OFFICE OF THE ENVIRONMENT
PRINCIPALITY OF LIECHTENSTEIN

# Liechtenstein's Greenhouse Gas Inventory 1990 - 2023

## National Inventory Document 2025

Submission of April 2025
under the United Nations Framework Convention on Climate Change
and under the Paris Agreement

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# Liechtenstein's Greenhouse Gas Inventory 1990–2023

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Submission of April 2025
under the United Nations Framework Convention on Climate Change (UNFCCC)

**Authors**

INFRAS, Zurich/Switzerland

| | |
|---|---|
| Bettina Schäppi | (Lead author) Executive Summary, Indirect Emissions |
| Felix Weber | Agriculture |
| Anna Ehrler | Introduction, Trends, Uncertainty Analysis, Energy, IPPU, Annex |
| David Giger | KCA, Energy, Recalculations and improvements |
| Sophie Kaufmann | IPPU |

Meteotest, Bern/Switzerland

| | |
|---|---|
| Beat Rihm | LULUCF |

CSD Engineers, Bern/Switzerland

| | |
|---|---|
| Markus Sommerhalder | Waste |

**Emission modelling**

Acontec, Schaan/Liechtenstein

Jürgen Beckbissinger, Nadia Jaeggi

**Office of Environment, Vaduz/Liechtenstein** (http://www.au.llv.li)

| | |
|---|---|
| Regula Imhof | Director of the Office of Environment, Quality Manager (QA/QC) |
| Karin Jehle | National Focal Point, Project manager, National Inventory Compiler (NIC), Emission data, National Allocation Plan , |
| Hanspeter Eberle | LULUCF |

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# Glossary

| | |
|---|---|
| AR4, AR5 | Fourth Assessment Report, Fifth Assessment Report of the IPCC |
| 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). (Since 2024: part of EZV) |
| 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 |
| CRT | Common Reporting Tables |
| 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 |
| EZV | Entsorgungszweckverband der Gemeinden Liechtensteins (Liechtensteins waste disposal administration union) |
| 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 | Gigajoule ($10^9$ Joule = 1'000 Mega Joule) |
| GRUDAF | Grundlagen für die Düngung im Acker – und Futterbau |
| GWh | Gigawatt hour (energy unit), one million kilowatt hours, 1 GWh = 3.6 TJ |
| GWP, ($GWP_{100}$) | Global Warming Potential (100-year time-horizon) |
| 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 | Kilohectare (1'000 ha) |
| kt | Kilotonne (1'000 tonnes) |
| kWh | Kilowatt hour (energy unit), 1 kWh = 3.6 MJ |
| LFO | Light fuel oil (Gas oil) |
| LGV | Liechtensteinische Gasversorgung (Liechtenstein's gas utility), since 2022 Liechtenstein Wärme (LW) |
| 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 |
| LW | Liechtenstein Wärme (Liechtenstein Heat), former name Liechtensteinische Gasversorgung (LGV) until 2021 |
| 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 | Megawatt hour (energy unit), 1 MWh = 3.6 GJ |
| 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 |
| NID | National Inventory Document (formerly NIR) |
| NIR | National Inventory Report (now NID) |
| NIS | National Inventory System |
| NMVOC | Non-Methane Volatile Organic Compounds |
| $N_2O$ | Nitrous oxide (laughing gas) |
| $NO_x$ | Nitrogen oxides |
| OA | Office for Agriculture, former name of today’s Division of Agriculture within the Office of Environment, since 2012 |
| OCI | Office of Construction and Infrastructure |
| ODS | Ozone-Depleting Substances (CFCs, halons etc.) |
| OE | Office of Environment |
| OEA | Office of Economic Affairs |
| OEP | Office of Environmental Protection, former name of today’s Office of Environment (OE) since 2012 |
| OFIVA | Office of Food Inspection and Veterinary Affairs |
| OS | Office of Statistics |
| PFC | Perfluorinated carbon compounds (e.g. Tetrafluoromethane) |
| QA/QC | Quality assurance/quality control: QA includes a system of review procedures conducted by persons not directly involved in the inventory development process; QC is a system of routine technical activities to control the quality of the inventory |
| SAEFL | Swiss Agency for the Environment, Forests and Landscape (former name of Federal Office of the Environment FOEN) |
| $SF_6$ | Sulphur hexafluoride, 2006 IPCC GWP: 22’800 (UNFCCC 2014, Annex III) |
| SFOE | Swiss Federal Office of Energy |
| SFSO | Swiss Federal Statistical Office |
| $SO_2$ | Sulphur dioxide |

| | |
|---|---|
| TJ | Terajoule ($10^{12}$ Joule = 1’000'000 Megajoule) |
| 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 GHG inventories and climate change

### ES.1.1 Background information on climate change

Research shows that significant negative effects of global climate warming in the Alpine region have developed in the last decades and further negative impacts are expected in the future. The observations show significant increases in temperature, in the number of summer days and a decrease in the number of frost days in Liechtenstein. Associated with warming, the zero-degree limit has also risen, the vegetation period has been extended significantly, and the biological beginning of spring has advanced.

The following effects are expected as a consequence of a further temperature rise (OE 2020h, Government 2018):

- The temperature increase projected in the RCP8.5 scenario between today and 2060 is expected to be around 2-3°C, with more pronounced heating in summer than in winter periods.
- The changes in precipitation by 2060 are still uncertain, but decreasing precipitation are most likely to occur in summer.
- The snowline is expected to increase from today around 850 m a.s.l. to about 1250 to 1500 m a.s.l.
- 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, landslides, and the reduction in the permafrost layer. The increasing weather instabilities may lead to floods in winter and droughts in summertime 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

**International commitments**

In 1995, the Principality of Liechtenstein ratified the United Nations Framework Convention on Climate Change (UNFCCC). Furthermore, Liechtenstein ratified both commitment periods of the Kyoto Protocol in 2004 and 2014, respectively, and the Paris Agreement in 2017.

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. With the adoption of the new Climate Strategy 2050 (Government 2023), the Parliament of Liechtenstein approved the increase of the

reduction target for 2030 to 55% below 1990 levels. This led to the revision of article 4 paragraph 1 of the Emissions Trading Act in May 2023 (Emissionshandelsgesetz, Government 2012). Prior to the 30th UN Climate Change Conference (UNFCCC COP 30), Liechtenstein will communicate its updated Nationally Determined Contribution to the UNFCCC.

**Submission of Greenhouse Gas Inventories**

In 2005, the first Greenhouse Gas Inventory of Liechtenstein was submitted in the Common Reporting Format (CRF) without National Inventory Report. From 2006–2014, Liechtenstein annually submitted its Greenhouse Gas Inventory together with the National Inventory Report prepared under the UNFCCC and under the Kyoto Protocol (OEP 2006–2011, OEP 2006a, 2007a, 2007b, 2012b, OE 2013–2014).

The submission of the Greenhouse Gas Inventory and National Inventory Report in 2015 was postponed and submitted in 2016. From 2016–2022, Liechtenstein annually submitted its Greenhouse Gas Inventory together with the National Inventory Report prepared under the UNFCCC and under the Kyoto Protocol (OE 2016a, OE 2016c, OE 2017–2022).

Since 2023 Liechtenstein annually submitted the Greenhouse Gas Inventory and National Inventory Document under the UNFCCC (OE 2023-2024).

**Reviews of Greenhouse Gas Inventories**

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, 2014, 2016, 2018, 2020 and 2022. The review of the GHG inventories and National Inventory Reports 2015 and 2016 took place simultaneously in September 2016 due to the postponed submission in 2015. In response to the Potential Problems formulated in the course of the review of the 2022 annual submission of Liechtenstein, Liechtenstein corrected an error in the preparation of emission data in sector 1B and submitted updated CRF tables in November 2022 (OE 2022g).

**National Inventory System (NIS) and inventory preparation process**

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, which 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. 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 CRT Reporter that generates the **reporting tables**.

The **National Inventory Document** follows in its structure the outline presented in "Guidance operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement" (UNFCCC 2021).

**National circumstances**

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 40'015 inhabitants (2023) and with an area of 160 $km^2$. Its neighbours are therefore important partners: Liechtenstein and Switzerland form a customs and monetary union governed by a customs treaty. On the basis of this union, Liechtenstein is linked to Swiss foreign trade strategies, with few exceptions, such as trade: 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 adopted and applied in Liechtenstein. For the determination of the GHG emissions, Liechtenstein appreciates having been authorised to apply a number of Swiss methods and Swiss emission factors.

# ES.2. Summary of trends related to national emissions and removals

**National total emissions**

Liechtenstein's greenhouse gas emissions in the year 2023 amount to 167.3kt $CO_2$ equivalent ($CO_2$eq) excluding LULUCF sources or sinks (including LULUCF: 160.0 kt $CO_2$eq). This refers to 4.18 t $CO_2$eq per capita.

Total emissions in 2023 (excl. LULUCF) have declined by 26.8% compared to 1990. Compared to 2022, they increased by 1.5%. When including LULUCF categories, total emissions increased by 1.5% between 2022-2023 and decreased by 31% between 1990-2023.

**Uncertainties**

Uncertainty analyses with Approach 1 is carried out and presented in chp. 1.6.3. Approach 1 results show the following results:

- Uncertainty of national total $CO_2$eq emissions **excluding LULUCF:**
  The Approach 1 level uncertainty for the year 2023 is estimated to be 5.19%, trend uncertainty (1990-2023) is 6.12% (see Table 1-8). The level uncertainty for the year 1990 amounts 6.87% (see Table 1-9).
- Uncertainty of national total $CO_2$eq emissions **including LULUCF**:
  The Approach 1 level uncertainty for the year 2023 is estimated to be 6.69%, trend

uncertainty (1990-2023) is 7.03% (see Table 1-10). The level uncertainty for the year 1990 amounts 6.83% (see Table 1-11).

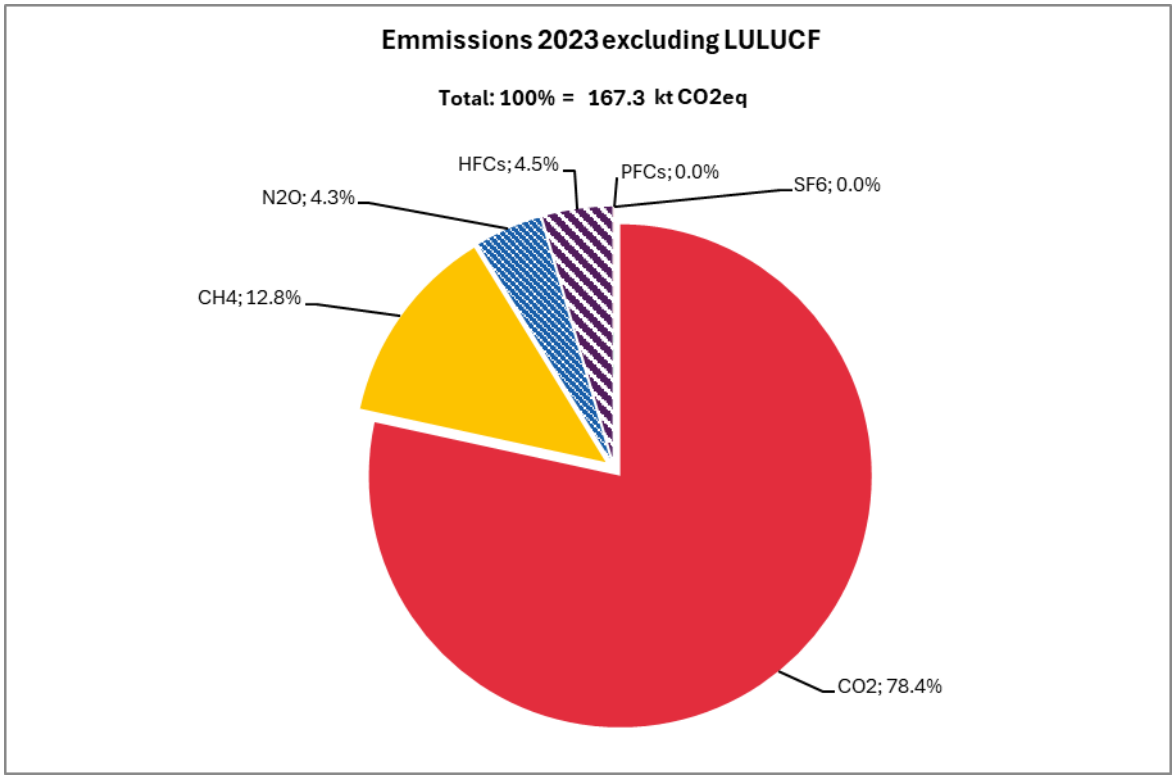
**Recalculations**

Some emissions have been recalculated due to updates in respective sectors. In this submission, there are major recalculations in the LULUCF sector, as new data from the National Forest Inventory 2022 (LWI 2025) were included in the calculations, and in the sector Agriculture due to updates in the model used to calculate the emissions.

The results are discussed in Chapter 10. For the base year 1990, the recalculations carried out in submission 2025 lead to a decrease of 0.24% in the national total emissions (excluding LULUCF categories). The national total emissions of the year 2022 decreased by 0.35% due to the recalculations (excluding LULUCF categories).

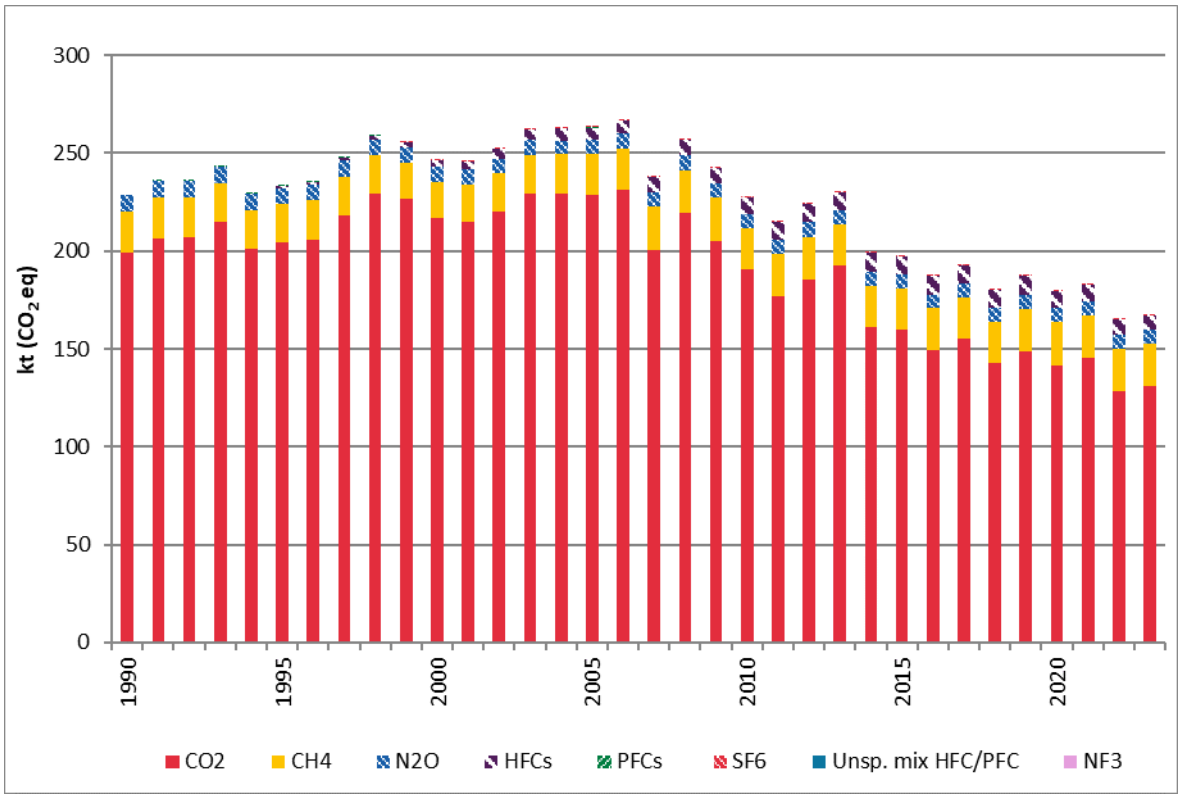
## ES.3. Overview of source and sink category emission estimates and trends

ES Figure 1 shows the emissions in 2023 by GHG. The main GHG is $CO_2$ with a share of 78.4%. $CH_4$ and $N_2O$ contribute with 12.8% and 4.3%, F-gases with about 4.5%, respectively.




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

ES Figure 2 illustrates that the emission shares of the various greenhouse gases are similar for the full time period. $CO_2$ accounts for the largest share of emissions, while $CH_4$, $N_2O$ and F-Gases are only minor contributors. Emissions have increased after 1990, reaching a maximum in 2006. From then onwards, a decreasing trend starts to develop, still showing fluctuations driven by the varying temperatures of winter seasons and fuel prices. In 2023, emissions have increased compared to the previous reporting year 2022 (excluding LULUCF categories).




ES Figure 2 Trend of Liechtenstein's GHG emissions by gases. $CO_2$, $CH_4$ and $N_2O$ correspond to the respective total emissions excluding LULUCF.

The emission shares (excl. LULUCF emissions) of the greenhouse gases developed as follows:

- The share of $CO_2$ emissions decreased from 87.1% in 1990 to 78.4% in 2023 (excl. LULUCF).
- The share of $CH_4$ increased from 9.2% in 1990 to 12.8% in 2023 (excl. LULUCF).
- The share of $N_2O$ increased from 3.7% (1990) to 4.3% (2023).
- The share of the sum of all F-gases (within total emissions excl. LULUCF) increased from 0.00004% (1990) to 4.5% (2023).

ES Table 2 represents the GHG emissions and removals by categories. Sector 1 Energy is the largest source of national emissions, contributing to 79.8% of the emissions (excluding LULUCF) in 2023. Emissions caused within the energy sector decreased by 33.6% over the period 1990–2023. The emissions from sector 2 Industrial processes and product use increased by a factor of about 12.8 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 in 2023 are 2.4% below the level of 1990. Emissions and removals in the sector 4 LULUCF form a net sink in 2023 and show a decrease of 305% compared to 1990. The emissions from sector 5 Waste have increased by 1.0% since 1990. They encompass a small amount of emissions because municipal solid waste disposal has ceased since 1974 and waste is exported to a Swiss solid waste incineration plant.

ES Table 1 Summary of Liechtenstein's GHG emissions in $CO_2$eq (kt) by gas. The last column shows the percentage change in emissions in 2023 as compared to the base year 1990. HFC emissions have increased by about a factor of 78'000 in 2023 compared to 1990.

| Greenhouse Gas Emissions | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | |
| $CO_2$ emissions incl. net $CO_2$ from LULUCF | 202.2 | 205.1 | 242.1 | 234.7 | 207.5 |
| $CO_2$ emissions excl. net $CO_2$ from LULUCF | 199.0 | 204.2 | 216.9 | 229.0 | 190.8 |
| $CH_4$ emissions incl. $CH_4$ from LULUCF | 21.0 | 19.6 | 18.3 | 20.5 | 21.1 |
| $CH_4$ emissions excl. $CH_4$ from LULUCF | 21.0 | 19.6 | 18.3 | 20.5 | 21.1 |
| $N_2O$ emissions incl. $N_2O$ from LULUCF | 8.7 | 8.7 | 8.1 | 7.7 | 7.8 |
| $N_2O$ emissions excl. $N_2O$ from LULUCF | 8.5 | 8.4 | 7.6 | 7.2 | 7.3 |
| HFCs | 0.0 | 1.1 | 3.5 | 6.4 | 8.4 |
| PFCs | NA,NO | 0.0 | 0.0 | 0.1 | 0.1 |
| $SF_6$ | NA,NO | NA,NO | 0.1 | 0.3 | 0.0 |
| Unspecified mix of HFCs and PFCs | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |
| $NF_3$ | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |
| **Total (including LULUCF)** | 232.0 | 234.5 | 272.2 | 269.6 | 244.9 |
| **Total (excluding LULUCF)** | 228.5 | 233.3 | 246.5 | 263.4 | 227.6 |

| Greenhouse Gas Emissions | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | |
| $CO_2$ emissions incl. net $CO_2$ from LULUCF | 163.7 | 160.3 | 148.8 | 155.2 | 151.4 |
| $CO_2$ emissions excl. net $CO_2$ from LULUCF | 161.2 | 159.7 | 149.7 | 155.5 | 142.6 |
| $CH_4$ emissions incl. $CH_4$ from LULUCF | 21.1 | 21.0 | 21.1 | 20.6 | 20.9 |
| $CH_4$ emissions excl. $CH_4$ from LULUCF | 21.1 | 21.0 | 21.1 | 20.6 | 20.9 |
| $N_2O$ emissions incl. $N_2O$ from LULUCF | 7.7 | 7.8 | 7.6 | 7.6 | 7.8 |
| $N_2O$ emissions excl. $N_2O$ from LULUCF | 7.2 | 7.2 | 7.1 | 7.1 | 7.2 |
| HFCs | 9.4 | 9.5 | 9.2 | 9.5 | 9.6 |
| PFCs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $SF_6$ | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| Unspecified mix of HFCs and PFCs | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |
| $NF_3$ | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |
| **Total (including LULUCF)** | **202.1** | **198.6** | **186.8** | **193.0** | **189.9** |
| **Total (excluding LULUCF)** | **199.0** | **197.5** | **187.1** | **192.7** | **180.4** |

| Greenhouse Gas Emissions | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | | % |
| $CO_2$ emissions incl. net $CO_2$ from LULUCF | 150.5 | 135.9 | 136.7 | 120.5 | 123.4 | -39.0% |
| $CO_2$ emissions excl. net $CO_2$ from LULUCF | 148.7 | 141.6 | 145.6 | 128.3 | 131.2 | -34.1% |
| $CH_4$ emissions incl. $CH_4$ from LULUCF | 21.8 | 21.9 | 21.6 | 21.4 | 21.5 | 2.0% |
| $CH_4$ emissions excl. $CH_4$ from LULUCF | 21.8 | 21.9 | 21.6 | 21.4 | 21.5 | 2.0% |
| $N_2O$ emissions incl. $N_2O$ from LULUCF | 7.9 | 7.8 | 7.8 | 7.8 | 7.6 | -12.5% |
| $N_2O$ emissions excl. $N_2O$ from LULUCF | 7.3 | 7.2 | 7.3 | 7.3 | 7.2 | -15.4% |
| HFCs | 9.3 | 8.8 | 8.2 | 7.8 | 7.5 | see caption |
| PFCs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - |
| $SF_6$ | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | - |
| Unspecified mix of HFCs and PFCs | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | - |
| $NF_3$ | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | - |
| **Total (including LULUCF)** | **189.6** | **174.4** | **174.3** | **157.7** | **160.0** | **-31.0%** |
| **Total (excluding LULUCF)** | **187.1** | **179.5** | **182.7** | **164.9** | **167.3** | **-26.8%** |

ES Table 2 Summary of Liechtenstein's GHG emissions by source and sink categories in $CO_2$ equivalent (kt). The last column indicates the percent change in emissions in 2023 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** | **201.3** | **208.9** | **209.7** | **217.8** | **203.8** | **207.0** | **208.9** | **221.4** | **232.3** | **229.7** |
| 1.A.1. Energy Industries | 0.2 | 0.8 | 1.9 | 2.0 | 1.8 | 2.1 | 2.6 | 2.5 | 2.9 | 2.9 |
| 1.A.2. Manufacturing ind. & construction | 36.3 | 35.9 | 36.3 | 37.6 | 35.6 | 35.7 | 35.7 | 37.6 | 40.3 | 39.8 |
| 1.A.3. Transport | 76.9 | 90.2 | 89.5 | 87.4 | 80.0 | 82.0 | 83.3 | 86.9 | 86.5 | 90.7 |
| 1.A.4. Other Sectors | 87.6 | 81.4 | 81.4 | 90.3 | 85.8 | 86.6 | 86.5 | 93.6 | 101.7 | 95.4 |
| 1.A.5. Other | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 1.B. Fugitive emissions from fuels | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | 0.8 | 0.9 |
| **2. IPPU** | **0.6** | **0.6** | **0.6** | **0.7** | **0.9** | **1.6** | **1.8** | **2.2** | **2.7** | **3.2** |
| **3. Agriculture** | **24.8** | **24.8** | **24.1** | **23.0** | **23.1** | **23.0** | **23.1** | **22.7** | **22.2** | **21.3** |
| **5. Waste** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** |
| ***Total (excluding LULUCF)*** | ***228.5*** | ***236.0*** | ***236.1*** | ***243.2*** | ***229.5*** | ***233.3*** | ***235.5*** | ***248.0*** | ***258.9*** | ***255.9*** |
| **4. LULUCF** | **3.6** | **-12.7** | **-1.4** | **-4.8** | **15.0** | **1.2** | **-7.3** | **9.0** | **0.9** | **-0.4** |
| ***Total (including LULUCF)*** | ***232.0*** | ***223.3*** | ***234.7*** | ***238.4*** | ***244.6*** | ***234.5*** | ***228.2*** | ***257.0*** | ***259.8*** | ***255.4*** |

| Source and Sink Categories | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | | | | | | |
| **1. Energy** | **220.1** | **217.8** | **223.1** | **232.4** | **232.0** | **231.6** | **233.8** | **203.4** | **222.2** | **208.1** |
| 1.A.1. Energy Industries | 2.8 | 2.9 | 2.5 | 2.8 | 3.0 | 3.1 | 2.9 | 2.6 | 2.9 | 3.0 |
| 1.A.2. Manufacturing ind. & construction | 36.4 | 36.4 | 37.9 | 41.2 | 39.8 | 39.1 | 40.5 | 33.9 | 36.3 | 27.5 |
| 1.A.3. Transport | 91.5 | 88.1 | 84.0 | 83.8 | 82.3 | 81.8 | 79.2 | 83.4 | 87.8 | 81.9 |
| 1.A.4. Other Sectors | 88.4 | 89.4 | 97.6 | 103.5 | 105.8 | 106.3 | 109.9 | 82.3 | 93.9 | 94.5 |
| 1.A.5. Other | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 1.B. Fugitive emissions from fuels | 0.9 | 1.0 | 1.0 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1.2 |
| **2. IPPU** | **4.0** | **4.8** | **5.5** | **6.2** | **6.8** | **7.1** | **7.5** | **8.2** | **8.8** | **8.3** |
| **3. Agriculture** | **20.7** | **21.8** | **22.2** | **22.3** | **22.4** | **23.0** | **24.0** | **24.4** | **24.6** | **24.5** |
| **5. Waste** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** |
| ***Total (excluding LULUCF)*** | ***246.5*** | ***246.1*** | ***252.4*** | ***262.6*** | ***262.8*** | ***263.4*** | ***267.0*** | ***237.7*** | ***257.4*** | ***242.6*** |
| **4. LULUCF** | **25.7** | **1.9** | **2.6** | **4.0** | **6.2** | **6.2** | **11.1** | **20.4** | **22.5** | **18.9** |
| ***Total (including LULUCF)*** | ***272.2*** | ***248.0*** | ***255.1*** | ***266.6*** | ***269.0*** | ***269.6*** | ***278.1*** | ***258.1*** | ***279.9*** | ***261.5*** |

