX = oxidation factor (fraction)

The general parameters are set as follows (all 2006 IPCC default values):

- k (methane generation rate) = 0.09/year
- DOC_F (fraction of DOC dissimilated) = 0.5
- Delay time (months) = 6
- Fraction of methane (F) in developed landfill gas = 0.5
- Conversion factor, C to CH_4 = 1.33
- Oxidation factor (OX) = 0

The values for the parameter degradable organic carbon (DOC) are provided for each waste fraction. For all waste types the 2006 IPCC default values are used, except for industrial waste. For industrial waste the default value for wood and straw is applied, as most of the industrial waste deposited in Liechtenstein is assumed to be wood waste.

The methane generation rate [1/yr] is chosen according to wet temperate conditions. For all waste types the 2006 IPCC default values are used, except for industrial waste. For industrial waste the default value for wood and straw is applied, again based on the fact that most of it is assumed to be wood waste.

Composition of landfilled municipal solid waste is estimated to be similar as the one in Switzerland. Therefore the same values have been applied (see Table 7-3).

Table 7-3 Composition of MSW going to solid waste disposal sites (BUS 1978).

| Fraction | Share |
|-----------------------|-------|
| Food | 24% |
| Garden | 4% |
| Paper | 36% |
| Wood | 4% |
| Textile | 4% |
| Nappies | 0% |
| Plastics, other inert | 28% |

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 (see 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.

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 chapter 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 (CO₂, CH₄, N₂O, 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 CH₄.

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 2015 and for the changing rates 2014/2015).

7.2.5 Category-specific recalculations: Solid Waste Disposal (5A)

The CH₄ emissions from solid waste disposal are estimated according to 2006 IPCC Guidelines. This was recommended by the expert review team during the centralized review 2016.

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)

Key category information 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 similar to the one in Switzerland.

Separately collected organic waste of households (generally food waste) is brought to a composting plant in Switzerland.

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

Table 7-5 Specification of source category 5B 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

Emissions are calculated by a Tier 2 method based on chapter 4.1.1 Biological treatment of solid waste in IPCC (2006).

The CH₄ and N₂O 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.

N₂O 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 CH₄/t of composted waste and 0.07 kg N₂O/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 (OE 2016g). In order to account for the numerous small compost sites in people's backyards, backyard composting has been estimated by an expert estimate. The amount of composting in small 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 7-6 Activity data of 5B Biological treatment of solid waste (kilotons as wet matter).

| Waste composting | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|
| Composted centrally | kt/a | 3.57 | 3.08 | 3.29 | 3.31 | 4.14 | 3.73 | 4.69 | 4.32 | 4.17 | 4.46 |
| 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 | kt/a | 3.85 | 3.32 | 3.54 | 3.56 | 4.44 | 4.00 | 5.01 | 4.60 | 4.43 | 4.74 |

| Waste composting | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|
| Composted centrally | kt/a | 5.21 | 4.25 | 5.50 | 5.51 | 5.34 | 6.61 | 5.44 | 5.98 | 6.86 | 5.26 |
| 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 | kt/a | 5.52 | 4.49 | 5.81 | 5.81 | 5.62 | 6.95 | 5.71 | 6.28 | 7.20 | 5.52 |

| Waste composting | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|--------------------------|------|------|------|------|------|------|------|
| Composted centrally | kt/a | 5.15 | 5.97 | 6.43 | 6.45 | 6.04 | 5.34 |
| Additionally in backyard | | 5.0% | 5.0% | 5.0% | 5.0% | 5.0% | 5.0% |
| Composted total | kt/a | 5.41 | 6.27 | 6.75 | 6.78 | 6.34 | 5.60 |

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. 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 CH₄ and N₂O 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 chapter 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 (CO₂, CH₄, N₂O, 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 CH₄ and N₂O.

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 2015 and for the changing rates 2014/2015).

7.3.5 Category-specific recalculations: Biological treatment of solid waste (5B)

In the last submission the activity data of backyard composting of the year 2014 has been overestimated by error, i.e. 105 % share of centralised composting quantity instead of 5%. This error has been corrected.

7.3.6 Category-specific Planned Improvements: Biological treatment of solid waste (5B)

7.4 Source Category 5C – Incineration and open burning of waste

7.4.1 Source Category Description: Incineration and open burning of waste (5C)

Key category information 5C

Source category 5C Incineration and open burning of waste is not a key source.

There are no waste incineration plants operating 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 burning of household wastes and of wastes on construction sites. They are reported under 5C2 Open burning of waste.

Table 7-7 Specification of source category 5C 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 incineration 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 CO₂ emissions are plastics.

Country-specific emission factors for CO₂, N₂O and CH₄ 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 7-8 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 ₂ O (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 (OE 2016h). 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 7-9 Activity data for source category 5C Incineration and open burning of waste (OS 2016c).

| 5C Open burning of waste | unit | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|--------------------------------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| MSW generated | kt | 10.64 | 10.44 | 10.93 | 10.16 | 6.29 | 6.73 | 6.80 | 7.02 | 7.27 | 7.65 |
| 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 | 0.053 | 0.052 | 0.055 | 0.051 | 0.031 | 0.034 | 0.034 | 0.035 | 0.036 | 0.038 |

| 5C Open burning of waste | unit | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|--------------------------------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| MSW generated | kt | 7.79 | 8.00 | 7.90 | 8.01 | 8.12 | 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 | 0.039 | 0.040 | 0.040 | 0.040 | 0.041 | 0.040 | 0.041 | 0.042 | 0.042 | 0.043 |

| 5C Open burning of waste | unit | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|--------------------------------|------|-------|-------|-------|-------|-------|-------|
| MSW generated | kt | 8.66 | 8.73 | 8.78 | 8.67 | 8.58 | 8.50 |
| Fraction incinerated illegally | | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| Waste incinerated illegally | kt | 0.043 | 0.044 | 0.044 | 0.043 | 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 chapter 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 (CO₂, CH₄, N₂O, 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 CO₂, CH₄ and N₂O.

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 2015 and for the changing rates 2014/2015).

7.4.5 Category-specific recalculations: Incineration and open burning of waste (5C)

The activity for years 1990 - 2004 didn't correspond to official statistics of Liechtenstein. This error has been corrected. Due to higher activity data in the base year the emissions in 1990 are higher as well (about 33%).

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 information 5D

Category 5D Wastewater treatment and discharge is not a key category.

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).

Wastewater deriving from public sewer systems is treated in the Municipal Waste Water Treatment Plant (MWWTP) in Bendern. Wastewater is treated in three steps: 1. mechanical treatment, 2. biological treatment, and 3. chemical treatment. The treated water is discharged into the river Rhine.

The sludge is stabilized in a digester where biogas is generated. Until 2013 the biogas was used in a co-generation unit to produce heat and power on-site. Since 2014 biogas is upgraded and fed into the natural gas network.

The digested sewage sludge is dewatered and dried. Dried sludge is transported to Switzerland and used as alternative fuel in a cement plant (AZV 2016).

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 the centralized (MWWTP) in Bendern. Two metal processing companies have toxic waste water which is pre-treated on site 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.

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.

Table 7-10 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 5D1) |
| 5D3 | Other | Not occurring in Liechtenstein |

7.5.2 Methodological Issues: Wastewater treatment and discharge (5D)

7.5.2.1 CH₄ Emissions

Methodology

Emissions are calculated by a Tier 3 method based on the decision tree in Fig. 6.2 and Fig. 6.3 in chapter 6. Wastewater treatment and discharge in IPCC (2006).

The amount of sewage gas produced is measured as well as the amounts recovered in boilers, co-generation plants, flared and up-graded. The CH₄ emissions are calculated by multiplying the respective sewage gas amounts times the technology specific emission factors.

Emission Factors

The emission factors are adopted from Switzerland. It is assumed that similar conditions prevail in Liechtenstein. The data are based on measurements (EMIS 2016/5D1 Wastewater treatment plants).

Table 7-11 CH₄ emission factors of source category 5D Wastewater treatment and discharge.

| 5D Waste Water Treatment | |
|--------------------------|------------------------|
| Source | kg CH ₄ /TJ |
| Boiler | 6.0 |
| CHP generation | 25.0 |
| Torches | 6.0 |

Activity Data

Activity data for CH₄ emissions from sewage gas treatment are the amount of gas treated, from losses and leakage from upgrading. 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.

Sewage gas is used in boilers, in co-generation plants, flared and up-graded (ARA Bendern 2016).

It is assumed that 0.75% of sewage gas amount (volume) used in boilers and co-generation plants is leaked (SFOE 2002).

The losses from sewage gas upgrading were measured by SVGW (SVGW 2016).

Table 7-12 Activity data for CH₄ emission calculation from sewage gas treatment in 5D Waste water treatment and discharge (AZV 2016, ARA Bendern 2016, SFOE 2012, SVGW 2016).

| Sewage gas treatment | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|-------------------------------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Sewage gas for boilers | TJ | 5.82 | 6.10 | 6.45 | 6.45 | 7.00 | 6.34 | 6.77 | 6.89 | 7.45 | 8.03 |
| Sewage gas for CHP generation | TJ | 6.27 | 6.69 | 7.21 | 7.37 | 8.18 | 7.55 | 8.22 | 8.56 | 9.48 | 10.41 |
| Sewage gas flared | TJ | 2.46 | 2.45 | 2.47 | 2.31 | 2.32 | 1.97 | 1.93 | 1.77 | 1.70 | 1.63 |
| Sewage gas losses | m ³ | 4'213 | 4'475 | 4'800 | 4'863 | 5'345 | 4'903 | 5'297 | 5'459 | 5'981 | 6'520 |
| Sewage gas for upgrading | m ³ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Sewage gas treatment | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|-------------------------------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Sewage gas for boilers | TJ | 8.10 | 7.79 | 7.47 | 7.74 | 8.08 | 7.78 | 8.42 | 9.06 | 9.35 | 8.83 |
| Sewage gas for CHP generation | TJ | 10.68 | 10.52 | 10.22 | 10.75 | 11.40 | 11.15 | 12.20 | 13.14 | 13.55 | 12.81 |
| Sewage gas flared | TJ | 1.47 | 1.17 | 0.99 | 0.86 | 0.72 | 0.52 | 0.42 | 0.45 | 0.47 | 0.44 |
| Sewage gas losses | m ³ | 6'660 | 6'483 | 6'286 | 6'591 | 6'960 | 6'772 | 255 | 459 | 2'091 | 1'224 |
| Sewage gas for upgrading | m ³ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Sewage gas treatment | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|-------------------------------|----------------|-------|-------|-------|-------|-----------|-----------|
| Sewage gas for boilers | TJ | 8.30 | 8.40 | 8.46 | 8.57 | 0.33 | 0.06 |
| Sewage gas for CHP generation | TJ | 12.04 | 12.18 | 12.40 | 13.69 | 22.18 | 22.41 |
| Sewage gas flared | TJ | 0.42 | 0.42 | 0.43 | 0.45 | 0.92 | 0.93 |
| Sewage gas losses | m ³ | 1'989 | 969 | 948 | 3'060 | 149 | 1'084 |
| Sewage gas for upgrading | m ³ | 0 | 0 | 0 | 0 | 1'044'011 | 1'065'714 |

7.5.2.2 N₂O Emissions

Methodology

N₂O emissions from centralized WWT plants are calculated in accordance with the 2006 IPCC Guidelines (IPCC 2006).

Emission Factors

N₂O emission factor is calculated based on country specific data.

Specific numbers for yearly protein consumption are 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 - 2015 are taken from Switzerland (FOEN 2016). According to IPCC 2006 an N fraction of 0.16 kg N per kg protein (F_{NPR} ; IPCC default value) is used. Emission factors differ from year to year, and range around 93 g N₂O per inhabitant.

Activity Data

The time-dependent data on population and annual per capita protein consumption are summarized in Table 7-13.

Table 7-13 Activity data for N₂O emission calculation in 5D Waste water treatment and discharge (OS 2016d, FOEN 2016).

| 5D Wastewater treatment and discharge | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---------------------------------------|-------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Population | inhabitants | 29'032 | 29'386 | 29'868 | 30'310 | 30'629 | 30'923 | 31'143 | 31'320 | 32'015 | 32'426 |
| Protein Consumption | kg/capita/a | 37.9 | 38.1 | 38.0 | 37.2 | 37.2 | 36.8 | 36.6 | 36.7 | 36.7 | 36.3 |

| 5D Wastewater treatment and discharge | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---------------------------------------|--------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Population | inhabitants | 32'863 | 33'525 | 33'863 | 34'294 | 34'600 | 34'905 | 35'168 | 35'356 | 35'589 | 35'894 |
| Protein Consumption | kg/capita/yr | 36.9 | 36.0 | 35.7 | 36.3 | 36.5 | 36.1 | 36.8 | 37.1 | 37.0 | 37.4 |

| 5D Wastewater treatment and discharge | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---------------------------------------|--------------|--------|--------|--------|--------|--------|--------|
| Population | inhabitants | 36'149 | 36'475 | 36'838 | 37'129 | 37'366 | 37'623 |
| Protein Consumption | kg/capita/yr | 38.0 | 38.5 | 38.5 | 38.5 | 38.5 | 37.1 |

7.5.3 Uncertainties and Time-Series Consistency: Wastewater treatment and discharge (5D)

For the current submission a simplified uncertainty analysis has been carried out as described in chapter 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 (CO₂, CH₄, N₂O, 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 CO₂, CH₄ and N₂O.

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 2015 and for the changing rates 2014/2015).

7.5.5 Category-specific recalculations: Wastewater treatment and discharge (5D)

CH₄ and N₂O emissions from wastewater treatment and discharge are estimated according to 2006 IPCC Guideline. This was recommended by the expert review team during the centralized review 2016.

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 CO₂ and N₂O emissions

Based on the new IPCC 2006 Guidelines (IPCC 2006) it is not mandatory to take into account indirect CO₂ emissions. Liechtenstein decided not to report indirect CO₂ 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

The quantitative impact of recalculations on emissions, i.e. the absolute difference that results from the recalculations between the previous and the latest submission, is documented for all key categories (values are taken from CRF Table 8.s1, 8.s2, 8.s3 and 8.s4).

1 Energy

Recalculation in the Reference Approach

- CO₂ emission factors of diesel, kerosene and gasoline are changed to the ones used in Switzerland (SFOE/FOEN 2014). This leads to a recalculation of CO₂ emissions from 1999-2014.
- Instead of assuming a constant share, the share of kerosene consumed in Liechtenstein is linearly interpolated for years with missing data. This leads to a recalculation for CO₂, CH₄ and N₂O emissions from 2003 to 2011 (FCCC/ERT 2016: 1.A.3.a Domestic aviation).
- A mistake in the share of alkylate gasoline was corrected, which leads to a recalculation of CO₂ emissions in 2014.

Recalculation in 1A1

There are no category-specific recalculations

Recalculation in 1A2

- 1A2g: The CO₂ emission factor of diesel is changed to the one used in Switzerland's GHG inventory (SFOE/FOEN 2014). This leads to a recalculation of CO₂ emissions from 1999-2014. In 2014, this leads to a reduction in CO₂ emissions from 1A2 of 0.02 kt CO₂.
- 1A2g: The N₂O and CH₄ emission factors of diesel is changed to the one used in Switzerland's GHG inventory (FOEN 2016). This leads to a recalculation of N₂O and CH₄ emissions from 1990-2014.

Recalculation in 1A3

- 1A3a: The share of kerosene consumed in Liechtenstein is linearly interpolated for years with missing data. This leads to a recalculation for CO₂, CH₄ and N₂O emissions from 2003 to 2011 (FCCC/ERT 2016).
- 1A3a: The CO₂ emission factor of kerosene is changed to the one used in Switzerland's GHG inventory (SFOE/FOEN 2014). This leads to a recalculation of CO₂ emissions from 1999-2014.

- 1A3b The N₂O and CH₄ emission factors of gasoline and diesel are changed to the ones used in Switzerland's GHG inventory (FOEN 2016). This leads to a recalculation of N₂O and CH₄ emissions from 1990-2014.
- 1A3b The CO₂ emission factors of gasoline and diesel are changed to the ones used in Switzerland's GHG inventory (FOEN 2016). This leads to a recalculation of CO₂ emissions from 1999-2014.
- In 2014, these recalculations lead to a reduction of CO₂ emissions from 1A3 by 0.2 kt CO₂. The increase in CH₄ emissions is negligible 10^{-11} kt.

Recalculation in 1A4

- 1A4a/1A4d: Revised activity data for biomass based on new statistics for wood consumption result in a recalculation for 2014 (CH₄, N₂O).
- 1A4b/1A4c Alkylate gasoline: an error in the activity data was corrected for years 2012 – 2014 (CO₂, CH₄, N₂O).
- 1A4b emission factor of CH₄ and N₂O for gasoline and diesel were changed to the factors used in the Swiss inventory 2016, leading to a recalculation for the entire time series 1990-2014.
- 1A4c emission factors of CH₄ and N₂O for gasoline and diesel were changed to the factors used in the Swiss inventory 2016, leading to a recalculation for the entire time series 1990-2014.
- 1A4c emission factor of CO₂ diesel were changed to the factor used in the Swiss inventory 2016, leading to a recalculation for the entire time series 1999-2014.
- In 2014, these recalculations lead to an increase of CO₂ emissions from 1A4 by 0.001 kt CO₂ and to an increase of CH₄ emissions by 0.06 kt CO₂eq.

Recalculation in 1B2

- 1B2 Gaseous fuels: By mistake, a methane content of 100% was assumed between 2005 and 2014 in the previous submission. This mistake was corrected for the current submission, leading to a recalculation of CH₄ emissions from 1B2 between 2005 and 2014. In 2014, this recalculation leads to a reduction of CH₄ emissions from 1B2 by 0.08 kt CO₂eq.

2 IPPU

- 2F1 Refrigeration and air conditioning: The time series of the number of households in Switzerland was revised using updated census data (SFSO 2016a), which leads to a recalculation for HFC-134a between 1990 and 2014.
- 2F1 Refrigeration and air conditioning: Continuous updating of the Swiss EMIS database causes a change in specific emission factors of Liechtenstein and therefore to a recalculation for HFC-143a, HFC-32, HFC-125, HFC134a und HFC 143a between 1990 and 2014.

- 2F1 Refrigeration and air conditioning: A mistake in the time series of households was corrected leading to a recalculation from 1990 to 2014.
- 2F2: Continuous updating of the Swiss EMIS database causes a change in specific emission factors of Liechtenstein and therefore to a recalculation for HFC134a in years 2008, 2009, 2012 and 2013.
- In 2014, these recalculations lead to a reduction of HFC emissions from 2F1 by 1.51 kt CO₂eq.
- 2G3: Continuous updating of the Swiss EMIS database causes a change in specific N₂O emission factors of Liechtenstein and therefore to a recalculation for N₂O in 2014.

Since Switzerland's GHG inventory 2017 was not yet available for Liechtenstein's submission 2017. For Switzerland, the following recalculations have been carried out in submission 2016, 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.
- 2F5 Solvents: Revision of import amounts (correction of import declarations of a specific import company).

3 Agriculture

- 3D: Switzerland has estimated N-inputs for co-substrates in agricultural biogas plants for the first time in its GHG inventory 2016, which leads to higher activity data of commercial fertilisers applied to agricultural soils (see FOEN 2016, p. 480). In 2014, this recalculation leads to an increase of N₂O emissions by 0.01 kt CO₂eq.