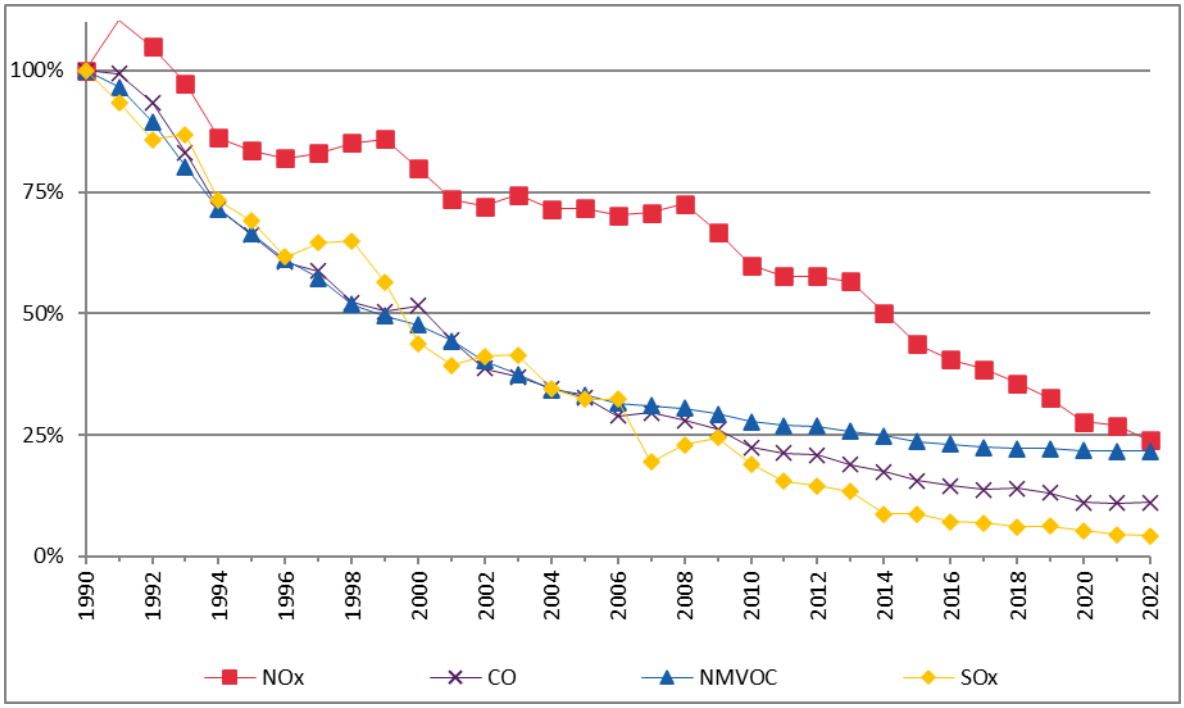
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | | | | | | |
| **1. Energy** | **193.5** | **179.4** | **187.9** | **195.2** | **163.6** | **162.2** | **152.1** | **158.0** | **145.1** | **151.2** |
| 1.A.1. Energy Industries | 3.3 | 3.1 | 2.8 | 3.0 | 2.5 | 2.0 | 2.2 | 2.1 | 2.2 | 3.4 |
| 1.A.2. Manufacturing ind. & construction | 26.1 | 23.6 | 25.7 | 26.4 | 27.3 | 27.6 | 25.9 | 27.7 | 24.6 | 24.1 |
| 1.A.3. Transport | 77.7 | 76.8 | 79.8 | 79.5 | 73.7 | 61.7 | 60.3 | 60.5 | 58.5 | 57.0 |
| 1.A.4. Other Sectors | 85.2 | 74.7 | 78.3 | 84.9 | 58.9 | 69.5 | 62.5 | 66.4 | 58.6 | 65.4 |
| 1.A.5. Other | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 1.B. Fugitive emissions from fuels | 1.3 | 1.2 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| **2. IPPU** | **8.8** | **9.2** | **9.5** | **9.7** | **9.9** | **9.9** | **9.5** | **9.8** | **10.0** | **9.6** |
| **3. Agriculture** | **23.6** | **24.4** | **24.7** | **23.6** | **23.9** | **23.8** | **23.8** | **23.3** | **23.7** | **24.6** |
| **5. Waste** | **1.7** | **1.7** | **1.7** | **1.7** | **1.6** | **1.6** | **1.6** | **1.6** | **1.6** | **1.6** |
| ***Total (excluding LULUCF)*** | ***227.6*** | ***214.7*** | ***224.0*** | ***230.1*** | ***199.0*** | ***197.5*** | ***187.1*** | ***192.7*** | ***180.4*** | ***187.1*** |
| **4. LULUCF** | **17.3** | **8.4** | **8.4** | **3.3** | **3.0** | **1.2** | **-0.3** | **0.3** | **9.4** | **2.4** |
| ***Total (including LULUCF)*** | ***244.9*** | ***223.2*** | ***232.4*** | ***233.4*** | ***202.1*** | ***198.6*** | ***186.8*** | ***193.0*** | ***189.9*** | ***189.6*** |

| Source and Sink Categories | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|
| | $CO_2$eq (kt) | | | | % |
| **1. Energy** | **144.1** | **148.1** | **130.8** | **133.6** | **-33.6%** |
| 1.A.1. Energy Industries | 2.4 | 2.6 | 2.3 | 2.9 | 1579% |
| 1.A.2. Manufacturing ind. & construction | 22.8 | 23.2 | 21.3 | 19.8 | -45.4% |
| 1.A.3. Transport | 52.5 | 55.8 | 50.1 | 54.1 | -29.7% |
| 1.A.4. Other Sectors | 65.0 | 65.2 | 55.8 | 55.6 | -36.5% |
| 1.A.5. Other | NO | NO | NO | NO | - |
| 1.B. Fugitive emissions from fuels | 1.3 | 1.4 | 1.4 | 1.3 | 214.7% |
| **2. IPPU** | **9.1** | **8.5** | **8.1** | **7.8** | **1185%** |
| **3. Agriculture** | **24.7** | **24.3** | **24.2** | **24.2** | **-2.4%** |
| **5. Waste** | **1.6** | **1.7** | **1.7** | **1.7** | **0.9%** |
| ***Total (excluding LULUCF)*** | ***179.5*** | ***182.7*** | ***164.9*** | ***167.3*** | ***-26.8%*** |
| **4. LULUCF** | **-5.2** | **-8.4** | **-7.3** | **-7.3** | **-305.2%** |
| ***Total (including LULUCF)*** | ***174.4*** | ***174.3*** | ***157.7*** | ***160.0*** | ***-31.0%*** |

# ES.4. Other information

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 2025 will take place at the end of April 2025, and **the overview and results provided below are from the submission to CLRTAP in 2024**. (Therefore, results for 2023 are not yet available.)

For the precursor substances $NO_x$, CO and NMVOC as well as for the gas $SO_2$, data are shown in ES Figure 3 (Acontec 2025). Emissions of road transportation are calculated by the territorial principle and, therefore, differ in methodology from emission estimation under the UNFCCC reporting (sales principle). For this reason, air pollutant emissions (ES Figure 3) may not consistently be compared to GHG emissions (ES Figure 2).




ES Figure 3 Trend of $NO_x$, CO, NMVOC and $SO_x$ emissions as of CLRTAP submission 2024 (OE 2024f).

## ES.5. Key Category Analysis

For 2023, among a total of 201 categories (excluding LULUCF categories), eleven have been identified as Approach 1 key categories by the CRT Reporter Software (CRF Table7) with an aggregated contribution of 96.1% of the national total emissions. Within those eleven key categories, seven stem from the energy sector, contributing 79.0% to total $CO_2$ equivalent emissions in 2023. The other key categories are from the sectors Agriculture (three categories, contribution 12.8%) and Industrial Processes and Product Use IPPU (one category, contribution 4.3%).

The three major sources, all from the energy sector, sum up to a contribution of 64.8% of the national total emissions:

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

When including LULUCF categories in the analysis, 21 among the 228 categories are key. Nine of the key categories are from the LULUCF sector. Furthermore, one additional category from the sector Agriculture is key when performing the KCA for the full inventory (including LULUCF categories).

## ES.6. Improvements introduced

In the current greenhouse gas inventory of Liechtenstein 1990–2023 (NID and CRT reporting tables), a major improvement was implemented in the LULUCF sector, as new data from the National Forest Inventory 2022 (LWI 2025) were included in the calculations. Also, the model used to calculate emissions in sector Agriculture was updated. The improvements in sector LULUCF and Agriculture and minor improvements in other source categories are documented in the source category specific chapters on recalculations and improvements.

# 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 for the 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 NID.

The OE also gratefully acknowledges the support of the Agroscope Reckenholz 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 fruitful cooperation.

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 Heat (LW, former name LGV) and Electric Power Company (LKW), Liechtenstein’s Waste Disposal Administration Union (EZV), Rotex Helicopter AG, Swiss Federal Office of Civil Aviation (FOCA), Swiss Federal Office for the Environment (FOEN), the sectoral experts and the NID authors. Their effort made it possible to finalise the inventory and the NID 2025.

# 1. National circumstances, institutional arrangements and cross-cutting information

## 1.1 Background information on Liechtenstein's greenhouse gas inventory and climate change

### 1.1.1 Principality of Liechtenstein

Liechtenstein is a small central European State between Switzerland and Austria in the Alpine region with a population of 40'015 inhabitants (2023) and with an area of 160 $km^2$.

Figure 1-1 The Principality of Liechtenstein. Vaduz is the capital.

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: 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 adopted 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.

### 1.1.2 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) and CH2011 (2011). In November 2018, the “Climate Scenarios for Switzerland” CH2018 (NCCS 2018) were published. The CH2018 scenarios are more detailed compared to previous studies and particularly more regionally differentiated.

The historic development and projections indicate that noticeable effects are to be expected. Liechtenstein published “Facts and figures about the climate in Liechtenstein” showing expected temperature and precipitation in the year 2060 (OE 2020h). The results of 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 findings by the CH2018 “Climate Scenarios for Switzerland” (NCCS 2018), CH2014-Impact study (CH2014-Impacts 2014), the CH2011 (CH2011 2011) report and the Swiss Academies Report no. 11 (SCNAT 2016). Also, results of a report of the International Bodensee Conference have been considered with specific findings for Liechtenstein (IBK 2007).

In 2013 and 2020, 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, FOEN/MeteoSwiss 2020). Impacts are analysed quantitatively in the CH2014-Impacts (2014) study. The results are also representative for Liechtenstein (OE 2020h). 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.

#### 1.1.2.1 Impacts

The Office of Environment (OE) Liechtenstein published a booklet with facts and figures about climate change in 2020 (OE 2020h). The mean annual temperature of Liechtenstein (location Vaduz) is 10.6°C for the current standard reference period 1991–2020. The mean annual temperature increased by 1.2°C compared to the reference period 1961–1990 (MeteoSwiss 2024). Figure 1-2 shows a time series of the temperature deviation in the years 1901–2019 from the mean temperature in Liechtenstein (1961–1990). The symbols are maps of Liechtenstein (see Figure 1-1 for details).

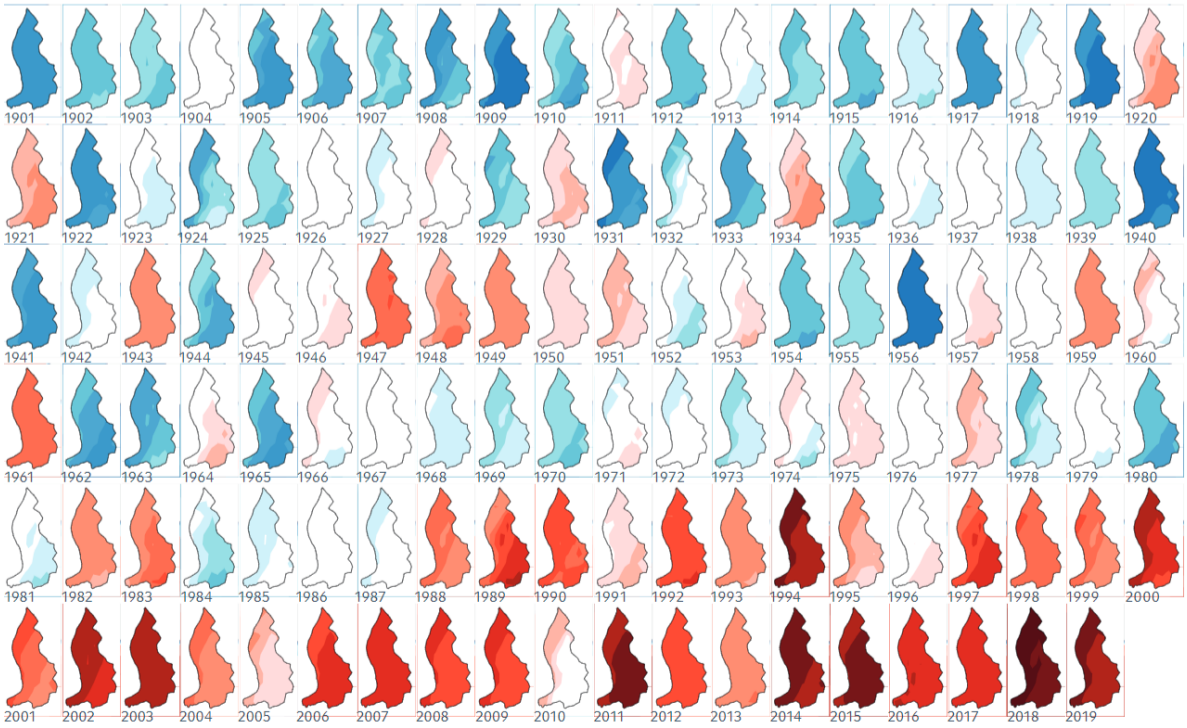



Figure 1-2 Deviation from mean annual temperature (mean of 1961–1990) in the principality of Liechtenstein between 1901 and 2019. Positive deviations are marked in red (max. +2.5°C), negative deviations in blue (min -2.5°C). Data: OE (2020h).

For the Principality of Liechtenstein, no long records of temperature measurements exist. The measurement station in Vaduz (Liechtenstein)[1] is only in operation since 1971. However, there are two measurement stations in Switzerland close to the border of Liechtenstein, Sargans (3 km up the Rhine valley from the border) and Bad Ragaz (5 km from the border), with temperature measurements since 1871. The temperature time series of Vaduz since 1971 shows high similarities to those of Sargans and Bad Ragaz. Since the beginning of the measurements in 1871, the temperature in Sargans and Bad Ragaz has increased by around 1.9°C. Since 1971, the number of summer days has increased from about 40 to about 50 days while the frosty days[2] have declined from around 90 to around 80 (Government 2018). These results most probably also apply to the valley regions of Liechtenstein. Between the reference period 1961–1990 and 1991–2020, Liechtenstein's annual mean temperature has risen by 1.2°C (MeteoSwiss 2024). This increase is up to three times higher as the world-wide temperature increase and has been observed in the other Alpine countries as well. Associated with the warming, the zero-degree isotherm has also risen by several hundred meters and the vegetation period has been extended by three to four weeks. Phenological observations show that the biological beginning of spring has been advancing by 1.5 to 2.5 days per decade. Further details are described in a specific chapter of Liechtenstein's Adaptation strategy (Government 2018).

[1] The station at Vaduz is part of the SwissMetNet, the official meteorological monitoring network of the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss).
[2] Frosty day: Temperature falls below 0°C.

According to the Swiss Climate Change Scenarios CH2018 (NCCS 2018), the future climate of Liechtenstein is expected to change significantly from the present and past conditions. In the scenario RCP8.5 (without mitigation measures) the mean temperature will increase by 2–3°C between today until 2060. In the scenario RCP2.6 (with ambitious mitigation measures) the mean temperature will increase by 0.5–2°C between today until 2060. Figure 1-4 illustrates the past and expected future changes in seasonal mean temperature over north-eastern Switzerland.

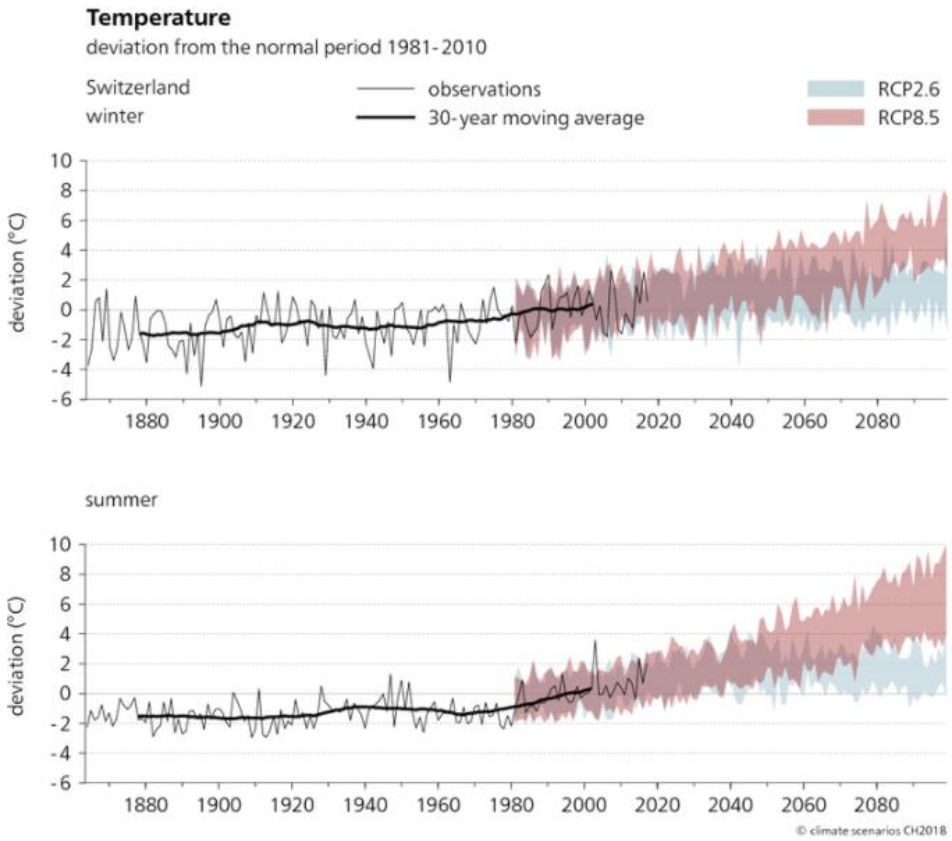



Figure 1-3 Past and expected future changes in seasonal temperature (°C) over north-eastern Switzerland for the scenario RCP2.6 (with mitigation measures) and RCP8.5 (without mitigation measures). The changes are depicted relative to the reference period 1981–2010 (from NCCS 2018).

Summer mean precipitation is projected to decrease by 16%, in the scenario RCP8.5. Mean precipitation in winter is expected to increase by 25% (Figure 1-4).

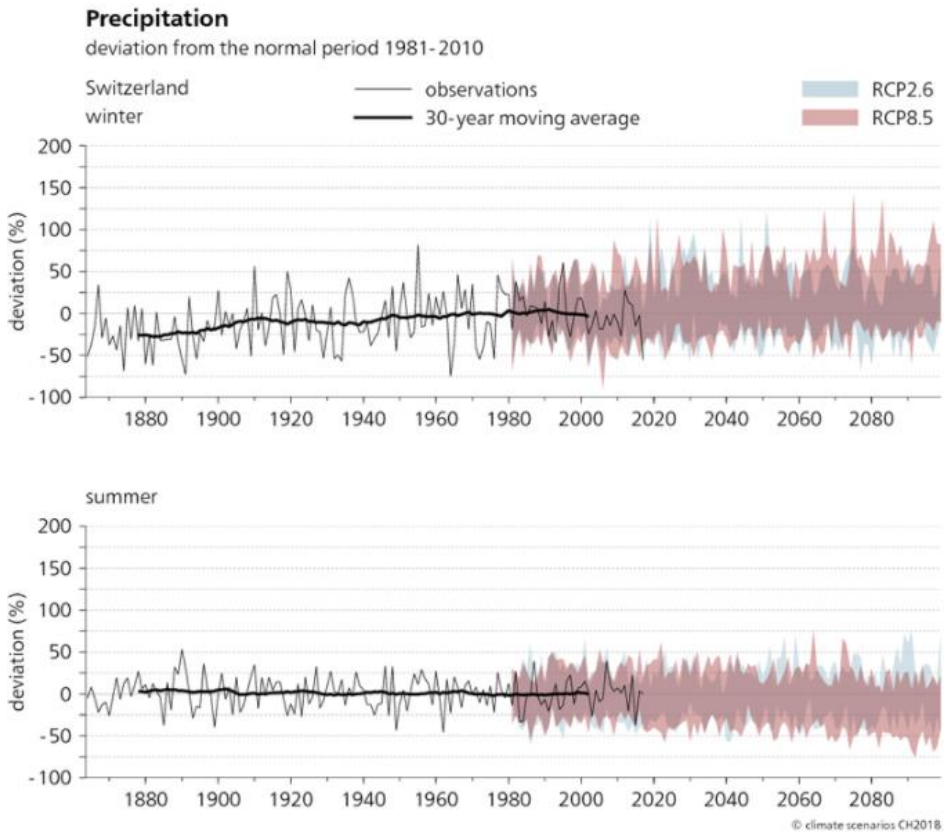



Figure 1-4 Past and expected future changes in seasonal precipitation (%) over north-eastern Switzerland for the scenario RCP2.6 (with mitigation measures) and RCP8.5 (without mitigation measures). The changes are depicted relative to the reference period 1981–2010 (from NCCS 2018).

For the year 2085, the expected changes in annual mean temperature and precipitation are represented in Figure 1-5 in a spatial resolution of 2 km.

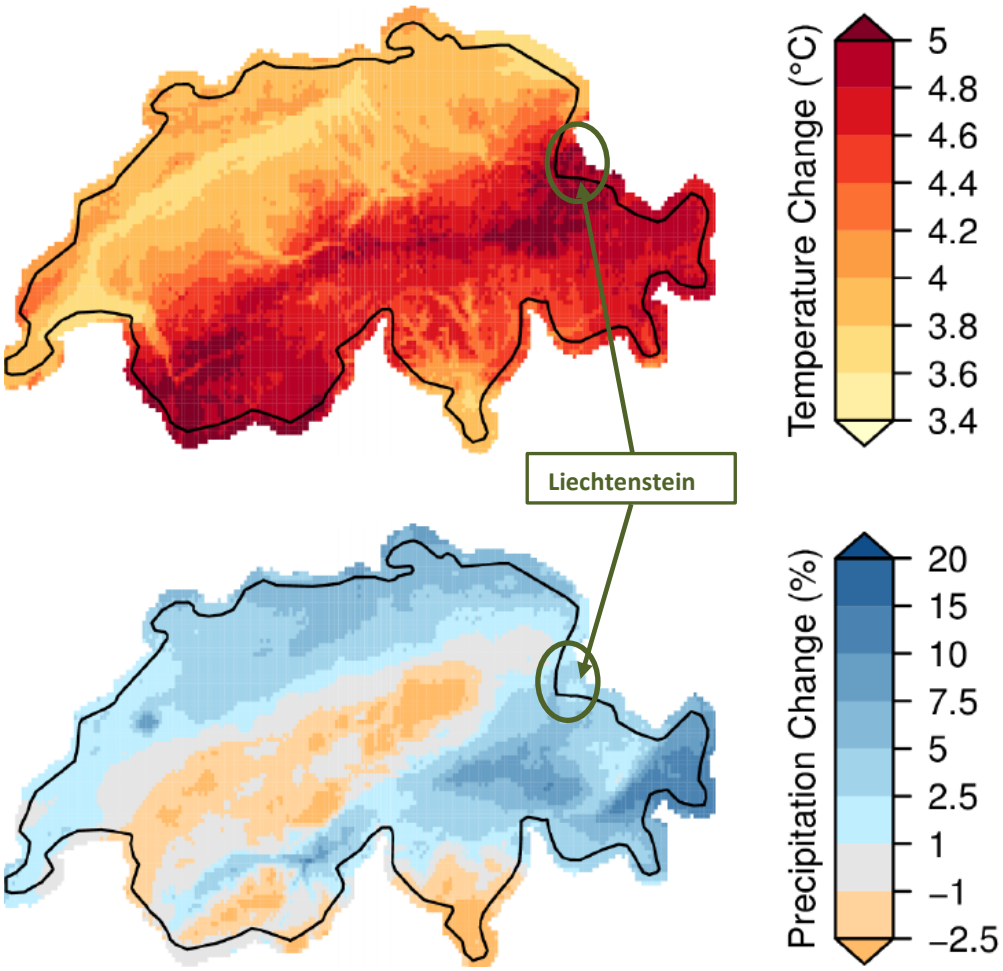



Figure 1-5 Ensemble median changes in annual mean temperature (upper map) and annual mean precipitation (lower map) for the "unabated emissions scenario" period 2085 in the high-resolution grid of 2 km for Switzerland and Liechtenstein (NCCS 2018).

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) with respect to the reference period 1981–2010. The number of summer days is expected to increase from 42 summer days per year to 75 in 2060 in the valley regions. The number of frost days is expected to decrease from 80 days to 50 days in 2060 (OE 2020h). In addition, a shift from solid (snow) to liquid (rain) precipitation is expected, which would increase flood risk primarily in the lowlands (NCCS 2018). The warming trend and changing precipitation patterns are also expected to have significant effects on ecosystems. The Biodiversity Monitoring Switzerland reports that climate change impacts are being observed even within short time periods. 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 vegetation period increased by 2 to 4 weeks since 1970 (OE 2020h).

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. Liechtenstein's adaptation strategy describes the expected effects (Government 2018). A specific risk analysis 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.

### 1.1.2.2 Vulnerability assessments

The following general effects can be expected as a consequence of further increasing $CO_2$ concentrations and the associated rise in temperature (Government 2018):

**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. 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.

**Biodiversity, 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.

**Natural hazards:** changes in weather patterns may lead to an increased risk of floods in winter and droughts in summertime. 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.

**Agriculture, energy production, water management:** A rise in temperature may have 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 production of hydropower will be influenced by changing precipitation patterns. Overall, increased competition for water resources (hydropower production, agriculture, industry, tourism, nature conservation) can be expected.

The international engagement of the insurance sector will likely suffer the most severe negative consequences from an increase in the probability of losses.

### 1.1.2.3 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 Climate Vision 2050 (Government 2020a), the Climate Strategy 2050 (Government 2023) and the former National Climate Protection Strategy (Government 2015), the Energy Strategy 2030 and Energy Vision 2050 (Government 2020), the revised Emissions Trading Act (Government 2012), the Energy Efficiency Act (Government 2008), the $CO_2$-Act (Government 2013), the Environmental Protection Act (Government 2008a), National Transport Policies, the Agricultural Report (Government 2022), the Forest Strategy (Government 2024) and the Action Plan on Air (OEP 2007e). The $CO_2$ Act, which is the main climate related legislation, is currently under revision. The revised $CO_2$ Act has been adopted in January 2025 and the revision of the $CO_2$Ordinance linked to the revised Act is still ongoing. The Action Plan on Biodiversity 2030+ was published in 2024 (Government 2024a). The

Liechtenstein's climate policy goal is to achieve its "Nationally Determined Contribution" (NDC) under the Paris Agreement. 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% by 2030 compared to 1990 (Government 2015a). A long-term climate strategy has been elaborated for Liechtenstein (Government 2023). The Climate Strategy 2050 includes a definition of the increase in the emission reduction target for 2030 and concrete measures for all sectors in order to achieve the target of the Climate Vision 2050 (climate neutrality by 2050). With the adoption of the new Climate Strategy 2050 in December 2022, the Parliament of Liechtenstein approved the increase of the reduction target for 2030 to 55% below 1990 levels. This target is reflected in article 4 paragraph 1 of the Emissions Trading Act. Prior to the 30$^{th}$ UN Climate Change Conference (UNFCCC COP 30), Liechtenstein will communicate its updated Nationally Determined Contribution to the UNFCCC.

**Adaptation:** it is already known that certain consequences related to climate change will become irreversible. Therefore, the second pillar 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 published and available in German language only (Government 2018). An update for the adaption strategy is foreseen for 2025.**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".

### 1.1.3 Background information on greenhouse gas inventory

#### 1.1.3.1 Framework

In 1995, the Principality of Liechtenstein ratified the United Nations Framework Convention on Climate Change (UNFCCC). Furthermore, Liechtenstein ratified the Kyoto Protocol (both commitment periods) to the UNFCCC in 2004 and the Paris Agreement in 2017.

#### 1.1.3.2 Submissions of Biennial Transparency Reports (formerly National Communications and Biennial Reports)

In 1995, 1998, 2002, 2006, 2010, 2014, 2017 and 2022, Liechtenstein submitted its National Communication Reports (NC1 to NC8) to the secretariat of the UNFCCC.

In 2013, 2016, 2017,2019, and 2022 Liechtenstein submitted Biennial reports BR1, BR2, BR3, BR4, BR5 to the secretariat. For BR2, a revised version was submitted in early 2017. An in-country review of Liechtenstein's NC8 and BR5 took place in April 2024 (FCCC/IDR.8/LIE–FCCC/TRR.5/LIE 2024). For both reports, the ERT states that the reporting is complete, transparent and mostly adheres to the UNFCCC reporting guidelines on NCs and BRs.

Beginning of 2025 Liechtenstein submitted its first Biennial Transparency Report (BTR 1).

#### 1.1.3.3 Former submissions of Greenhouse Gas Inventories

**First commitment period (2008–2012) of Kyoto Protocol**

In 2005, the first Greenhouse Gas Inventory of Liechtenstein was submitted in the Common Reporting Format (CRF) without National Inventory Report. From 2006–2014 Liechtenstein annually submitted its Greenhouse Gas Inventory together with the National

Inventory Report prepared under the UNFCCC and under the Kyoto Protocol (OEP 2006–2011, OEP 2006a, 2007a, 2007b, 2012b, OE 2013–2014).

**Second commitment period (2013–2020) of Kyoto Protocol**

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

The submission of the Greenhouse Gas Inventory and National Inventory Report in 2015 was postponed and submitted in 2016. From 2016–2022 Liechtenstein annually submitted its Greenhouse Gas Inventory together with the National Inventory Report prepared under the UNFCCC and under the Kyoto Protocol (OE 2016a, OE 2016c, OE 2016d, OE 2017–2024).

**Paris Agreement**

In 2023 and 2024 Liechtenstein submitted the Greenhouse Gas Inventory and National Inventory Document under the UNFCCC (OE 2023-2024).

**Reviews of former Greenhouse Gas Inventories**

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, 2014, 2016, 2018, 2020 and 2022. The review of the GHG inventories and National Inventory Reports 2015 and 2016 took place simultaneously in September 2016 due to the postponed submission in 2015. In response to the Potential Problems formulated in the course of the review of the 2022 annual submission of Liechtenstein, Liechtenstein corrected an error in the preparation of emission data in sector 1B and submitted updated CRF tables in November 2022 (OE 2022g).

## 1.2 National circumstances and institutional arrangements

### 1.2.1 National Entity and National Inventory System (NIS)

As part of a comprehensive project, the Government mandated its Office of Environment (OE) in 2005 to design and establish the National Inventory System (NIS) in order to ensure full compliance with the reporting requirements.

Figure 1-6 gives a schematic overview of the institutional setting of the process of inventory preparation within the NIS.

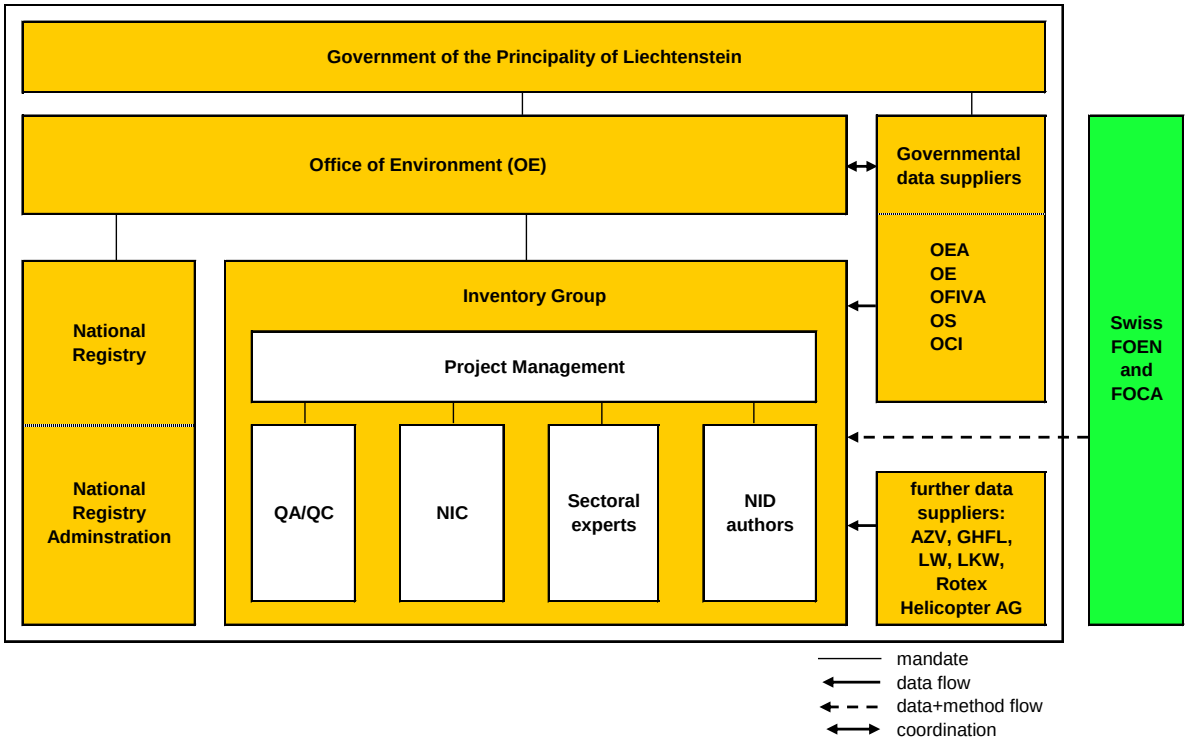



Figure 1-6 National Inventory System: Institutional setting and data suppliers. OE: Office of Environment; OEA: Office of Economic Affairs; OFIVA: Office of Food Inspections and Veterinary Affairs; OS: Office of Statistics: OCI: Office of Construction and Infrastructure; AZV: Liechtenstein's wastewater administration union; GHFL: Corporate society for the Storage of Gas Oil in the Principality of Liechtenstein; LW: Liechtenstein Heat; 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 establishment of the National Inventory System (NIS) under the Paris Agreement. Please note that the Office of Environment was reorganised in 2013. The Office of Agriculture (OA), the Office of Forest, Nature and Land Management (OFNLM) and the Office of Environmental Protection (OEP) were merged to the Office of Environment (OE). The former Office of Land Use Planning (SLP) was reorganised in 2013 and the Local Land Use Planning Bureau is now incorporated into the Office of Construction and Infrastructure (OCI).

The Office of Environment (OE) is in charge of compiling the emission data, bears overall responsibility for Liechtenstein's national greenhouse gas inventory and is acting as the national registry administrator. Its project manager and national focal point is:

Karin Jehle
Gerberwerg 5, P.O. Box 1861, 9490 Vaduz, Principality of Liechtenstein
karin.jehle@llv.li; Tel.: +423 236 6196

The project manager also coordinates in cooperation with the director of the OE the data flow from the governmental data suppliers to the inventory group.

The inventory group consists of the project manager, who is also the National Inventory Compiler (NIC), the Quality Manager (QA/QA) and several external experts: sectoral specialists for modelling the greenhouse gas emissions and removals and the NID authors.

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.

### 1.2.2 Inventory preparation process

#### 1.2.2.1 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 manger, the project manager and NIC as well as the emission modeler and the NID authors participate. At the initial meeting, the work is scheduled and priorities with regard to inventory development are set. Decisions regarding planned improvements are taken using the latest key category analysis to prioritize the enhancements. Source and sink categories which are key categories shall be improved in accordance with the ERT recommendations. Additional improvements to these categories are usually foreseen for the next annual submission (priority 1) unless specified otherwise. All other potential improvements (priority 2) are subject to availability of resources (see IDP in chp. 10.4, Table 10-4). The entire data compilation process is carried out from June to October. Normally, the UN reviews are conducted in September. The findings of the ERT typically lead to corrections of errors or to modifications in the methods. In October, another meeting of the core group takes place, where potential improvement options are analysed. Decisions about modifications are made and the progress of data compilation is continuously analysed. The compilation includes multiple quality control activities, in particular quality checks of different versions of the reporting tables (CRF) from October to December. At the end of this process, improvements are made, the final inventory data is generated, and the inventory development plan (IDP) is updated.

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. Liechtenstein submits the NID 2025 in spring 2025.

The NID 2025 was prepared using the CRT reporter software and the CRT reporting tables (e.g. for the KCA, for preparation of data tables and QA/QC activities).

After inventory preparation, the NID undergoes a multistage quality control cycle too (see Table 1-1). NID authors, the emission modeler, the head of the inventory group, the

project manager as well as additional staff of the Office of Environment (OE) and sector experts review the drafts of the NID jointly. If the internal review suggests major revisions, they are taken up in the inventory development plan for future improvements. 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 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | 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 | | | | | | | | | | | | |

### 1.2.2.2 Data collection and processing

Data is supplied by governmental and external data suppliers.

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 Heat / Liechtenstein Wärme (LW), former name until 2021 Liechtensteinische Gasversorgung (LGV)
- Electric power company / Liechtensteinische Kraftwerke (LKW)
- Entsorgunszweckverband (EZV)
- Heliport Balzers (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 for data collection 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 2024) also includes the fossil fuel consumption of the Principality of Liechtenstein, except for gas consumption of Liechtenstein, which is excluded from SFOE (2024). 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.

Figure 1-7 illustrates the simplified data flow leading to the CRF/CRT tables required for reporting under the UNFCCC and the Paris Agreement. For roles and responsibilities of the contributors see Figure 1-6.

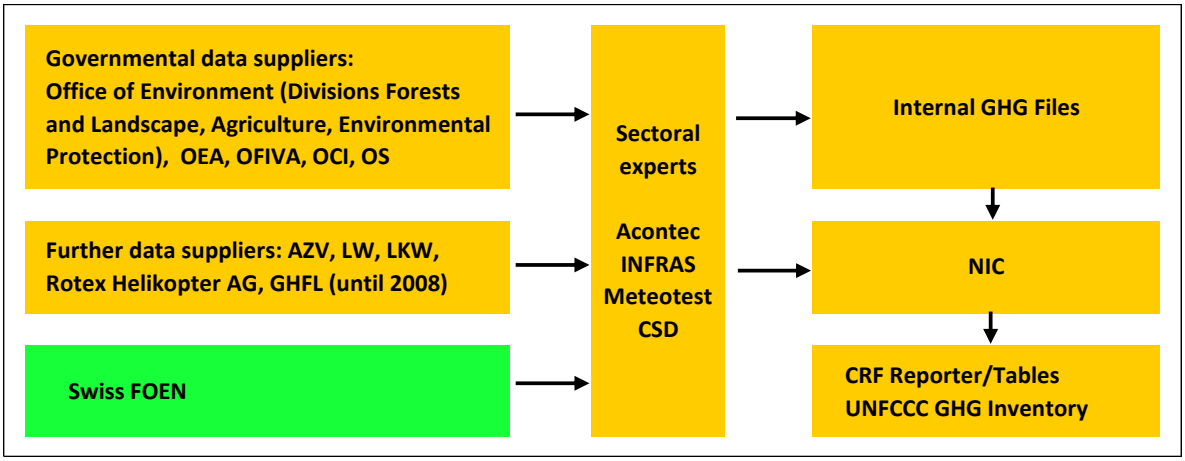



Figure 1-7 Data suppliers and data collection for setting up the UNFCCC GHG Inventory (see Glossary for abbreviations).

#### 1.2.2.3 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 NID and thus also for this report.

### 1.2.3 Documentation and archiving of information

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 for five years.

Also, the data generated in the NID compilation process such as the NID itself, QA/QC documents, KCA files, uncertainty analysis, review documents are archived by INFRAS within its archiving system that is maintained in the ISO 9001:2015 quality management system by INFRAS (SQS 2021). The administration of Liechtenstein has also a backup system in place and automatic backups are stored for five years. Hard copy files are stored in the archive for 10 years. CRF reporter software stores the data as well and the GHG inventory file is accessible from the UNFCCC website. Two hard copies of the NID are sent to the national library each year.

Finally, the entire information exchange by email between all people involved in updating the NID 2025 is stored in PST format.

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

### 1.2.4 Processes for official consideration and approval of inventory

QA/QC activities and the inventory submission are coordinated by the Office of Environment and documented in the checklists shown in Annex 4. The final GHG-inventory is presented to the Director of the Office of Environment, who is also the quality manger, and to the project manager/NIC for official approval. The submission is coordinated and carried out by the project manager/NIC.

## 1.3 Brief general description of methodologies and data sources used

### 1.3.1 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. 1.1.1). 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 incorporated into Liechtenstein's laws 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 is especially valid 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 paragraphs, a short summary of the methods used is given for each sector.

**1 Energy**

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

**2 Industrial processes and product use**

- HFC and PFC emissions from 2F1 Refrigeration and air conditioning are reported and are calculated with the rule of proportion applied on the Swiss emissions using country-specific activity data as representative for the conversion (e.g. no. of inhabitants).
- $SF_6$ emissions from 2G1 Electrical equipment are reported based on country-specific data.
- $N_2O$ emissions from 2G3 product uses 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 are estimated from the Swiss emissions using the number of inhabitants as a reference value for the rough estimate of Liechtenstein's emissions.
- NMVOC emissions from 2D3 Other are delineated from the Swiss emissions using the number of inhabitants as a reference value for the rough estimate of Liechtenstein's emissions.
- Other emissions from industrial processes and product use ($CO_2$, $CH_4$, $N_2O$) are not occurring.

**3 Agriculture**

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

**4 LULUCF**

- Emissions and removals are reported for 4A to 4G, 4(III) and 4(IV). Most of the methods and the emission factors are adopted from Switzerland, for forest land also 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 NID (FOEN 2024).

### 1.3.2 Specific assumptions for the year 2023

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 for the year 2023 were available as projections in the EMIS (Swiss Emission Information System) database of the Swiss Federal Office for the Environment dated from April 2024 corresponding to the emission data which Switzerland submitted in April 2024 in its NID to the UNFCCC (FOEN 2024). This data for the year 2023 is used, for example, in category 2F.

Table 1-2 Notation keys for applied methods and emission factors 2021 (see also CRT table Summary3s). Legend: D = IPCC default; CS = country-specific; M = model; T1, T2, T3 = Tier 1, 2, 3; NA = not applicable.

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES ($CO_2$, $CH_4$, and $N_2O$) | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| | 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 | T1, 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 | | | | |
| D. Non-energy products from fuels & solvent use | T1 | D | NA | NA | NA | NA |
| G. Other product manufacture and use | NA | NA | NA | NA | CS | CS |
| **3. Agriculture** | **T1** | **D** | **T2** | **CS, D, M** | **T1, T3** | **CS, D** |
| A. Enteric fermentation | | | T2 | CS, M | | |
| B. Manure management | | | T2 | CS, D, M | T3 | CS, D |
| D. Agricultural soils | | | | | T1, T3 | CS, D |
| H. Urea application | T1 | D | | | | |
| **4. Land use, land-use change and forestry** | **T2** | **CS, D** | **NA** | **NA** | **T2** | **D** |
| A. Forest land | T2 | CS | NA | NA | NA | NA |
| B. Cropland | T2 | CS | NA | NA | T2 | D |
| C. Grassland | T2 | CS | NA | NA | T2 | D |
| D. Wetlands | T2 | CS | NA | NA | T2 | D |
| E. Settlements | T2 | CS | NA | NA | T2 | D |
| F. Other land | T2 | CS | NA | NA | T2 | D |
| G. Harvested wood products | T2 | D | | | | |
| **5. Waste** | **T2** | **CS** | **T2, T3** | **CS, D** | **T2, T3** | **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 | | | T3 | CS, D | T3 | 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 CRT Tables Summary3sdo 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 deviate in some positions from information given in the CRT Tables.

### 1.3.3 Reference approach for the energy sector

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

## 1.4 Brief Description of Key Categories

The key category analysis (KCA) is performed based on the automatic KCA implemented in the CRT Reporter Software. The software indicates to every source and sink category whether it is key or not (CRT 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 2023 level and trend assessment without LULUCF categories
- Reporting year 2023 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.

### 1.4.1 KCA excluding LULUCF categories

For 2023, among a total of 201 categories (excluding LULUCF categories), eleven have been identified as Approach 1 key categories by the CRT Reporter Software (CRT Table7) with an aggregated contribution of 96.1% of the national total emissions (see Table 1-3).

There are nine categories which are key categories according to level and trend assessment, one category which is only a key category according to level assessment and one category which is only a key category according to trend assessment.

Within those eleven key categories, seven stem from the energy sector, contributing 79.0% to total $CO_2$ equivalent emissions in 2023. The other key categories are from the sectors Agriculture (three categories, contribution 12.8%) and Industrial Processes and Product Use IPPU (one category, contribution 4.3%).

The three major sources, all from the energy sector, sum up to a contribution of 64.8% of the national total emissions:

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

Compared to newest inventory year of the previous submission (reporting year 2022), the following change has occurred in the KCA for the reporting year 2023 of the current submission:

- 1B2b Fugitive Emissions from Fuels – Oil and Natural Gas – Natural Gas – $CH_4$ is still a key category according to trend assessment but no longer a key category according to level assessment[3].
- 3D1 Direct $N_2O$ Emissions From Managed Soils – $N_2O$ still a key category according to level assessment but is no longer a key category according to trend assessment.

Table 1-3 List of Liechtenstein's Approach 1 key categories 2023 excluding LULUCF. Sorted by share of total emissions.

| **Key Category Analysis 2023 (excluding LULUCF)**<br>**IPCC Source Categories (and fuels, if applicable)** | GHG | Emissions 2023 [kt CO2eq] | Share of Total Emissions | Cumulative Total | Result of Assessment |
|---|---|---|---|---|---|
| 1.A.3.b Road Transportation | CO2 | 53.51 | 32.0% | 32.0% | KC Level, KC Trend |
| 1.A.4 Other Sectors - Gaseous Fuels | CO2 | 28.90 | 17.3% | 49.2% | KC Level, KC Trend |
| 1.A.4 Other Sectors - Liquid Fuels | CO2 | 25.97 | 15.5% | 64.8% | KC Level, KC Trend |
| 3.A Enteric Fermentation | CH4 | 15.89 | 9.5% | 74.3% | KC Level, KC Trend |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO2 | 10.21 | 6.1% | 80.4% | KC Level, KC Trend |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO2 | 9.54 | 5.7% | 86.1% | KC Level, KC Trend |
| 2.F.1 Refrigeration and Air conditioning | F-gases | 7.24 | 4.3% | 90.4% | KC Level, KC Trend |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | CO2 | 2.81 | 1.7% | 92.1% | KC Level, KC Trend |
| 3.D.1 Direct N2O Emissions From Managed Soils | N2O | 2.76 | 1.7% | 93.7% | KC Level |
| 3.B Manure Management | CH4 | 2.71 | 1.6% | 95.3% | KC Level, KC Trend |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | CH4 | 1.28 | 0.8% | 96.1% | KC Trend |

For the base year 1990, the level key category analysis is given in Table 1-4 below.

There are seven level key categories. Due to recalculations there have been slight changes in the amount of $CO_2$-eq emitted by the key categories 3A Enteric Fermentation – $CH_4$ (from 15.59 t $CO_2$-eq down to 15.42 t $CO_2$-eq) and 3D1 Direct $N_2O$ Emissions From Managed Soils – $N_2O$ (from 3.57 t $CO_2$-eq down to 3.28 t $CO_2$-eq). These changes however have no effect on the key categories and their order of contribution to total emissions.

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

| **Key Category Analysis 1990 (excluding LULUCF)**<br>**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 | CO2 | 76.71 | 33.6% | 33.6% | KC Level |
| 1.A.3.b Road Transportation | CO2 | 75.29 | 33.0% | 66.5% | KC Level |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO2 | 20.99 | 9.2% | 75.7% | KC Level |
| 3.A Enteric Fermentation | CH4 | 15.42 | 6.7% | 82.5% | KC Level |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO2 | 15.20 | 6.7% | 89.1% | KC Level |
| 1.A.4 Other Sectors - Gaseous Fuels | CO2 | 10.21 | 4.5% | 93.6% | KC Level |
| 3.D.1 Direct N2O Emissions From Managed Soils | N2O | 3.28 | 1.4% | 95.0% | KC Level |

Throughout the sectoral chapters 3 - 7, the corresponding key categories excluding LULUCF are documented for each source.

[3] Already in the previous submission, it was assumed that 1B2b $CH_4$ was incorrectly labelled as a level key category by the CRF reporter.

### 1.4.2 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 step by the CRT Reporter.

The Approach 1 key category analysis for the year 2023 including LULUCF categories consists of a total of 228 categories, whereof 21 are key categories (see Table 1-5).

Nine categories are identified key from the LULUCF sector and contribute a total of 18.1% to total emissions:

- 4A1 Forest land remaining forest land, $CO_2$
- 4A2 Land Converted to Forest Land, $CO_2$
- 4B1 Cropland remaining cropland, $CO_2$
- 4C1 Grassland Remaining Grassland
- 4C2 Land Converted to Grassland, $CO_2$
- 4D13 (new 4D1c) Other Wetlands Remaining Other Wetlands
- 4E1 Settlements Remaining Settlements
- 4E2 Land Converted to Settlements
- 4G Harvested Wood Products

Furthermore, one additional category from the agriculture sector is key when performing the KCA for the full inventory (including LULUCF categories):

- 3B Manure management, $N_2O$

Compared to newest inventory year of the previous submission (reporting year 2022), the following changes have occurred in the KCA for the reporting year 2023 of the current submission:

- 1B2b Fugitive Emissions from Fuels – Oil and Natural Gas – Natural Gas – $CH_4$ is still a key category according to trend assessment but no longer according to level assessment
- 3B Manure Management – $N_2O$ is newly a key category according to trend assessment, but no longer according to level assessment.
- 3D1 Direct $N_2O$ Emissions From Managed Soils – $N_2O$ is still a key category according to level assessment, but no longer according to trend assessment.
- 4C1 Grassland Remaining Grassland – $CO_2$ is newly a key category according to level assessment.
- 4E1 Settlements Remaining Other Land – $CO_2$ is newly a key category according to trend assessment.
- 4G Harvested Wood Products – $CO_2$ is - in addition to trend- newly also a key category according to level assessment

In the KCA 1990 including LULUCF categories, four key categories contributing 5.6% to total emissions are identified from the LULUCF sector (see Table 1-6):

- 4A2 Land Converted to Forest Land, $CO_2$
- 4B1 Cropland remaining cropland, $CO_2$
- 4D13 Other Wetlands Remaining Other Wetlands, $CO_2$
- 4G Harvested wood products, $CO_2$

Additionally, two categories from the agriculture sector are key when performing the KCA for the full inventory (including LULUCF categories):

- 3B Manure management, $CH_4$
- 3D2 Indirect $N_2O$ Emissions from Managed Soils, $N_2O$

Compared to the KCA for the year 1990 of the previous submission, the following changes have occurred in the KCA for the year 1990 of the current submission:

- 4E2 Land Converted to Settlements is no longer a key category.

Table 1-5 List of Liechtenstein's Approach 1 key categories 2023 including LULUCF. Sorted by share of total emissions.

| **Key Category Analysis 2023 (including LULUCF)**<br>**IPCC Source Categories (and fuels, if applicable)** | GHG | Emissions 2023 abs. values [kt CO2eq] | Share of Total Emissions | Cumulative Total | Result of Assessment |
|---|---|---|---|---|---|
| 1.A.3.b Road Transportation | CO2 | 53.51 | 26.0% | 26.0% | KC Level, KC Trend |
| 1.A.4 Other Sectors - Gaseous Fuels | CO2 | 28.90 | 14.0% | 40.0% | KC Level, KC Trend |
| 1.A.4 Other Sectors - Liquid Fuels | CO2 | 25.97 | 12.6% | 52.7% | KC Level, KC Trend |
| 3.A Enteric Fermentation | CH4 | 15.89 | 7.7% | 60.4% | KC Level, KC Trend |
| 4.A.1 Forest Land Remaining Forest Land | CO2 | 14.05 | 6.8% | 67.2% | KC Level, KC Trend |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO2 | 10.21 | 5.0% | 72.2% | KC Level, KC Trend |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO2 | 9.54 | 4.6% | 76.8% | KC Level, KC Trend |
| 4.A.2 Land Converted to Forest Land | CO2 | 8.39 | 4.1% | 80.9% | KC Level, KC Trend |
| 2.F.1 Refrigeration and Air conditioning | F-gases | 7.24 | 3.5% | 84.4% | KC Level, KC Trend |
| 4.B.1 Cropland Remaining Cropland | CO2 | 3.56 | 1.7% | 86.1% | KC Level, KC Trend |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | CO2 | 2.81 | 1.4% | 87.5% | KC Level, KC Trend |
| 3.D.1 Direct N2O Emissions From Managed Soils | N2O | 2.76 | 1.3% | 88.8% | KC Level |
| 3.B Manure Management | CH4 | 2.71 | 1.3% | 90.1% | KC Level, KC Trend |
| 4.C.2 Land Converted to Grassland | CO2 | 2.55 | 1.2% | 91.4% | KC Level, KC Trend |
| 4.E.2 Land Converted to Settlements | CO2 | 2.31 | 1.1% | 92.5% | KC Level, KC Trend |
| 4.G Harvested Wood Products | CO2 | 2.18 | 1.1% | 93.6% | KC Level, KC Trend |
| 4.D.1.3 Other Wetlands Remaining Other Wetlands | CO2 | 2.04 | 1.0% | 94.6% | KC Level, KC Trend |
| 4.C.1 Grassland Remaining Grassland | CO2 | 1.61 | 0.8% | 95.3% | KC Level |
| 3.B Manure Management | N2O | 1.39 | 0.7% | 96.0% | KC Trend |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | CH4 | 1.28 | 0.6% | 96.6% | KC Trend |
| 4.E.1 Settlements Remaining Settlements | CO2 | 0.57 | 0.3% | 96.9% | 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)**<br>**IPCC Source Categories (and fuels, if applicable)** | GHG | Emissions 1990 abs. values [kt $CO_2$eq] | Share of Total Emissions | Cumulative Total | Result of Assessment |
|---|---|---|---|---|---|
| 1.A.4 Other Sectors - Liquid Fuels | CO2 | 76.71 | 31.0% | 31.0% | KC Level |
| 1.A.3.b Road Transportation | CO2 | 75.29 | 30.4% | 61.4% | KC Level |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO2 | 20.99 | 8.5% | 69.9% | KC Level |
| 3.A Enteric Fermentation | CH4 | 15.42 | 6.2% | 76.1% | KC Level |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO2 | 15.20 | 6.1% | 82.2% | KC Level |
| 1.A.4 Other Sectors - Gaseous Fuels | CO2 | 10.21 | 4.1% | 86.4% | KC Level |
| 4.A.2 Land Converted to Forest Land | CO2 | 5.08 | 2.1% | 88.4% | KC Level |
| 4.B.1 Cropland Remaining Cropland | CO2 | 4.18 | 1.7% | 90.1% | KC Level |
| 3.D.1 Direct N2O Emissions From Managed Soils | N2O | 3.28 | 1.3% | 91.4% | KC Level |
| 3.B Manure Management | CH4 | 2.94 | 1.2% | 92.6% | KC Level |
| 4.G Harvested Wood Products | CO2 | 2.69 | 1.1% | 93.7% | KC Level |
| 4.D.1.3 Other Wetlands Remaining Other Wetlands | CO2 | 2.01 | 0.8% | 94.5% | KC Level |
| 3.D.2 Indirect N2O Emissions From Managed Soils | N2O | 1.93 | 0.8% | 95.3% | KC Level |

## 1.5 Brief general description of QA/QC plan and implementation

### 1.5.1 Quality assurance and quality control

For the submission 2008, the QA/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 4. The classification of the QA/QC activities follows the IPCC Guidelines (IPCC 2006). According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories 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.