4 LULUCF

- 4A–4F: The new AREA survey for the year 2014 was integrated in the calculations for interpolation and extrapolation. This led to recalculations of areas for the years 2009–2014, as the former extrapolation was replaced by an interpolation. Very small changes also occurred in the years 1990–2008 as the updated database now covers a total of 16'054 hectares (instead of (16'050) for the whole country.
- 4A1: A major recalculation for 1990–2014 was due to a methodical improvement in calculating loss of living biomass in productive forests (CC12): Instead of using a constant value for the whole period, annual losses are calculated based on annual wood harvesting statistics (see chp. 6.4.2.3). This method was used already in the last submission for the reporting under the Kyoto Protocol and is now applied also for the UNFCCC reporting.
- Quantified impacts of recalculations regarding LULUCF key categories are documented in the chapters of the corresponding source categories (see chp. 6.4.5–6.9.5). They range between +2.24 kt CO₂eq and -0.15 kt CO₂eq.

5 Waste

- 5A: CH₄ emissions from solid waste disposal are estimated according to 2006 IPCC Guideline. This was recommended by the expert review team during the centralized review 2016.
- 5B: In the last submission the activity data of backyard composting in year 2014 has been overestimated by error, i.e. 105 % share of centralised composting quantity instead of 5%. This error has been corrected.
- 5C: The activity for years 1990 - 2004 did not correspond to official statistics of Liechtenstein. This error has been corrected. Due to higher activity data in the base year the emissions in 1990 are higher as well (about 33%).
- 5D: CH₄ and N₂O emissions from wastewater treatment and discharge are estimated according to 2006 IPCC Guidelines. This was recommended by the expert review team during the centralized review 2016.

10.1.2 Recalculations KP-LULUCF

- Forest management cap: The cap was recalculated based on the revised Initial Report (OE 2006, resubmission December 2016).
- Afforestation, Deforestation, Forest Management: The new AREA survey for the year 2014 was integrated in the calculations for interpolation and extrapolation of the activity data (chp. 6.3.5). This led to recalculations of areas for the years 2009-2014, as the former extrapolation was replaced by an interpolation. Very small changes also occurred in the years 1990-2008.

10.2 Implications for emission levels 1990 and 2014

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 national total emissions amounts to a total increase of 0.03 kt CO₂eq (0.01%) without emissions/removals from LULUCF.
- Including LULUCF, the difference in national total emissions amounts to a total decrease of 1 kt CO₂eq (0.4%).

Table 10-1 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submission in 2016 "Prev." (Re-Submission of Nov 2016, OE 2016d) and after the recalculation according to the present submission 2017 "Latest". The differences "Differ." are defined as latest minus previous submission. Where there is no difference between the two submissions (i.e. no recalculations), this is indicated with a dash.

| Recalculation | CO ₂ | | | CH ₄ | | | N ₂ O | | | Sum (CO ₂ , CH ₄ and N ₂ O) | | |
|----------------------------|---------------------------------|--------|---------|-----------------|--------|---------|------------------|--------|---------|--|--------|---------|
| | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. |
| Emissions for 1990 | | | | | | | | | | | | |
| Source and sink categories | CO ₂ equivalent (kt) | | | | | | | | | CO ₂ equivalent (kt) | | |
| 1 Energy | 198.7 | 198.7 | - | 1.3 | 1.2 | -0.02 | 1.1 | 1.1 | 0.03 | 201.1 | 201.1 | 0.01 |
| 2 IPPU (without F-gases) | NO | NO | NO | NO | NO | NO | 0.5 | 0.5 | - | 0.5 | 0.5 | - |
| 3 Agriculture | 0.1 | 0.1 | - | 16.7 | 16.7 | - | 8.7 | 8.7 | 0.01 | 25.5 | 25.5 | 0.01 |
| 4 LULUCF | 4.3 | 3.2 | -1.07 | NO | NO | NO | 0.3 | 0.3 | - | 4.6 | 3.5 | -1.07 |
| 5 Waste | 0.0 | 0.0 | 0.01 | 1.6 | 1.6 | 0.00 | 0.6 | 0.6 | 0.00 | 2.2 | 2.2 | 0.01 |
| Sum (without F-gases) | 203.0 | 202.0 | -1.06 | 19.5 | 19.5 | -0.02 | 11.2 | 11.2 | 0.04 | 233.8 | 232.7 | -1.04 |

| Recalculation | HFC | | | PFC | | | SF ₆ | | | Sum (F-gases) | | |
|----------------------------|---------------------------------|--------|---------|-------|--------|---------|-----------------|--------|---------|---------------------------------|--------|---------|
| | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. |
| Emissions for 1990 | | | | | | | | | | | | |
| 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) | | |
|---|---------------------------------|--------------|-------------|
| | Prev. | Latest | Differ. |
| Emissions for 1990 | | | |
| Source and sink categories | CO ₂ equivalent (kt) | | |
| Total CO₂ eq Em. with LULUCF | 233.8 | 232.7 | -1.0 |
| | 100.0% | 99.6% | -0.4% |
| Total CO₂ eq Em. without LULUCF | 229.2 | 229.2 | 0.03 |
| | 100.0% | 100.0% | 0.01% |

The analogous recalculation results for 2014 are shown in Table 10-2 and have the following effects on emissions:

- The difference in national total emissions amounts to a total decrease of 0.4 kt CO₂eq (0.2%) without emissions/removals from LULUCF.
- Including LULUCF, the difference in national total emissions amounts to a decrease of 2.6 kt CO₂eq (1.3%).

Table 10-2 Overview of implications of recalculations on 2014 data. Emissions are shown before the recalculation according to the previous submission in 2016 "Prev." (OE 2016d) and after the recalculation according to the present submission 2017 "Latest". The differences "Differ." are defined as latest minus previous submission. Where there is no difference between the two submissions (i.e. no recalculations), this is indicated with a dash.

| Recalculation | CO ₂ | | | CH ₄ | | | N ₂ O | | | Sum (CO ₂ , CH ₄ and N ₂ O) | | |
|----------------------------|---------------------------------|--------|---------|-----------------|--------|---------|------------------|--------|---------|--|--------|---------|
| | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. |
| Emissions for 2014 | | | | | | | | | | | | |
| Source and sink categories | CO ₂ equivalent (kt) | | | | | | | | | CO ₂ equivalent (kt) | | |
| 1 Energy | 161.5 | 161.3 | -0.21 | 2.0 | 2.0 | -0.02 | 0.8 | 0.8 | 0.02 | 164.3 | 164.1 | -0.21 |
| 2 IPPU (without F-gases) | NO | NO | NO | NO | NO | NO | 0.2 | 0.2 | 0.00 | 0.2 | 0.2 | 0.00 |
| 3 Agriculture | 0.0 | 0.0 | - | 16.3 | 16.3 | - | 8.1 | 8.1 | 0.01 | 24.4 | 24.4 | 0.01 |
| 4 LULUCF | 11.1 | 13.3 | 2.24 | NO | NO | NO | 0.4 | 0.4 | -0.03 | 11.6 | 13.8 | 2.21 |
| 5 Waste | 0.0 | 0.0 | - | 2.3 | 1.6 | -0.76 | 0.9 | 0.8 | -0.13 | 3.3 | 2.4 | -0.88 |
| Sum (without F-gases) | 172.6 | 174.7 | 2.03 | 20.6 | 19.8 | -0.77 | 10.4 | 10.3 | -0.13 | 203.7 | 204.8 | 1.12 |

| Recalculation | HFC | | | PFC | | | SF ₆ | | | Sum (F-gases) | | |
|----------------------------|---------------------------------|--------|---------|-------|--------|---------|-----------------|--------|---------|---------------------------------|--------|---------|
| | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. |
| Emissions for 2014 | | | | | | | | | | | | |
| Source and sink categories | CO ₂ equivalent (kt) | | | | | | | | | CO ₂ equivalent (kt) | | |
| 2 IPPU (F-gases only) | 12.1 | 10.6 | -1.51 | 0 | 0 | 0.00 | 0.1 | 0.1 | 0.00 | 12.3 | 10.8 | -1.51 |

| Recalculation | Sum (all gases) | | |
|---|---------------------------------|--------------|-------------|
| | Prev. | Latest | Differ. |
| Emissions for 2014 | | | |
| Source and sink categories | CO ₂ equivalent (kt) | | |
| Total CO₂ eq Em. with LULUCF | 216.0 | 215.6 | -0.4 |
| | 100.0% | 99.8% | -0.2% |
| Total CO₂ eq Em. without LULUCF | 204.4 | 201.8 | -2.6 |
| | 100.0% | 98.7% | -1.3% |

10.2.2 Implications emission levels for KP-LULUCF

Table 10-3 shows the differences in the KP-LULUCF tables on emissions/removals in 2014.

Table 10-3 Overview of implications of recalculations on 2014 data for KP-LULUCF. Emissions are shown according to the previous submission (OE 2016d), and after the recalculation according to the present submission "Latest".

| Year 2014 | CO ₂ equivalent (kt) | | |
|----------------------------|---------------------------------|--------|------------|
| | Previous | Latest | Difference |
| Source and Sink Categories | | | |
| Afforestation | -0.274 | -0.252 | 0.022 |
| Deforestation | 4.379 | 4.571 | 0.193 |
| Forest Management | 5.140 | 5.136 | -0.004 |
| Harvested Wood Products | -1.398 | -1.398 | 0.000 |
| Total emission/removal | 7.846 | 8.057 | 0.210 |

10.3 Implications for emissions trends, including time series consistency

10.3.1 Implications trends GHG inventory

Due to recalculations, the emission trend 1990–2014 reported in submission 2016 has changed. The emission trend showed a decrease by -10.8% before the recalculations (previous submission, national total without emissions/removals from LULUCF). After the recalculations in the latest submission 2017, the decreasing trend is slightly stronger (-11.95%).

Table 10-4 Change of the emission trend 1990–2014 due to recalculations carried out in the latest submission 2017. “Previous” refers to the values from re-submission 2016 (OE 2016d)

| Recalculation | 1990 | | 2014 | | change 1990/2014 | |
|--------------------|-------------------------|--------|----------|--------|------------------|---------|
| | previous | latest | previous | latest | previous | latest |
| | CO ₂ eq (kt) | | | | % | |
| Total excl. LULUCF | 229.18 | 229.21 | 204.42 | 201.82 | -10.80% | -11.95% |

All time series in the present submission are consistent.

10.3.2 Implications trends KP-LULUCF

The recalculations shown in Table 10-3 (year 2014) are relevant for trends in KP-LULUCF as the year 2014 is covered by the 2nd CP. The years 2008-2012 are not mandatory and are only reported to improve transparency. Nevertheless, the years 2008-2015 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 2016c) contains the history of the recommendations and encouragements of the ERT in the past review processes up to the last review in 2016 (see chp. 1.2.3.2 QA/QC plan on p. 35 in OE 2016c), showing which recommendations had been implemented. Planned improvements for the submission 2018 – 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 A8.3 of this NIR.

10.4.2 Recalculations KP-LULUCF

See Chapter 10.1.2

PART 2: Supplementary information required under the Kyoto Protocol

Part 2 presents the supplementary information required under the Kyoto Protocol (KP), 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 chose 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 2013-2015, 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 2015.

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 ₂ O emissions from managed soil ⁽⁵⁾ | Biomass burning ⁽⁹⁾ | | | |
| | | | | | Mineral | Organic ⁽³⁾ | | | N ₂ O | CH ₄ ⁽⁷⁾ | | | N ₂ O | N ₂ O | N ₂ O | CO ₂ ⁽¹⁰⁾ |
| Article 3.3 activities | | | | | | | | | | | | | | | | |
| Afforestation and reforestation | R | R | NR | NR | R | NO | 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 | NO |
| Article 3.4 activities | | | | | | | | | | | | | | | | |
| Forest management | R | R | NR | NR | NR | NO | R | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Cropland management | NA | NA | NA | NA | NA | NA | | | | | | | | | | |
| Grazing land management | NA | NA | NA | NA | NA | NA | | | | | | | | | | |
| Revegetation | NA | 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 | 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 CO₂ emissions/removals from organic soils, including CO₂ emissions from dissolved organic carbon associated with drainage and rewetting. On-site CO₂ emissions/removals from drainage and rewetting from organic soils and off-site CO₂ 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⁾ N₂O 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⁾ CH₄ and N₂O 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⁾ CH₄ emissions from drained soils and drainage ditches should be reported here, as appropriate.

⁽⁸⁾ N₂O 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 CO₂ emissions from biomass burning are not already included under changes in carbon stocks, they should be reported under biomass burning. Parties that include CO₂ emissions from biomass burning in their carbon stock change estimates

Table 11-2 KP(LULUCF) NIR 2 - Land Transition Matrix 2015.

Table NIR 2. LAND TRANSITION MATRIXAreas and changes in areas between the previous and the current inventory year^{(1), (2)}

| | ARTICLE 3.3 ACTIVITIES | | ARTICLE 3.4 ACTIVITIES | | | | | Other ⁽⁶⁾ | Total area at the end of the previous inventory year ⁽⁷⁾ |
|--|---------------------------------|---------------|----------------------------------|----------------------------------|--------------------------------------|---------------------------|---|----------------------|---|
| | 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) | | |
| | (kha) | | | | | | | | |
| Article 3.3 activities | | | | | | | | | |
| Afforestation and reforestation | 0.03 | NO | | | | | | | 0.03 |
| Deforestation | | 0.19 | | | | | | | 0.19 |
| Article 3.4 activities | | | | | | | | | |
| Forest management | | 0.01 | 6.18 | | | | | | 6.18 |
| 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 | 0.03 | 0.20 | 6.18 | NA | NA | NA | NA | NA | 6.41 |

⁽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 deforestation column and in the forest management row.

⁽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 reported under cropland management, grazing land management,

⁽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 in this matrix.

Table 11-3 KP(LULUCF) NIR 3 – Key Categories.

TABLE NIR 3. SUMMARY OVERVIEW FOR KEY CATEGORIES FOR LAND USE, LAND-USE CHANGE AND 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 | CO2 | -- | yes | | is key, level |
| Deforestation | CO2 | 4C2, 4E2 | yes | | is key, level & trend |
| Forest Management | CO2 | 4A1 | yes | | is key, level & trend |
| 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 CO₂ equivalent emissions (positive sign) and removals (negative sign) for activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol in 2015.

| Activity, year 2015 | Area kha | Net CO ₂ emission/removal kt CO ₂ | N ₂ O emission kt N ₂ O | Net CO ₂ eq emission/removal kt CO ₂ eq |
|----------------------------|-------------|---|--|---|
| A.1 Afforestation | 0.034 | -0.26 | NO | -0.26 |
| A.2 Deforestation | 0.188 | 4.51 | 0.00021 | 4.57 |
| B.1 Forest management (FM) | 6.176 | -0.46 | NO | -0.46 |
| 4.C HWP from FM | --- | -1.37 | NO | -1.37 |
| Total emission/removal | | 2.42 | 0.00021 | 2.48 |
| B.1.1 FMRL 2013-2020 | --- | | | 0.36 |

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 chp. 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 (including 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 m²) 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 chp. 6.2.1). 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 of deforestation

Deforestation is the permanent and direct human-induced conversion of areas fulfilling the definition of forest to areas not fulfilling the definition of forest. A conversion from forest land to non-forest land is according to IPCC (2014) also classified as deforestation if it is caused by natural processes and is followed by land use which prevents a re-establishment of forest.

Implementation

According to this definition, Liechtenstein calculates the area of deforestation as the sum of forest land converted to cropland, grassland, settlement or wetland according to the land-use changes observed in the AREA surveys (see chp. 6.2 and 6.3). For cropland, grassland and settlement (LULUCF categories 4B2, 4C2 and 4E2, respectively) it is obvious that the new land use prevents regeneration of forest. For the unmanaged wetlands (LULUCF category 4D2), this condition is not given but a human-induced disturbance cannot be excluded on the basis of the AREA data available so far.

The conversion of forest land to other land (LULUCF category 4F2) observed in the AREA surveys is non-anthropogenic and there is no human activity in the converted areas that would prevent a re-establishment of forest. This can be concluded from the data, definitions and processes used in AREA: Other land (CC61) is an area covered by rocks, sand, scree or glaciers. For distinguishing natural areas and human-influenced areas, the human interpreters of the aerial photographs also consider the spatial context of the neighbourhood. E.g., an area covered by scree is either reported as other land (CC61, e.g. a natural mountain slope) or as settlement (CC51 'buildings and construction', e.g. a gravel quarry) depending on the spatial context. Therefore the areas 'FL-OL' in 4F2 are not classified as deforestation.

Definition of the time interval for tracking deforestation

Harvesting or forest disturbance that is followed by the re-establishment of a forest is distinguished from deforestation as follows: If a re-establishment of forest occurs within six years after the observed loss of forest the loss is considered temporary (not permanent) and the land remains forest land. If there is no re-establishment of forest after six years the area is subject to deforestation.

Consistent application of the time interval for tracking deforestation

In this submission a provisional method for applying the time interval is used. In the next submission an improved method will be used fulfilling the requirements of the Expert Review Team (OE 2016d) as shown in chp. 11.1.5.

The provisional method can be described as follows: 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 six years later in the 2008 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 (defined by the time interval for tracking deforestation). The provisional correction for temporary loss of forest cover is calculated as a gross correction factor (0.94) which is multiplied with the FL-L areas of 4B2, 4C2, 4D2 and 4E2 for all years 1990-2015.

Further Comments:

Active measures leading to deforestation are 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.

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 m²; 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.

11.1.5 Planned improvements

According to the response to potential problems identified by the UNFCCC Expert Review Team (OE 2016d) the time interval for tracking deforestation was explicitly defined (6 years) and the definition of direct human-induced loss of forest (deforestation) was stated more precisely (see chp. 11.1.3.2).

In the next submission, the defined time interval for tracking deforestation will be implemented consistently in the calculation of emissions by deforestation. This will be done as follows:

Liechtenstein uses data from periodic aerial surveys (AREA) to determine the land-use change from forest to non-forest land. The results of five surveys are available that were realised in 1984, 1996, 2002, 2008 and 2014. A next survey may be expected in 2020. All surveys are based on the same spatial units so that between the surveys there is a consistent representation and tracking of lands (see chp. 6.3.2). After the last survey, land is tracked on a statistical basis.

Based on these data the area of temporary forest loss will be calculated at any point of time respecting the definition of the time interval (six years). I.e. for the period 1990-1996 deforestation will be calculated as yearly forest loss between the surveys 1984-1996 considering the portion of temporary loss, which will be derived from the results of the survey six years later (2002). The same procedure will be applied to the periods 1997-2002, 2003-2008 and 2009-2014. After 2014, land-use changes and temporary portion are extrapolated in time as long as no newer survey is available.

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 (16.054 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 chp. 6.3.

11.2.2.1 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 chp. 11.3.1.1. The changes in areas between the activities under Article 3, paragraph 3 and Article 3, paragraph 4 are listed in CRF-Table NIR-2 (see Table 11-2).

Forest areas under Forest Management are subdivided into productive forests (CC12) and unproductive forests (CC13; for a description see chp.6.4.2.4). Productive forests reveal a high heterogeneity in terms of elevation, growth conditions and tree species composition. 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) as shown in chp. 6.2.2. 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.