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 people involved.

The QA/QC activities are coordinated by Mrs. Regula Imhof, the Director of the Office of Environment (e-mail: regula.imhof@llv.li, phone: +423 236 61 97). The QA/QC activities are organised within the Inventory Group, see National Inventory System depicted in Figure 1-6.

The following people are involved in the QA/QC activities:

- NIC / project manager,
- Sectoral experts,
- NID authors.

Operational tasks are delegated to the NID lead author. She distributes checklists to the project manager being also the National Inventory Compiler, to the sectoral experts and to other NID 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 NID (see Annex 4).

The quality management shall enable the party to principally fulfil the reporting requirements. 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.

The QA/QC activities are well established and are part of the entire inventory process. Specific quality assurance activities (QA; ensuring the quality of the inventory, determining conformity of procedures and identifying areas of improvement) and quality control activities (QC; generic quality checks related to calculations, data processing, completeness, and documentation) are described in the QA/QC plan in Annex A4.1. All activities are planned and documented in checklists (see Annexes A4.2 for QC and A4.3 for QA activities). Special attention in the QA/QC activities are given to emissions from key categories.

### 1.5.2 Inventory development plan (IDP)

Liechtenstein maintains an inventory development plan (IDP). The IDP summarises all issues detected from internal and external QA/QC activities (in particular recommendations and encouragements made by the expert review team ERT) as well as possible planned improvements of the inventory. Planned improvements are prioritised according to the latest key category analysis and with regard to the uncertainty analyses (see chp. 10.4).

The latest review of Liechtenstein’s greenhouse gas inventory took place in September 2022. The findings of the ERT were published in February 2023 in the report of the individual review of the annual submission of Liechtenstein submitted in 2022 (FCCC/ARR 2023).

The following table shows the planned improvements from the IDP that have been implemented in the current submission. Planned improvements for future submissions, improvements that will not be implemented and improvements that have already been

implemented are documented in the sector chapters and summarised in chp. 10.4 of this NID.

| Reference | Identified Issues, e.g. recommendations or planned improvements | Status | Comment/Reason NID | Sector |
|---|---|---|---|---|
| Internal decision | Since 2021, wood biomass is used in combined heat and power plants. In the current submission, the total consumption of wood biomass and the resulting emissions are attributed to sectors 1A4a and 1A4b. The allocation of wood biomass consumption to commercial, institutional and residential buildings (1A4a and 1A4b) and to public electricity and heat production (1A1a) will be implemented in the next submission. | Implemented in submission 2025 | The allocation of biomass consumption for heating purposes in buildings (1A4a and 1A4b) and in combined heat and power plants (1A1) will be implemented in the next submission. | 1 Energy |
| Internal decision | 5D Wastewater treatment and discharge: Concerning N2O emissions, year-round measurement campaigns on representative Swiss wastewater treatment plants have been performed and evaluated (Gruber et al. 2021) leading to the recalculations reported in Switzerlands submission 2023. A new country-specific method has been established incl. assessment of per capita nitrogen load to wastewater.<br><br>Data for per capita protein consumption in future submission will be taken from “Nahrungsmittelbilanz der Schweiz” Agristat, instead from NID CHE Submission. Agristat is the origin data source. | Implemented in submission 2025 | Proteinkonsum direkt aus Nährstoffstatistik CH nehmen und bisherige Berechnungsmethode aber beibehalten. Aufwand für Anpassung und Nutzen wäre unverhältnismässig. | 5 Waste |
| Internal decision | 5.B Biological treatment of solid waste: The activity data of the year 2022 concerning centralized composting is wrong. The mistake is going to be corrected in the next submission. | Implemented in submission 2025 | The mistake is going to be corrected. | 5 Waste |

## 1.5.3 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 take place.

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

If the national total emissions (without LULUCF) of the two countries are compared, very similar and highly correlated trends are found. In 1990, Liechtenstein's emissions were 0.42% of the Swiss emissions. After a slight increase between 1993 and 2009, this share is 0.40% in 2022. In the same years, the share of inhabitants slightly changed from 0.43% to 0.45%. This 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. (Simultaneously, it shows that the per capita emissions in Liechtenstein were reduced more strongly in Liechtenstein than in Switzerland.)

- 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 2024). They show that the local air pollution levels of $NO_2$, $O_3$ and PM10 in Liechtenstein vary in the same range as in the Swiss neighbouring measurement sites (FOEN 2024c).

## 1.6 General uncertainty assessment

### 1.6.1 Approach 1

In the current inventory, Approach 1 uncertainty is evaluated with level (2023, 1990) and trend (1990–2023) analyses. Approach 1 is based on propagation of error. Uncertainty in the emission level in 2023 and in the trend between the reporting year (2023) and the base year (1990) is estimated for the inventory total and for the single source categories and gases using uncertainty ranges of corresponding activity data and emission factors. All uncertainties are given as half of the 95% confidence interval divided by the mean and expressed as a percentage (approximately two standard deviations) as suggested by the 2006 IPCC Guidelines (IPCC 2006).

As in previous submissions, a simplified uncertainty analysis has been carried out. The simplification means that uncertainty analysis individually accounts for the key categories, whereas the rest of the categories were aggregated by gas and treated as four "rest" categories $CO_2$, $CH_4$, $N_2O$ and F-gases, to which a semi-quantitative uncertainty (see below, Table 1-7) was attributed.

In the automatic KCA of the CRT 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 A2.1 for further information).

Results of the uncertainty analyses are used for prioritizing the improvements of national inventory accuracy.

### 1.6.2 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 NID (FOEN 2024) and expert estimates.

**All uncertainty figures are to be interpreted as corresponding to half of the 95% confidence interval.** Distributions are symmetric for Approach 1 analysis.

For key categories, individual uncertainties are used. Those are described in the respective sector chapters. For the remaining categories, qualitative estimates of uncertainties are applied. The terms used are “high”, “medium” and “low” data quality. To each term, quantitative uncertainties as shown in Table 1-7 are used. They are motivated by the comparison of uncertainty analyses of several countries carried out by De Keizer et al. (2007), as presented at the 2nd Internat. Workshop on Uncertainty in Greenhouse Gas Inventories (Vienna 27–28 Sep 2007).

Table 1-7 Semi-quantitative uncertainties (95% level) for categories, for which no explicit uncertainty is known. Note that there is no source of $NF_3$ in Liechtenstein, therefore no values are indicated.

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

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

### 1.6.3 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 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.

Uncertainty of national total $CO_2$eq emissions **excluding LULUCF:**
The Approach 1 level uncertainty for the year 2023 is estimated to be 5.19%, trend uncertainty (1990-2023) is 6.12% (see Table 1-8). The level uncertainty for the year 1990 amounts 6.87% (see Table 1-9).

Uncertainty of national total $CO_2$eq emissions **including LULUCF**:
The Approach 1 level uncertainty for the year 2023 is estimated to be 6.69%, trend uncertainty (1990-2023) is 7.03% (see Table 1-10). The level uncertainty for the year 1990 amounts 6.83% (see Table 1-11).

Compared to the **previous submission in 2024 (reporting year 2022),** the results of the current Approach 1 analyses show higher uncertainties for the assessment excluding and including LULUCF.

- Level uncertainty 2022 (previous submission): 5.43% (excluding LULUCF) and 6.34% (including LULUCF)
- Trend uncertainty 1990–2023 (previous submission): 6.11% (excluding LULUCF) and 6.51% (including LULUCF)

The results for the uncertainty analysis for the year 2023 excluding and including LULUCF categories are similar to the previous submission, since both, the emissions (per sectors) and the uncertainty estimates per category have remained similar. However, the following changes occur:

- The overall uncertainty for 2023 excluding LULUCF categories is 0.2 percentage points lower than in the previous submission for the level assessment and 0.01 percentage points higher for the trend assessment. This slight reduction in level uncertainty is primarily due to updated uncertainty values from FOEN 2024 in the agriculture sector (e.g., lower uncertainties for AD and EF in category 3D1 $N_2O$) and the IPPU sector (lower uncertainties for AD and EF in category 2F1 F-gases). Additionally, uncertainty in sector 1A3b $CO_2$ decreased, as emissions from gasoline, associated with lower AD uncertainty, have increased relative to diesel emissions, which have higher AD uncertainty.
- Overall uncertainty for 2023 including LULUCF is 0.3 percentage points higher than in the previous submission for the level assessment and 0.5 percentage points higher for the trend assessment. This increase is mainly due to category 4A1being a larger sink in 2023, contributing to a higher overall uncertainty.

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 (2023) and trend (1990-2023) 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 2023 emissions or removals** | **AD unc.** | **EF unc.** | **Comb. unc.** | **Contr. to variance by Category in 2023** | **Type A sensi-tivity** | **Type B sensi-tivity** | **Unc. in trend in nat. emissions introduced by EF unc.** | **Unc. in trend in nat. emissions introduced by AD unc.** | **Unc. intro-duced into the trend in total national emissions** |
| (categories excluding LULUCF) | | | | | | kt $CO_2$ eq | kt $CO_2$ eq | % | % | % | - | % | % | % | % | - |
| **1A1** | **1. Energy** | A. Fuel combustion activities | 1. Energy industries | Gaseous F. | $CO_2$ | 0.1 | 2.8 | 5.0 | 0.3 | 5.0 | 0.007 | 0.01 | 0.02 | 0.004 | 0.119 | 0.014 |
| **1A2** | | | 2. Manufacturing industries & construction | Liquid F. | $CO_2$ | 21.0 | 9.5 | 20.0 | 0.1 | 20.0 | 1.301 | 0.03 | 0.06 | 0.002 | 1.613 | 2.602 |
| | | | | Gaseous F. | $CO_2$ | 15.2 | 10.2 | 5.0 | 0.3 | 5.0 | 0.093 | 0.00 | 0.06 | 0.001 | 0.431 | 0.186 |
| **1A3b** | | | 3. Transp.; b. Road Transp. | | $CO_2$ | 75.3 | 53.5 | 8.7 | 0.1 | 8.7 | 7.672 | 0.01 | 0.32 | 0.001 | 3.917 | 15.342 |
| **1A4** | | | 4. Other Sectors | Liquid F. | $CO_2$ | 76.7 | 26.0 | 15.9 | 0.1 | 15.9 | 6.080 | 0.13 | 0.16 | 0.009 | 3.487 | 12.159 |
| | | | | Gaseous F. | $CO_2$ | 10.2 | 28.9 | 4.0 | 0.3 | 4.0 | 0.477 | 0.09 | 0.17 | 0.028 | 0.974 | 0.949 |
| **1B2b** | | B. Fugitive Emissions from Fuels | 2. Oil and Natural Gas; b. Nat. Gas | | $CH_4$ | 0.4 | 1.3 | 35.4 | 35.4 | 50.0 | 0.147 | 0.004 | 0.01 | 0.152 | 0.384 | 0.170 |
| **2F1** | **2. IPPU** | F. Product uses as substitutes for ODS | 1. Refrigeration and air conditioning | | F-gases | 0.0001 | 7.2 | 10.0 | 10.0 | 14.2 | 0.377 | 0.03 | 0.04 | 0.318 | 0.614 | 0.478 |
| **3A** | **3. Agriculture** | A. Enteric Ferment. | | | $CH_4$ | 15.4 | 15.9 | 6.5 | 19.2 | 20.3 | 3.708 | 0.02 | 0.09 | 0.386 | 0.867 | 0.901 |
| **3B** | | B. Manure Management | | | $CH_4$ | 2.9 | 2.7 | 6.5 | 54.6 | 55.0 | 0.793 | 0.002 | 0.02 | 0.133 | 0.148 | 0.040 |
| **3D1** | | D. Agricul-tural Soils | 1. Direct Soil Emissions | | $N_2O$ | 3.3 | 2.8 | 13.9 | 80.5 | 81.7 | 1.821 | 0.002 | 0.02 | 0.127 | 0.324 | 0.121 |
| **non-key rest** | | | | | $CO_2$ | 0.4 | 0.3 | 7.1 | 7.1 | 10.0 | 0.000 | 0.00 | 0.00 | 0.00 | 0.02 | 0.000 |
| | | | | | $CH_4$ | 2.3 | 1.6 | 21.2 | 21.2 | 30.0 | 0.080 | 0.00 | 0.01 | 0.01 | 0.28 | 0.080 |
| | | | | | $N_2O$ | 5.2 | 4.4 | 56.6 | 56.6 | 80.0 | 4.401 | 0.00 | 0.03 | 0.15 | 2.10 | 4.423 |
| | | | | | F-gases | - | 0.3 | 14.1 | 14.1 | 20.0 | 0.001 | 0.00 | 0.00 | 0.02 | 0.03 | 0.001 |
| **Total** | | | | | | **228.5** | **167.3** | | | | **26.96** | | | | | **37.47** |
| | | | | | | | | *Percentage uncertainty in total inventory:* | | | **5.19** | | | | *Trend uncertainty:* | **6.12** |

Table 1-9 Approach 1 level (1990) uncertainty excluding LULUCF.

| A | | | | | B | C | E | F | G | H |
|---|---|---|---|---|---|---|---|---|---|---|
| **IPCC Source category** | | | | | **Gas** | **Base year emissions or removals** | **AD unc.** | **EF unc.** | **Comb. unc.** | **Contr. to variance by Category in 1990** |
| (categories excluding LULUCF) | | | | | | kt $CO_2$ eq | % | % | % | - |
| **1A2** | | A. Fuel combustion activities | 2. Manufacturing industries & construction | Liquid F. | $CO_2$ | 21.0 | 20.0 | 0.1 | 20.0 | 3.378 |
| | | | | Gaseous F. | $CO_2$ | 15.2 | 5.0 | 0.3 | 5.0 | 0.111 |
| **1A3b** | | | 3. Transp.; b. Road Transp. | | $CO_2$ | 75.3 | 8.7 | 0.1 | 8.7 | 8.149 |
| **1A4** | | | 4. Other Sectors | Liquid F. | $CO_2$ | 76.7 | 15.9 | 0.1 | 15.9 | 28.455 |
| | | | | Gaseous F. | $CO_2$ | 10.2 | 4.0 | 0.3 | 4.0 | 0.032 |
| **3A** | **3. Agriculture** | A. Enteric Fermentation | | | $CH_4$ | 15.4 | 6.5 | 19.2 | 20.3 | 1.874 |
| **3D1** | | D. Agricul-tural Soils | 1. Direct Soil Emissions | | $N_2O$ | 3.3 | 13.9 | 80.5 | 81.7 | 1.376 |
| **non-key rest** | | | | | $CO_2$ | 0.6 | 7.1 | 7.1 | 10.0 | 0.001 |
| | | | | | $CH_4$ | 5.6 | 21.2 | 21.2 | 30.0 | 0.543 |
| | | | | | $N_2O$ | 5.2 | 56.6 | 56.6 | 80.0 | 3.282 |
| | | | | | F-gases | 0.0001 | 14.1 | 14.1 | 20.0 | 0.000 |
| **Total** | | | | | | **228.5** | | | | **47.20** |
| | | | | | | | | *Percentage uncertainty in total inventory:* | | **6.87** |

Table 1-10 Approach 1 level (2023) and trend (1990–2023) 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 2023 emissions or removals | AD unc. | EF unc. | Comb. unc. | Contr. to variance by Category in 2023 | 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. intro-duced into trend in total national emissions |
| (categories including LULUCF) | | | | | | | kt $CO_2$ eq | kt $CO_2$ eq | % | % | % | - | % | % | % | % | - |
| 1A1 | 1. Energy | A. Fuel combustion activities | 1. Energy industries | Gaseous F. | | $CO_2$ | 0.1 | 2.8 | 5.0 | 0.3 | 5.0 | 0.008 | 0.01 | 0.02 | 0.004 | 0.12 | 0.015 |
| 1A2 | | | 2. Manufacturing ind. & constr. | Liquid F. | | $CO_2$ | 21.0 | 9.5 | 20.0 | 0.1 | 20.0 | 1.422 | 0.02 | 0.06 | 0.002 | 1.69 | 2.845 |
| | | | | Gaseous F. | | $CO_2$ | 15.2 | 10.2 | 5.0 | 0.3 | 5.0 | 0.102 | 0.001 | 0.06 | 0.000 | 0.45 | 0.203 |
| 1A3b | | | 3. Transport; b. Road Transportation | | | $CO_2$ | 75.3 | 53.5 | 8.7 | 0.1 | 8.7 | 8.388 | 0.01 | 0.33 | 0.001 | 4.10 | 16.775 |
| 1A4 | | | 4. Other Sectors | Liquid F. | | $CO_2$ | 76.7 | 26.0 | 15.9 | 0.1 | 15.9 | 6.647 | 0.12 | 0.16 | 0.01 | 3.65 | 13.294 |
| | | | | Gaseous F. | | $CO_2$ | 10.2 | 28.9 | 4.0 | 0.3 | 4.0 | 0.521 | 0.09 | 0.18 | 0.03 | 1.02 | 1.037 |
| 1B2b | | B. Fugitive Emissions from Fuels | 2. Oil, nat. gas, other em. from energy prod. | | | $CH_4$ | 0.4 | 1.3 | 35.4 | 35.4 | 50.0 | 0.161 | 0.004 | 0.01 | 0.15 | 0.40 | 0.184 |
| 2F1 | 2. IPPU | F. Prod. uses as subst. for ODS | 1. Refriger. & air cond. | | | F-gases | 0.0001 | 7.2 | 10.0 | 10.0 | 14.2 | 0.412 | 0.03 | 0.05 | 0.31 | 0.64 | 0.510 |
| 3A | 3. Agriculture | A. Enteric Ferment. | | | | $CH_4$ | 15.4 | 15.9 | 6.5 | 19.2 | 20.3 | 4.054 | 0.02 | 0.10 | 0.44 | 0.91 | 1.011 |
| 3B | | B. Manure Managem. | | | | $CH_4$ | 2.9 | 2.7 | 6.5 | 54.6 | 55.0 | 0.867 | 0.00 | 0.02 | 0.16 | 0.15 | 0.050 |
| | | | | | | $N_2O$ | 1.2 | 1.4 | 35.5 | 56.6 | 66.8 | 0.339 | 0.00 | 0.01 | 0.14 | 0.44 | 0.209 |
| 3D1 | | D. Agricultural Soils | 1. Dir. Soil Em. | | | $N_2O$ | 3.3 | 2.8 | 13.9 | 80.5 | 81.7 | 1.991 | 0.00 | 0.02 | 0.17 | 0.34 | 0.145 |
| 4A1 | 4. LULUCF | A. Forest Land | 1. Forest land remaining forest land | | | $CO_2$ | -0.1 | -14.1 | 2.7 | 34.9 | 35.0 | 9.449 | 0.06 | 0.09 | 2.10 | 0.34 | 4.536 |
| 4A2 | | | 2. Land converted to Forest Land | | | $CO_2$ | -5.1 | -8.4 | 17.2 | 34.9 | 38.9 | 4.156 | 0.02 | 0.05 | 0.73 | 1.27 | 2.163 |
| 4B1 | | B. Cropland | 1. Cropland remaining cropland | | | $CO_2$ | 4.2 | 3.6 | 30.8 | 23.0 | 38.4 | 0.731 | 0.003 | 0.02 | 0.07 | 0.97 | 0.944 |
| 4C1 | | C. Grassland | 1 Grassland Remaining Grassland | | | $CO_2$ | 1.6 | 1.6 | 6.0 | 47.0 | 47.4 | 0.227 | 0.002 | 0.01 | 0.10 | 0.09 | 0.018 |
| 4C2 | | | 2. Land con-verted to grassland | | | $CO_2$ | 0.5 | 2.6 | 13.6 | 32.4 | 35.1 | 0.315 | 0.01 | 0.02 | 0.31 | 0.31 | 0.189 |
| 4D1 | | D. Wetlands | 1. Wetlands remaining wetlands | | | $CO_2$ | 2.0 | 2.0 | 10.5 | 50.0 | 51.1 | 0.425 | 0.003 | 0.01 | 0.14 | 0.19 | 0.056 |
| 4E1 | | E. Settle-ments | 1 Settlements Remaining Settlements | | | $CO_2$ | 0.0 | -0.6 | 6.4 | 57.1 | 57.5 | 0.042 | 0.003 | 0.00 | 0.14 | 0.03 | 0.022 |
| 4E2 | | | 2. Land con-verted to settlements | | | $CO_2$ | 1.9 | 2.3 | 19.4 | 31.6 | 37.1 | 0.285 | 0.004 | 0.01 | 0.14 | 0.40 | 0.176 |
| 4G | | G. HWP | | | | $CO_2$ | -2.7 | 2.2 | 50.0 | 54.8 | 74.2 | 1.021 | 0.02 | 0.014 | 0.95 | 0.96 | 1.835 |
| non-key rest | | | | | | $CO_2$ | 1.4 | 1.2 | 7.1 | 7.1 | 10.0 | 0.006 | 0.00 | 0.01 | 0.01 | 0.08 | 0.006 |
| | | | | | | $CH_4$ | 2.3 | 1.6 | 21.2 | 21.2 | 30.0 | 0.087 | 0.00 | 0.01 | 0.00 | 0.30 | 0.087 |
| | | | | | | $N_2O$ | 4.2 | 3.5 | 56.6 | 56.6 | 80.0 | 3.036 | 0.00 | 0.02 | 0.14 | 1.74 | 3.054 |
| | | | | | | F-gases | - | 0.3 | 14.1 | 14.1 | 20.0 | 0.001 | 0.00 | 0.00 | 0.02 | 0.03 | 0.001 |
| **Total** | | | | | | | **232.0** | **160.0** | | | | **44.69** | | | | | **49.36** |
| | | | | | | | | | | | *Percentage uncertainty in total inventory:* | **6.69** | | | | *Trend uncertainty:* | **7.03** |

Table 1-11 Approach 1 level (1990) uncertainty including LULUCF.

| IPCC Source category | | | | | Gas | Base year emissions or removals | AD unc. | EF unc. | Comb. unc. | Contr. to variance by Category in 1990 |
|---|---|---|---|---|---|---|---|---|---|---|
| (categories including LULUCF) | | | | | | kt $CO_2$ eq | % | % | % | - |
| 1A2 | 3. Agriculture | A. Fuel combustion activities | 2. Manufacturing industries & construction | Liquid F. | $CO_2$ | 21.0 | 20.0 | 0.1 | 20.0 | 3.275 |
| | | | | Gaseous F. | $CO_2$ | 15.2 | 5.0 | 0.3 | 5.0 | 0.108 |
| 1A3b | | | 3. Transp.; b. Road Transp. | | $CO_2$ | 75.3 | 8.7 | 0.1 | 8.7 | 7.901 |
| 1A4 | | | 4. Other Sectors | Liquid F. | $CO_2$ | 76.7 | 15.9 | 0.1 | 15.9 | 27.589 |
| | | | | Gaseous F. | $CO_2$ | 10.2 | 4.0 | 0.3 | 4.0 | 0.031 |
| 3A | | A. Enteric Ferment. | | | $CH_4$ | 15.4 | 6.5 | 19.2 | 20.3 | 1.817 |
| 3B | | B. Manure Management | | | $CH_4$ | 2.9 | 6.5 | 54.6 | 55.0 | 0.486 |
| 3D1 | | D. Agricul-tural Soils | 1. Direct Soil Emissions | | $N_2O$ | 3.3 | 13.9 | 80.5 | 81.7 | 1.334 |
| 3D2 | | D. Agricul-tural Soils | 2. Indirect Soil Emissions | | $N_2O$ | 1.9 | 26.8 | 60.3 | 66.0 | 0.301 |
| 4A2 | | A. Forest land | 2. Land converted to forest land | | $CO_2$ | -5.1 | 17.2 | 34.9 | 38.9 | 0.726 |
| 4B1 | 4. LULUCF | B. Cropland | 1. Cropland remaining cropland | | $CO_2$ | 4.2 | 30.8 | 23.0 | 38.4 | 0.480 |
| 4D1 | | D. Wetlands | 1. Wetlands remaining wetlands | | $CO_2$ | 2.0 | 10.5 | 50.0 | 51.1 | 0.197 |
| 4G | | G. HWP | | | $CO_2$ | -2.7 | 50.0 | 54.8 | 74.2 | 0.739 |
| non-key rest | | | | | $CO_2$ | 5.4 | 7.1 | 7.1 | 10.0 | 0.055 |
| | | | | | $CH_4$ | 2.7 | 21.2 | 21.2 | 30.0 | 0.119 |
| | | | | | $N_2O$ | 3.5 | 56.6 | 56.6 | 80.0 | 1.476 |
| | | | | | F-gases | 0.0001 | 14.1 | 14.1 | 20.0 | 0.000 |
| **Total** | | | | | | **232.0** | | | | **46.63** |
| | | | | | | | | *Percentage uncertainty in total inventory:* | | **6.83** |

The level uncertainties are also evaluated by gas according to the results of the Approach 1 uncertainty assessment excluding LULUCF for the year 2023.

Table 1-12 Level uncertainties by gas 2023 for the total national emissions excluding LULUCF.

| Gas | Emissions 2023 (excluding LULUCF) kt CO2 eq | Mean absolute uncertainty kt CO2 eq | Mean relative uncertainty |
|---|---|---|---|
| CO2 | 131.2 | 6.6 | 5% |
| CH4 | 21.5 | 3.6 | 17% |
| N2O | 7.2 | 4.2 | 58% |
| F-gases | 7.5 | 1.0 | 14% |
| **Total** | **167.3** | **8.7** | **5.19%** |

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.

### 1.6.4 Results of Approach 2 uncertainty evaluation in previous submission

An Approach 2 uncertainty analysis was not conducted in the current submission for the latest reporting year. However, Approach 2 uncertainty results from a previous submission (reporting year 2020, see box below) show that the resulting uncertainties with Approach 1 for the reporting year 2023 are in a similar range as with previous Approach 2 results.

**Results of the Approach 2 uncertainty analysis for the reporting year 2020:**

The Approach 2 level uncertainty (2020) in the national total annual $CO_2$ equivalent emissions **excluding LULUCF** was 4.92% (95% confidence interval from -4.88% to 4.96%), trend uncertainty (1990–2020) was 6.25%.

The Approach 2 level uncertainty (2020) in the national total annual $CO_2$ equivalent emissions **including LULUCF** was 5.28% (95% confidence interval from -5.26% to 5.31%), trend uncertainty (1990–2020) was 6.42%.

## 1.7 General Assessment of completeness

### 1.7.1 Information on completeness

Liechtenstein's current GHG inventory is complete for all gases concerning the Paris Agreement.

Explanations for using the notation keys “NE” and “IE” are provided in CRT table 9.

### 1.7.2 Description of insignificant categories

The use of other carbon-containing fertilisers (3I) was not estimated (NE) for Liechtenstein, as the emissions are below the threshold of significance in accordance with paragraph 37(b) of the UNFCCC Annex I Inventory reporting guidelines.

### 1.7.3 Total aggregate emissions considered insignificant

The total GHG-emissions excluding LULUCF in 2023 amount to 167.3 kt $CO_2$ eq. The significance threshold for aggregated emissions equals to 0.84 kt $CO_2$ eq.

The emissions from UAN application in category 3I are very likely <0.005 kt $CO_2$ in the year 2023 (1% of emissions of source category 3H Urea application), which means that it accounts for less than 0.001% of total GHG emissions (excl. LULUCF) and is well below the significance threshold.

## 1.8 Metrics

This inventory is prepared using the 100-year time-horizon global warming potential ($GWP_{100}$) values from the IPCC Fifth Assessment Report (AR5) (Myhre et al. 2013).

## 1.9 Summary of any flexibility applied

No flexibility applied.

# 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 1990–2023.

## 2.1 Description of emission and removal trends for aggregated GHG emissions and removals

Liechtenstein's greenhouse gas emissions in the year 2023 amount to 167.3kt $CO_2$ equivalent ($CO_2$eq) excluding LULUCF sources or sinks (including LULUCF: 160.0 kt $CO_2$eq). This refers to 4.18 t $CO_2$eq per capita.

Total emissions in 2023 (excl. LULUCF) have declined by 26.8% compared to 1990. Compared to 2022, they increased by 1.5%. When including LULUCF categories, total emissions increased by 1.5% between 2022-2023 and decreased by 31% between 1990-2023.

Among the different greenhouse gases, $CO_2$ accounts for the largest share of total emissions. Table 2-1 shows the emissions for individual gases and sectors in Liechtenstein for the year 2023. The most important emission sources are fuel combustion activities in the Energy sector. Emissions of $CH_4$ and $N_2O$ mainly originate from the sector 3 Agriculture, and F-gas emissions stem from the sector 2 Industrial processes and product use (IPPU). The table also provides information about international bunkers.

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

| **Emissions 2023** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **HFCs** | **PFCs** | **$SF_6$** | **Total** |
|---|---|---|---|---|---|---|---|
| | **$CO_2$ equivalent (kt)** | | | | | | |
| 1 Energy | 131.1 | 1.75 | 0.79 | - | - | - | 133.6 |
| 2 IPPU | 0.11 | NO | 0.13 | 7.50 | 0.001 | 0.02 | 7.8 |
| 3 Agriculture | 0.04 | 18.6 | 5.60 | - | - | - | 24.2 |
| 5 Waste | 0.01 | 1.11 | 0.63 | - | - | - | 1.7 |
| **Total (excluding LULUCF)** | **131.2** | **21.5** | **7.2** | **7.5** | **0.001** | **0.02** | **167.3** |
| 4 LULUCF | -7.8 | NO | 0.49 | - | - | - | -7.3 |
| **Total (including LULUCF)** | **123.4** | **21.5** | **7.6** | **7.5** | **0.001** | **0.02** | **160.0** |
| *International Bunkers* | *1.24* | *0.00* | *0.01* | - | - | - | *1.25* |

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

Accounting for 78.4% of the total emissions in 2023 (excluding emissions from LULUCF), $CO_2$ is the most dominant greenhouse gas emitted in Liechtenstein. $CH_4$ emissions represent 12.8% and $N_2O$ emissions 4.3% of the total emissions.

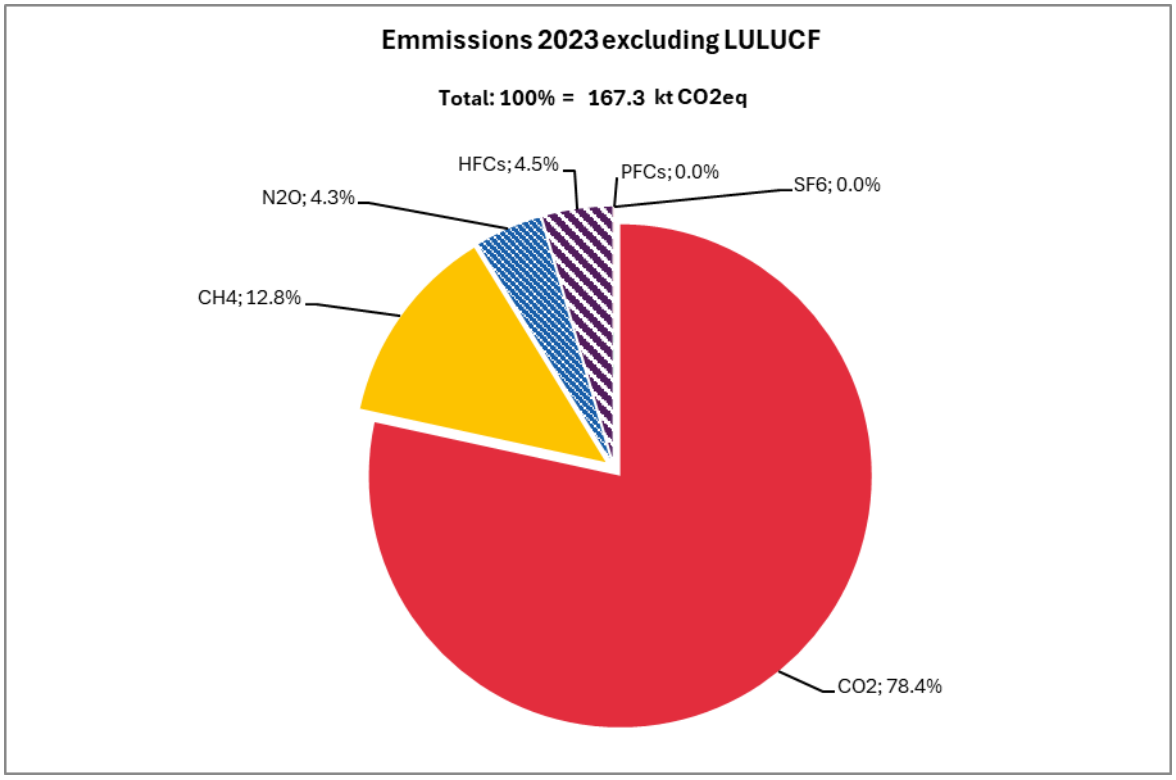



Figure 2-1 Liechtenstein's GHG emissions by gases excluding LULUCF emissions.

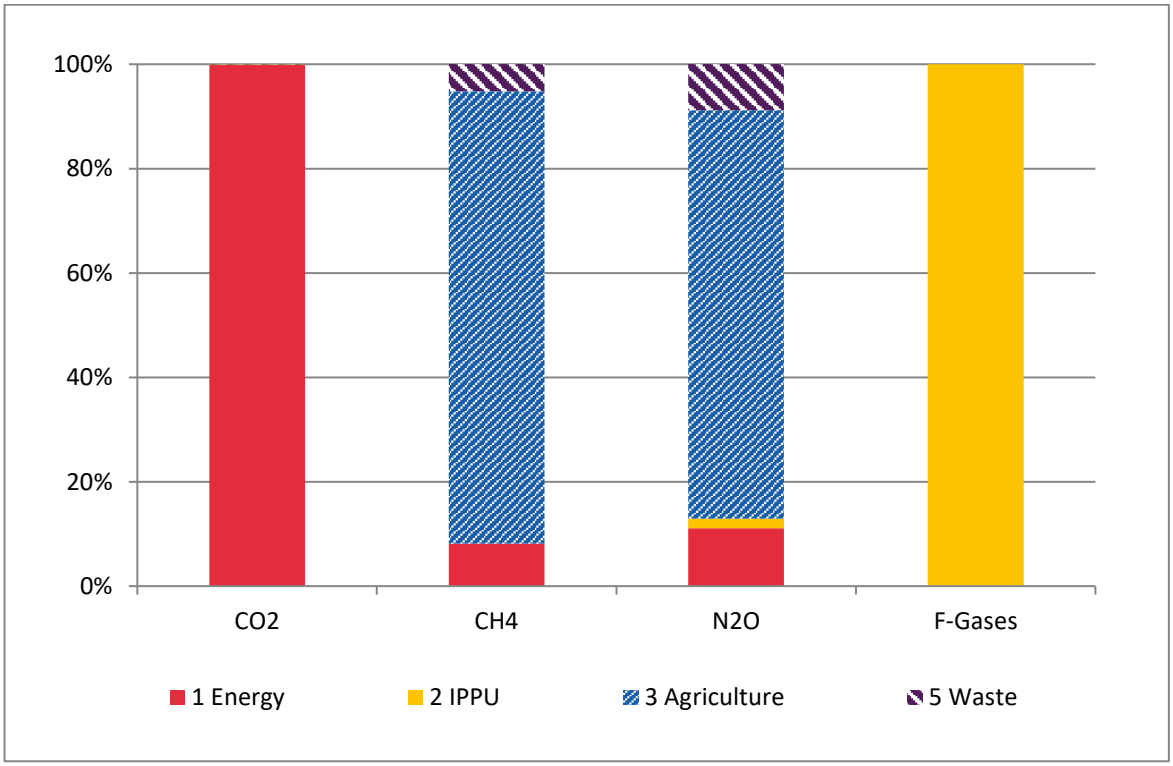



Figure 2-2 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions in 2023.

## 2.2 Description of emission and removal trends by sector and by gas

### 2.2.1 Emission trends by gas

Emission trends 1990–2023 by gas are summarised in Table 2-2 and in Figure 2-3.

Table 2-2 Summary of Liechtenstein's GHG emissions in $CO_2$eq (kt) by gas. The last column shows the percentage change in emissions in 2023 as compared to the base year 1990. HFC emissions have increased by about a factor of 78'000 in 2023 compared to 1990.

| Greenhouse Gas Emissions | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | |
| $CO_2$ emissions incl. net $CO_2$ from LULUCF | 202.2 | 205.1 | 242.1 | 234.7 | 207.5 |
| $CO_2$ emissions excl. net $CO_2$ from LULUCF | 199.0 | 204.2 | 216.9 | 229.0 | 190.8 |
| $CH_4$ emissions incl. $CH_4$ from LULUCF | 21.0 | 19.6 | 18.3 | 20.5 | 21.1 |
| $CH_4$ emissions excl. $CH_4$ from LULUCF | 21.0 | 19.6 | 18.3 | 20.5 | 21.1 |
| $N_2O$ emissions incl. $N_2O$ from LULUCF | 8.7 | 8.7 | 8.1 | 7.7 | 7.8 |
| $N_2O$ emissions excl. $N_2O$ from LULUCF | 8.5 | 8.4 | 7.6 | 7.2 | 7.3 |
| HFCs | 0.0 | 1.1 | 3.5 | 6.4 | 8.4 |
| PFCs | NA,NO | 0.0 | 0.0 | 0.1 | 0.1 |
| $SF_6$ | NA,NO | NA,NO | 0.1 | 0.3 | 0.0 |
| Unspecified mix of HFCs and PFCs | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |
| $NF_3$ | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |
| **Total (including LULUCF)** | 232.0 | 234.5 | 272.2 | 269.6 | 244.9 |
| **Total (excluding LULUCF)** | 228.5 | 233.3 | 246.5 | 263.4 | 227.6 |

| Greenhouse Gas Emissions | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | |
| $CO_2$ emissions incl. net $CO_2$ from LULUCF | 163.7 | 160.3 | 148.8 | 155.2 | 151.4 |
| $CO_2$ emissions excl. net $CO_2$ from LULUCF | 161.2 | 159.7 | 149.7 | 155.5 | 142.6 |
| $CH_4$ emissions incl. $CH_4$ from LULUCF | 21.1 | 21.0 | 21.1 | 20.6 | 20.9 |
| $CH_4$ emissions excl. $CH_4$ from LULUCF | 21.1 | 21.0 | 21.1 | 20.6 | 20.9 |
| $N_2O$ emissions incl. $N_2O$ from LULUCF | 7.7 | 7.8 | 7.6 | 7.6 | 7.8 |
| $N_2O$ emissions excl. $N_2O$ from LULUCF | 7.2 | 7.2 | 7.1 | 7.1 | 7.2 |
| HFCs | 9.4 | 9.5 | 9.2 | 9.5 | 9.6 |
| PFCs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $SF_6$ | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| Unspecified mix of HFCs and PFCs | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |
| $NF_3$ | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |
| **Total (including LULUCF)** | **202.1** | **198.6** | **186.8** | **193.0** | **189.9** |
| **Total (excluding LULUCF)** | **199.0** | **197.5** | **187.1** | **192.7** | **180.4** |

| Greenhouse Gas Emissions | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | | % |
| $CO_2$ emissions incl. net $CO_2$ from LULUCF | 150.5 | 135.9 | 136.7 | 120.5 | 123.4 | -39.0% |
| $CO_2$ emissions excl. net $CO_2$ from LULUCF | 148.7 | 141.6 | 145.6 | 128.3 | 131.2 | -34.1% |
| $CH_4$ emissions incl. $CH_4$ from LULUCF | 21.8 | 21.9 | 21.6 | 21.4 | 21.5 | 2.0% |
| $CH_4$ emissions excl. $CH_4$ from LULUCF | 21.8 | 21.9 | 21.6 | 21.4 | 21.5 | 2.0% |
| $N_2O$ emissions incl. $N_2O$ from LULUCF | 7.9 | 7.8 | 7.8 | 7.8 | 7.6 | -12.5% |
| $N_2O$ emissions excl. $N_2O$ from LULUCF | 7.3 | 7.2 | 7.3 | 7.3 | 7.2 | -15.4% |
| HFCs | 9.3 | 8.8 | 8.2 | 7.8 | 7.5 | see caption |
| PFCs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - |
| $SF_6$ | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | - |
| Unspecified mix of HFCs and PFCs | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | - |
| $NF_3$ | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | - |
| **Total (including LULUCF)** | **189.6** | **174.4** | **174.3** | **157.7** | **160.0** | **-31.0%** |
| **Total (excluding LULUCF)** | **187.1** | **179.5** | **182.7** | **164.9** | **167.3** | **-26.8%** |

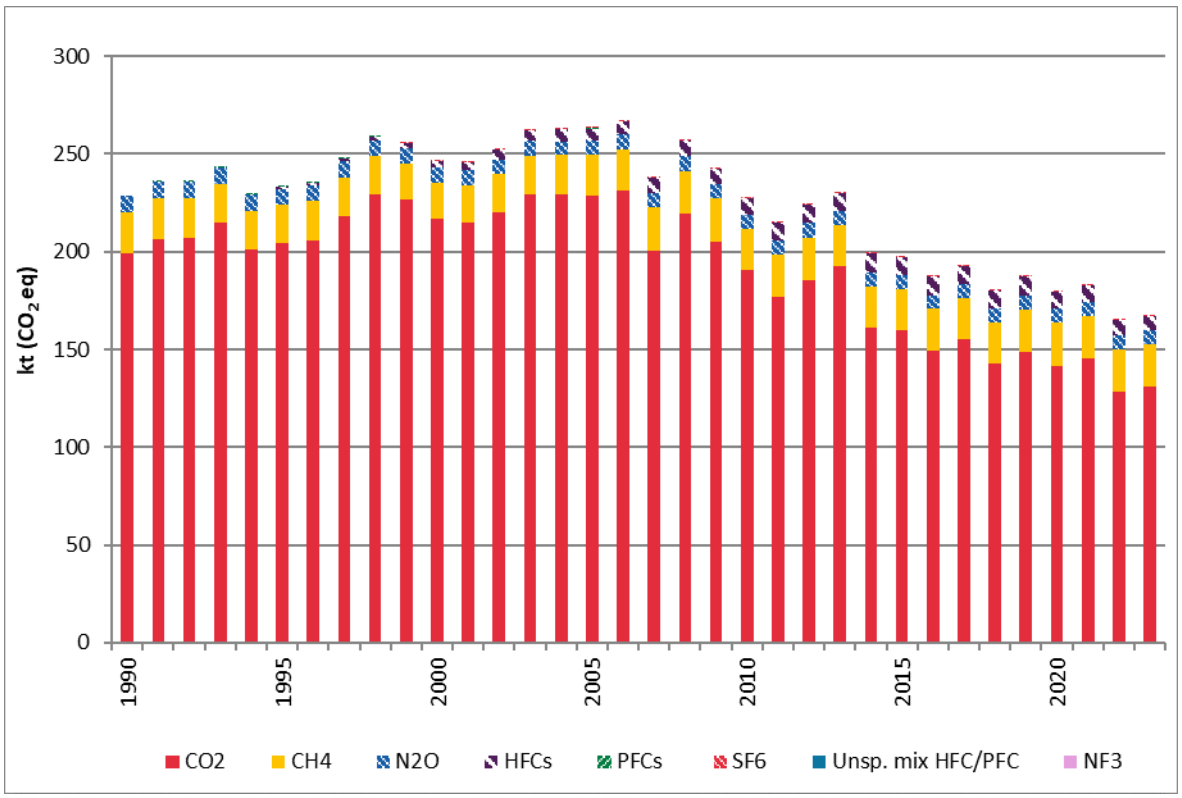



Figure 2-3 Trend of Liechtenstein's greenhouse gas emissions by gases. $CO_2$, $CH_4$ and $N_2O$ correspond to the respective total emissions excluding LULUCF. Note that $NF_3$ emissions are not occurring.

As shown in Table 2-2 and Figure 2-3, total emissions excluding and including LULUCF emissions are clearly below base year emissions. Emissions have increased after 1990, reaching a maximum in 2006. From then onwards, a decreasing trend starts to develop. Emission trends for the individual gases can be described as follows:

- Total emissions (in $CO_2$eq) excluding LULUCF sources or sinks decreased by 26.8% from 1990 to 2023.
- Total emissions (in $CO_2$eq) including LULUCF show a decrease of 31.0% in 2023 compared to 1990 levels.
- $CO_2$ emissions (excluding net $CO_2$ from LULUCF) have declined by 34.01% between 1990 and 2023. In comparison to the previous reporting year 2022, $CO_2$ emissions (excluding net $CO_2$ from LULUCF) increased by 2.2% in 2023. In general, the most important drivers of net $CO_2$ emissions are fuel prices and winter temperatures (heating degree days), influencing the source categories contributing to a large share of $CO_2$ emissions under 1A Fuel combustion (1A2 Manufacturing industries and construction, 1A3 Transport and 1A4 Other sectors). The share of $CO_2$ emissions decreased from 87.1% in 1990 to 78.4% in 2023 (excl. LULUCF).
- $CH_4$ emissions (excluding $CH_4$ from LULUCF) have increased by 2.0% since 1990. Compared to 2022, $CH_4$ emissions (excluding LULUCF) show a increase of 0.2% in 2023. The $CH_4$ emissions are mainly determined by the number of livestock (in particular cattle) which strongly influence $CH_4$ emissions from enteric fermentation. Livestock numbers have been reduced between 1990–2000 and have increased again since

(however, still being below the 1990 level). The share of $CH_4$ increased from 9.2% in 1990 to 12.8% in 2023 (excl. LULUCF).

- $N_2O$ emissions (excluding $N_2O$ from LULUCF) have declined by 15.4% in 2023 compared to 1990. Compared to 2022, $N_2O$ emissions (without LULUCF) in 2023 decreased by 2.2%. The main source of $N_2O$ emissions is agriculture (manure management and agricultural soils). The share of $N_2O$ increased from 3.7% (1990) to 4.3% (2023).
- HFC emissions increased due to their role as substitutes for CFCs. $SF_6$ emissions originate from electrical transformation stations and play a minor role for the total of the synthetic gases (F-gases). PFC emissions are occurring since 1997 and are increasing on a low level. The share of the sum of all F-gases (within total emissions excl. LULUCF) increased from 0.00004% (1990) to 4.5% (2023).

### 2.2.2 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 $CO_2$eq (kt). The last column shows the percent change in emissions in 2023 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** | **201.3** | **208.9** | **209.7** | **217.8** | **203.8** | **207.0** | **208.9** | **221.4** | **232.3** | **229.7** |
| 1.A.1. Energy Industries | 0.2 | 0.8 | 1.9 | 2.0 | 1.8 | 2.1 | 2.6 | 2.5 | 2.9 | 2.9 |
| 1.A.2. Manufacturing ind. & construction | 36.3 | 35.9 | 36.3 | 37.6 | 35.6 | 35.7 | 35.7 | 37.6 | 40.3 | 39.8 |
| 1.A.3. Transport | 76.9 | 90.2 | 89.5 | 87.4 | 80.0 | 82.0 | 83.3 | 86.9 | 86.5 | 90.7 |
| 1.A.4. Other Sectors | 87.6 | 81.4 | 81.4 | 90.3 | 85.8 | 86.6 | 86.5 | 93.6 | 101.7 | 95.4 |
| 1.A.5. Other | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 1.B. Fugitive emissions from fuels | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | 0.8 | 0.9 |
| **2. IPPU** | **0.6** | **0.6** | **0.6** | **0.7** | **0.9** | **1.6** | **1.8** | **2.2** | **2.7** | **3.2** |
| **3. Agriculture** | **24.8** | **24.8** | **24.1** | **23.0** | **23.1** | **23.0** | **23.1** | **22.7** | **22.2** | **21.3** |
| **5. Waste** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** |
| ***Total (excluding LULUCF)*** | ***228.5*** | ***236.0*** | ***236.1*** | ***243.2*** | ***229.5*** | ***233.3*** | ***235.5*** | ***248.0*** | ***258.9*** | ***255.9*** |
| **4. LULUCF** | **3.6** | **-12.7** | **-1.4** | **-4.8** | **15.0** | **1.2** | **-7.3** | **9.0** | **0.9** | **-0.4** |
| ***Total (including LULUCF)*** | ***232.0*** | ***223.3*** | ***234.7*** | ***238.4*** | ***244.6*** | ***234.5*** | ***228.2*** | ***257.0*** | ***259.8*** | ***255.4*** |

| Source and Sink Categories | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | | | | | | |
| **1. Energy** | **220.1** | **217.8** | **223.1** | **232.4** | **232.0** | **231.6** | **233.8** | **203.4** | **222.2** | **208.1** |
| 1.A.1. Energy Industries | 2.8 | 2.9 | 2.5 | 2.8 | 3.0 | 3.1 | 2.9 | 2.6 | 2.9 | 3.0 |
| 1.A.2. Manufacturing ind. & construction | 36.4 | 36.4 | 37.9 | 41.2 | 39.8 | 39.1 | 40.5 | 33.9 | 36.3 | 27.5 |
| 1.A.3. Transport | 91.5 | 88.1 | 84.0 | 83.8 | 82.3 | 81.8 | 79.2 | 83.4 | 87.8 | 81.9 |
| 1.A.4. Other Sectors | 88.4 | 89.4 | 97.6 | 103.5 | 105.8 | 106.3 | 109.9 | 82.3 | 93.9 | 94.5 |
| 1.A.5. Other | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 1.B. Fugitive emissions from fuels | 0.9 | 1.0 | 1.0 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1.2 |
| **2. IPPU** | **4.0** | **4.8** | **5.5** | **6.2** | **6.8** | **7.1** | **7.5** | **8.2** | **8.8** | **8.3** |
| **3. Agriculture** | **20.7** | **21.8** | **22.2** | **22.3** | **22.4** | **23.0** | **24.0** | **24.4** | **24.6** | **24.5** |
| **5. Waste** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** |
| ***Total (excluding LULUCF)*** | ***246.5*** | ***246.1*** | ***252.4*** | ***262.6*** | ***262.8*** | ***263.4*** | ***267.0*** | ***237.7*** | ***257.4*** | ***242.6*** |
| **4. LULUCF** | **25.7** | **1.9** | **2.6** | **4.0** | **6.2** | **6.2** | **11.1** | **20.4** | **22.5** | **18.9** |
| ***Total (including LULUCF)*** | ***272.2*** | ***248.0*** | ***255.1*** | ***266.6*** | ***269.0*** | ***269.6*** | ***278.1*** | ***258.1*** | ***279.9*** | ***261.5*** |

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | | | | | | |
| **1. Energy** | **193.5** | **179.4** | **187.9** | **195.2** | **163.6** | **162.2** | **152.1** | **158.0** | **145.1** | **151.2** |
| 1.A.1. Energy Industries | 3.3 | 3.1 | 2.8 | 3.0 | 2.5 | 2.0 | 2.2 | 2.1 | 2.2 | 3.4 |
| 1.A.2. Manufacturing ind. & construction | 26.1 | 23.6 | 25.7 | 26.4 | 27.3 | 27.6 | 25.9 | 27.7 | 24.6 | 24.1 |
| 1.A.3. Transport | 77.7 | 76.8 | 79.8 | 79.5 | 73.7 | 61.7 | 60.3 | 60.5 | 58.5 | 57.0 |
| 1.A.4. Other Sectors | 85.2 | 74.7 | 78.3 | 84.9 | 58.9 | 69.5 | 62.5 | 66.4 | 58.6 | 65.4 |
| 1.A.5. Other | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 1.B. Fugitive emissions from fuels | 1.3 | 1.2 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| **2. IPPU** | **8.8** | **9.2** | **9.5** | **9.7** | **9.9** | **9.9** | **9.5** | **9.8** | **10.0** | **9.6** |
| **3. Agriculture** | **23.6** | **24.4** | **24.7** | **23.6** | **23.9** | **23.8** | **23.8** | **23.3** | **23.7** | **24.6** |
| **5. Waste** | **1.7** | **1.7** | **1.7** | **1.7** | **1.6** | **1.6** | **1.6** | **1.6** | **1.6** | **1.6** |
| ***Total (excluding LULUCF)*** | ***227.6*** | ***214.7*** | ***224.0*** | ***230.1*** | ***199.0*** | ***197.5*** | ***187.1*** | ***192.7*** | ***180.4*** | ***187.1*** |
| **4. LULUCF** | **17.3** | **8.4** | **8.4** | **3.3** | **3.0** | **1.2** | **-0.3** | **0.3** | **9.4** | **2.4** |
| ***Total (including LULUCF)*** | ***244.9*** | ***223.2*** | ***232.4*** | ***233.4*** | ***202.1*** | ***198.6*** | ***186.8*** | ***193.0*** | ***189.9*** | ***189.6*** |

| Source and Sink Categories | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|
| | $CO_2$eq (kt) | | | | % |
| **1. Energy** | **144.1** | **148.1** | **130.8** | **133.6** | **-33.6%** |
| 1.A.1. Energy Industries | 2.4 | 2.6 | 2.3 | 2.9 | 1579% |
| 1.A.2. Manufacturing ind. & construction | 22.8 | 23.2 | 21.3 | 19.8 | -45.4% |
| 1.A.3. Transport | 52.5 | 55.8 | 50.1 | 54.1 | -29.7% |
| 1.A.4. Other Sectors | 65.0 | 65.2 | 55.8 | 55.6 | -36.5% |
| 1.A.5. Other | NO | NO | NO | NO | - |
| 1.B. Fugitive emissions from fuels | 1.3 | 1.4 | 1.4 | 1.3 | 214.7% |
| **2. IPPU** | **9.1** | **8.5** | **8.1** | **7.8** | **1185%** |
| **3. Agriculture** | **24.7** | **24.3** | **24.2** | **24.2** | **-2.4%** |
| **5. Waste** | **1.6** | **1.7** | **1.7** | **1.7** | **0.9%** |
| ***Total (excluding LULUCF)*** | ***179.5*** | ***182.7*** | ***164.9*** | ***167.3*** | ***-26.8%*** |
| **4. LULUCF** | **-5.2** | **-8.4** | **-7.3** | **-7.3** | **-305.2%** |
| ***Total (including LULUCF)*** | ***174.4*** | ***174.3*** | ***157.7*** | ***160.0*** | ***-31.0%*** |