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).

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 chp. 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 chp. 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.

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.6.4.2.6. 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.6.1.3.2) 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 6-8). 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) 1990-2015. 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.

| Year | altitude zone | | | | cumulated | | |
|------|---------------|------|------|-------|------------|-----------|-------|
| | z1 | z2 | z3 | total | ≤ 20 years | >20 years | total |
| 1990 | 1.00 | 0.08 | 1.58 | 2.67 | 2.67 | | 2.67 |
| 1991 | 1.00 | 0.08 | 1.58 | 2.67 | 5.33 | | 5.33 |
| 1992 | 1.00 | 0.08 | 1.58 | 2.67 | 8.00 | | 8.00 |
| 1993 | 1.00 | 0.08 | 1.58 | 2.67 | 10.67 | | 10.67 |
| 1994 | 1.00 | 0.08 | 1.58 | 2.67 | 13.33 | | 13.33 |
| 1995 | 1.00 | 0.08 | 1.58 | 2.67 | 16.00 | | 16.00 |
| 1996 | 1.00 | 0.08 | 1.58 | 2.67 | 18.67 | | 18.67 |
| 1997 | 0.50 | 0.50 | 0.50 | 1.50 | 20.17 | | 20.17 |
| 1998 | 0.50 | 0.50 | 0.50 | 1.50 | 21.67 | | 21.67 |
| 1999 | 0.50 | 0.50 | 0.50 | 1.50 | 23.17 | | 23.17 |
| 2000 | 0.50 | 0.50 | 0.50 | 1.50 | 24.67 | | 24.67 |
| 2001 | 0.50 | 0.50 | 0.50 | 1.50 | 26.17 | | 26.17 |
| 2002 | 0.50 | 0.50 | 0.50 | 1.50 | 27.67 | | 27.67 |
| 2003 | 0.17 | 0.17 | 0.33 | 0.67 | 28.33 | | 28.33 |
| 2004 | 0.33 | 0.00 | 0.00 | 0.33 | 28.67 | | 28.67 |
| 2005 | 0.33 | 0.00 | 0.00 | 0.33 | 29.00 | | 29.00 |
| 2006 | 0.33 | 0.00 | 0.00 | 0.33 | 29.33 | | 29.33 |
| 2007 | 0.33 | 0.00 | 0.00 | 0.33 | 29.67 | | 29.67 |
| 2008 | 0.33 | 0.00 | 0.00 | 0.33 | 30.00 | | 30.00 |
| 2009 | 0.17 | 0.00 | 0.33 | 0.50 | 30.50 | | 30.50 |
| 2010 | 0.17 | 0.00 | 0.33 | 0.50 | 28.33 | 2.67 | 31.00 |
| 2011 | 0.17 | 0.00 | 0.33 | 0.50 | 26.17 | 5.33 | 31.50 |
| 2012 | 0.17 | 0.00 | 0.33 | 0.50 | 24.00 | 8.00 | 32.00 |
| 2013 | 0.17 | 0.00 | 0.33 | 0.50 | 21.83 | 10.67 | 32.50 |
| 2014 | 0.17 | 0.00 | 0.33 | 0.50 | 19.67 | 13.33 | 33.00 |
| 2015 | 0.17 | 0.00 | 0.33 | 0.50 | 17.50 | 16.00 | 33.50 |

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 chp.11.1.3.2).

The N₂O 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 chp. 6.4.2.3). For calculating the loss, annual harvesting statistics were used in addition to the NFI results (see Table 6-14 in chp. 6.4.2.3).

Carbon stocks in soil, litter and dead wood of productive forests (CC12) are assumed to be constant (see chp.6.4.2.8). On unproductive forest land (CC13), all carbon pools are constant (see chp.6.4.2.4).

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

CRF-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 ($-0.001 \text{ t C ha}^{-1} \text{ yr}^{-1}$) and that the changes in litter and dead wood fluctuate approximately between -0.1 and $0.1 \text{ t C ha}^{-1} \text{ yr}^{-1}$. Overall, these pools together were a sink for every year since 1997 (except in 2008 they were a small source of $0.01 \text{ t C ha}^{-1} \text{ yr}^{-1}$). 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 cap: The cap was recalculated based on the revised Initial Report (OE 2006, resubmission December 2016).
- Afforestation, Deforestation, Forest Management: The new AREA survey for the year 2014 was integrated in the calculations for interpolation and extrapolation of the activity data (chp. 6.3.5). This led to recalculations of areas for the years 2009-2014, as

the former extrapolation was replaced by an interpolation. Very small changes also occurred in the years 1990-2008.

11.3.2 Uncertainties and time-series consistency

11.3.2.1 Afforestation

AD uncertainty is calculated (as shown in chp. 6.3.3) combining the AREA-interpretation uncertainty (1.1% from 4A2, Table 6-9) and the sampling uncertainty (33.6% with a sample size of 33 ha-points): 33.6%.

EF uncertainty is 40.3% adopting the value of LULUCF category 4A2 (see chp. 6.4.3). The combined total uncertainty for afforestation is therefore 52.5%. Thus the net CO₂ removal by afforestation in 2015 is -0.26 ± 0.14 kt CO₂.

11.3.2.2 Deforestation

AD uncertainty is calculated (as shown in chp. 6.3.3) combining the AREA-interpretation uncertainty (5.2% from 4C2, Table 6-9) and the sampling uncertainty (14.3% with a sample size of 188 ha-points): 15.2%.

EF uncertainty is of 40.3% adopting the value of LULUCF category 4C2 (see chp. 6.6.3) as this is the main process for conversion of forest land. Therefore, the combined total uncertainty for deforestation is 43.1%. The net CO₂ emissions by deforestations in 2015 are 4.57 ± 1.97 kt CO₂eq.

11.3.2.3 Forest management

AD and EF uncertainties are adopted from LULUCF-category 4A1 (2.7% and 47.9%, respectively, see chp. 6.4.3). The combined uncertainty is 47.9%. The net emissions attributed to forest management in 2015 are -0.46 ± 0.22 kt CO₂.

11.3.2.4 Harvest wood products (HWP)

Uncertainty calculations for HWP are presented in chp. 6.11.3. The combined uncertainty is 75.8%. As result the total HWP removals in 2015 are -1.37 ± 1.04 kt CO₂.

11.3.2.5 Total combined uncertainty

The total uncertainty of emissions and sinks by afforestation, deforestation, forest management and HWP in 2015 is 2.24 kt CO₂eq. The net CO₂ emissions are therefore 2.48 ± 2.24 kt CO₂eq.

Time series are consistent.

11.3.3 Category-specific QA/QC and verification

In chp. 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 chp. 1.2.3.

11.4 Article 3.3. (Afforestation and Deforestation)

Figure 11-1 shows removals of CO₂ eq from Afforestations and emissions of CO₂ 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.

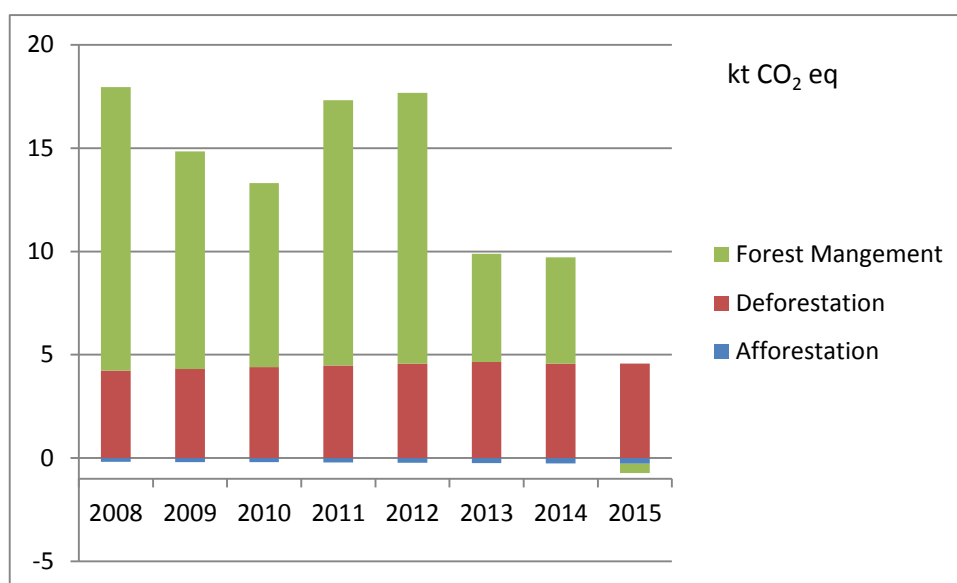


Figure 11-1 The CO₂ removals (negative sign) and emissions (positive sign) from Afforestation, Deforestation and Forest Management, 2008–2015, in kt CO₂ eq.

Since carbon from living biomass is immediately removed after clear-cutting, Deforestations can be considered as a “quick carbon-losing 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

11.4.1.1 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.

11.4.1.2 Afforestation

Liechtenstein is very restrictive in reporting Afforestations under the Kyoto Protocol and only reports planted or otherwise human-induced Afforestations (CC11). The annual rate of Afforestation since 1990 is assessed by AREA (see chp. 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.

11.4.1.3 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 chp. 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 chp. 11.1.3.2 where the temporary loss of forest cover by natural disturbance or management is estimated.

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 chp. 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 chp. 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 Deforestation under the Kyoto Protocol.

11.5 Article 3.4 (Forest Management)

Net CO₂ emissions from the Kyoto Protocol activity Forest Management for the years 2008 until 2015 are shown in Figure 11-1. Gains were adopted from Liechtenstein's NFI (see chp. 6.4.2.1) which covers the period 1998-2010. Losses were calculated with NFI-results and harvesting statistics (see chp. 6.4.2.3). In this period, cut and mortality was generally

higher than growth and therefore, Forest Management represents a carbon source in most years.

For the second commitment period the following specific information applies:

- Conversion of natural forests to planted forests is not applicable for Liechtenstein.
- Methodological consistency between the reference level and reporting for forest management is attained as described in chp. 11.7.
- Liechtenstein does not apply the provision of Carbon Equivalent Forests for emissions/removals from the harvest and conversion of forest plantations to non-forest land (decision 2/CMP.7, annex, paragraphs 37–39).

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 CRF-Table "accounting" (Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol).

11.6 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 chp. 1.5.1.2 and are displayed in Table 1-5 for the year 2015. The smallest UNFCCC category, considered key based on an approach 1 assessment is "1.A.3.b Road Transportation, CH₄" with a contribution of 0.10 kt CO₂ eq (share 0.0%).

The following LULUCF activities under the Kyoto Protocol are listed in Kyoto Table NIR-3 (Table 11-3):

- Afforestation and Reforestation (-0.26 kt CO₂ 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.
- Deforestation (4.57 kt CO₂ 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 (-0.46 kt CO₂ 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 (-1.37 kt CO₂ eq; Table 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
- 4A1 Forest Land remaining Forest Land: related to Forest Management
- 4G Harvested Wood Products (HWP): is the same as in KP-LULUCF.

For Liechtenstein, 4A2 (Land converted to Forest Land) is not quite well related to Afforestation because 4A2 is dominated by natural (not human-induced) conversions.

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 CO₂ 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 11-6):

- Wood harvesting; carbon stock changes in living biomass: The calculations by OEP (2011d) were based on a forest area of 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 11-6 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 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 6-7). This leads to a correction of the FMRL for this pool by 0.24 kt CO₂ eq yr⁻¹ (see Table 11-6). OEP (2011d) used a mean net decrease in growing stock of -0.232 m³ 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 CO₂/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 11-6).

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 (chp. 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 m³). With this production value the time series of gains and losses shown in chp. 6.11 were extended until 2020 (

Table 11-7). The resulting average CO₂ removal 2013-2020 is -1.18 kt CO₂ yr⁻¹, which was used to correct the FMRL (Table 11-6).

Table 11-7 Calculation of the annual CO₂ 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 CO₂ | -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 CO₂ | -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 CO₂ | -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 2015, no natural disturbances causing emissions exceeding the upper confidence interval (background level plus margin) occurred. Thus, no emissions from natural disturbances are excluded for 2015.

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 2015.

11.9 Harvested Wood Products (HWP)

11.9.1 General methodological issues

Methodology, estimates and uncertainties of carbon stock changes in the HWP pools are described in chp. 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 chp. 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.

11.9.2 Specific issues for the second commitment period

11.9.2.1 How emissions from the HWP pool accounted for in the first commitment period on the basis of instantaneous oxidation have been excluded

As shown in chp. 6.11.2 the methodology from the KP-Supplement (IPCC 2014) is used. Net CO₂ emissions and removals from HWP were reported for the first time in the Submission 2015. For calculating the HWP pool, only sawnwood with a half-live of 35 years was included. Thus, Liechtenstein implemented the Annex to decision 2/CMP.7 for the calculation of HWP with paragraph 16 stating: "Emissions from harvested wood products already accounted for during the first commitment period on the basis of instantaneous oxidation shall be excluded" from the accounting for the second commitment period.

11.9.2.2 How the HWP resulting from deforestation have been accounted on the basis of instantaneous oxidation

As shown in chp. 6.11.2 the calculation of the HWP pool is made only on the basis of Swiss activity data for sawnwood production (FOEN 2015) where the wood harvest from deforestation was excluded.

11.9.2.3 How CO₂ emissions from HWP in SWDS and from wood harvested for energy purposes have been accounted on the basis of instantaneous oxidation

There is no numerical input under "solid waste disposal" in Table4.Gs1. In chp. 6.11.2 it is stated that "the same methodology was used for reporting under the UNFCCC and

accounting under the KP for HWPs in Liechtenstein.” The HWP pool calculated for Liechtenstein only consists of sawnwood.

11.9.2.4 How emissions/removals from changes in the HWP pool accounted for do not include imported harvested wood products

As shown in chp. 6.11.2 the feedstock related to sawnwood was derived from the data reported by Switzerland where HWPs originating from import were excluded (FOEN 2015; chapter 6.11.2). Due to the customs union between Liechtenstein and Switzerland (chp. 1.4.1) there are no separate data related to import/export for Liechtenstein alone.

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

Annex I Parties are required to report their national registries' holdings and transactions of Kyoto units and inform about related issues as specified in Decision 15/CMP.1 Section E. The following chapters serve this purpose.

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, ICER and RMU) for 2016 were submitted together with this report (NIR 2015). Details are disclosed in the corresponding file RREG1_LI_2016_1_1.zip. 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: No discrepant transaction occurred in 2015. Therefore, no R-2 report was submitted .

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-confidential and publicly accessible on website

<https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml>.

| | |
|--|---|
| <p>13/CMP.1 annex II paragraph 45</p> <p>Account information</p> | <p>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</p> <p>The data of all accounts can be viewed online at: https://ets-registry.webgate.ec.europa.eu/euregistry/LI/public/reports/publicReports.xhtml</p> <p>Representative name and contact information is classified as confidential due to Article 83 paragraph 8 and 9 Registry Regulation No. 1193/2011.</p> |
| <p>13/CMP.1 annex II paragraph 46</p> <p>Joint implementation project information</p> | <p>This information is available on the website: http://www.llv.li/#/12414</p> |
| <p>13/CMP.1 annex II paragraph 47</p> <p>Unit holding and transaction information</p> | <p>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.</p> <p>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</p> <p>(b) In 2015 there was no issuance of AAU.</p> <p>(c) In 2015 no ERUs were issued.</p> <p>(e) No RMUs were issued for the reporting year 2015 in 2016. For the current reporting year, no verified units for issuance RMUs are available at the time of submission.</p> <p>(g) No RMUs were cancelled on the basis of activities under Article 3, paragraph 3 and 4 in the reported year.</p> <p>(h) No ERU, CER, AAU and RMU were cancelled on the basis of</p> |

| | <p>activities under Article 3, paragraph 1 in the reported year.</p> <p>(i) In 2016, no AAU, no ERU and no CER were voluntary cancelled. No RMU was cancelled.</p> <p>(j) In 2016, no ERUs, no CERs, no AAUs, and no RMUs, no tCER, no ICER were retired.</p> <p>(k) There was no actual carry over of ERU, CER, AAU or RMU from the previous commitment period. The planned carry-over will include 42'984 AAUs.</p> | | | | | | | | | | | | | | |
|---|---|--|--|-----|------------------------|-----|---|-----|---|-----|-----------------------------|------|-----------------------------|------|-----------------------------|
| <p>13/CMP.1 annex II paragraph 48</p> <p>Authorized legal entities information</p> | <p>The following legal entities are authorized by the Member State to hold Kyoto units:</p> <table border="1"> <thead> <tr> <th></th> <th>Legal entities authorised by Liechtenstein to hold units</th> </tr> </thead> <tbody> <tr> <td>AAU</td> <td>Federal Government, TA</td> </tr> <tr> <td>ERU</td> <td>Each account holder of OHA, PHA, TA and NHA</td> </tr> <tr> <td>CER</td> <td>Each account holder of OHA, PHA, TA and NHA</td> </tr> <tr> <td>RMU</td> <td>Federal Government only, TA</td> </tr> <tr> <td>tCER</td> <td>Federal Government only, TA</td> </tr> <tr> <td>ICER</td> <td>Federal Government only, TA</td> </tr> </tbody> </table> <p>OHA: Operator Holding Account (installation and aircraft)</p> <p>PHA: Person Holding Account</p> <p>TA: Trading Account</p> <p>NHA: National Holding Account</p> | | 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 | ICER | Federal Government only, TA |
| | 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 | | | | | | | | | | | | | | |
| ICER | 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>). This information comprises names 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 competitiveness. 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 cannot 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 | Total emissions with LULUCF in 2013 times eight |
| [t CO ₂ equivalent] | [t CO ₂ equivalent] |
| $1'570'840 \times 90/100 = 1'413'756$ | $246'625 \times 8 = 1'973'000$ |

Accordingly, a commitment period reserve of **1'413'756 t CO₂ equivalent (1'413.756 kt CO₂ equivalent)** results for Liechtenstein.

12.6 KP-LULUCF Accounting

Information on the accounting of the KP-LULUCF will be included in Liechtenstein's National Inventory Report 2016.

13. Information on Changes in National System

The National System remained unchanged for the inventory cycle leading to the submission 2017. After uniquely adapting the schedule of the National System due to the implementation of the IPCC 2006 Reporting Guidelines (IPCC 2006), the schedule is now again as it was in submission 2014 and earlier (compare chp. 1.2.2, Table 1-1).

14. Information on Changes in National Registry

Directive 2009/29/EC was adopted in 2009 and 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.

Thus, the following changes to Liechtenstein's national registry have 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 | None. |
| 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 | <p>New tables were added to the CSEUR database for the implementation of the CP2 SEF functionality.</p> <p>Versions of the CSEUR released after 6.7.3 (the production version at the time of the last Chapter 14 submission) introduced other minor changes in the structure of the database.</p> <p>These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model, including the new tables, is provided in Annex A.</p> <p>No change to the capacity of the national registry occurred during the reported period.</p> |

| Reporting Item | Description |
|---|--|
| <p>15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards</p> | <p>Changes introduced since version 6.7.3 of the national registry are listed in Annex B.</p> <p>Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). Annex H testing was completed in January 2017 and the test report is provided.</p> <p>No other change in the registry's conformance to the technical standards occurred for the reported period.</p> |
| <p>15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures</p> | <p>No change of discrepancies procedures occurred during the reported period.</p> |
| <p>15/CMP.1 annex II.E paragraph 32.(f) Change regarding security</p> | <p>The mandatory use of hard tokens for authentication and signature was introduced for registry administrators.</p> |
| <p>15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information</p> | <p>No change to the list of publicly available information occurred during the reporting period.</p> |
| <p>15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address</p> | <p>No change of the registry internet address occurred during the reporting period.</p> |
| <p>15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures</p> | <p>No change of data integrity measures occurred during the reporting period.</p> |
| <p>15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results</p> | <p>Changes introduced since version 6.7.3 of the national registry are listed in Annex B. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as Annex B.</p> <p>Annex H testing was carried out in January 2017 and the test report is provided.</p> |

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 responding 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, one has to have in mind that Liechtenstein is a very small country (160 km²) 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 CO₂ 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.

In 2015 the Government that Liechtenstein will aim at a reduction of greenhouse gases by 40 % compared to 1990 by 2030. The assumptions underlying this reduction target are based on the possibility to achieve emission reductions abroad which may be accounted towards Liechtensteins reduction target in 2030. However, primary focus will be given on domestic emission reductions. In order to minimize adverse impacts related with the possibility to reduce part of its reduction target abroad the Government also decided on certain quality conditions that hat to be met to that respect. Emission reductions which have been realized by Liechtenstein outside its territory therefore have to prove added ecological value, need to demonstrate social and ethical eligibility towards the people of the host country. In addition to that projects that lead to these emission reductions have to be in line with the principles of the International Humanitarian Cooperation and Development (IHZE) as contained in Art. 1 of the IHZE Act.

These Conditions have been passed by the Governement within its revised Climate Strategy of October 2015 (Government 2015).

16. Other Information

There is no other information to be reported.

Annexes to the National Inventory Report

Annex 1: Key categories

All relevant information regarding the key category analysis is given in chp. 1.5.

Annex 2: Detailed discussion of methodology and data for estimating CO₂ emissions from fossil fuel combustion

No supplementary information.

Annex 3: Other detailed methodological descriptions for individual source or sink categories

A3.1 Road Transportation

Chapter 3.2.7.2 states that the of 1A3b Road transportation emissions are calculated with a Tier 2 method using Swiss implied emission factors. For CH₄ and N₂O, the country-specific implied emission factors of the Swiss GHG inventory are applied. Here some information concerning the modelling approach are provided:

The emission computation is based on two sets of data (FOEN 2010):

- Emission factors: specific emissions in grams per activity data unit.
- Traffic activity data: vehicle kilometres travelled (hot emissions), number of starts/stops and vehicle stock (cold start, evaporation emissions and running losses) or fuel consumption per vehicle category.

Emission modelling consists of three parts:

- hot emissions: $E_{hot} = VKT \cdot EF_{hot}$
- start emissions: $E_{start} = N_{start} \cdot EF_{start}$
- evaporative emissions: $E_{evap,i} = N_{evap,i} \cdot EF_{evap,i}$

with

- $EF_{hot}, EF_{start}, EF_{evap}$: Emission factors for ordinary driving conditions (hot motor), cold start and evaporative (VOC) emissions (after stops, running losses, diurnal losses)
- VKT : Vehicle km travelled
- N_{start} : Number of starts
- i runs over three evaporation categories: stops, running losses, diurnal losses
- $N_{evap,i}$: Number of stops (i = "after stops") or number of vehicles (i = "running losses" and "diurnal losses")

Emission factors for all other gases than CO₂ and SO₂ 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 “Handbook of Emission Factors for Road Transport” (see INFRAS 2010, TUG 2009). Version 3.1 is presented and documented on the website <http://www.hbefa.net/>. The general emission factor methodology is documented in TUG (2009). The resulting emission factors are published on CD ROM (“Handbook of emission factors for Road Transport”, INFRAS 2010). They refer to the so-called “traffic situations”, which represents characteristic patterns of driving behaviour and which serve as a key to the disaggregation of the activity data. 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.

A3.2 Enteric Fermentation

Emissions of agricultural activities are estimated according to the model in the Swiss National Inventory (FOEN 2016). Detailed data for estimating emission factors within category 3A Enteric Fermentation in submission 2016 are depicted in the annex of Switzerland’s NIR in tables A-22 and A-25 (FOEN 2016). Find a copy of these tables below.

Table A - 1 Data for estimating enteric fermentation emission factors for cattle. Taken from FOEN 2016.

| Type | Age ^a | Weight ^a kg | Weight Gain ^a kg/day | Feeding Situation / Further Specifications | Milk ^b kg/day | Work hrs/day | Pregnant ^a % 305 days of lactation | Digestibility of Feed % ^d | Y _m ^d % | Em. Factor kg/head/year ^e |
|--------------------------------|------------------|---------------------------|------------------------------------|---|-----------------------------|-----------------|--|---|----------------------------------|---|
| Mature Dairy Cattle | NA | 650 | 0 | | 16.1-22.6 ^c | 0 | | 72 | 6.90 | 135.69 |
| Other Mature Cattle | NA | 550 | 0 | | 8.2 | 0 | | 60 | 6.50 | 87.43 |
| Fattening Calves | 0-98 days | 60-200 | 1.43 | Rations of unskimmed milk and supplement feed when life weight exceeds 100 kg. Rations are apportioned on two servings per day. | 0 | 0 | 0 | 65 | 0.00 | 0.00 |
| Pre-Weaned Calves | 0-10 month | 60-325 | 1 | "Natura beer" production, milk from mother cow and additional feed. | 0 | 0 | 0 | 65 | 6.50 | 19.53 |
| Breeding Calves | 0-4 month | 50-120 | 0.8 | Feeding plan for a dismission with 14 to 15 weeks. Milk, feed concentrate (100kg in total), hay (80 kg in total). | 0 | 0 | 0 | 65 | 6.50 | 28.80 |
| Breeding Cattle (4-12 months) | 4-12 month | 120-300 | 0.8 | Premature race (Milk-race) | 0 | 0 | 0 | 60 | 6.50 | |
| Breeding Cattle (> 1 year) | 12-28/30 month | 300-600 | 0.8 | Premature race (Milk-race) | 0 | 0 | 0 | 60 | 6.50 | 55.03 |
| Fattening Calves (0-4 months) | 0-4 month | 70-175 | 0.86 | Diet based on milk or milk-powder and feed concentrate, hay and/or silage | 0 | 0 | 0 | 65 | 6.50 | |
| Fattening Cattle (4-12 months) | 4-12 month | 175-550 | 1.3 | Feeding recommendations for fattening steers, concentrate based | 0 | 0 | 0 | 60 | 6.50 | 44.18 |

a Data source: RAP 1999 and calculations according to Soliva 2006.

b Milk production in kg/day is calculated by dividing the average annual milk production per head by 305 days (lactation period).

c data source: Swiss farmers union (SBV 2014).

d data source: IPCC 2006 and Zeitz et al. 2012.

e For better comparability emission factors of young cattle were converted to kg/head/year although the time span of most of the individual categories is less than 365 days.

Table A - 2 Data for estimating manure management CH₄ emission factors. Taken from FOEN 2016.

| Type | Weight kg ^a | Digestibility of Feed % ^b | Energy Intake MJ/day | Feed Intake kg/day | % Ash Dry Basis ^b | VS kg/head/day | B ₀ m ³ CH ₄ /kg VS ^b |
|--------------------------------|---------------------------|---|-------------------------|------------------------|---------------------------------|-------------------|--|
| Mature Dairy Cattle | 650 | 72 | 259 - 301 | 15.89 ^c | 8.9 - 9.1 | 4.08 - 4.79 | 0.24 |
| Other Mature Cattle | 550 | 60 | 205.1 | 10.96 ^c | 8 | 4.50 | 0.18 |
| Fattening Calves | 60 – 200 | 65 | 47.6 | 2.02 ^a | 8 | 0.93 | 0.18 |
| Pre-Weaned Calves | 60 – 325 | 65 | 55.7 | 2.98 ^a | 8 | 1.08 | 0.18 |
| Breeding Calves | 50 – 120 | 65 | 26.9 | 1.5 ^a | 8 | 0.52 | 0.18 |
| Breeding Cattle (4-12 months) | 120 – 300 | 60 | 89.2 | 4.88 ^a | 8 | 1.96 | 0.18 |
| Breeding Cattle (> 1 year) | 300 – 600 | 60 | 129.1 | 7.78 ^a | 8 | 2.83 | 0.18 |
| Fattening Calves (0-4 months) | 70 – 175 | 65 | 55.6 | 3.27 ^a | 8 | 1.08 | 0.18 |
| Fattening Cattle (4-12 months) | 175 – 550 | 60 | 124.6 | 6.82 ^a | 8 | 2.73 | 0.18 |
| Sheep | Not determined | 60 | 21 - 24 | 1.09-1.24 ^c | 8 | 0.4 ^b | 0.19 |
| Goats | Not determined | 60 | 25 - 28 | 1.21-1.26 ^c | 8 | 0.3 ^b | 0.18 |
| Horses | Not determined | 70 | 107 - 108 | 7.73-7.83 ^c | 4 | 1.72 ^b | 0.33 |
| Mules and Asses | Not determined | 70 | 39 - 40 | Not estimated | 4 | 0.94 ^b | 0.33 |
| Swine | Not determined | 75 | 26 - 32 | Not estimated | 2 | 0.31 ^b | 0.45 |
| Poultry | Not determined | Not estimated | 1.2 - 1.6 ^d | Not estimated | Not estimated | 0.01 ^b | 0.37 |

a RAP 1999

b IPCC 1997c and IPCC 2006

c Flich et al. 2009

d metabolizable energy (ME)

A3.3 2F Product uses as ODS substitutes and 2G N₂O from Product use

Emissions of F-gases from source category 2F and N₂O emissions from source category 2G are calculated based on specific emission factors derived from emissions reported in Switzerland's GHG inventory (FOEN 2016) and conversion factors that are derived from proxy data, such as number of households, passenger cars, inhabitants and employees in the second and third sector (see Table 4-6 and Table 4-7). The conversion factors shown in Figure A - 1 correspond to the ratio of these proxy data between Liechtenstein and Switzerland. So if the relative increase in Liechtenstein's and Switzerland's proxy data is identical, the conversion factor remains constant. If the increasing trend in Switzerland is stronger as compared to Liechtenstein (e.g. number of passenger cars 2005-2006), the conversion factor is reduced. Therefore, the resulting trend in emissions is not directly proportional to the trend in the emissions reported in the Swiss GHG inventory (FOEN 2016).

Therefore, the overall trend depends on both the evolution of these conversion factors as well as evolution of emissions of F-gases in Switzerland (FOEN 2016).

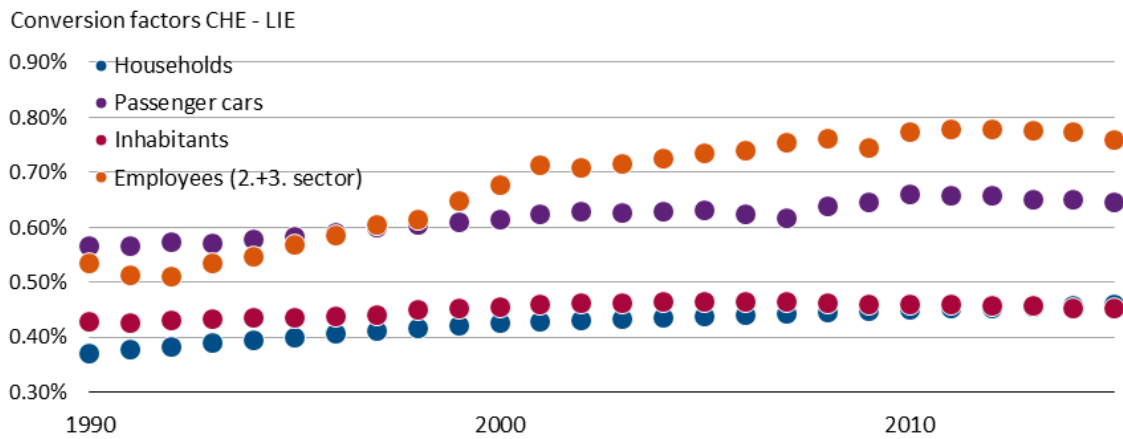


Figure A - 1 Conversion factors used to derive emissions in Liechtenstein from emissions reported in Switzerland's national GHG inventory.

Annex 4: CO₂ 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.

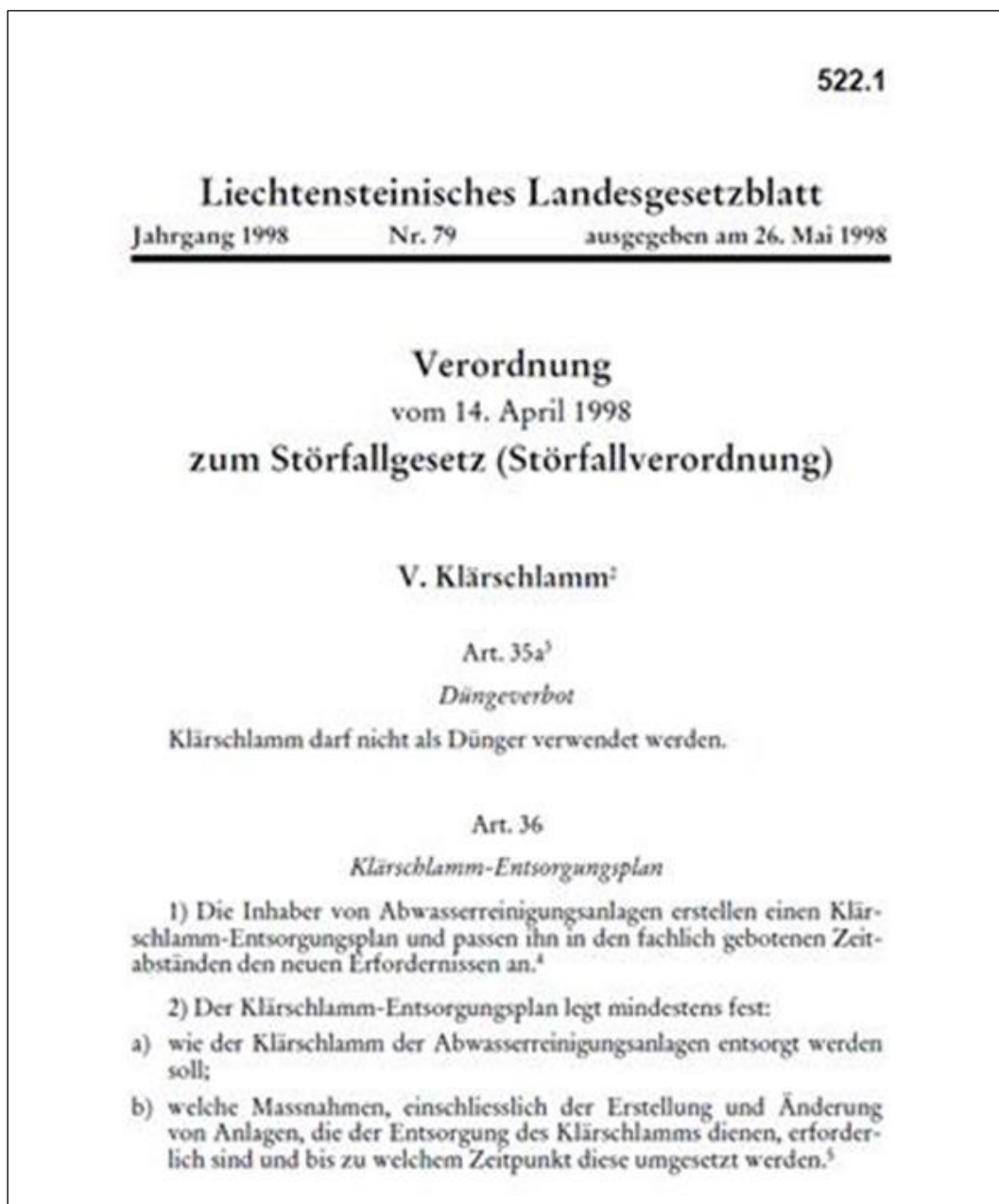
Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

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 fertiliser is prohibited in Liechtenstein. The corresponding regulation (in German only) is given below:



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:

$$U_{\%,EF} = \sqrt{\sum_i (Em_{\%,i} * U_{\%,EF,i})^2} \quad (1) \quad \text{error propagation for emission factors}$$

$$U_{\%,AD} = \sqrt{\sum_i (Em_{\%,i} * U_{\%,AD,i})^2} \quad (2) \quad \text{error propagation for activity data}$$

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 - 3.