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

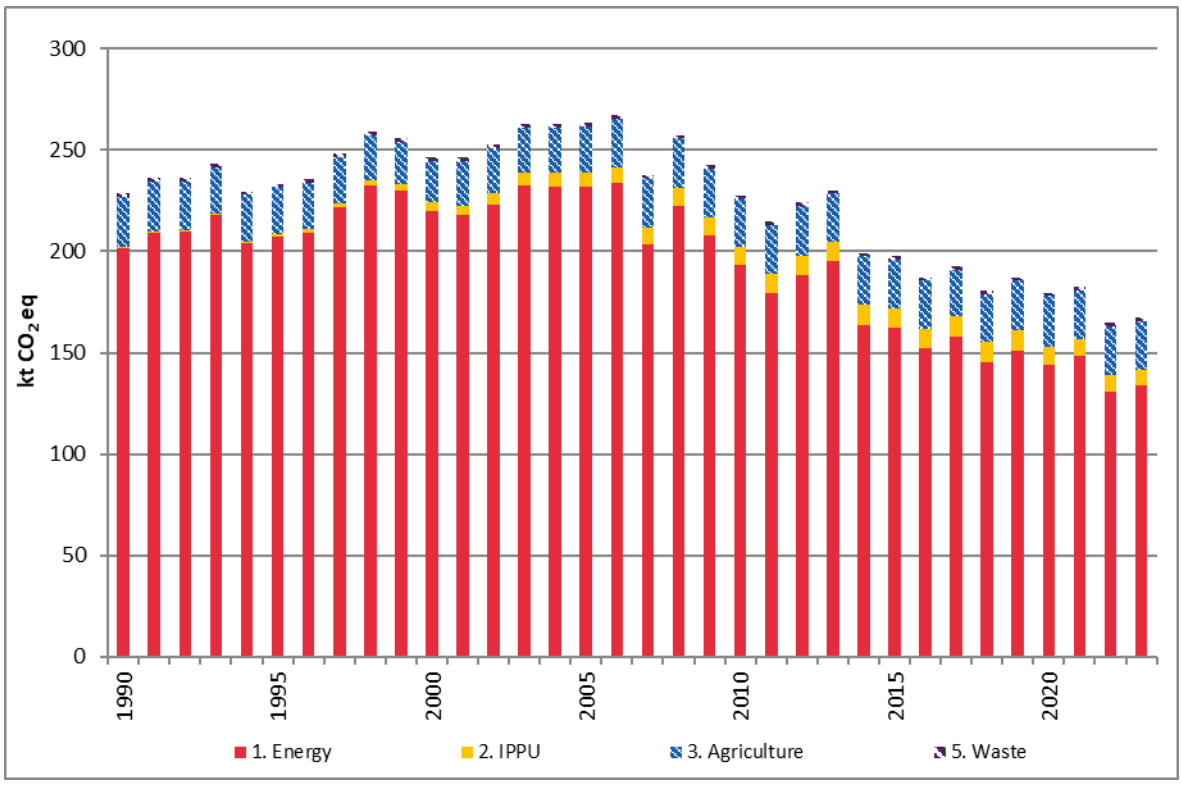



Figure 2-4 Trend of Liechtenstein's greenhouse gas emissions by main source categories in $CO_2$eq (kt) (excl. net $CO_2$ from LULUCF).

The following emission trends are observed in the sectors:

**Sector 1 Energy**

In 2023, 79.8% of Liechtenstein's GHG emissions (excluding LULUCF) originate from sector 1 Energy, which is 0.5 percentage points less than in 2022. The share of sector 1 Energy in the total emissions declined by 8.3 percentage points since 1990. Also, the total emissions of the sector 1 Energy have clearly decreased in comparison to 1990 levels (by 33.6%). The source categories within sector 1 Energy show the following trends between 1990 and 2023:

- 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 a factor of 17 since 1b990.
- 1A2 Manufacturing industries and construction: Total emissions from this source category have declined by 45.4% since 1990. Gaseous fuels are the more important energy carrier in Liechtenstein in 2023. In 2023, emissions from gaseous fuels decreased by 32.8% compared to 1990 and decreased by 11.4% compared to 2022. Liquid fuel emissions decreased by 54.4% compared to 1990.
- 1A3 Transport: Up to 2006, fuel consumption in road transportation was mostly in line with a general development of road-vehicle kilometres of all vehicle categories. Total emissions started decreasing since 2013. Between 2022 and 2023, emissions from 1A3 increased by 7.9%, which is mainly caused by an increase in gasoline consumption. In 2023, road traffic volume in Liechtenstein increased compared to 2022 (Government 2024b), which may have contributed to the increase in fuel consumption. Also in

Switzerland, road traffic volumes increased in 2023 compared to 2022 (SFSO 2024f). The overall trend in sector 1A3b shows a decrease of 29.7% (1990–2023). The decrease is mainly related to fuel tourism (see chp. 3.2.7.2; SFOE 2018) and an increasing share of electric vehicles.

- 1A4 Other sectors: GHG emissions in source category 1A4 have decreased by 0.4% compared to the previous reporting year 2022. An important driver of emissions from category 1A4 are heating degree days, which generally correlate well with the use of heating fuels. The number of heating degree days in 2023 was slightly higher lower than in 2022 (see Figure 2-5). The fact that emissions still declined suggests a decoupling of heating degree days and energy consumption, likely due to energy efficiency and energy saving measures.
  Various emission reduction measures in Liechtenstein are influencing the fuel consumption. For instance, the increase in the $CO_2$ levy in 2016, which caused an increase in sales of gas oil in 2015 and a reduced apparent consumption in 2016 and subsequently again an increase in 2017. The fuel levy was further increased in 2018. Also, in 2018, the relative reduction of sales of gas oil is stronger than the relative decrease of heating degree days, and, vice versa, the increase of gas oil sales in 2019 is higher as it would have been expected due to the increase of heating degree days. The installation of a district heating pipeline in 2009, is still an important factor leading to the stronger declining trend of the $CO_2$ emissions as the number of buildings connected to the heating pipeline is still increasing every year. Also, subsidies for geothermal heat pumps contribute to the decline in gas oil consumption.

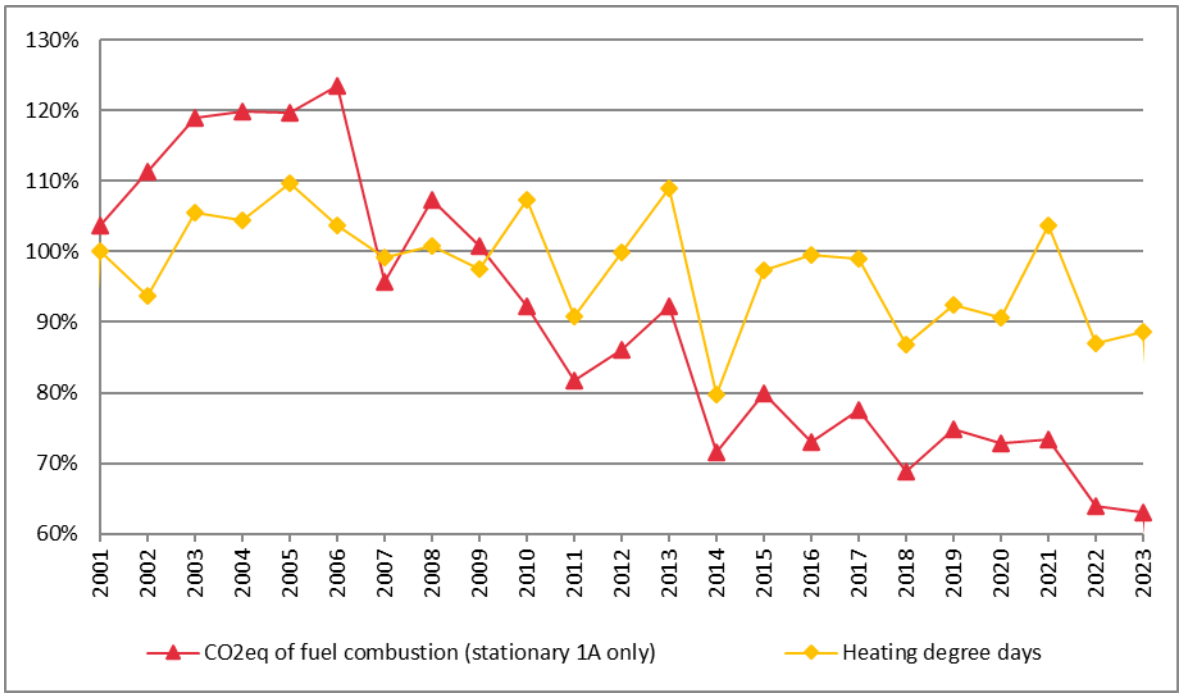



Figure 2-5 Relative trend for $CO_2$ emissions from 1A Fuel Combustion compared with the number of heating degree days. The drop of emissions in 2007 is driven by high oil and gas prices.

- 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 installation and subsequent extension of Liechtenstein's gas supply network since 1990, fugitive emissions have strongly increased over the period 1990–2023 (214.7%).

**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. Sector IPPU contributes to 4.6% of the total GHG-emissions (excluding LULUCF) in 2023. Nevertheless, the use of F-gases has increased substantially over the period 1990–2023, leading to a relative increase in emissions in sector 2 of about a factor of 12.8. The most important source category is 2F Product uses as substitutes for ozone-depleting substances (ODS) due to the replacement of CFCs with HFCs. The main factors influencing the increase in HFC emissions in refrigeration and air conditioning are the increasing population of Liechtenstein (37.8% increase in 2023 compared with 1990), the increasing number of households in Liechtenstein (+73.3%), the increasing number of employees in the industrial and service sectors (+119.3%) and the increasing number of registered cars (+85.5%).

**Sector 3 Agriculture**

In 2023, sector Agriculture contributes to 14.5% of total GHG-emissions (excluding LULUCF) in Liechtenstein. Agricultural emissions in 2023 are 2.4% below the 1990 level. The main parameter influencing $CH_4$ and $N_2O$ emissions from agriculture are animal numbers (in particular cattle and swine). A second relevant development in enteric fermentation is the increasing productivity of dairy cattle (high-yield cattle), which results in higher (per animal) emission factors. The emissions from manure management also closely follow the development of the cattle population. Under the agricultural soils category, the emissions from animal manure applied to soils is the most important subcategory and also depends on the cattle population number, as well as a change in husbandry systems from stall towards loose housing systems (in the course of the agricultural policy reforms during the 1990s and the early twenty-first century).

**Sector 4 LULUCF**

Figure 2-6 shows $CO_2$ emissions or removals by sources and sinks from LULUCF categories in Liechtenstein. The dominant categories when looking at the changes in $CO_2$ 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 and storm events. The reasons for the relatively high net $CO_2$ emissions in 1990 and 2000 are the European storms Vivian (February 1990) and Lothar (December 1999), respectively, which caused great damages in the forest stands and markedly increased harvesting. In January 1994, the Rhine valley and especially Liechtenstein was hit by a strong foehn storm with large wind throws (see http://www.sturmarchiv.ch).

In a medium-term perspective, harvesting rates in Liechtenstein's forests appeared to expand between 2001 and 2008 mainly due to increased use of energy wood. Harvesting rates started to decline after 2012 due to the international and domestic economic framework conditions. In 2018, harvesting rates were relatively high due to salvage logging on areas affected by storms and pests. However, the 2022 forest inventory (LWI 2025) shows a net increase in forest carbon stock between 2010 and 2022: harvesting rates and mortality were decreasing strongly causing net sinks in the LULUCF sector from 2020 onwards.

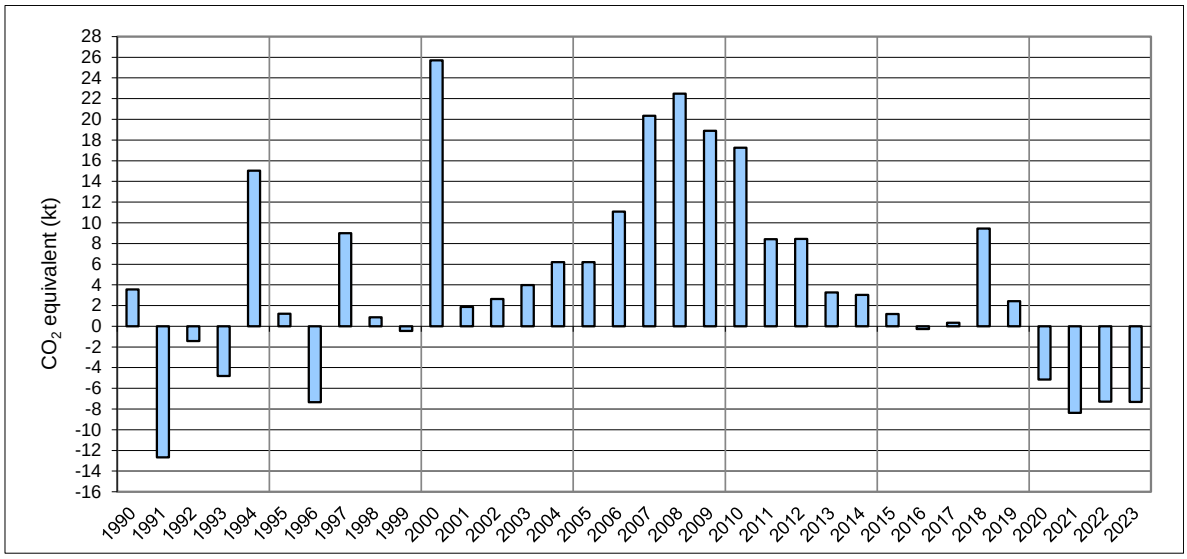



Figure 2-6 Liechtenstein's $CO_2$ emissions/removals of source category 4 LULUCF in kt $CO_2$ equivalent.

**Sector 5 Waste**

In Liechtenstein, only little emissions occur from the sector Waste contributing to 1% of total GHG emissions excl. LULUCF in 2023, since all municipal solid waste is exported to a Swiss incineration plant. The waste sector shows a slight increase between 1990 and 2023 (0.9%). The development of the greenhouse gas emissions is dominated by source category 5D Wastewater treatment and discharge. In source category 5D Wastewater treatment and discharge, sewage gas has only been used as fuel for boilers or co-generation up to 2014. Since then, all sewage gas is upgraded and supplied to the gas grid, which results in significant lower greenhouse gas emissions in this source category. In source category 5A Solid waste disposal, a steady decrease of greenhouse gas emissions can be observed due to stopped landfilling in 1974.

### 2.2.3 Emission trends for precursor greenhouse gases and $SO_2$

Liechtenstein is member to the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) and submits data on air pollutants including indirect GHG. The submission in 2025will take place at the end of April 2025, and **the overview and results**

**provided below are from the submission to CLRTAP in 2024**. (Therefore, results for 2023 are not yet available.)

For the precursor substances $NO_x$, CO and NMVOC as well as for the gas $SO_2$, data from the current state of knowledge in air pollution reporting is shown in Table 2-4 (Acontec 2025). 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. In particular, there would be inconsistencies within activity data and accordingly within implied emission factors of the results of the two approaches. Therefore, the data is not reported in CRT table 6.

Table 2-4 Development of $NO_x$, CO, NMVOC and $SO_x$ emissions (in t) as of submission 2024 (OE 2024f).

| **Precursor gases and $SO_2$** | **1990** | **1995** | **2000** | **2005** | **2010** |
|---|---|---|---|---|---|
| | **tonnes** | | | | |
| $NO_x$ | 672 | 561 | 536 | 481 | 402 |
| CO | 3’367 | 2’228 | 1’736 | 1’102 | 755 |
| NMVOC | 1’540 | 1’022 | 733 | 512 | 427 |
| $SO_x$ | 107 | 74 | 47 | 35 | 20 |

| **Precursor gases and $SO_2$** | **2013** | **2014** | **2015** | **2016** | **2017** |
|---|---|---|---|---|---|
| | **tonnes** | | | | |
| $NO_x$ | 672 | 561 | 536 | 481 | 402 |
| CO | 3’367 | 2’228 | 1’736 | 1’102 | 755 |
| NMVOC | 1’540 | 1’022 | 733 | 512 | 427 |
| $SO_x$ | 107 | 74 | 47 | 34.6 | 20.3 |

| **Precursor gases and $SO_2$** | **2018** | **2019** | **2020** | **2021** | **2022** | **1990-2022** |
|---|---|---|---|---|---|---|
| | **tonnes** | | | | | **%** |
| $NO_x$ | 672 | 561 | 536 | 481 | 402 | -40% |
| CO | 3’367 | 2’228 | 1’736 | 1’102 | 755 | -78% |
| NMVOC | 1’540 | 1’022 | 733 | 512 | 427 | -72% |
| $SO_x$ | 106.8 | 73.7 | 46.7 | 34.6 | 20.3 | -81% |

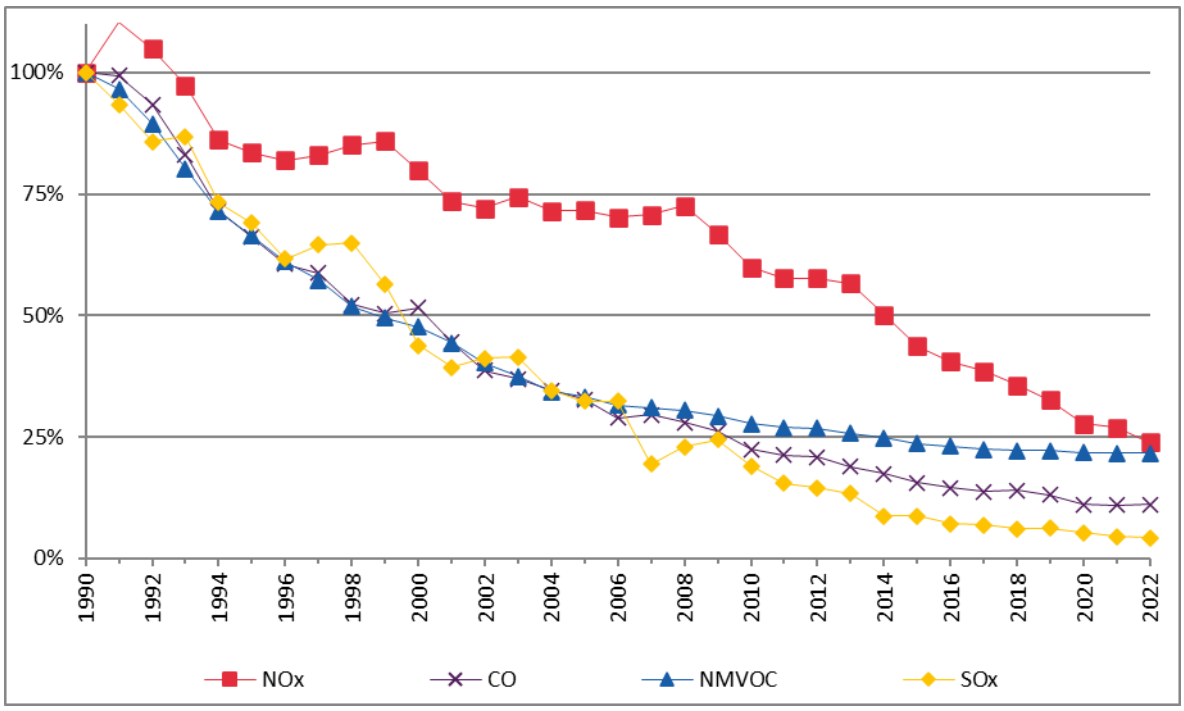



Figure 2-7 Trend of $NO_x$, CO, NMVOC and $SO_x$ emissions as of CLRTAP submission 2023 (OE 2024f).

The complete CLRTAP Inventory data can be found on the internet (see OE 2024f):

https://www.ceip.at/status-of-reporting-and-review-results/2024-submission

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# 3. Energy (CRT sector 1)

## 3.1 Overview of the sector

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. 133.6 kt $CO_2$ equivalents were emitted within this sector in 2023, which corresponds to 79.8% of total emissions (167.3kt $CO_2$ equivalent, excluding LULUCF). The emissions of the time period 1990–2023 are depicted in Figure 3-1.

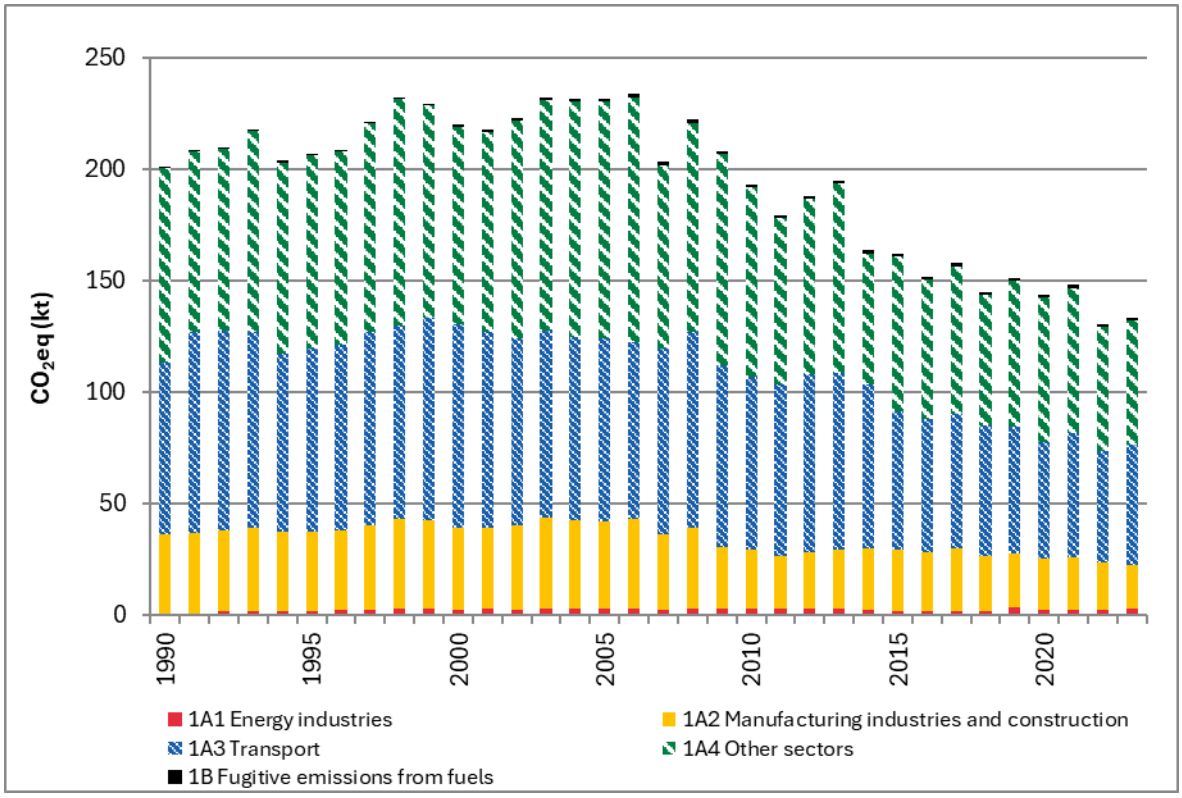



Figure 3-1 Liechtenstein's GHG emissions of the sector 1 Energy by sub-sectors. Note that there are no emissions in sub-sector 1A5.

Table 3-1 summarises the emissions from sector 1 Energy by individual gases 1990–2023. The numbers do neither include emissions from international bunkers (aviation) nor $CO_2$ emissions from biomass burning since none of those are accounted for in the UNFCCC.

Table 3-1 GHG emissions of sector 1 Energy by gas in $CO_2$ equivalent (kt) and the relative change (last column).

| Gas | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | |
| $CO_2$ | 198.7 | 204.0 | 216.6 | 228.7 | 190.6 |
| $CH_4$ | 1.4 | 1.5 | 1.7 | 2.0 | 1.9 |
| $N_2O$ | 1.1 | 1.6 | 1.7 | 0.9 | 1.0 |
| **Sum** | **201.3** | **207.0** | **220.1** | **231.6** | **193.5** |

| Gas | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | |
| $CO_2$ | 161.0 | 159.5 | 149.5 | 155.3 | 142.4 |
| $CH_4$ | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| $N_2O$ | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| **Sum** | **163.6** | **162.2** | **152.1** | **158.0** | **145.1** |

| Gas | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | | % |
| $CO_2$ | 148.5 | 141.4 | 145.4 | 128.2 | 131.1 | -34.0% |
| $CH_4$ | 1.9 | 1.8 | 1.8 | 1.8 | 1.8 | 22.3% |
| $N_2O$ | 0.9 | 0.8 | 0.9 | 0.9 | 0.8 | -30.7% |
| **Sum** | **151.2** | **144.1** | **148.1** | **130.8** | **133.6** | **-33.6%** |

Table 3-2 shows more details of the emissions of sector 1 Energy in 2023. The table includes emissions from international bunkers (aviation) and from biomass burning in two separate rows, which are both not accounted for under the UNFCCC.