Table A - 3 Aggregation with Gaussian error propagation for the five relevant key categories.

| 1A3b CO₂ | (Sub)Categories | | Aggr. Uncertainties |
|---|------------------------|---------------|----------------------------|
| | <i>gasoline</i> | <i>diesel</i> | <i>total/implied</i> |
| U _% Emissions | 10.0% | 15.0% | 9.0% |
| U _% Activity Data | 10.0% | 15.0% | 9.0% |
| U _% Emission Factor | 0.1% | 0.1% | 0.1% |
| 1A3b CH₄ | (Sub)Categories | | Aggr. Uncertainties |
| | <i>gasoline</i> | <i>diesel</i> | <i>total/implied</i> |
| U _% Emissions | 60.0% | 60.0% | 58.0% |
| U _% Activity Data | 10.0% | 15.0% | 9.7% |
| U _% Emission Factor | 59.2% | 58.1% | 57.2% |
| 1A4 Liquid fuels CO₂ | (Sub)Categories | | Aggr. Uncertainties |
| | <i>1A4a</i> | <i>1A4b</i> | <i>total/implied</i> |
| U _% Emissions | 20.0% | 20.0% | 15.8% |
| U _% Activity Data | 20.0% | 20.0% | 15.8% |
| U _% Emission Factor | 0.1% | 0.1% | 0.1% |
| 1A4 Gaseous fuels CO₂ | (Sub)Categories | | Aggr. Uncertainties |
| | <i>1A4a</i> | <i>1A4b</i> | <i>total/implied</i> |
| U _% Emissions | 5.1% | 5.1% | 3.9% |
| U _% Activity Data | 5.0% | 5.0% | 3.9% |
| U _% Emission Factor | 1.1% | 1.1% | 0.9% |
| 1A4 Biomass CH₄ | (Sub)Categories | | Aggr. Uncertainties |
| | <i>1A4a</i> | <i>1A4b</i> | <i>total/implied</i> |
| U _% Emissions | 30.0% | 30.0% | 28.8% |
| U _% Activity Data | 20.0% | 20.0% | 19.2% |
| U _% Emission Factor | 22.4% | 22.4% | 21.5% |

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 - 4 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 Schättli, BRI Beat Rihm, FEW Felix Weber, HE Hanspeter Eberle, HK Helmut Kindle, HS Heike Summer, JB Jürgen Beckbissinger, JH Jürg Heldstab, MSM Markus Sommerhalder, SB Sven Braden.

| Quality Control System for Climate Reporting Liechtenstein Submission 2017 | | | | |
|--|--|-------------------|----------|---------|
| 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 documented | Acontec-internal checks, comparison with methods chosen | SE/NIC | 25.10.16 | JB, HK |
| | INFRAS-internal checks, comparison with methods chosen | NA | 18.11.16 | JH |
| 2. Check for transcription errors in data input and reference | plausibility check of the basic input data for Solvent and Ind calculation | SE | 27.10.16 | JB |
| | plausibility check of the basic input data from the LWA | SE | 01.11.16 | JB |
| | check input Data for SF6 Emission calculation | SE | 02.11.16 | JB |
| | check stationary Energy | NA | 24.11.16 | BES |
| | check IPPU | NA | 25.11.16 | BES |
| | check Waste | NA | 24.11.16 | MSM |
| | Agriculture: Plausibility check of data in background tables Acontec. Issues identified and discussed with Acontec | SE | 23.11.16 | FEW, JB |
| 3. Check that emissions are calculated correctly | Ongoing checks of the calculated emissions in all sectors | SE | 14.11.16 | JB |
| | Clarification of data/figures | PM | 23.11.16 | BES, JH |
| | INFRAS-internal control: Plausibility checks, "Delta-Analysis" combined with KCA, INFRAS-internal control of time series | NA | 24.11.16 | JH |
| | INFRAS-internal checks during generation of tables/figure in Chapter. 2 Trends (independent control by second person JH) | SE | 18.11.16 | 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 | 19.11.16 | JB |
| | check energy-activity-data (reference approach) | NA | 24.11.16 | BES |
| | check Energy | SE | 19.11.16 | JB |
| | check Energy | NA | 24.11.16 | BES |
| | check IPPU | SE | 14.11.16 | JB |
| | check IPPU | NA | 25.11.16 | BES |
| | check Agriculture | SE | 16.11.16 | JB |
| | check Agriculture | NA | 23.11.16 | FEW |
| | check LULUCF | SE | 17.11.16 | JB |
| | check LULUCF | NA | 30.11.16 | BRI |
| | check Waste | SE | 29.11.16 | JB |
| | check Waste | NA | 06.12.16 | MSM |
| | check KP-LULUCF | SE | 10.04.17 | HS |
| | check KP-LULUCF | NA | 06.01.17 | BRI |

Continued on next page

| | | | | |
|---|---|----------------|--------------------------|----------------------------|
| 5. Check the integrity of database | integrity checked | SE | 22.11.16 | JB |
| 6. Check for consistency in data between source categories | check general data consistency | SE | 24.11.16 | JB |
| | check Energy (stationary) | NA | 28.11.16 | BES |
| | check Energy (mobile) | NA | 28.11.16 | BES |
| | check IPPU | NA | 29.11.16 | BES |
| | check Agriculture | NA | 23.11.16 | JH |
| | check LULUCF | NA | 30.11.16 | BRI |
| | check Waste | NA | 29.11.16 | MSM |
| 7. Check that the movement of inventory data among processing steps is correct | check KP-LULUCF | NA | 06.01.17 | BRI |
| | Processing checked | NIC | 27.03.17 | HK |
| | Data transfer from the land-use statistics to the LULUCF tables and clarification of comprehensive questions with JB | SE | 23.11.16 | HS |
| | check Agriculture | SE | 14.11.16 | JB |
| | plausibility check / control of overall emissions from agriculture in CO2 equivalents, in total and for the source categories for all years | SE | 14.11.16 | JB |
| 8. Check that uncertainties in emissions and removals are estimated or calculated correctly | check LULUCF | SE | 10.04.17 | HS |
| | check Energy | NA | 12.12.16 | JH, FEW |
| | check IPPU | NA | 12.12.16 | JH, FEW |
| | check Agriculture | NA | 13.12.16 | JH, FEW |
| | check Waste | NA | 12.12.16 | MSM, FEW |
| 9. Check time series consistency | check (KP-)LULUCF | SE | 12.12.2016 (09.01.17) | BRI |
| | check for temporal consistency in time series input data for each category. | NIC | 29.11.16 | JB |
| | check in the algorithm/method used for calculations throughout the time series. | NIC | 29.11.16 | JB |
| | check methodological and data changes resulting in recalculations. | NA | 05.12.16 | JH, BES |
| 10. Check completeness | check that the effects of mitigation activities have been appropriately reflected in time series calculations. | NIC | 27.3.2017/10 .04.2017 | HK, HS |
| | Completeness check for all sectors | SE | 07.11.16 | JB |
| 11. Trend checks | Completeness check for all sectors | NA | 17.11.16 | JH |
| | 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 errors. | NIC/SE/NA | 18.11.16 | JB, JH, FEW, BES, MSM, BRI |
| | Check value of implied emission factors across time series. | NIC | 27.03.17 | HK |
| 12. Review of internal | Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series. | NIC/SE | 18.11.16 | JB, JH, FEW, BES, MSM, BRI |
| | Internal OE check of documentation; Clarification of open questions with SE | PM/PMA | 10.04.17 | HS |
| Further (country-specific) activities | Procedure | Respon- | Date | Visa |
| 13. Compare estimates for key categories to previous estimates | check of KCA previous/latest key categories | SE | 01.12.16 | BES |
| 14. Compare CRF tables with previous year | check Energy | NA | 31.11.16 | JH/BES |
| | check IPPU | NA | 01.12.16 | BES |
| | check Agriculture | NA | 18.11.16 | FEW |
| | check Waste | NA | 24.11.16 | MSM |
| | check LULUCF | NA | 30.11.16 | BRI |
| | check KP-LULUCF | NA | 06.01.17 | 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 | 31.03.17 | AG |
| | check: Energy (stationary) | NA | 02.12.16 | BES |
| | check: Solvents | NA | 02.12.16 | BES |
| | Clarification of comprehensive questions in different sectors with SE | PM/NA | 10.04.17 | HS |
| | Two independent checks of Energy (mobile) | SE | 05.12.16 | BES, JH |
| | check waste | NA | 06.12.16 | MSM |
| | check Agriculture | SE | 22.11.16 | FEW |
| 16. Where LIE uses Swiss-specific EF: Where changes in the Swiss EF occur, check whether the changes are also adequate for LIE | check LULUCF | SE | 22.12.16 | BRI |
| | Clarify the changes of emission factors in IPPU and Agriculture | SE | 05.12.16 | BES |
| 17. Check correctness of KCA, comparison with previous results | Plausibility checks of KCA | PM | 06.04.17 | 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 | 23.12.16 | JH |

Continued on next page

| | | | | |
|---|--|---------------|------------------------------------|--------------|
| 18. Check correctness of uncertainty analysis, comparison with previous results | internal plausibility checks for all sectors | NA | 20.12.16 | FEW, JH |
| | internal plausibility checks for KP-LULUCF | NA | 09.01.17 | BRI, JH |
| 19. Check of transcription errors CRF --> NIR (numbers, tables, figures) | INFRAS internal plausibility checks | NA | 06.12.16 | BES/JH |
| | check waste | NA | 20.12.16 | 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 | 21.12.16; 22.12.16; 23.12.16 | JH, FEW, BES |
| 20. Check AD in NIR and CRF and compare data with reference data sources | check waste | NA | 20.01.17 | MSM |
| 21. Check for complete and correct references in NIR | INFRAS-internal checks | NA | 04.04.17 | JH |
| 22. Check for correctness, completeness, transparency and quality of NIR | Proofread of complete draft NIR | NA | 11.04.17 | JH |
| | final proofread Executive Summary, feedback to HS | NFP | 27.03.17 | HK |
| | final proofread inventory/NIR, feedback and discussion with HS | QM | 31.03.17 | AG |
| | final proofread inventory/NIR, discussion with JH and JB | PM | 06.04.17 | HS |
| | final proofread inventory/NIR, feedback to HS | PMA | 31.03.17 | SB |
| | final proofread inventory/NIR, feedback to HS | SC | 20.09.16 | HE |
| | Internal OE discussions on the inventory/NIR draft with AG,SB, HE and HS | PM/PMA | 06.04.17 | HS |
| | Feedback from OE internal discussions | PM/PMA | 06.04.17 | HS |
| | Final proofreading inventory/NIR | PM/PMA | 10.04.17 | HS |
| 23. Check for completeness of submission documents | Final check and Submission | PM/NIC NFP | 13.04.17 | 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 | 13.04.17 | JH, BRI |
| | Internal Review of documents submitted in April 2017; all relevant documents archived | NIC | 12.04.17 | JB |

A8.2 Checklists for QA activities (internal review)

Table A - 5 Checklists for QA activity internal review.

Liechtenstein's National Inventory Report Review form for internal review of NIR submission 2016

| | |
|---------------------|-----------------------|
| Reviewer | Helmut Kindle |
| Institution | Office of Environment |
| phone | +423 236 61 97 |
| e-mail | helmut.kindle@llv.li |
| Chapter(s) reviewed | ES, Ch. 1 |

| | |
|---------------|--|
| NIR author | Juerg Heldstab |
| Institution | INFRAS |
| phone | +41 44 205 95 11 |
| phone, e-mail | juerg.heldstab@infrass.ch |

Reviewer's comments yellow und answers of authors (green)

Please cross-check consistency between CRF tables and text in NIR

done

Reviewers comments performed

Date / Signum 21.3.2017 / HK

Taken note of review

Date / Signum 23.3.2017 / JH

If necessary: Additional comments of reviewer (yellow) and author's answers

Datum / Signum 27.3.2017/KIHE

Review form for internal review of NIR submission 2016

| | |
|---------------------|------------------------|
| Reviewer | Andreas Gstöhl |
| Institution | Office of Environment |
| phone | +423 236 61 86 |
| e-mail | andreas.gstoehl@llv.li |
| Chapter(s) reviewed | ES, CH 1 |

| | |
|---------------|--|
| NIR author | Juerg Heldstab (JH) |
| Institution | INFRAS |
| phone | +41 44 205 95 11 |
| phone, e-mail | juerg.heldstab@infras.ch |

Reviewer's comments yellow und answers of authors (green)

ES.4. Other information: updated information for the 2017 submission

done

Reviewers comments performed

Date / Signum 31.03.2017 / Andreas Gstöhl

Taken note of review

Date / Signum 3.4.2017 / JH

If necessary: Additional comments of reviewer (yellow) and author's answers

Datum / Signum 5.4.2017 / Andreas Gstoehl

Liechtenstein's National Inventory Report Review form for internal review of NIR submission 2017

| | |
|---------------------|-----------------------|
| Reviewer | Heike Summer |
| Institution | Office of Environment |
| phone | +423 236 61 96 |
| e-mail | heike.summer@llv.li |
| Chapter(s) reviewed | all |

| | |
|---------------|--|
| NIR authors | Juerg Heldstab, Felix Weber, Bettina Schaeppi |
| Institution | INFRAS |
| phone | +41 44 205 95 11 |
| phone, e-mail | juerg.heldstab@infras.ch |

Reviewer's comments yellow und answers of authors (green)

Please check data from CRF Tables with data in NIR. Check if reporting year is updated. Check all tables for rounding errors.

done

Reviewers comments performed

Date / Signum 10.04.2017 / Heike Summer

Taken note of review

Date / Signum 11.-12.4.2017 / JH, FEW, BES

If necessary: Additional comments of reviewer (yellow) and author's answers

| |
|--|
| |
| |
| |

Datum / Signum 12.4.2017 / Heike Summer

A8.3 Inventory development plan submission 2017

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, FCCC/ARR/2013/LIE, FCCC/ARR/2014/LIE and FCCC/ERT/2016/LIE resulting from the Centralized Reviews in 2007, 2009, 2010, 2011, 2012, 2013, 2014 and 2016.

The IDP summarizes the recommendations and planned improvements and illustrates the implementation status of those. The meanings of the headers are shown on this page.

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 (according 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.

Table A - 6 Inventory development plan for Liechtenstein's greenhouse gas inventory 2017.

| IDP No. | Recommendations/Planned improvements | Reference | Status | Comment/Reason NIR | Sector |
|---------|---|----------------------------------|--------------------------------|---|----------------------|
| 5 | Conduct internal review complemented with systematic external review. | Review 2013 | Ongoing implementation | 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 sufficiently assured. The party is continuously trying to improve internal review procedures. | Cross-cutting Issues |
| 6 | Complete CRF table 2(II)s2 | ARR 2013 / 41 | will not be implemented | Liechtenstein only reports actual emissions. | 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 | Ongoing implementation | The party will check how systematic additional quality control procedures can be implemented for future submissions and is continuously improving QC procedures. | 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 | Ongoing implementation | The party will check how systematic additional quality control procedures can be implemented for future submissions and is continuously improving existing QC procedures. | Cross-cutting Issues |
| 24 | Implement additional QC procedures to avoid mistakes or discrepancies between the CRF tables and the NIR. | ARR 2013 / 21 | Ongoing implementation | The party will check how systematic additional quality control procedures can be implemented for future submissions and is continuously improving existing QC procedures. | Energy |
| 25 | Report lubricants and bitumen activities in CRF tables 1.A(b) and 1.A(d). | ARR 2013 / 26; Table 5 | Ongoing implementation | The party does not report indirect emissions, therefore Bitumen activities are not reported. There are no refining activities in Liechtenstein. So far, Lubricants are reported only for two stroke engines. Other uses of lubricants are not reported. Liechtenstein will examine, whether other relevant lubricants can be calculated based on data available in the Swiss GHG inventory. | Energy |
| 26 | Report secondary fuels consumed in the country and complete the lubricants and bitumen AD in the CRF tables. | ARR 2013 / 27 | Ongoing implementation | The party does not report indirect emissions, therefore Bitumen activities are not reported. There are no refining activities in Liechtenstein. So far, Lubricants are reported only for two stroke engines. Other uses of lubricants are not reported. Liechtenstein will examine, whether other relevant lubricants can be calculated based on data available in the Swiss GHG inventory. | 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 | Planned improvement for 2018 | The share of biofuel is identical to the share of biofuel reported by Switzerland. LIE will apply the same shares as Switzerland. | Energy |
| 31 | An error occurred within Table 1.A(a)s3. Emission factors for biomass concerning CO ₂ , CH ₄ and N ₂ O are overestimated for the years 2013 and 2014 (see IDP in Annex 8). According to Liechtenstein's inventory development plan no future improvements are planned under source-category 1A3. | Internal decision | Implemented in submission 2017 | Error was corrected for submission 2017 | Energy |
| 50 | Please clarify why feeding situation and work cells in CRF table 4A are filled by notation key NE. In accordance with p. 4.12 of GPG 2000 animals grazing large areas expend significant energy to acquire feed. So net energy for animal activity depending on feeding situation should be considered when estimating GE using country-specific approach. Additional energy is required for drafting animals as well. If drafting animals are not occur in Liechtenstein may be it is relevant to use notation key NA instead of NE? | Review 2014 | Implemented in submission 2017 | According to the Office of Environment no draft animals occur in Liechtenstein. The specific notation key will be set to NA. The feeding situation is not used in the emission calculation model and are therefore not applicable. The values for the feeding situation in CRF Table3.As2 cannot be changed to NA because the CRF reporter sets the notation key itself. | Agriculture |
| 52 | 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. | Internal decision | Ongoing implementation | | Agriculture |

(continued on next page)

Table A - 6 Continued.

| IDP No. | Recommendations/Planned improvements | Reference | Status | Comment/Reason NIR | Sector |
|---------|--|---------------------|--------------------------------|---|-----------|
| 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. | ARR 2013 / 97 | Implemented in submission 2017 | It is not possible to compare wood-fuel with deforestation. A reference to the wood harvesting statistics (OE 2016f) was added in the energy chapter (3.2.8). | LULUCF |
| 61 | Data from a new areal survey are available. They provide a new basis for estimating emissions from sector 4 LULUCF. | Internal decision | Implemented in submission 2017 | Data will be implemented in the estimation of emissions from sector 4 LULUCF | LULUCF |
| 62 | 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). | Internal decision | Implemented in submission 2017 | Already implemented for KP-LULUCF in submission 2016. Planned improvement for 2017. | LULUCF |
| 63 | short additional methodological description is required concerning "uncertainties for the LULUCF sector ... provided by the Office of Environment. | ARR 2014 / 77 | Implemented in submission 2017 | The party plans to implement this issue for the submission 2017. Uncertainties will be estimated based on the sample size of the new areal survey. | LULUCF |
| 74 | The activity data of backyard composting have been overestimated by error, i.e. 105% share of centralised composting quantity instead of 5%. | Internal decision | Implemented in submission 2017 | This error was corrected for submission 2017. | Waste |
| 75 | Error activity data of waste do not correspond to official statistics of LIE for years 1990-2004. | Internal decision | Implemented in submission 2017 | This error will be corrected for submission 2017. Data from official statistics will be reported. | Waste |
| 76 | New landfill model IPCC 2006 will be implemented | Internal decision | Implemented in submission 2017 | The new landfillmodel was implemented in submission 2017. | Waste |
| 77 | Methane emissions from sewage gas processing will be reported. | Internal decision | Implemented in submission 2017 | Methane emissions from sewage gas processing are included in submission 2017. | Waste |
| 78 | Methane and N2O emissions from waste water treatment are not reported according to IPCC 2006. | Internal decision | Implemented in submission 2017 | The new IPCC 2006 model was implemented based on the parameters used in Switzerland. | Waste |
| 79 | Distinguish harvesting or forest disturbance that is followed by the re-establishment of a forest from deforestation: apply consistently the time interval for tracking Deforestation (6 years). | Saturday Paper 2016 | Planned improvement for 2018 | The party is planning to implement a consistent time interval of 6 years. | KP-LULUCF |
| 80 | An error in the CO2 emission factor of biodiesel 2007-2009 (73.6 t/TJ instead of 73.4 t/TJ) was identified. | Internal decision | Planned improvement for 2018 | An error in the CO2 emission factor of biodiesel 2007-2009 (73.6 t/TJ instead of 73.4 t/TJ) will be corrected for submission 2018. | Energy |

Annex 9: Voluntary supplementary information for article 3 paragraph 3 of the Kyoto Protocol: Kyoto tables

No supplementary information in addition to chp. 11.

References

- Acontec 2006:** Greenhouse Gas Inventory Fürstentum Liechtenstein. Berechnungsmethoden. Acontec. Schaan [in German].
- Acontec 2016:** Time series of precursor gases and SO₂, current state of knowledge (21st April 2016). E-Mail communication from J. Beckbissinger (Acontec) on 21.04.2016.
- Agroscope 2014c:** Fütterungstool zur Ermittlung des Energie- und Stickstoffumsatzes von Milchkühen in der Schweiz. Agroscope, Institut für Nutztierwissenschaften (INT). Posieux, Schweiz.
- Amon, B., Amon, T., Boxberger, J., Alt, C. 2001:** Emissions of NH₃, N₂O and CH₄ from dairy cows housed in a farmyard manure tying stall (housing, manure storage, manure spreading). Nutrient Cycling in Agroecosystems 60 (1-3): 103-113.
- ARA Bendern 2016:** Amount of sewage gas treatment in ARA Bendern. E-Mail from Philipp Elkuch an Jürgen Beckbissinger. 24.10.2016.
- ARE/SAEFL 2001:** Le paysage sous pression, suite 2. [Landschaft unter Druck, 2. Fortschreibung]. Federal Office for Spatial Development, Bern and Swiss Agency for the Environment, Forests and Landscape, Bern.
<http://www.bafu.admin.ch/publikationen/publikation/00855/index.html?lang=fr>
[13.01.2017]
- ART 2008:** Uncertainty in agricultural CH₄ and N₂O emissions of Switzerland. Internal documentation by Bretscher, D. and Leifeld, J., Agroscope Reckenholz-Tänikon Research Station, Zürich.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en>
[16.12.2016]
- ART 2009b:** Emission factor drained peatlands Switzerland – A brief analysis of recent studies and comparison to EF used in the Swiss GHG Inventory. Internal documentation by Leifeld, J., Agroscope Reckenholz-Tänikon Research Station, Zürich.
<http://www.bafu.admin.ch/ghginv-ref> [13.01.2017]
- ART 2011a:** Summary of the available published data on root biomass and root carbon in Swiss grasslands. Internal documentation by Leifeld, J., Agroscope Reckenholz-Tänikon Research Station, Zürich.
<http://www.bafu.admin.ch/ghginv-ref> [13.01.2017]
- ART/SHL 2012:** Categorization of livestock animals in Switzerland. D. Bretscher and T. Kupper. Agroscope Research Station Zürich (ART), Schweizerische Hochschule für Landwirtschaft Zollikofen (SHL). March 2012.
<http://www.bafu.admin.ch/ghginv-ref> [13.01.2017]
- AZV 2016:** Abwasserzweckverband der Gemeinden Liechtensteins. Geschäftsbericht 2015
http://www.azv.li/fileadmin/user_upload/Download/Geschaeftsbericht_2015.pdf
[16.12.2016]

- Battelle 1994:** Methanfreisetzung bei der Erdgasnutzung in der Schweiz und Vergleich mit anderen Emittenten. Studie im Auftrag des Schweizerischen Verein des Gas- und Wasserfaches SVGW. Battelle Ingenieurtechnik, Zürich.
- Brändli, U.-B. (Red.) 2010:** Schweizerisches Landesforstinventar. Ergebnisse der dritten Aufnahme 2004-2006. [Results of the third Swiss national forest inventory 2004-2006]. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf. Bundesamt für Umwelt, Bern, 312 S.
<http://www.lfi.ch/publikationen/publ/lfi3.php?lang=de> [06.01.2017]
- Bretscher, D. 2015:** Internal technical documentation on Liechtenstein's agricultural model based on the revised IPCC 2006 guidelines. D. Bretscher on behalf of INFRAS for Liechtenstein's National Inventory Report, 2015.
- Broggi, M.F. 1987:** Der Landschaftswandel im Talraum des Fürstentums Liechtenstein. Diss. Ed: Historischer Verein für das Fürstentum Liechtenstein.
- Bühlmann, T. 2014:** Durch Stickstoffdeposition induzierte Emissionen von Stickoxiden und Lachgas aus (semi-)natürlichen Ökosystemen. Analyse der schweizerischen Situation mit Vorschlägen zur Umsetzung im Schweizerischen Emissionsinventar (EMIS). Bundesamt für Umwelt (BAFU), Juli 2014. Bern; Schweiz.
- Bühlmann, T., Hiltbrunner, E., Körner, Ch., Rihm, B., Achermann, B. 2015:** Induction of indirect N₂O and NO emissions by atmospheric nitrogen deposition in (semi-)natural ecosystems in Switzerland. Atmospheric Environment 103(0): 94-101.
- BUS 1978:** Stand der kommunalen Abfallbeseitigung in der Schweiz. Bern, 1. Januar 1978.
- CH2011 2011:** Swiss Climate Change Scenarios CH2011, published by C2SM, MeteoSwiss, ETH, NCCR Climate, and OcCC, Zurich Switzerland, 88p.
<http://www.ch2011.ch/de> [22.11.2016]
- CH2014-Impacts 2014:** Toward Quantitative Scenarios of Climate Change Impacts in Switzerland, published by OCCR, FOEN, MeteoSwiss, C2SM, Agroscope, and ProClim, Bern, Switzerland, 136 pp.
http://ch2014-impacts.ch/res/files/CH2014-Impacts_report.pdf [22.11.2016]
- CG 2015:** Rechenschaftsbericht 2015. Chancellery of the Government (CG) of Liechtenstein, Vaduz.
<http://www.llv.li/#/117471/> [16.12.2016].
- Crutzen, P.J., Aselmann, I., Seiler, W. 1986:** Methane production by domestic animals, wild ruminants, other herbivorous fauna, and humans. Tellus 38B(3-4): 271-284.
- CSD 2013:** Swiss Greenhouse Gas Inventory Submission 2012. National Review of Sector Industrial Processes. On behalf of the Federal Office for the Environment, Bern. Basel.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [23.11.2016]

- De Keizer, C., Ramirez, A., van der Sluijs, J. 2007:** Uncertainty Ranges and Correlations Assumed in Tier 2 Studies of Several European Countries. In: Proceedings of the 2nd International Workshop on Uncertainties in Greenhouse Gas Inventories, 27-28 September 2007, Laxenburg, Austria: 35-39.
<http://www.ibspan.waw.pl/ghg2007/GHG-total.pdf> [9.01.2017]
- Didion, M. 2014:** Impacts of forest management on carbon stock changes in litter and soil in Swiss forests. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. Commissioned by the Federal Office for the Environment FOEN, Bern.
<http://www.bafu.admin.ch/ghginv-ref> [13.01.2017]
- Düggelin, C., Abegg, M. 2011:** Modelle zur Biomasse- und Holzvolumenschätzung im Schweizer Gebüschwald. Schweizerische Zeitschrift für Forstwesen 162 (2): 32-40.
<http://dx.doi.org/10.3188/szf.2011.0032> [13.01.2017]
- EDI/BFS 2009:** Arealstatistik Fürstentum Liechtenstein 1984-1996-2002-2008, Abteilung Raumentwicklung und Nachhaltigkeit, Schlussbericht Teil 1, Methoden, Neuchatel 25.11.2009
- Eicher and Pauli 2006:** Review of the National Greenhouse Gas Inventory - Categories Energy and Industrial Processes. Final Report 27 April 2006.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [05.01.2017]
- EMEP/EEA 2013:** Air Pollutant Emission Inventory Guidebook 2013, European Environment Agency.
<http://www.eea.europa.eu/publications/emep-eea-guidebook-2013> [16.12.2016]
- EMIS 2016/(NFR-Code):** Comments to EMIS database (Switzerland) concerning data for 2015. Internal documents. Federal Office of the Environment, Bern, 2016.
- EMPA 1999:** Written communication from Dr. H.W. Jäckle (EMPA, Dübendorf) to Andreas Liechti (FOEN, Bern), 09.03.1999.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [06.12.2016]
- Estermann, B. L., Wettstein, H.-R., Sutter, F., Kreuzer, M. 2001:** Nutrient and energy conversion of grass-fed dairy and suckler beef cattle kept indoors and on high altitude pasture. Animal Research 50(6): 477-493.
- FAL/RAC 2001:** Grundlagen für die Düngung im Acker- und Futterbau 2001. Eidgenössische Forschungsanstalt für Agrarökologie und Landbau / Eidgenössische Forschungsanstalt für Pflanzenbau. Agrarforschung, June 2001, Zürich-Reckenholz / Nyon.
- FCCC/ARR 2007:** Report of the individual review of the greenhouse gas inventory of Liechtenstein submitted in 2006 (FCCC/ARR/2006/LIE), 18.11.2007
<http://unfccc.int/resource/docs/2007/arr/lie.pdf> [22.11.2016]
- FCCC/ARR 2009:** Report of the individual review of the annual submission of Liechtenstein submitted in 2007 and 2008 (FCCC/ARR/2008/LIE), 01.04.2009
<http://unfccc.int/resource/docs/2009/arr/lie.pdf> [22.11.2016]

- FCCC/ARR 2010:** Report of the individual review of the annual submission of Liechtenstein submitted in 2010 (FCCC/ARR/2009/LIE), 19.03.2010
<http://unfccc.int/resource/docs/2010/arr/lie.pdf> [22.11.2016]
- FCCC/ARR 2010a:** Report of the individual review of the annual submission of Liechtenstein submitted in 2010 (FCCC/ARR/2010/LIE), 07.12.2010
<http://unfccc.int/resource/docs/2010/arr/lie2.pdf> [22.11.2016]
- FCCC/ARR 2011:** Report of the individual review of the annual submission of Liechtenstein submitted in 2011 (FCCC/ARR/2011/LIE), 13.06.2012
<http://unfccc.int/resource/docs/2012/arr/lie.pdf> [22.11.2016]
- FCCC/ARR 2012:** Report of the individual review of the annual submission of Liechtenstein submitted in 2012 (FCCC/ARR/2012/LIE), 11.03.2013
<http://unfccc.int/resource/docs/2013/arr/lie.pdf> [22.11.2016]
- FCCC/ARR 2013:** Report of the individual review of the annual submission of Liechtenstein submitted in 2013 (FCCC/ARR/2013/LIE), 07.04.2014
<http://unfccc.int/resource/docs/2014/arr/lie.pdf> [22.11.2016]
- FCCC/ARR 2014:** Report of the individual review of the annual submission of Liechtenstein submitted in 2014 (FCCC/ARR/2014/LIE), 13.04.2015
<http://unfccc.int/resource/docs/2015/arr/lie.pdf> [22.11.2016]
- FCCC/ERT 2016:** Provisional Main Findings- Liechtenstein, Review of the 2015 and 2016 annual submission, 26 September – 1 October 2016
- FCCC/IRR 2007:** Report of the review of the initial report of Liechtenstein.
FCCC/IRR/2007/LIE 13 December 2007.
<http://unfccc.int/resource/docs/2007/irr/lie.pdf> [10.01.2017]
- Fernández, C., Espinós, F.J., López, M.C., García-Diego, F.J., Cervera, C. 2013:**
Representation of a mathematical model to predict methane output in dairy goats.
Computers and Electronics in Agriculture 91(0): 1-9.
- Flisch, R., Sinaj, S., Charles, R., Richner, W. 2009:** Grundlagen für die Düngung im Acker- und Futterbau 2009 (GRUDAF). Forschungsanstalt Agroscope Changins-Wädenswil ACW und Agroscope Reckenholz-Tänikon ART, Agrarforschung 16 (2).
- FOEN 2010:** Pollutant Emissions from Road Transport, 1990 to 2035. Updated in 2010.
Environmental studies no. 1021. Federal Office for the Environment, Bern.
<http://www.bafu.admin.ch/publikationen/publikation/01565/index.html?lang=en>
[13.01.2017]
- FOEN 2011:** Switzerland's Greenhouse Gas Inventory 1990-2009. National Inventory Report 2009. Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Swiss Federal Office for the Environment, Bern, 15 April 2011.
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php [09.01.2017]

- FOEN 2013:** Switzerland's Greenhouse Gas Inventory 1990-2011. National Inventory Report 2011. Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Swiss Federal Office for the Environment, Bern, 15 April 2013.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15525/index.html?lang=en>
[13.01.2017]
- FOEN 2015:** Switzerland's Greenhouse Gas Inventory 1990-2013. National Inventory Report 2015. Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Swiss Federal Office for the Environment, Bern, 27 April 2015.
<http://www.bafu.admin.ch/klima/13879/13880/14577/index.html?lang=en>
[13.01.2017]
- FOEN 2015a:** Faktenblatt. CO₂-Emissionsfaktoren des Treibhausgasinventars der Schweiz. Federal Office for the Environment, Bern.
<http://www.bafu.admin.ch/klima/13879/13880/14486/index.html?lang=de>
[13.01.2017]
- FOEN 2016:** Switzerland's Greenhouse Gas Inventory 1990-2014. National Inventory Report 2016. Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Swiss Federal Office for the Environment, Bern, 15 April 2016.
<http://www.bafu.admin.ch/klima/13879/13880/15473/index.html?lang=en>
[8.12.2016]
- FOEN 2016a:** Extract of the EMIS database, Federal Office for the Environment (FOEN), "BAFU_EMIS-Daten_Submission2016_160504.xlsx" Bern/CH, 4.5.2016.
- FOEN/Meteoswiss 2013:** Climate change in Switzerland. Indicators of driving forces, impact and response. (Summary of the publication «Klimaänderung in der Schweiz»)
<http://www.bafu.admin.ch/publikationen/publikation/01709/index.html?lang=en>
[22.11.2016]
- Gasette 2014:** Gasette – Energieversorgung au seiner Hand. Ausgabe Nr. 02/2014, 55. Jahrgang.
http://www.erdgas.ch/publikationen/gasette/archiv/?eID=tx_damdownloadcenter&action=downloadFile&file=18447 [9.12.2016]
- GHFL 2007:** Letter from Genossenschaft für Heizöl-Lagerhaltung im Fürstentum Liechtenstein (GHFL; Cooperative society for the storage of gas oil in the Principality of Liechtenstein; Ms. Helga Faritsch) to Mr. J. Beckbissinger/Acontec AG, 20.09.2007.
- GHFL 2008:** Telephone from Genossenschaft für Heizöl-Lagerhaltung im Fürstentum Liechtenstein (GHFL; Cooperative society for the storage of gas oil in the Principality of Liechtenstein; Ms. Helga Faritsch) to Mr. J. Beckbissinger/Acontec AG, 15.07.2008.
- Giuliani, S. 2014:** Energiebedarfswerte der Nutztiere für die Periode 1990-2012. Written communication from Silvano Giuliani (SBV, Swiss Farmers Union) to Daniel Bretscher (ART, Reckenholz), 21.10.2014.

- Government 1980:** Währungsvertrag zwischen der Schweizerischen Eidgenossenschaft und dem Fürstentum Liechtenstein. 0.951.951.4. Vaduz/Bern.
<http://www.admin.ch/ch/d/sr/i9/0.951.951.4.de.pdf> [23.11.2016], [in German]
- Government 1991:** Government of the Principality of Liechtenstein. Waldgesetz (WaldG) 25. März 1991.
- Government 2004:** Government of the Principality of Liechtenstein. Landwirtschaftliches Leitbild 2004. Vaduz 2004.
http://www.llv.li/files/au/pdf-llv-au-bericht_und_antrag_endfassung_26.10.04.pdf [16.12.2016], [in German]
- Government 2008:** Energy Efficiency Act: Gesetz über die Förderung von Energieeffizienz und der erneuerbaren Energien. Government of Liechtenstein. Liechtenstein Law Gazette. Year 2008, No. 116. Issue on 20. May 2008. Vaduz.
<https://www.gesetze.li/lilexprod/showpdf.jsp?media=pdf&lglid=2008116000&gueltigdate=15032016> [22.11.2016], [in German]
- Government 2012:** Emissions Trading Act (EHG). Liechtenstein Law Gazette. Year 2012, No. 346, issue on 15th November 2012. Vaduz.
<https://www.gesetze.li/lilexprod/showpdf.jsp?media=pdf&lglid=2012346000&gueltigdate=15032016> [22.11.2016], [in German]
- Government 2012a:** Government of the Principality of Liechtenstein. Energiestrategie Liechtenstein 2020. Vaduz 2012.
http://www.regierung.li/files/attachments/Energiestrategie_Langfassung_635466385105448750.pdf?t=635936541807817442%20%20 [22.11.2016], [in German]
- Government 2015:** Klimastrategie der Regierung des Fürstentums Liechtenstein. Regierung des Fürstentums Liechtenstein, Ministerium für Infrastruktur und Umwelt sowie Sport. Oktober 2015
<http://www.llv.li/files/au/klimastrategie-fl-2015.pdf> [22.11.2016], [in German]
- Government 2016:** Government Principality of Liechtenstein. Liechtenstein's Second Initial Report under the Kyoto Protocol. 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. 15.4.2016.
<http://www.llv.li/files/au/ir-cp2-li.pdf> [22.11.2016]
- Hadorn, R., Wenk, C. 1996:** Effect of different sources of dietary fibre on nutrient and energy utilization in broilers. 2. Energy and N-balance as well as whole body composition. Archiv für Geflügelkunde 60: 22-29.
- Hindrichsen, I.K., Wettstein, H.-R., Machmüller, A., Bach Knudsen, K.E., Madsen, J., Kreuzer, M. 2006:** Methane emission, nutrient degradation and nitrogen turnover in dairy cows and their slurry at different milk production scenarios with and without concentrate supplementation. Agricultural Ecosystems and Environment 113: 150–161.
- Hürdler, J., Prasuhn, V., Spiess, E. 2015:** Abschätzung diffuser Stickstoff- und Phosphoreinträge in die Oberflächengewässer der Schweiz. MODIFFUS 3.0. – Bericht im Auftrag des Bundesamtes für Umwelt BAFU, Agroscope, Zürich, ca. 115 S.