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

| Emissions 2023 | $CO_2$ | $CH_4$ | $N_2O$ | Total | |
|---|---|---|---|---|---|
| Sources | $CO_2$ equivalent (kt) | | | | % |
| **1. Energy** | **131.1** | **1.8** | **0.8** | **133.6** | ***100.0%*** |
| **1.A. Fuel combustion activitity** | **131.1** | **0.5** | **0.8** | **132.3** | ***99.0%*** |
| 1.A.1. Energy Industries | 2.8 | 0.0 | 0.0 | 2.9 | ***2.1%*** |
| 1.A.2. Manufacturing industries and construction | 19.8 | 0.0 | 0.1 | 19.8 | ***14.8%*** |
| 1.A.3. Transport | 53.6 | 0.1 | 0.4 | 54.1 | ***40.5%*** |
| 1.A.4. Other Sectors | 54.9 | 0.3 | 0.3 | 55.6 | ***41.6%*** |
| 1.A.5. Other | NO | NO | NO | NO | - |
| **1.B. Fugitive emissions from fuels** | **0.0** | **1.3** | **NO** | **1.3** | ***1.0%*** |
| **1.D.1. International bunkers** | **1.2** | **0.0** | **0.0** | **1.2** | - |
| **1.D.3. $CO_2$ emissions from biomass** | **23.5** | **-** | **-** | **23.5** | - |

Emissions from sector 1 Energy may be characterised as follows:

- Concerning the total emissions ($CO_2$eq) from sector 1 Energy, a trend of -33.6% can be observed between 1990 and 2023. From 2022 to 2023 emissions increased by 2.1%. This increase is mainly caused by an increase in emissions in sector 1A3 Transport and 1A1 Energies. The increase in gasoline consumption in sector 1A3b is the main reason for the increase in emissions in sector 1A3. With a smaller impact on the result, but nevertheless noteworthy is the increase in gaseous fuels consumed in sector 1A1a, which increased by 24%.
- The three source categories 1A2, 1A3 and 1A4 dominate the emissions of sector 1 Energy and cover altogether 96.9% (129.5 kt $CO_2$eq) of total emissions of sector 1.
  - 1A3 Transport accounts for 40.5% of the emissions in 2023.
  - 1A4 Other sectors (commercial/institutional, residential) contributes to 41.6% of the total energy-related emissions.
  - 1A2 Manufacturing industries and construction contributes to 14.8% of the emissions.
  - 1A1 Energy industries and 1B Fugitive emissions only play a minor role. In 2023, they cover 2.1% and 1.0%, respectively, of the total sector 1 emissions.
- The only occurring bunker emissions originate from a helicopter base in Balzers, Liechtenstein. Only few flights are domestic, most of them are business flights to Switzerland and Austria, producing bunker emissions of 1.2 kt $CO_2$ eq.
- $CO_2$ emissions from biomass add up to 23.5 kt. They originate from use of biofuels in transport, wood burning (heating, power) and the burning of sewage gas (heating, power) as well as the consumption of biogas produced from sewage gas, which is fed into the general gas network.

- The far most important gas emitted from source category 1 Energy is $CO_2$. It accounts for 98.7% of the category in 1990 and for 98.1% in 2023.
- In 2023, $CH_4$ emissions accounted for 1.3% of total emissions in the sector 1 Energy. The increasing trend since 1990 (+22.3%) is a result of the increase in consumption of natural gas and the subsequent increase of fugitive emissions of methane (increase by 214.7%). The $CH_4$ emissions of source category 1A4 have increased by 8.4% since 1990. The $CH_4$ emissions from road transportation show a reduction of 86.2%, mainly due to the growing number of gasoline passenger cars with catalytic converters.
- $N_2O$ emissions accounted for 0.6% of the total sector 1 Energy emissions in 1990 and for 0.6% in 2023.

The Liechtenstein greenhouse gas inventory identifies 7 key categories within the energy sector (key category analysis excluding LULUCF categories, see Chapter 1.4). The emissions in 1990 and 2023 of these categories are depicted in Figure 3-2. In 2023, $CO_2$ emissions from 1A3b Road Transportation are most dominant.

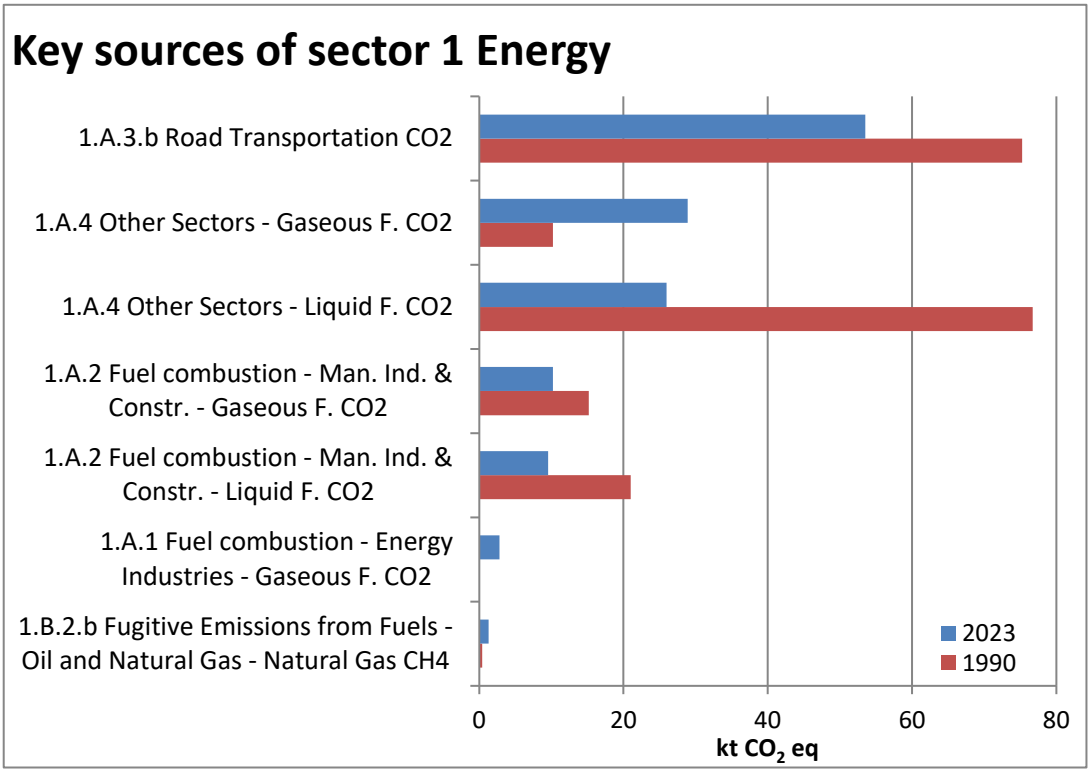



Figure 3-2 Key sources in the energy sector (KCA excl. LULUCF). Emissions in $CO_2$ equivalents (kt) per key source category in 2023 and in the base year 1990.

## 3.2 Fuel combustion (1A)

### 3.2.1 Comparison of the sectoral approach with 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 Paris Agreement 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 $CO_2$, are taken from the Swiss greenhouse gas inventory. The oxidation factor is set to 1.0 because the combustion installations in Liechtenstein have very good combustion properties. Combined emissions of CO and unburnt VOC range between 0.1 and 0.3% of $CO_2$ emissions for oil and gas combustion. The assumption of complete oxidation is also in line with the 2006 IPCC Guidelines that recommend 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 the reference approach in submission 2024 have been taken from Table 3-5 (see CRT Table1.A(b)) and are therefore identical to the ones used for the sectoral approach.

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

Table 3-3 and Figure 3-3 show the differences between reference and sectoral (national) approaches 1990–2023. Energy consumption differs by 1.86% in 2023, whereas $CO_2$ emissions show a difference of 2.0% in 2023.

The difference of the $CO_2$ emissions between the reference and the sectoral approach can be explained by different measurement methods of the two approaches. There are small differences in $CO_2$ emissions, since the reference approach does not account for biomass content of natural gas, gasoline and diesel. Consequently, the $CO_2$ emissions resulting from the reference approach are higher as in the sectoral approach, which accounts for the share of biomass in these fuels.

In Liechtenstein the share of biomass in gasoline and diesel is increasing since around 1995. Therefore, the differences between the two approaches are increasing, too.

The energy consumption is identical between the two approaches, since the sectoral approach is also based on total energy consumption according to the national energy statistics (OS 2024a), which is split into the different sectors.

In addition, small differences in $CO_2$ emissions are due to the fact that a small fraction of the gas consumed is not burnt but lost in the distribution network. The reference approach does not account for these losses and assumes complete burning of the natural gas, therefore leading to higher total emissions. Consequently, the emissions according to the reference approach, are higher as compared to the sectoral approach results.

Table 3-3 Differences in energy consumption and $CO_2$ emissions between the reference and the sectoral (national) approach. The difference is calculated according to [(RA-SA)/SA] 100% with RA = reference approach, SA = sectoral (national) approach. For calculating the difference in energy consumption between the two approaches, data 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** | **1995** | **2000** | **2005** | **2010** |
| | percent (%) | | | | |
| Energy consumption | 0.03 | 0.04 | 0.07 | 0.11 | 0.17 |
| $CO_2$ emissions | 0.01 | 0.03 | 0.05 | 0.09 | 0.15 |
| | | | | | |
| | **2014** | **2015** | **2016** | **2017** | **2018** |
| | percent (%) | | | | |
| Energy consumption | 0.34 | 0.56 | 0.92 | 1.34 | 1.84 |
| $CO_2$ emissions | 0.33 | 0.58 | 0.98 | 1.44 | 2.00 |
| | | | | | |
| | **2019** | **2020** | **2021** | **2022** | **2023** |
| | percent (%) | | | | |
| Energy consumption | 1.79 | 1.77 | 1.65 | 1.79 | 1.86 |
| $CO_2$ emissions | 1.93 | 1.92 | 1.80 | 1.94 | 2.00 |

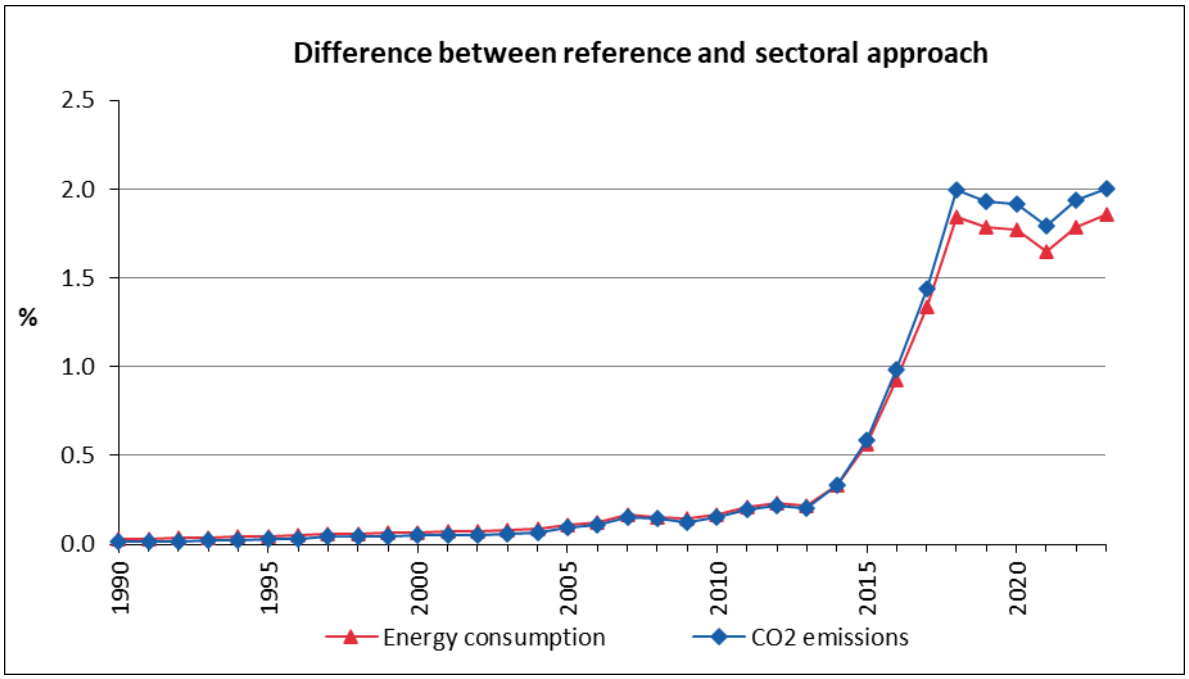



Figure 3-3 Time series for the differences between reference and sectoral approach. Numbers are taken from the table above.

**Recalculation in the Reference Approach**

- The activity data for biodiesel and bioethanol 1997-2022 were updated, since updated shares of biofuels are available from the Swiss customs statistics, which is applied in Switzerland's road transportation model (INFRAS 2024).

Further recalculations in the energy sector are documented in the respective sectoral chapters (1A1, 1A2, 1A3 and 1A4).

### 3.2.2 International bunker fuels (1D)

For Liechtenstein, the only source of international bunker emissions is civil aviation originating from one helicopter base "Heliport Balzers" Total emissions of civil aviation are calculated as described in section 3.2.7.2 using a Tier 1 method. For the year 2023, the effective consumption for domestic and international flights was provided by the operating company of the helicopter base (see Table 3-4).

Total kerosene consumption is based on collected data for the year 1995 and for the years since 2001 (Rotex Helicopter AG 2006, 2007, …, 2024). For the years 1990–1994, the collected data for total kerosene consumption in 1995 is used as a constant value since no other data is available. For the years 1996–2000, total kerosene consumption is linearly interpolated between the data collected for 1995 and for 2001. Surveys were conducted for the years 1995, 2001 and 2002 in order to estimate domestic fuel consumption in Liechtenstein (Rotex Helicopter AG 2006). For the years 1990–1994, the survey results for domestic kerosene consumption in 1995 are used as a constant value since no other data is available. For the years 1996–2000 and 2003–2011, total kerosene consumption is linearly interpolated between the survey results for 1995 and 2001 and for the survey result 2002 and collected data 2012, respectively. Since 2012, data on domestic kerosene consumption is collected (Rotex Helicopter AG 2012-2024).

Kerosene consumption for international flights (international bunkers aviation) is calculated by subtracting domestic consumption from total consumption for the entire time series.

In 2023, there are only three helicopters stationed in Liechtenstein. Activity data is highly dependent on the annual demand for these helicopters. Thus, emissions change significantly in years with high or low demand for flying (passengers and freight transportation). In 2023 kerosene consumption increases slightly compared to 2022 due to higher flight activities.

Marine bunker emissions are not occurring.

Table 3-4 Kerosene (civil aviation) based on sales principle: Total kerosene consumption, domestic flights (reported under 1A3a) and International flights (bunker, memo item). International flights are calculated by subtracting kerosene consumed in domestic aviation from total kerosene consumption. Data source for surveys (highlighted in blue) and collected data (highlighted in green): Rotex Helicopter AG (Rotex Helicopter AG 2006-2024).

| Year | **Civil aviation - Kerosene (TJ)** | | | |
|---|---|---|---|---|
| | Total | 1A3a Domestic aviation | Information on data for total and domestic aviation | International bunkers aviation |
| 1990 | 6.87 | 1.03 | *Constant values (equal to survey from 1995)* | 5.84 |
| 1991 | 6.87 | 1.03 | | 5.84 |
| 1992 | 6.87 | 1.03 | | 5.84 |
| 1993 | 6.87 | 1.03 | | 5.84 |
| 1994 | 6.87 | 1.03 | | 5.84 |
| 1995 | 6.87 | 1.03 | *Total consumption: collected data; Domestic aviation: Survey* | 5.84 |
| 1996 | 7.04 | 1.04 | *Linear interpolation (between survey from 1995 and from 2001)* | 6.00 |
| 1997 | 7.21 | 1.05 | | 6.16 |
| 1998 | 7.39 | 1.06 | | 6.33 |
| 1999 | 7.56 | 1.07 | | 6.49 |
| 2000 | 7.74 | 1.08 | | 6.66 |
| 2001 | 7.91 | 1.09 | *Total consumption: collected data; Domestic aviation: Survey* | 6.82 |
| 2002 | 7.26 | 1.14 | | 6.12 |
| 2003 | 7.93 | 1.11 | *Total consumption: collected data; Domestic aviation: linear interpolation (between survey from 2002 and collected data from 2012)* | 6.82 |
| 2004 | 5.68 | 1.08 | | 4.60 |
| 2005 | 7.67 | 1.04 | | 6.62 |
| 2006 | 12.32 | 1.01 | | 11.31 |
| 2007 | 12.18 | 0.98 | | 11.20 |
| 2008 | 11.93 | 0.95 | | 10.98 |
| 2009 | 14.21 | 0.92 | | 13.29 |
| 2010 | 12.46 | 0.89 | | 11.57 |
| 2011 | 13.34 | 0.86 | | 12.48 |
| 2012 | 16.10 | 0.83 | *Collected data* | 15.28 |
| 2013 | 15.18 | 0.74 | | 14.44 |
| 2014 | 17.05 | 0.85 | | 16.20 |
| 2015 | 17.16 | 0.81 | | 16.36 |
| 2016 | 13.14 | 0.56 | | 12.59 |
| 2017 | 12.09 | 0.35 | | 11.75 |
| 2018 | 15.38 | 0.40 | | 14.98 |
| 2019 | 16.48 | 1.14 | | 15.34 |
| 2020 | 13.65 | 0.81 | | 12.83 |
| 2021 | 14.02 | 0.84 | | 13.18 |
| 2022 | 14.85 | 0.85 | | 13.99 |
| 2023 | 18.08 | 1.05 | | 17.03 |

### 3.2.3 Feedstocks and non-energy use of fuels

Energy data are taken from Liechtenstein's energy statistics (OS 2024a). 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, the amount is calculated based on Swiss import, export and production data (FOEN 2024b). The total amount of apparent consumption in Liechtenstein and Switzerland is split proportional to the length of paved roads in Liechtenstein (630 km in 2017, OS 2017e) and Switzerland (71'520 km in 2015, SFSO 2017e) respectively. A constant split is applied, since the road length does not show a strong variation from year to year.

The amount of lubricants used in Liechtenstein is estimated based on the Swiss import and export and production data (FOEN 2024b). The total amount of apparent consumption in Liechtenstein and Switzerland is split proportional to the number of inhabitants in Liechtenstein and Switzerland respectively (see Table 4-4).

### 3.2.4 Country-specific issues

#### 3.2.4.1 $CO_2$ emission factors and net calorific values (NCV)

The $CO_2$ emission factors and the net calorific values (NCV) used for the calculation of the 2023 emissions 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, diesel and kerosene are shown in Table 3-6.

Table 3-5 $CO_2$ emission factors and net calorific values (NCV) for fuels in 2023. Except for gasoline, diesel and kerosene emission factors are assumed constant for the entire time series. The time series of gasoline, diesel and kerosene are shown in Table 3-6.

| Fuel | CO2 Emission Factor 2023 | | Net calorific values (NCV) |
|---|---|---|---|
| | t $CO_2$ / TJ | t $CO_2$ / t | TJ / t |
| Hard coal | 92.7 | 2.60 | 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 | 69.3 | 2.95 | 0.0425 |
| Biofuel (vegetable oil) | 73.3 | 2.76 | 0.0376 |
| Biodiesel | 73.3 | 2.79 | 0.0380 |
| Bioethanol | 73.8 | 1.96 | 0.0265 |
| Sewage gas | 100.5 | 1.93 | 0.0192 |

Table 3-6 $CO_2$ emission factors of gasoline, diesel and kerosene 1990–2023. For bioethanol, the same emission factors are applied as for gasoline and for biodiesel the same emission factors are applied as for diesel.

| Fuel | unit | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Gasoline | t $CO_2$/TJ | 73.9 | 73.9 | 73.9 | 73.9 | 73.8 |
| Diesel | t $CO_2$/TJ | 73.6 | 73.6 | 73.6 | 73.5 | 73.4 |
| Kerosene | t $CO_2$/TJ | 73.2 | 73.2 | 73.1 | 73.0 | 72.9 |
| | | | | | | |
| **Fuel** | **unit** | **2014** | **2015** | **2016** | **2017** | **2018** |
| Gasoline | t $CO_2$/TJ | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 |
| Diesel | t $CO_2$/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| Kerosene | t $CO_2$/TJ | 72.8 | 72.8 | 72.8 | 72.8 | 72.8 |
| | | | | | | |
| **Fuel** | **unit** | **2019** | **2020** | **2021** | **2022** | **2023** |
| Gasoline | t $CO_2$/TJ | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 |
| Diesel | t $CO_2$/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| Kerosene | t $CO_2$/TJ | 72.8 | 72.8 | 72.8 | 72.8 | 72.8 |

### Data sources of NCV

The NCV of Jet kerosene and Alkylate gasoline are taken from the Swiss overall energy statistics of the year 2000 (SFOE 2001). The NCV of hard coal, gas oil, gasoline, diesel oil and LPG are taken from the energy statistic of Liechtenstein (OS 2024g. For bioethanol and biodiesel, the NCV are taken from the Handbook of Emission Factors for Road Transport HBEFA 4.1 (INFRAS 2022a).

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

### Data sources of $CO_2$ emission factors

The $CO_2$ emission factors of fossil fuels are taken from the Swiss overall energy statistics of the year 2000 (SFOE 2001) with the following exceptions:

- Emission factors of diesel oil and kerosene are taken from the measurement campaign mentioned above (EMPA 1999, Intertek 2008, Intertek 2012),
- Emission factors of gasoline, diesel, bioethanol and biodiesel are taken from INFRAS (2022a).
- The emission factor of LPG is based on FOEN 2024
- The emission factor of natural gas is taken from the IPCC 2006 Guidelines (IPCC 2006).
- The emission factor of sewage gas assumes that 35% of the volume of the sewage gas is $CO_2$ and 65% $CH_4$.

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

### 3.2.4.2 Energy statistics (activity data)

**National energy statistics and modifications**

In general, the data is taken from Liechtenstein's energy statistics (OS 2024a, OS 2024b). Some additional data sources are used as it is explained in the following sections. The results are summarised in Table 3-7.

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

***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 3-7 Time series of Liechtenstein's fuel consumption based on the sales principle, including bunker fuel consumption (kerosene only) and biomass. Data sources: OS (2024a, OS 2024b), OEP (2006c), OEP (2008) and Rotex Helicopter AG (2006–2024).

| **Fuel** | **1990** | **1995** | **2000** | **2005** | **2010** |
|---|---|---|---|---|---|
| | TJ | | | | |
| Gasoline | 819 | 903 | 977 | 774 | 594 |
| Diesel | 250 | 230 | 298 | 369 | 475 |
| Gas Oil | 1’264 | 1’058 | 925 | 980 | 693 |
| Natural Gas | 455 | 742 | 960 | 1’284 | 1’079 |
| LPG | 13.3 | 8.1 | 5.5 | 3.7 | 5.3 |
| Hard Coal | 1.04 | 0.73 | 0.67 | 0.25 | 0.06 |
| Kerosene (domestic) | 1.030 | 1.030 | 1.080 | 1.045 | 0.888 |
| **Sum** | **2’804** | **2’944** | **3’168** | **3’411** | **2’848** |
| 1990=100% | 100% | 105% | 113% | 122% | 102% |
| | | | | | |
| *Kerosene (bunker)* | 5.84 | 5.84 | 6.66 | 6.62 | 11.57 |
| | | | | | |
| ***Biomass*** | | | | | |
| *Wood* | 42.9 | 36.2 | 87.9 | 90.1 | 182.9 |
| *Sewage gas* | 15.6 | 17.0 | 21.7 | 20.8 | 22.2 |
| *Biofuel* | 0.0 | 0.0 | 0.3 | 1.2 | 2.0 |
| ***Sum biomass*** | **58.5** | **53.2** | **109.9** | **112.1** | **207.2** |

| **Fuel** | **2014** | **2015** | **2016** | **2017** | **2018** |
|---|---|---|---|---|---|
| | TJ | | | | |
| Gasoline | 510 | 410 | 384 | 376 | 369 |
| Diesel | 556 | 498 | 518 | 546 | 531 |
| Gas Oil | 470 | 569 | 452 | 487 | 395 |
| Natural Gas | 856 | 914 | 908 | 953 | 884 |
| LPG | 3.6 | 3.7 | 3.6 | 3.5 | 3.8 |
| Hard Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Kerosene (domestic) | 0.85 | 0.81 | 0.56 | 0.35 | 0.40 |
| **Sum** | **2’397** | **2’395** | **2’266** | **2’366** | **2’183** |
| 1990=100% | 85% | 85% | 81% | 84% | 78% |
| | | | | | |
| *Kerosene (bunker)* | 16.20 | 16.36 | 12.59 | 11.75 | 14.98 |
| | | | | | |
| ***Biomass*** | | | | | |
| *Wood* | 187.0 | 209.4 | 202.5 | 189.1 | 225.4 |
| *Sewage gas* | 1.0 | 0.5 | 1.8 | 2.5 | 1.8 |
| *Biofuel* | 4.7 | 9.2 | 15.7 | 25.1 | 32.5 |
| ***Sum biomass*** | **192.7** | **219.0** | **219.9** | **216.6** | **259.7** |

| **Fuel** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023** |
|---|---|---|---|---|---|---|
| | TJ | | | | | % |
| Gasoline | 363 | 326 | 341 | 303 | 419 | -49% |
| Diesel | 514 | 493 | 523 | 485 | 413 | 65% |
| Gas Oil | 491 | 477 | 408 | 365 | 402 | -68% |
| Natural Gas | 896 | 863 | 963 | 809 | 749 | 65% |
| LPG | 3.6 | 3.7 | 3.4 | 3.0 | 9.0 | -32% |
| Hard Coal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -100% |
| Kerosene (domestic) | 1.14 | 0.81 | 0.84 | 0.85 | 1.05 | 2% |
| **Sum** | **2’268** | **2’163** | **2’240** | **1’966** | **1’994** | **-29%** |
| 1990=100% | 81% | 77% | 80% | 70% | 71% | |
| | | | | | | |
| *Kerosene (bunker)* | 15.34 | 12.83 | 13.18 | 13.99 | 17.03 | 192% |
| | | | | | | |
| ***Biomass*** | | | | | | |
| *Wood* | 206.9 | 163.9 | 158.9 | 193.0 | 184.1 | 329% |
| *Sewage gas* | 1.4 | 0.5 | 0.9 | 1.8 | 0.5 | -97% |
| *Biofuel* | 32.6 | 30.7 | 28.9 | 27.2 | 28.2 | - |
| ***Sum biomass*** | **241.0** | **195.1** | **188.7** | **222.1** | **212.9** | **264%** |

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 2011 | 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 |
| 2016 | 10’535 | 0 | 10’535 | 0.840 | 12’542 | 0.845 | 10’598 | 455 |
| 2017 | 11’358 | 0 | 11’358 | 0.840 | 13’521 | 0.845 | 11’426 | 490 |
| 2018 | 9’197 | 0 | 9’197 | 0.840 | 10’949 | 0.845 | 9’252 | 397 |
| 2019 | 11’449 | 0 | 11’449 | 0.840 | 13’630 | 0.845 | 11’517 | 494 |
| 2020 | 11’108 | 0 | 11’108 | 0.840 | 13’224 | 0.845 | 11’174 | 479 |
| 2021 | 9’511 | 0 | 9’511 | 0.840 | 11’323 | 0.845 | 9’568 | 410 |
| 2022 | 8’514 | 0 | 8’514 | 0.840 | 10’136 | 0.845 | 8’565 | 367 |
| 2023 | 9’376 | 0 | 9’376 | 0.840 | 11’162 | 0.845 | 9’432 | 405 |

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

Gas oil supply is measured in volume units (litres, m$^3$) and later reported to the Office of Environment in mass units (t). This conversion is made with a (rounded) density of 0.840 t/m$^3$, whereas the more precise density is 0.845 t/m$^3$ (FOEN 2011). Therefore, the Consumption 1 is corrected accordingly, resulting in Consumption 2, as is shown in Table 3-8. Using country-specific net calorific values provided by the Energy statistics of Liechtenstein (OS 2024g), 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 2024a) 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 origin 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 2000–2016. 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 1990–2023 are consistent.

The data from the energy statistics is used for **gasoline** consumption in 1990. For the years 1991–1999, a moving average over three years is applied (e.g. 1991: arithmetic mean of 1990, 1991 and 1992). Since 2000, the values of the second survey are used (OE 2024e). 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 2024e).
- 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. Since 2002, 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 2001-2023 (see Rotex Helicopter AG 2006-2024) 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 $CO_2$ emissions from the combustion of biomass and the consumption of biofuels is included in the relevant chapters 3.2.5.2 (1A1 Energy industries), 3.2.6.2 (1A2 Manufacturing industries and construction), 3.2.7.2 (1A3 Transport), 3.2.8.2 (1A4 Other sectors) and 7 (Waste sector).