- IBK 2007:** Auswirkungen des Klimawandels und mögliche Anpassungsstrategien, AWEL Zürich and Commission for Environment (Platform climate protection and energy) of the International Bodensee Conference, Zürich December 2007. Download in PDF format from:
<http://www.bodenseekonferenz.org/bausteine.net/f/8771/IBKBerichtKlimaauswirkungen.pdf?fd=3> [22.11.2016], [in German]
- INFRAS 2004:** Luftschadstoff-Emissionen des Strassenverkehrs 1980-2030. Bundesamt für Umwelt, Wald und Landschaft / INFRAS. Schriftenreihe Umwelt Nr. 355, Bern. Download in PDF format from
<http://www.hbefa.net/> [13.01.2017], [in German]
- INFRAS 2010:** The Handbook Emission Factors for Road Transport (HBEFA), version 3.1 (MS AccessXP runtime application and report). INFRAS in cooperation with further editors: FOEN/Switzerland; Umweltbundesamt Dessau/Germany; Umweltbundesamt Wien/Austria; Swedish Road Administration, ADEME/France; SFT/Norway. Bern. 30.01.2010.
<http://www.hbefa.net/e/index.html> [13.01.2017]
- INFRAS 2015:** Online database of emission factors, activity data and emissions of non-road vehicles.
<http://www.bafu.admin.ch/luft/00596/06906/offroad-daten/index.html?lang=en> [13.12.2016]
- INFRAS/Egli Engineering 2015:** Analyse klimabedingter Risiken und Chancen in der Schweiz – Regionale Fallstudie Kanton Uri. INFRAS und Egli Engineering AG im Auftrag des Bundesamtes für Umwelt (BAFU).
http://www.bafu.admin.ch/klima/13877/14401/14897/index.html?lang=fr&download=NHzLpZeg7t,lnp6lONTU042l2Z6ln1ae2lZn4Z2qZpnO2Yuq2Z6gpJCHen57g2ym162epYbg2c_JkbnokSn6A-- [22.11.2016], [in German]
- Intertek 2008:** Bestimmung der Heizwerte und CO₂-Emissionsfaktoren von Brenn- und Treibstoffen. Untersuchungsbericht Nr. 170375. Intertek Caleb Brett im Auftrag des Bundesamtes für Umwelt BAFU. FOEN internal document. Schlieren/Bern.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [09.12.2016]
- Intertek 2012:** Bestimmung der Heizwerte und CO₂-Emissionsfaktoren von Brenn- und Treibstoffen. Untersuchungsbericht Nr. 111377. Intertek im Auftrag des Bundesamtes für Umwelt BAFU. FOEN internal document. Schlieren.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [09.12.2016]
- IPCC 2006:** Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T. and Tanabe K.
<http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html> [22.11.2016]

- IPCC 2014: 2013:** Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement). Intergovernmental Panel on Climate Change. Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland
<http://www.ipcc-nggip.iges.or.jp/public/kpsg/index.html> [22.11.2016]
- IQNet 2014:** International Certification Network and SQS Switzerland. Certification for INFRAS to have implemented and to maintain a management system which fulfils the requirements of the following standards: ISO 9001:2008, 140001:2004. Issued on 2014-07-03, validity data 2017-07-02, registr. no. CH-14069.
- Külling, D. R., Dohme, F., Menzi, H., Sutter, F., Lischer, P., Kreuzer, M. 2002:** Methane emissions of differently fed dairy cows and corresponding methane and nitrogen emissions from their manure during storage. Environmental Monitoring and Assessment 79 (2): 129-150.
- Külling, D. R., Menzi, H., Sutter, F., Lischer, P., Kreuzer, M. 2003:** Ammonia, nitrous oxide and methane emissions from differently stored dairy manure derived from grass- and hay-based rations. Nutrient Cycling in Agroecosystems 65 (1): 13-22.
- Kupper, T., Bonjour, C., Achermann, B., Zaucker, F., Rihm, B., Menzi, H. 2013:** Ammoniakemissionen in der Schweiz 1990-2010 und Prognose bis 2020. Hochschule für Agrar-, Forst- und Lebensmittelwissenschaften, Zollikofen. URL:
<http://www.agrammon.ch/dokumente-zum-download/> [16.12.2016]
- Leifeld, J., Bassin, S., Fuhrer, J. 2003:** Carbon stocks and carbon sequestration potentials in agricultural soils in Switzerland. Schriftenreihe der FAL 44. Zürich-Reckenholz.
- Leifeld, J., Bassin, S., Fuhrer, J. 2005:** Carbon stocks in Swiss agricultural soils predicted by land-use, soil characteristics, and altitude. Agriculture, Ecosystems & Environment 105 (1/2): 255-266.
- LGV 2016:** Annual Report of Liechtenstein's Gas Utility 2015 (Geschäftsbericht 2015 der Liechtensteinischen Gasversorgung).
http://lgv.gmgnet.li/files/attachments/LGV_Geschaeftsbericht_2015.pdf
[8.12.2016], [in German]
- LKW 2010:** Email from Jürg Tinner, Liechtensteinische Kraftwerke to Acontec AG on 11 October 2010 [in German].
- LWI 2012:** Liechtenstein's National Forest Inventory (Liechtensteinisches Landeswaldinventar (LWI) – Ergebnisse der dritten Erhebung 2010). Office of Environmental Protection (OEP, former AWLN), Vaduz.
http://www.llv.li/files/au/pdf-llv-au-landeswaldinventar_2012_awnl.pdf
[13.01.2017]
- Mangino, J., Bartram, D., Brazy, A. 2001:** Development of a methane factor to estimate emissions from animal waste lagoons. U.S.EPA's 17th Annual Emission Inventory Conference, Atlanta GA; U.S. EPA.

- Martínez-Fernández, G., Abecia, L., Ramos-Morales, E., Martín-García, A.I., Molina-Alcaide, E., Yáñez-Ruiz, D.R. 2014:** Effects of propyl propane thiosulfinate on nutrient utilization, ruminal fermentation, microbial population and methane emissions in goats. *Animal Feed Science and Technology* 191(0): 16-25.
- Mathys, L., Thürig E. 2010:** Baumbiomasse in der Landschaft. [Living biomass of trees in Non-Forest Land]. Final report, Sigmaphan and WSL on behalf of the Federal Office for the Environment, Bern.
<http://www.bafu.admin.ch/ghginv-ref> [13.01.2017]
- MeteoSwiss 2015a:** Climate normals Vaduz – Reference period 1981-2010. Federal Office of Meteorology and Climatology MeteoSwiss.
http://www.meteoswiss.admin.ch/product/output/climate-data/climate-diagrams-normal-values-station-processing/VAD/climsheet_VAD_np8110_e.pdf [22.11.2016]
- MeteoSwiss 2015b:** Climate normals Vaduz – Reference period 1961-1990. Federal Office of Meteorology and Climatology MeteoSwiss.
http://www.meteoswiss.admin.ch/product/output/climate-data/climate-diagrams-normal-values-station-processing/VAD/climsheet_VAD_np6190_e.pdf [22.11.2016]
- Meteotest 2012:** THG-Inventar Liechtenstein, Review Sektor LULUCF. B. Rihm (Meteotest) im Auftrag des Fürstentums Liechtenstein, Amt für Umweltschutz. Bern. 24. Aug. 2012.
- Meyer, H., Coenen, M., 2002:** Pferdefütterung. Parey Buchverlag Berlin, 4. Auflage; ISBN 3-8263-3398-5.
- Minonzio, G., Grub, A., Fuhrer, J. 1998:** Methanemissionen der schweizerischen Landwirtschaft. Schriftenreihe Umwelt Nr. 298. FOEN / BUWAL, Bern.
- MK Consulting 2015:** Tanktourismus und Eurokurs, MK Consulting im Auftrag der Erdölvereinigung EVUP, Bern.
https://www.erdoel.ch/images/pdf/Studie_Tanktourismus_d.pdf [19.12.2016]
- Moeri, A.C. 2007:** Kohlenstoffvorräte in Schweizer Waldböden mit besonderer Berücksichtigung der organischen Auflage. Diplomarbeit bei der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft (WSL). Geographisches Institut der Universität Zürich.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [23.12.2016]
- Mohn, J. 2011:** Bestimmung des Anteils biogener und fossiler CO₂ Emissionen aus Schweizer KVAs. Eidg. Materialprüfungsanstalt und Forschungsanstalt. Schlussbericht. Im Auftrag des Bundesamts für Umwelt.
<http://www.bafu.admin.ch/klima/13879/13880/15423/index.html?lang=en> [13.01.2017]
- Moller, H.B., Sommer, S.G., Ahring, B.K. 2004:** Biological degradation and greenhouse gas emissions during pre-storage of liquid animal manure. *Journal of Environmental Quality* 33 (1): 27-36.

- Morel, I., Chassot, A., Schlegel, P., Jans, F., Kessler, J. 2015:** Fütterungsempfehlungen für die Mutterkuh. Fütterungsempfehlungen für Wiederkäuer (Grünes Buch). Agroscope Posieux. Posieux; Schweiz.
- Nigsch, N. 2012:** No forest fires in Liechtenstein since 1985. Written communication from Norman Nigsch (Amt für Wald, Natur und Landschaft) to Patrick Insinna (Amt für Umweltschutz, Vaduz).
- North, N., Kljun, N., Kasser, F., Heldstab, J., Maibach, M., Reutimann, J., Guyer, M. 2007:** Klimaänderung in der Schweiz. Indikatoren zu Ursachen, Auswirkungen, Massnahmen. Umweltzustand Nr. 0728. Bundesamt für Umwelt, Bern. 77 pp.
<http://www.bafu.admin.ch/publikationen/publikation/00065/index.html?lang=de>
[06.01.2017]
- Nousiainen, J., Rinne, M., Huhtanen, P. 2009:** A meta-analysis of feed digestion in dairy cows. 1. The effects of forage and concentrate factors on total diet digestibility. Journal of dairy science 92(10): 5019-5030.
- Nussbaum, M., Papritz, A., Baltensweiler, A., Walthert, L. 2012:** Organic Carbon Stocks of Swiss Forest Soils. Final Report. Institute of Terrestrial Ecosystems, ETH Zürich and Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf.
<http://dx.doi.org/10.3929/ethz-a-007555133> [13.01.2017]
- Nussbaum, M., Papritz, A., Baltensweiler, A., Walthert, L. 2014:** Estimating soil organic carbon stocks of Swiss forest soils by robust external-drift kriging. Geoscientific Model Development 7: 1197-1210.
<http://dx.doi.org/10.5194/gmd-7-1197-2014> [13.01.2017]
- OA 2002:** Annual census on livestock numbers in agriculture. Data until 2002 edited by the Office of Agriculture (Landwirtschaftsamt). Data after 2002 edited by OFIVA. Published in „Statistisches Jahrbuch, Kap. 5.1 Land- und Forstwirtschaft“. Vaduz
<http://www.llv.li/#/1859> [15.12.2016], [in German]
- OcCC 2007:** Climate Change and Switzerland 2050. Expected Impacts on Environment, Society and Economy. The Advisory Body on Climate Change, Bern.
<http://www.proclim.ch/products/ch2050/ch2050-report.html> [22.11.2016]
- OcCC 2008:** Das Klima ändert – was nun? Der neue UN-Klimabericht (IPCC 2007) und die wichtigsten Ergebnisse aus Sicht der Schweiz. The Advisory Body on Climate Change, Bern. <http://www.proclim.ch/4dcgi/occc/de/Report?524> [22.11.2016]
- OcCC 2012:** Klimaziele und Emissionsreduktion – Eine Analyse und politische Vision für die Schweiz. The Advisory Body on Climate Change, Bern.
<http://proclimweb.scnat.ch/portal/ressources/2623.pdf> [22.11.2016]
- OE 2013:** Liechtenstein's Greenhouse Gas Inventory 1990–2011. CRF Tables and National Inventory Report 2011. Submission of 15 of March 2013 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environment (OE), Vaduz.

- OE 2013b:** CO₂-Act: Gesetz über die Reduktion der CO₂-Emissionen (CO₂-Gesetz). Liechtenstein Law Gazette. Year 2013, No. 358. Issue on 11. November 2013. Vaduz. <https://www.gesetze.li/lilexprod/showpdf.jsp?media=pdf&lglid=2013358000&gueligdate=05052016> [22.11.2016]
- OE 2013c:** Bericht über die wirtschaftliche Entwicklung der Landwirtschaftsbetriebe im Fürstentum Liechtenstein, Agrarbericht 2011. Office of Environment (OE), Vaduz, 2013. http://www.llv.li/files/au/pdf-au-agrarbericht_2011.pdf [16.12.2016]
- OE 2014:** Liechtenstein's Greenhouse Gas Inventory 1990–2012. CRF Tables and National Inventory Report 2012. Submission of 14 April 2014 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environment (OE), Vaduz.
- OE 2015a:** Agrarflächen 2013. Interne Statistik. Amt für Umwelt, Abteilung Landwirtschaft, Vaduz, 2015. For the previous years there are corresponding statistics available by the Office of Environment, Division of Agriculture (note that in former years the editor was the Office of Agriculture, which now is a division of the Office of the Environment).
- OE 2015b:** E-mail from the Office of Environment (H. Summer) to Acontec (J. Beckbissinger) of 15th Feb. 2015.
- OE 2016:** Liechtenstein's Second Initial Report under the Kyoto Protocol. Office of Environment (OE), Vaduz, Principality of Liechtenstein, 15 April 2016 and resubmission 19 December 2016. http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/second_commitment_period_2013-2020/items/9499.php [13.01.2017]
- OE 2016a:** Liechtenstein's Greenhouse Gas Inventory 1990-2013. CRF Reporting Tables and National Inventory Report 2013. Submission of 15 of April 2016 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environment (OE), Vaduz.
- OE 2016b:** Liechtenstein's submission under the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP), Inventory 1990–2014. Office of Environment (OE), Vaduz, 2016. http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2016_submission_s/ [20.12.2016]
- OE 2016c:** Liechtenstein's Greenhouse Gas Inventory 1990-2014. CRF Reporting Tables and National Inventory Report 2014. Submission of 27 May 2016 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environment (OE), Vaduz.
- OE 2016d:** Liechtenstein's Greenhouse Gas Inventory 1990-2014. Review of the National Inventory Report, September 2016. Response by Party to potential problems identified by the UNFCCC Expert Review Team (ERT) and updated CRF data 1990-2014. Resubmission 14 November 2016. Office of Environment (OE), Vaduz.

- OE 2016e:** Results of census about diesel and gasoline sales. E-Mail communication from H. Summer (OE) to J. Beckbissinger (Acontec) on 21.03.2016.
- OE 2016f:** Wood harvesting statistics for Liechtenstein's forest 1986-2015 (Informationen zu Holznutzung und Anpflanzung). E-Mail communication from H. Summer, Office of Environment (OE), Vaduz, 5.8.2016.
- OE 2016g:** Waste quantities treated in centralized composting plants. E-Mail from Sven Bürzle (OE) to Jürgen Beckbissinger. Vaduz, 24.10.2016.
- OE 2016h:** Quantity of waste illegally incinerated. E-Mail from Heike Summer (OE) to Jürgen Beckbissinger. Vaduz, 13.09.2016.
- OE 2016i:** Facts and figures about the climate in Liechtenstein (Zahlen und Fakten zum Klima in Liechtenstein). Office of Environment (OE), Vaduz.
<http://www.llv.li/files/au/faktenblatt-klima-lichtenstein.pdf> [12.04.2017], [in German]
- OEA 2010:** Publikationen zur Liechtensteinischen Volkszählung 2010, Band 4: Haushalte und Familien. Amt für Volkswirtschaft. Vaduz.
- OEP 2002:** Strassenverkehrsemissionen im Fürstentum Liechtenstein 1990, 2000, 2010, Schlussbericht. Office of Environmental Protection (OEP) / INFRAS; Bern/Vaduz, 18. Januar 2002 [in German].
- OEP 2006:** Liechtenstein's Greenhouse Gas Inventory 1990–2004. National Inventory Report 2006. Submission of 22 December 2006 to the Framework Convention on Climate Change (UNFCCC). Office of Environmental Protection (OEP), Vaduz.
- OEP 2006a:** Liechtenstein's Initial Report under Article 7, paragraph 4 of the Kyoto Protocol. Office of Environmental Protection (OEP), Vaduz, 22 December 2006.
- OEP 2006c:** Treibstoffabsatz 1990 FL. Fürstentum Liechtenstein. Office of Environmental Protection (OEP) / Acontec; Vaduz/Schaan [in German].
- OEP 2006d:** Map of Liechtenstein showing altitude class and soil types, Vaduz.
- OEP 2007:** Liechtenstein's Greenhouse Gas Inventory 1990–2005. CRF Tables and National Inventory Report 2006. Submission of 10 May 2007 to the Framework Convention on Climate Change (UNFCCC). Office of Environmental Protection (OEP), Vaduz.
- OEP 2007a:** Liechtenstein's Greenhouse Gas Inventory 1990-2004. In-country review of the Initial Report and the National Inventory Report, 11-15 June 2007. Response by Party to potential problems identified by the UNFCCC Expert Review Team (ERT). Revised version 9 August 2007. Office of Environmental Protection (OEP), Vaduz.
- OEP 2007b:** Liechtenstein's Initial Report under Article 7, paragraph 4 of the Kyoto Protocol. Corrigendum, 19 September 2007. Office of Environmental Protection (OEP), Vaduz.
- OEP 2007c:** Email by Helmut Kindle/OEP to Ernst Basler + Partner on July 2, 2007.
- OEP 2007e:** Action Plan on Air. Massnahmenplan Luft des Fürstentums Liechtenstein. Vaduz.
http://www.llv.li/files/au/pdf-llv-au-massnahmenplan_luft_200709.pdf [22.11.2016], [in German]

- OEP 2007g:** Email by Helmut Kindle/OEP to Ernst Basler + Partner on June 12, 2007.
- OEP 2008:** Liechtenstein's Greenhouse Gas Inventory 1990–2006. CRF Tables and National Inventory Report 2008. Submission of 29 February 2008 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environmental Protection (OEP), Vaduz.
- OEP 2008b:** Environmental Protection Act. Liechtenstein Law Gazette. Year 2008, No. 199. Issue on 28. July 2008. Vaduz.
<https://www.gesetze.li/lilexprod/showpdf.jsp?media=pdf&lglid=2008199000&gueltigdate=15032016> [22.11.2016], [in German].
- OEP 2009:** Liechtenstein's Greenhouse Gas Inventory 1990–2007. CRF Tables and National Inventory Report 2009. Submission of 2 April 2009 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environmental Protection (OEP), Vaduz.
- OEP 2010:** Liechtenstein's Greenhouse Gas Inventory 1990–2008. CRF Tables and National Inventory Report 2010. Submission of 11 of March 2010 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environmental Protection (OEP), Vaduz.
- OEP 2011:** Liechtenstein's Greenhouse Gas Inventory 1990–2009. CRF Tables and National Inventory Report 2010. Submission of 11 of March 2011 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environmental Protection (OEP), Vaduz.
- OEP 2011c:** Results of census about diesel and gasoline sales. Email communication (data file attached: Offizielle Daten Treibstoffhebungen AFU.xls) from P. Insinna (AFU) to J. Beckbissinger (Acontec) on 10.10.2011.
- OEP 2011d:** Liechtenstein's Submission on Reference Levels for Forest Management under the Kyoto Protocol (FMRL). Office of Environmental Protection (OEP), Vaduz.
https://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_liechtenstein_2011.pdf [06.01.2017]
- OEP 2012a:** E-mail from A. Gstoehl (OEP) to J. Heldstab (INFRAS) confirming that the share of backyard composting assumed so far is the most precise estimate available. Vaduz. 12.01.2012.
- OEP 2012b:** Liechtenstein's Greenhouse Gas Inventory 1990–2010. CRF Tables and National Inventory Report 2011. Submission of 11 of March 2012 under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. Office of Environmental Protection (OEP), Vaduz.
- OEP 2012c:** Results of census about diesel and gasoline sales. E-Mail communication from P. Insinna (OEP) to J. Beckbissinger (Acontec) on 16.08.2012
- OFIVA/OE 2015:** Tierbestand, Erhebungen des Tierseuchenfonds für das Jahr 2014; Amt für Lebensmittelkontrolle und Veterinärwesen in Zusammenarbeit mit der Abteilung Landwirtschaft des Amtes für Umwelt, Vaduz, 2015. See also the same statistics for former years 2011 and 2012.

- OS 2001:** Energiestatistik 2001 Fürstentum Liechtenstein. Office of Statistics (Amt für Statistik, früher Amt für Volkswirtschaft), Vaduz 2001
http://www.llv.li/files/as/pdf-llv-avw-statistik-energiestatistik_2001 [8.12.2016]
- OS 2014d:** Landwirtschaftsstatistik 2013 Fürstentum Liechtenstein. Office of Statistics (Amt für Statistik), Vaduz 2014.
http://www.llv.li/files/as/Landwirtschaftsstatistik_2013_Internet.pdf [16.12.2016].
- OS 2016a:** Energiestatistik 2015 Fürstentum Liechtenstein. Office of Statistics (Amt für Statistik), Vaduz 2016.
<http://www.llv.li/files/as/energiestatistik-2015.pdf> [07.12.2016]
- OS 2016b:** Beschäftigungsstatistik 2015 Fürstentum Liechtenstein. Office of Statistics (Amt für Statistik), Vaduz 2016.
<http://www.llv.li/files/as/beschaefigungsstatistik-31-dezember-2015.pdf> [19.12.2016]
- OS 2016c:** Statistisches Jahrbuch Liechtensteins 2016. Fürstentum Liechtenstein. Office of Statistics, Vaduz 2016.
<http://www.llv.li/files/as/jahrbuch-2016.pdf> [19.12.2016]
- OS 2016d:** Bevölkerungsstatistik vertiefte Ergebnisse 31. Dezember 2015. Fürstentum Liechtenstein. Office of Statistics, Vaduz 2016.
<http://www.llv.li/files/as/bevolkerungsstatistik-vertiefte-ergebnisse-31-dezember-2015.pdf> [19.12.2016]
- OS 2016e:** Beschäftigungsstatistik 2015. Fürstentum Liechtenstein. Office of Statistics, Vaduz 2016. <http://www.llv.li/files/as/beschaefigungsstatistik-31-dezember-2015.pdf> [19.12.2016]
- OSTLUFT 2015:** Luftqualität 2014: OSTLUFT - Die Luftqualitätsüberwachung der Ostschweizer Kantone und des Fürstentums Liechtenstein, Juni 2015
<http://www.ostluft.ch/index.php?id=78> [6.01.2017]
- Park, K.H., Thompson, A.G., Marinier, M., Clark, K., Wagner-Riddle, C. 2006:** Greenhouse gas emissions from stored liquid swine manure in a cold climate. *Atmospheric Environment* 40 (4): 618-627.
- Ramin, M., Huhtanen, P. 2012:** Development of non-linear models for predicting enteric methane production. *Acta Agriculturae Scandinavica, Section A — Animal Science* 62(4): 254-258.
- RAP 1999:** Fütterungsempfehlungen und Nährwerttabellen für Wiederkäuer. Landwirtschaftliche Lehrmittelzentrale, vierte Auflage, Zollikofen.
- Rotex Helicopter AG 2006:** Written communication from Manfred Nipp to Jürgen Beckbissinger. Acontec on 19 September 2006, Subject: Kerosinverbrauch 1994.
- Rotex Helicopter AG 2007:** e-mail communication (kerosene consumption in data file attached: "Flugminuten Acontec.xls") from Rhein Helikopter AG to J. Beckbissinger (Acontec) on 16 February 2007. Subsequent telephone communication Ms Riedi (Rhein Helikopter AG) with J. Beckbissinger (Acontec) to complete the data with the share of domestic/ international on 14 March 2007.

- Rotex Helicopter AG 2008:** e-mail communication (kerosene consumption in data file attached: "Flugminuten Acontec.xls") from Rhein Helikopter AG to J. Beckbissinger (Acontec) on 12 August 2008.
- Rotex Helicopter AG 2009:** e-mail and telephone communication from Rotex Helicopter AG (Zinsmeister) and Rhein Helikopter AG (Forrer) respectively, to J. Beckbissinger (Acontec) on 3 August 2009.
- Rotex Helicopter AG 2010:** e-mail communication from Rotex Helicopter AG (Zinsmeister) and Rhein Helikopter AG (Forrer) respectively, to J. Beckbissinger (Acontec) on 23 August 2010.
- Rotex Helicopter AG 2011:** e-mail communication from Rotex Helicopter AG (Zinsmeister) and Rhein Helikopter AG (Forrer) respectively, to J. Beckbissinger (Acontec) on 11. Mai 2011.
- Rotex Helicopter AG 2012:** e-mail communication from Rotex Helicopter AG (Zinsmeister) and Rhein Helikopter AG (Forrer) respectively, to J. Beckbissinger (Acontec) on 09. Mai 2012.
- Rotex Helicopter AG 2013:** e-mail communication from Rotex Helicopter AG (Ganter) and Swiss Helicopter AG (Forrer) respectively, to J. Beckbissinger (Acontec) on 25. September 2013.
- Rotex Helicopter AG 2014:** e-mail communication from Rotex Helicopter AG (A. Pangerl) to J. Beckbissinger (Acontec) on 02. Mai 2014.
- Rotex Helicopter AG 2015:** e-mail communication from Rotex Helicopter AG (R. Spichtig) to J. Beckbissinger (Acontec) on 17. April 2015.
- Rotex Helicopter AG 2016:** e-mail communication from Rotex Helicopter AG (R. Spichtig) to J. Beckbissinger (Acontec) on 14. Januar 2016.
- Rytec 2010:** National Greenhouse Gas Inventory of Switzerland, Review of the waste sector. Rytec - Waste Technology + Energy Concepts. Final report, Muensingen/Switzerland, 7 October 2010.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en>
[23.12.2016]
- SAEFL 2000:** Handbuch Emissionsfaktoren für stationäre Quellen. Ausgabe 2000. Bundesamt für Umwelt, Wald und Landschaft, Reihe Vollzug Umwelt, Bern.
- SAEFL 2005e:** Arbeitsblatt Emissionsfaktoren Feuerungen. Stand Oktober 2005. Swiss Agency for the Environment, Forests and Landscape.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en>
[16.12.2016], [in German]
- SBV 2007:** Statistiques et évaluations concernant l'agriculture et l'alimentation, 2006. [Statistische Erhebungen und Schätzungen über Landwirtschaft und Ernährung, 2006]. Swiss Farmers Union, Brugg. [available in German and French]

- SBV 2014:** Statistiques et évaluations concernant l'agriculture et l'alimentation, 2013. [Statistische Erhebungen und Schätzungen über Landwirtschaft und Ernährung, 2013]. Swiss Farmers Union, Brugg
<http://www.sbv-usp.ch/de/statistik/> [15.12.2016], [in German and French]
- SCA 2013:** Request by phone from J. Beckbissinger (Acontec) to Roland Clément (SCA). 27.09.2013 Schaan.
- Schjoerring, J.K., Mattsson, M. 2001:** Quantification of ammonia exchange between agricultural cropland and the atmosphere: measurements over two complete growth cycles of oilseed rape, wheat, barley and pea. *Plant and Soil* 228(1): 105-115.
- Schmid, M., Neftel, A., Fuhrer, J. 2000:** Lachgasemissionen aus der Schweizer Landwirtschaft. [Emissions de protoxyde d'azote de l'agriculture Suisse]. Schriftenreihe der FAL 33. Zürich-Reckenholz.
- Schwarz 2001:** Emissionen des Kältemittels R-134a aus mobilen Klimaanlageanlagen. Jährliche Emissionsraten von bis zu sieben Jahre alten Pkw-Klimaanlagen. [Emission of Refrigerant R-134a from Mobile Air-Conditioning Systems Annual Rate of Emission from Passenger-Car Air-Conditioning Systems up to Seven Years Old]. Gutachten durch die Oeko-Recherche GmbH für das Umweltbundesamt (FKZ 360 09 006), Frankfurt.
<http://www.oekorecherche.de/sites/default/files/publikationen/vollr134a.pdf> [19.12.2016]
- Schwarz 2005:** Emissionen und Emissionsprognosen von H-FKW, FKW und SF6 in Deutschland – Aktueller Stand und Entwicklung eines Systems zur jährlichen Ermittlung. Gutachten durch die Oeko-Recherche GmbH für das Umweltbundesamt (FKZ 202 41 356), Frankfurt.
<http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3000.pdf> [19.12.2016]
- SCNAT 2008:** Biodiversität und Klima – Konflikte und Synergien im Massnahmenbereich Ein Positionspapier der Akademie der Naturwissenschaften Schweiz (SCNAT), ISBN: 978-3-907630-31-0. Bern.
<http://www.naturalsciences.ch/organisations/biodiversity> [05.01.2017]
- SCNAT 2016:** Brennpunkt Klima Schweiz. Grundlagen, Folgen und Perspektiven. Swiss Academics Reports 11 (5). Ed. Swiss Academy of Sciences SCNAT
http://www.naturalsciences.ch/organisations/proclim/activities/brennpunkt/downloads?_ga=1.155440827.1659782858.1483519929 [13.01.2017]
- SFOE 2001:** Schweizerische Gesamtenergiestatistik 2000. Statistique globale suisse de l'énergie 2000. Bundesamt für Energie, Bern
http://www.bfe.admin.ch/themen/00526/00541/00542/00631/index.html?lang=de&dossier_id=00763 [16.12.2016], [in German and French]

- SFOE 2002:** Swiss Federal Office for Energy: Ökobilanz Klärgasverstromung. Projekt 41863 Verfügung 83688. Bern, November 2002.
http://www.bfe.admin.ch/forschungbiomasse/02390/02720/03176/index.html?lang=de&dossier_id=03408
<http://www.naturemade.ch/de/unterkategorie-dokumente.html?file=files/PDF/KINrgasverstromung%2017.11.02.pdf> [16.03.2016]
- SFOE/FOEN 2014:** Messung von Heizwerten und CO₂-Emissionsfaktoren von Erdölprodukten 2013. Statistische Analyse der Messresultate, Bern.
- SFOE 2016:** Schweizerische Gesamtenergiestatistik 2015. Statistique globale suisse de l'énergie 2015. Swiss Federal Office of Energy, Bern.
http://www.bfe.admin.ch/themen/00526/00541/00542/00631/index.html?lang=de&dossier_id=00763 [06.01.2017], [in German and French]
- SFSO 2005:** Eidgenössische Volkszählung 2000 Haushalte und Familien. Swiss Federal Statistical Office.
- SFSO 2006a:** Arealstatistik 2004/09 - Kategorienkatalog. Bodenbedeckung, Bodennutzung. Sektion Geoinformatik.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [15.12.2016]
- SFSO 2016a:** Privathaushalte nach Kanton und Haushaltsgrösse. Swiss Federal Statistical Office
<https://www.bfs.admin.ch/bfsstatic/dam/assets/1362677/master> [19.12.2016].
- SFSO 2016b:** Erwerbstätige (Inlandkonzept) nach Geschlecht, Nationalität und Wirtschaftssektoren. Durchschnittliche Quartals- und Jahreswerte. Swiss Federal Statistical Office
<https://www.bfs.admin.ch/bfs/de/home/statistiken/arbeits-erwerb.assetdetail.336049.htm> [19.12.2016].
- SFSO 2016c:** Fahrzeuge Strasse – Bestand. Swiss Federal Statistical Office
<https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/verkehrsinfrastruktur-fahrzeuge/fahrzeuge.assetdetail.1600993.html> [19.12.2016]
- SFSO 2016d:** Bevölkerung – Die wichtigsten Zahlen. Swiss Federal Statistical Office
<http://www.bfs.admin.ch/bfs/portal/de/index/themen/01/01/key.html> [19.12.2016].
- Soliva, C.R. 2006:** Report to the attention of IPCC about the data set and calculation method used to estimate methane formation from enteric fermentation of agricultural livestock population and manure management in Swiss agriculture. On behalf of the Federal Office for the Environment, Bern. ETH Zurich, Institute of Animal Science.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [23.11.2016]

- Soliva, C.R. 2006a:** Dokumentation der Berechnungsgrundlage von Methan aus der Verdauung und dem Hofdünger landwirtschaftlicher Nutztiere. Im Auftrag des Bundesamtes für Umwelt, Bern. ETH Zürich, Institut für Nutztierwissenschaften. <http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [23.11.2016], [in German]
- Sommer, S.G., Petersen, S.O., Sorensen, P., Poulsen, H.D., Moller, H.B. 2007:** Methane and carbon dioxide emissions and nitrogen turnover during liquid manure storage. *Nutrient Cycling in Agroecosystems* 78 (1): 27-36.
- Spiess, E., Prasuhn, V. 2006:** Weniger Nitrat im Grundwasser dank Ökomassnahmen. *AGRAR Forschung* 13(1): 4-9.
- Staerfl, S. M., Amelchanka, S. L., Kälber, T., Soliva, C. R., Kreuzer, M., Zeitz, J. O. 2012:** Effect of feeding dried high-sugar ryegrass ('AberMagic') on methane and urinary nitrogen emissions of primiparous cows. *Livestock Science* 150(1-3): 293-301.
- Stehfest, E., Bouwman, L. 2006:** N₂O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions. *Nutrient Cycling in Agroecosystems* 74(3): 207-228.
- Stricker, B. 2012:** Energiebedarfswerte der Pferde, Esel und Ponys. Written communication from Brigitte Stricker (ALP-Haras, Agroscope Liebefeld-Posieux research station) to Daniel Bretscher (ART, Reckenholz), August-October 2012. <http://www.bafu.admin.ch/klima/13879/13880/15423/index.html?lang=en> [15.12.2016]
- SVGW 2016:** Schweizerischer Verein des Gas- und Wasserfaches. Measurements of leakage from seepage gas up-grade. Bendern, 03.06.2016.
- Swiss Confederation 2005:** Ordinance of 18 May 2005 on Risk Reduction related to the Use of certain particularly dangerous Substances, Preparations and Articles (Ordinance on Chemical Risk Reduction, ORRChem). SR Number 814.81. As on 1 August 2011. http://www.admin.ch/ch/d/sr/814_81/index.html [16.12.2016], [in German, French and Italian]
- TA-SWISS 2010:** Future Perspectives of 2nd Generation Biofuels. Rainer Zah, Claudia Binder, Stefan Bringezu, Jürgen Reinhard, Alfons Schmid, Helmut Schütz. vdf Hochschulverlag AG an der ETH Zürich. ISBN 978-3-7281-3334-2. Zentrum für Technologiefolgen-Abschätzung TA-SWISS 55/2010, Zürich.
- Thürig, E., Kaufmann, E., Frisullo, R., Bugmann, H. 2004:** Evaluation of the growth function of an empirical forest scenario model. *Forest Ecology and Management* 204 (2005), p. 51-66.
- Thürig, E., Palosuo, T., Bucher, J., Kaufmann, E. 2005:** The impact of windthrow on carbon sequestration in Switzerland: a model-based assessment. *Forest Ecology and Management* 210: 337-350. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T6X-4FR8PMC-3&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&_view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=92483bf9c1a1285d05e684f0267a7698 [13.01.2017]

- Thürig, E., Schmid, S. 2008:** Jährliche CO₂ Flüsse im Wald. Berechnungsmethode für das Kyoto Protokoll. [Annual CO₂ fluxes in forests: Calculation method for the Kyoto Protocol]. Schweizerische Zeitschrift für Forstwesen. Submitted.
www.bafu.admin.ch/ghginv-ref [13.01.2017]
- Thürig, E., Herold, A. 2013:** Recalculation of emission factors in Swiss forests for the Swiss GHGI. Internal documentation of technical adjustments of data delivery and more recent data. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. www.bafu.admin.ch/ghginv-ref [13.01.2017]
- TUG 2009:** Emission Factors from the Model PHEM for the HBEFA Version 3, Institute for Internal Combustion Engines and Thermodynamics, Report Nr. I-20/2009 Haus-Em 33/08/679, University of Technology, Graz.
- UBA 2004:** Nationales System Emissionsinventare. Zentrales System Emissionen (ZSE). Auszug aus der Datenbank ZSE (Inventar) für verschiedene Quellgruppen nach IPCC. Datenausspielung; U. Döring vom 20.04.2004. Umweltbundesamt, Berlin.
- UBA 2005:** Emissionen, Aktivitätsraten und Emissionsfaktoren von fluorierten Treibhausgasen (F-Gasen) in Deutschland für die Jahre 1995 – 2002. Texte: 14 / 05. Umwelt Bundes Amt. Berlin.
<http://www.umweltbundesamt.de/publikationen/methoden-indikatorenentwicklung-fuer-kenndaten> [16.12.2016]
- UBA 2007:** Daten von H-FKW, FKW und SF₆ für die nationale Emissionsberichterstattung gemäß Klimarahmenkonvention für die Berichtsjahre 2004 und 2005“ "Fluorierte Treibhausgase". Gutachten durch die Oeko-Recherche GmbH für das Umweltbundesamt (FKZ 205 41 217/01), Frankfurt.
<http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3439.pdf> [16.12.2016]
- UBA/Ökorecherche 2012:** Entsorgung von Kältemitteln aus stationären Anlagen, Emissionsfaktor der Entsorgung, Emissionsberichterstattung von F-Gasen in der Kälte- und Klimatechnik. UBA Umweltbundesamt Berlin – 24.10.12. Öko-Recherche Büro für Umweltforschung und -beratung GmbH, W. Schwarz, Barbara Gschrey. Umweltbundesamt Berlin - 24. Oktober 2012, Ergebnisse des Forschungsvorhabens 1. Gewerbekälte und 2. Industriekälte
http://www.umweltbundesamt.de/sites/default/files/medien/419/dokumente/4_entsorgung_statanlagen1.pdf [16.12.2016]
- UNFCCC 2009:** Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol.
http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/pdf/annotated_nir_outline.pdf [23.11.2016]
- UNFCCC 2011:** Report of the technical assessment of the forest management reference level submission of Liechtenstein submitted in 2011 (FCCC/TAR/2011/LIE).
<http://unfccc.int/resource/docs/2011/tar/lie01.pdf> [13.01.2017]

- UNFCCC 2014:** Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention. Decision 24/CP.19 (FCCC/CP/2013/10/Add.3)
<http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf> [06.01.2017]
- Van der Weerden, T.J., Jarvis, S.C. 1997:** Ammonia emission factors for N fertilizers applied to two contrasting grassland soils. *Environmental Pollution* 95(2): 205-211.
[http://dx.doi.org/10.1016/S0269-7491\(96\)00099-1](http://dx.doi.org/10.1016/S0269-7491(96)00099-1) [10.01.2017]
- Vorreiter, L. 1949:** Holztechnisches Handbuch. Band I: Allgemeines, Holzkunde, Holzschutz und Holzvergütung. Verlag Georg Fromme & Co., Wien.
- Vermorel, M., Martin-Rosset, W., Vernet, J. 1997:** Energy utilization of twelve forages or mixed diets for maintenance by sport horses. *Livestock Production Science* 47(2): 157-167.
- vTI 2011:** Review of the LULUCF Sector of Switzerland's Greenhouse Gas Inventory 1990–2008. Johann Heinrich von Thünen-Institut Bundesinstitut für Ländliche Räume, Wald und Fischerei. Institut für Agrarrelevante Klimaforschung. Braunschweig/Germany.
<https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html> [05.01.2017]
- Walther U., Menzi, H., Ryser, J.-P., Flisch, R., Jeangros, B., Maillard, A., Siegenthaler, A., Vuilloud, P.A. 1994:** Grundlagen für die Düngung im Acker- und Futterbau (GRUDAF). *Agrarforschung* 1(7): 1-40.
http://www.agrarforschung.ch/de/inh_det.php?id=724 [16.12.2016]
- Weerden and Jarvis 1997:** T. van der Weerden, S.C. Jarvis: Ammonia emission factors for N fertilizers applied to two contrasting grassland soils. *Environmentla Pollution*, Vol. 95, 2 No pp.2005-211
https://www.researchgate.net/publication/8611127_Ammonia_emission_factors_for_N_fertilizers_applied_to_two_contrasting_grassland_soils [16.12.2016]
- Xinmin, J. 2004:** Die Methanemissionen der Schweizer Gasindustrie. Abschätzung der Gasemissionen [Methane emissions from Swiss gas industry. Estimation of methane emissions]. *Gas, Wasser, Abwasser* 5/2004: 337-345.
<http://www.bafu.admin.ch/klima/13879/13880/14577/15536/index.html?lang=en> [06.01.2017]
- Zeitz, J. O., Soliva, C. R., Kreuzer, M. 2012:** Swiss diet types for cattle: how accurately are they reflected by the Intergovernmental Panel on Climate Change default values? *Journal of Integrative Environmental Sciences*, 9:sup1,199-216.
<http://dx.doi.org/10.1080/1943815X.2012.709253> [16.12.2016]