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

## Energy statistics and contribution to the IPCC source categories

### *Gas oil*

There is currently no data on the specific contribution of source categories 1A2, 1A4a and 1A4b to total gas oil consumption in 1A Fuel combustion available. Therefore, the following shares are estimated based on expert judgement for all years from 1990 to 2023: The Energy Statistics of Liechtenstein (e.g. OS 2024a) 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 2023. 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 2023.

Table 3-9 Estimated share of source categories in total consumption of gas oil in 1A Fuel combustion (assumed constant for the entire time series).

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

### *Natural gas*

The data on total consumption of natural gas in Liechtenstein is provided by the gas and heat utility (LW 2024) and published in the national energy statistics (OS 2024a).

For the partition of natural gas consumption between the different combustion activities in 1A, only limited data is available. Even though the gas and heat 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. Since 2011, data are provided by an annual census of diesel and gasoline sales in Liechtenstein.

The amount of alkylate sold (activity data) was surveyed in a census in 2011 encompassing all selling stations and consumers (OEP 2011c). Since 2012 data on alkylate gasoline are provided by an annual census about diesel and gasoline sales in Liechtenstein. Before 2011, no data on alkylate gasoline consumption are available. Therefore, the data of the year 2011 is extrapolated to 1995 in order to create a complete 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, since purchasing only started in second half of 1995. Before 1995 no alkylate gasoline was used in Liechtenstein.

### *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 1990–2023 (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 2024). 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.

***Biomass (wood)***

The energy statistics (OS 2024a) of Liechtenstein provides data on the total wood consumption as a fuel in combustion plants. Wood fuel is used in the following source categories:

- 1A1a: Public electricity and heat production
- 1A4a: Other sectors - commercial/institutional
- 1A4b: Other sectors - residential

The allocation of wood fuel consumption to the different source categories is described in the following sections.

*1A1a Public electricity and heat production*

Activity data for wood fuels used in the wood gasification process in a combined heat and power (CHP) plant in sector 1A1a is derived from the energy statistics on power generation (OS 2024b). The statistic includes data on the energy output of the CHP plant using wood as a fuel. To estimate the primary energy input from wood fuel, the reported energy output (OS 2024b) is multiplied by a conversion factor of 2.916667 (based on expert judgement).

*1A4a Other sectors - commercial/institutional and 1A4b Other sectors – residential*

The wood fuel consumption (wf) in 1A4a and 1A4b is calculated according to the following formulas:

$$wf\ 1A4a = 0.6 * total\ wf - wf\ 1A1a$$

$$wf\ 1A4b = 0.4 * total\ wf$$

Total wood fuel consumption (total wf) is taken from the energy statistics (OS 2024a).

The shares of wood fuel consumption in 1A4a and 1A4b are based on expert judgement.

**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.

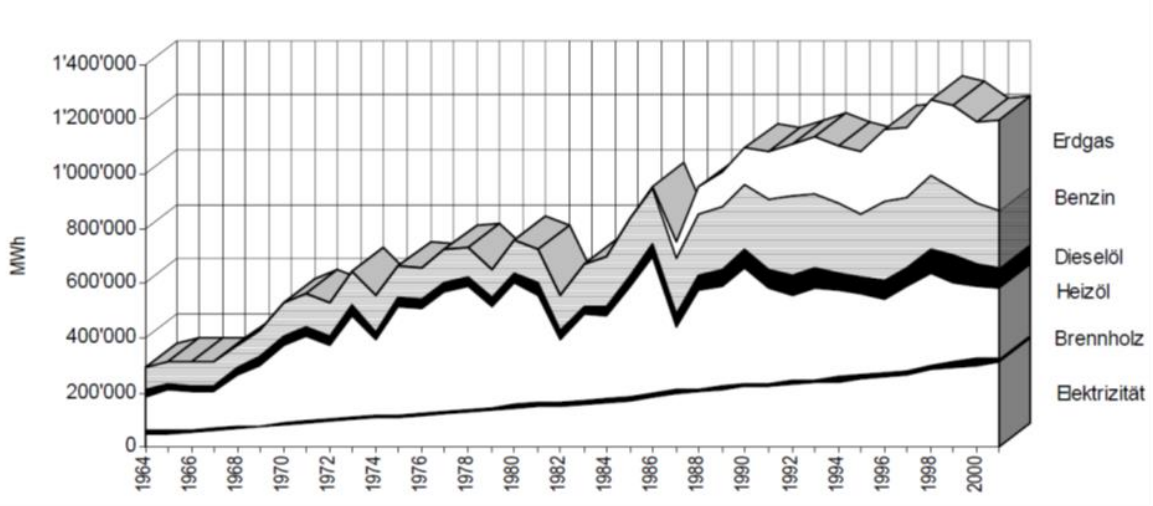



Figure 3-4 Liechtenstein's energy consumption and fuel shares 1964–2001 (OS 2001) in MWh. From top to bottom, the following fuels are shown: natural gas (Erdgas), gasoline (Benzin), diesel (Dieselöl), gas oil (Heizöl), wood (Brennholz), electricity (Elektrizität).

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 2001). 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. Notes: [1)] in operation since 1995, [2)] in operation since 2000.

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

## 3.2.5 Energy industries (1A1)

### 3.2.5.1 Category description: Energy industries (1A1)

**Key category information 1A1**

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

According to IPCC guidelines, source category 1A1 Energy industries comprise 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, biogas or wood 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 2023, 31% of Liechtenstein's electricity consumption was produced domestically and 69% was imported (see Table 3-15). In absolute values, the electricity consumption 2023 amounts to around 401 GWh. This corresponds to a decrease of 1.9% compared to 2022. Domestic electricity generation increased by 24.9% mainly due to increases in hydro and solar power generation. The electricity imports decreased by 10.6% compared to 2022.

Table 3-15 Electricity consumption, generation and imports in Liechtenstein (OS 2024b).

| Electricity consumption, generation and imports in Liechtenstein 2023 | MWh | Share |
|---|---|---|
| Total electricity consumption in Liechtenstein | 401'452 | 100% |
| Electricity generation in Liechtenstein 2023 | 125'494 | 31% |
| Hydro power | 77'170 | 19% |
| Natural gas co-generation | 1'775 | 0.4% |
| Biogas co-generation | 24 | 0.0% |
| Biomass co-generation | 575 | 0.1% |
| Photovoltaic | 45'950 | 11.4% |
| Electricity imports in Liechtenstein 2023 | 275'958 | 69% |

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 natural gas and biogas or wood biomass fuelled combined heat and power generation plants.

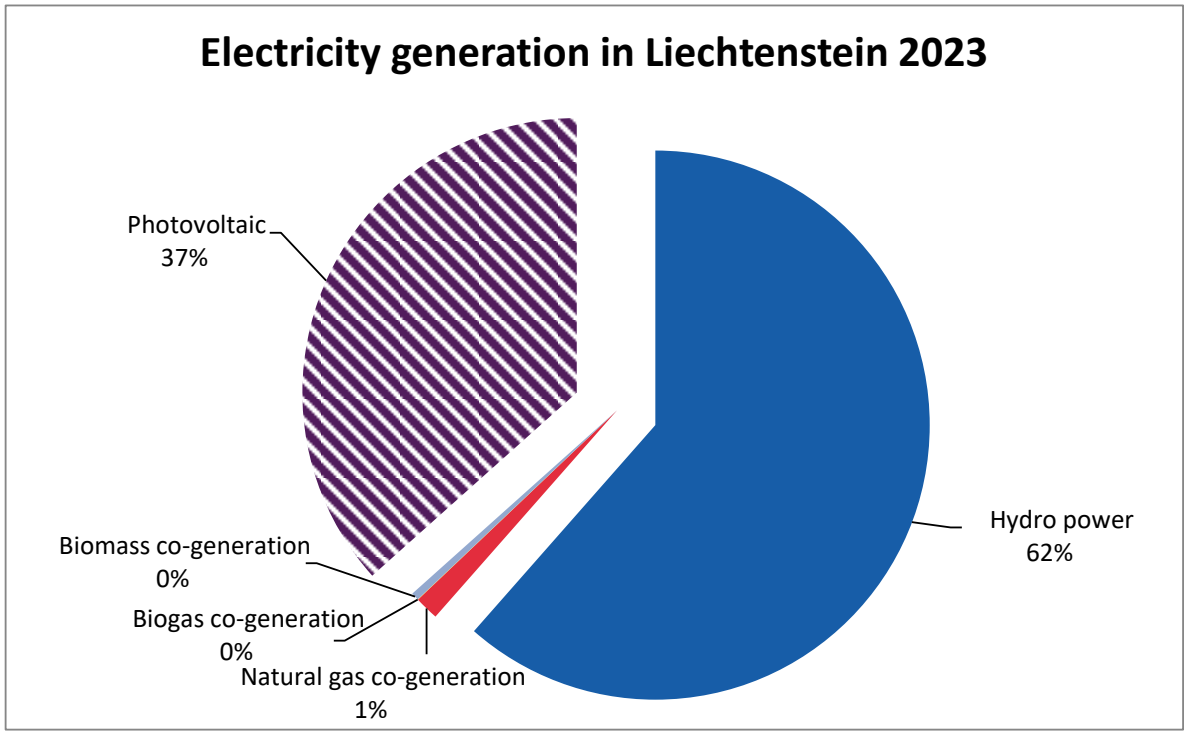



Figure 3-5 Structure of electricity generation in Liechtenstein 2023. Data source: Energy Statistics 2023 (OS 2024b).

Renewable sources account for 98.6% of domestic electricity generation in Liechtenstein. Compared to 2022, the electricity produced by photovoltaic plants has increased by 26.4%. Photovoltaic is thus representing 37% of the total domestic electricity production in 2023.

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.

Electricity generation is based on natural gas and biogas co-generation. Since 2021, wood biomass is also used in a combined heat and power plant reported in public electricity and heat production. Therefore, source category 1A1 includes emissions from gaseous fuels, biogas from wastewater treatment plants and wood biomass.

### 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 for calculation of emissions of $CO_2$ and $CH_4$. For emissions of $N_2O$ from natural gas a Tier 1 method is applied. Aggregated fuel consumption data from the Energy Statistics of Liechtenstein (OS 2024a) is used to calculate emissions. As mentioned above, natural gas and biomass (sewage gas and wood biomass) are occurring within this source category 1A1a. The wastewater treatment plant

(WWTP) 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 reported under 2D1 (see chp. 4.5).

The sources are characterised by similar industrial combustion processes and the same emission factors for all processes using natural gas and biogas of this source category are applied.

In a combined heat and power (CHP) plant, wood biomass is used as a fuel through the wood gasification process. Wood gasification in a CHP plant is a two-stage process that converts wood into a combustible gas mixture, which is then used to generate energy.

**Emission factors**

***Natural gas***

The $CO_2$ emission factor of natural gas corresponds to the IPCC default value (IPCC 2006). The $CH_4$ emission factor of natural gas is country-specific and representative for engines used in Switzerland and Liechtenstein (lean fuel-air-ratio). Hence, emission factors have been taken from Switzerland (SAEFL 2005e), see Table 3-16. The $N_2O$ emission factor corresponds to the default value from IPCC (2006).

BiomassCountry-specific emission factors for biogas from wastewater treatment plants are taken from SAEFL (2005e). The emission factor of biogenic $CO_2$ has been adapted to take into account $CO_2$ being present in the biogas as a product of fermentation already prior to combustion.

No specific emission factors are available for the combustion of wood fuel through the wood gasification process in a combined heat and power (CHP) plant. Therefore, the emission factors are based on those used for wood combustion in 1A4a commercial/institutional. The $CO_2$ and $N_2O$ emission factors for wood combustion in 1A4a are taken from IPCC 2006 Guidelines (Vol. 2, Chp. 2, Table 2.4). The $CH_4$ emission factor for wood combustion in 1A4a is derived from FOEN 2022a. The emission factors for $CH_4$ and $N_2O$ for the combustion of wood fuel through the wood gasification process in a CHP plant in category 1A1a are the same as for wood combustion in category 1A4a. For $CO_2$, an emission factor of 50.4 t/TJ is used, corresponding to 45% of a complete combustion of wood fuel (as in category 1A4a). This emission factor is based on expert judgement.

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 2023 (public co-generation).

| Source/fuel | $CO_2$ [t/TJ] | $CO_2$ biogenic [t/TJ] | $CH_4$ [kg/TJ] | $N_2O$ [kg/TJ] |
|---|---|---|---|---|
| **1A1a Public electricity and heat production** | | | | |
| Natural gas | 56.1 | NO | 25.0 | 0.1 |
| Biomass (Biogas from WWTP) | NO | 56.1 | 25.0 | 0.1 |
| Biomass (Sewage gas) | NO | 100.5 | 6.0 | 11.0 |
| Biomass (Wood) | NO | 50.4 | 10.0 | 4.0 |

### Activity data

Activity data on natural gas consumption (in TJ) for Public electricity and heat production (1A1a) is extracted from the energy statistics (OS 2024a). Activity data on sewage gas consumption from wastewater treatment plants is provided by plant operators (for data see section 7.5.2). Activity data for wood used as a fuel through the wood gasification process in a CHP plant is derived from the energy statistics (OS 2024b) (for more information see section 3.2.4.2).

In 2023, 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 and wood). Natural gas consumption increased by a factor of about 23 from 1990 to 2023. The rapid increase in the years 1990 – 1992 is due to the significant expansion of the natural gas network and increasing number of 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, as sewage gas is processed to biogas since November 2013. The biogas produced is fed to the general gas network. Since 2021, wood is used as a fuel through the wood gasification process in a combined heat and power plant and is also reported as biomass in 1A1a. Therefore, biomass consumption increased from 2020 to 2021.

While in 1990, biomass contributed with 88% to electricity production and heat fuel consumption, it only represents about 14% in 2023.

Table 3-17 Activity data for natural gas and biomass consumption in 1A1a Public electricity and heat production.

| **Source/fuel** | **1990** | **1995** | **2000** | **2005** | **2010** | |
|---|---|---|---|---|---|---|
| **1A1a Public electricity and heat production** | TJ | | | | | |
| Natural gas | 2.16 | 35.64 | 47.52 | 54.00 | 56.16 | |
| Biomass | 15.57 | 16.98 | 21.70 | 20.82 | 22.24 | |
| | | | | | | |
| **Source/fuel** | **2014** | **2015** | **2016** | **2017** | **2018** | |
| **1A1a Public electricity and heat production** | TJ | | | | | |
| Natural gas | 44.24 | 36.02 | 38.16 | 37.26 | 38.32 | |
| Biomass | 2.13 | 1.39 | 2.63 | 3.38 | 2.85 | |
| | | | | | | |
| **Source/fuel** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023** |
| **1A1a Public electricity and heat production** | TJ | | | | | % |
| Natural gas | 60.17 | 42.90 | 45.30 | 40.52 | 50.12 | 2220% |
| Biomass | 3.06 | 1.76 | 7.09 | 9.53 | 7.94 | -49% |

#### 3.2.5.3 Uncertainty assessment 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

The following recalculations lead to changes in $CO_2$, $CH_4$ and $N_2O$ emissions resulting in an increase of 0.02 kt $CO_2$eq in 2022:

- 1A1a: Since 2021, wood biomass is used as a fuel through the wood gasification process in a combined heat and power plant. Until submission 2024, total consumption of wood biomass and the resulting emissions were reported in categories 1A4a and 1A4b. In the current submission, the allocation of wood biomass consumption to 1A1a and to 1A4a/1A4b was implemented (for more information see section 3.2.4.2), leading to a recalculation of activity data and emissions of $CO_2$, $CH_4$ and $N_2O$ in 1A1a for the years 2021 and 2022.

#### 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 Manufacturing industries and construction (1A2)

#### 3.2.6.1 Category description: Manufacturing industries and construction (1A2)

**Key category information 1A2**

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

$CO_2$ from the combustion 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.

Since 2021, no companies in Liechtenstein are participating in the European Emission Trading Scheme (EU-ETS).

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 2024a) is used to calculate emissions under 1A2e. The emission sources are characterised by rather similar industrial combustion processes and thus homogeneous emission factors can be assumed. Therefore, a top-down approach is appropriate and identical emission factors for each fuel type are applied for these source categories. 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

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

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

$CO_2$ and $CH_4$ emissions from combustion of natural gas are also calculated using the IPCC default emission factors (IPCC 2006**).** 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.

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

The $CO_2$ emission factor of diesel taken from Switzerland. For three years, measurements are available (EMPA 1999, Intertek 2008, Intertek 2012), for the other years the emission factor is interpolated or kept constant, see Table 3-6.

The $N_2O$ and $CH_4$ emission correspond to the implied emission factors of Switzerland's Handbook of Emission Factors of non-road vehicles (INFRAS 2015) for the whole time series.

Emission factors of biodiesel are assumed to be equal to the emission factors of fossil diesel in 1A2g.

Table 3-19 Emission factors for sources in 1A2 in 2023

| Source/fuel | $CO_2$ [t/TJ] | $CO_2$ biogenic [t/TJ] | $CH_4$ [kg/TJ] | $N_2O$ [kg/TJ] |
|---|---|---|---|---|
| **1A2e Food processing, beverages and tobacco** | | | | |
| Gas oil | 73.7 | - | 1.0 | 0.6 |
| Natural gas | 56.1 | - | 1.0 | 0.1 |
| Biomass (Biogas from WWTP) | | 56.1 | 1.0 | 0.1 |
| **1A2g Other off-road vehicles and machinery** | | | | |
| Diesel | 73.3 | - | 0.4 | 3.3 |
| Biodiesel | | 73.3 | 0.4 | 3.3 |

## Activity data

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

Activity data on gas oil consumption are based on aggregated fuel consumption data from the energy statistics of Liechtenstein (OS 2024a). It is further assumed that 20% of Liechtenstein's gas oil consumption can be attributed to the food processing, beverages and tobacco industry.

Activity data on consumption of natural gas is provided by Liechtenstein's gas and heat utility (LW 2024). Data are taken from OS (2024a).

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.

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

Activity data includes the consumption of diesel oil from non-road machineries in construction and industry. Diesel is blended with a small share of biodiesel. The share of biodiesel is assumed to be identical to the share of biodiesel in Switzerland. For Switzerland, the share of biodiesel is determined based on data from the Swiss customs statistic, which is applied in Switzerland's road transportation model (INFRAS 2024).

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 1A2g for the entire time series 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.

| Source/fuel | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| **1A2e Food processing, beverages and tobacco** | | | TJ | | |
| Gas oil | 252.8 | 211.7 | 185.0 | 196.0 | 138.6 |
| Natural gas | 270.9 | 317.4 | 351.5 | 375.5 | 218.8 |
| Biomass (Biogas from WWTP) | NO | NO | NO | NO | NO |
| **1A2g Other off-road vehicles and machinery** | | | | | |
| Diesel | 32.1 | 29.7 | 40.2 | 47.9 | 47.6 |
| Biodiesel | NO | NO | 0.05 | 0.16 | 0.20 |

| Source/fuel | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| **1A2e Food processing, beverages and tobacco** | | | TJ | | |
| Gas oil | 94.0 | 113.8 | 90.4 | 97.5 | 78.9 |
| Natural gas | 276.5 | 258.6 | 260.2 | 277.9 | 256.5 |
| Biomass (Biogas from WWTP) | 6.8 | 6.3 | 5.8 | 6.6 | 6.9 |
| **1A2g Other off-road vehicles and machinery** | | | | | |
| Diesel | 65.3 | 62.6 | 62.5 | 65.3 | 58.2 |
| Biodiesel | 0.44 | 0.90 | 1.66 | 2.85 | 3.51 |

| Source/fuel | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|
| **1A2e Food processing, beverages and tobacco** | | | TJ | | | % |
| Gas oil | 98.2 | 95.3 | 81.6 | 73.1 | 80.4 | -68% |
| Natural gas | 227.2 | 206.9 | 230.6 | 205.3 | 182.0 | -33% |
| Biomass (Biogas from WWTP) | 6.3 | 6.0 | 6.0 | 5.2 | 4.9 | - |
| **1A2g Other off-road vehicles and machinery** | | | | | | |
| Diesel | 54.7 | 55.9 | 56.6 | 58.6 | 49.3 | 54% |
| Biodiesel | 3.36 | 3.33 | 2.72 | 2.78 | 2.50 | - |

Table 3-20 documents the decrease of gas oil consumption by 68% from 1990 to 2023. This decrease is correlated with the extension of the natural gas network 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. A similar development is observed between 2017 and 2019.

Between 1990 and 2023 the consumption of gaseous fuels decreased by 33% including a sharp decrease 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. Between 2017 and 2023 the district heating network was further expanded. Fluctuations in the natural gas consumption are a result of the changing heating needs in cold or warm winters.

This shift in fuel mix is the reason for $CO_2$ emissions from liquid fuels and gaseous fuels in category 1A2 being key categories with regards to the trend 1990-2023. Between 2013 and 2014, there is a strong increase in biomass consumption, as 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. In addition,

the biodiesel which is blended with regular diesel contributes to an increase in biomass consumption in source category 1A2g.

#### 3.2.6.3 Uncertainty assessment 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

In 2022, the following recalculations lead to minor changes (<0.001 kt $CO_2$eq) in $CO_2$, $CH_4$ and $N_2O$ emissions.

- 1A2g: The activity data for biodiesel and bioethanol 1997-2022 were updated, since updated shares of biofuels are available from the Swiss customs statistics, which is applied in Switzerland's road transportation model (INFRAS 2024).

#### 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 Transport (1A3)

#### 3.2.7.1 Category description: Transport (1A3)

**Key category information 1A3b**

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

This source category 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 (for additional information, see activity data or chp. 3.2.2). Liechtenstein's emissions are calculated based on fuel consumption, flying hours and fleet composition of the single helicopter base "Heliport Balzers". Emission factors are constant for the entire time series (see Table 3-22).

Activity data partly consists of surveys and collected data from the helicopter company Rotex Helicopter AG. For years where no data was available, constant values or interpolations were used.

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 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). The $CO_2$ emission factors are derived from the carbon content of fuels (see Table 3-5 and Table 3-6) similar as in the Swiss GHG inventory (FOEN 2024). For $CH_4$ and $N_2O$, country-specific emission factors from Switzerland's road transportation model (INFRAS 2023) are applied. The activity data corresponds to the amounts of

gasoline and diesel fuel sold in Liechtenstein (sales principle). These data are taken from the national energy statistics modified as mentioned in Chapter 3.2.4.2.

Since the energy statistic of Liechtenstein (OS 2024a) provides only data on total fuel consumption, it is not possible to split emissions according to vehicle type under 1A3bi-1A3biv. Therefore, total emissions from road transport are reported under 1A3bi using implied emission factors accounting for all vehicle types. For the other vehicle categories no emissions are reported under 1A3bii – 1 A3biv and the notation key IE is applied.

Note that a large number of Austrian and German citizens are working in Liechtenstein (2023: 43’162 registered employees, and about 24’602 commuters, whereof 39.2% are non-Swiss citizens, see OS 2024f) and buying part of their gasoline in Liechtenstein. The method of reporting the fuel sold at all gasoline stations in the country guarantees that indeed the sales principle is applied and not a territorial principle as might be the case by applying a traffic model, which, for Liechtenstein, would considerably underestimate the fuel sold. 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 15 January 2015, resulted in a strong appreciation of the Swiss franc, which led to a switch in the direction of fuel tourism (SFOE 2018).

#### *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 $CO_2$ emission factor for kerosene is taken from Table 3-5 (SFOE/FOEN 2014). The $CH_4$ and $N_2O$ 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 1990–2023.

| Source/fuel | $CO_2$ [t/TJ] | $CH_4$ [kg/TJ] | $N_2O$ [kg/TJ] |
|---|---|---|---|
| **1A3a Domestic aviation (helicopters only)** | | | |
| Kerosene | 72.8 | 0.5 | 2.0 |

### *Road transportation (1A3b)*

$CO_2$

- $CO_2$ emission factors for fossil gasoline, diesel oil, bioethanol and biodiesel: The emission factors are adopted from Switzerland's road transportation model (INFRAS 2023) (see Table 3-5 and Table 3-6 in chp. 3.2.4.1), which is also applied in Switzerland's GHG inventory. The fleet composition of Liechtenstein is very similar to Switzerland. Accordingly, in Liechtenstein's inventory a weighted average emission factor from all vehicle categories in Switzerland (passenger cars, light duty vehicles, motorcycles, heavy duty vehicles, buses, coaches) is used for each fuel type.
- $CO_2$ emission factor for natural gas: emission factor corresponds to the IPCC default value (IPCC 2006).
- $CO_2$ emission factors for biogas: Since 2013, Liechtenstein produces biogas from sewage gas treatment and uses a part of this biogas in road transportation. The emission factors are equal to natural gas.
- $CO_2$ emission factors for vegetable oil: 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. The emission factor is assumed to be identical to conventional diesel. In 2010, the production of biofuels ceased. Note that this is not considered to be a "production of biofuels" and thus in CRT 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. The biogenic fraction is not reported under 1A3b but under Memo items "biomass" for respective years. Please note that this holds only for emissions from vegetable oil. $CO_2$ emissions of biofuels (bioethanol and biodiesel) are reported under 1.A.3.b under biomass, but are not accounted in that category. Thus, they are not part of the totals presented in Table 1s1, cell B23, but instead under Memo items Table1s2, cell B33.
- The $CO_2$ emission factor for lubricants (used in a blend with gasoline for motorcycles) stems from the IPCC 2006 Guidelines (IPCC 2006).

$CH_4$, $N_2O$

$CH_4$, $N_2O$ for gasoline, diesel oil, biodiesel and bioethanol: the emission factors from Switzerland's road transportation model for the whole period 1990-2023 (INFRAS 2023). The road transportation model applies the emission factors from Switzerland's Handbook of Emission Factors version 4.2 (INFRAS 2022a). Note that the regulation for

emission concepts of the two countries is identical: Switzerland and Liechtenstein adopt the same limit values for pollutants on the same schedule as the countries of the European Union. The fleet composition of the two countries, the $CO_2$ emissions of light motor vehicles (passenger cars, light duty vehicles, motorcycles) and the emissions of heavy motor vehicles (heavy duty vehicles, buses, coaches) are similar in Liechtenstein and Switzerland. A quantitative analysis based on Switzerland's road transportation model (INFRAS 2004, Annex A5) and of Liechtenstein (OEP 2002, Table 7, p. 16) reveals that the contribution of light motor vehicles to the $CO_2$ emissions of the total (light and heavy motor vehicles) is 80% in Liechtenstein and 85% in Switzerland. Note that these results are derived based on the territorial principle. From the viewpoint of the sales principle, both numbers would be higher due to 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.

- $CH_4$, $N_2O$ emission factors for natural gas: For $CH_4$ and $N_2O$ the emission factor from Switzerland's road transportation model is used (INFRAS 2023).
- $CH_4$, $N_2O$ emission factors for biogas: For biogas from sewage gas treatment, implied emission factors 1A3b for natural gas are used (see Table 3-23).
- Production of liquid biofuel occurred only from 2007 to 2009. For this period, $CH_4$, $N_2O$ emission factors for biofuel are assumed to be identical to those of fossil diesel used in 1A3b Road transportation.
- $CH_4$ and $N_2O$ emission factors for lubricants (used in a blend with gasoline for motorcycles) are assumed to be identical to $CH_4$ and $N_2O$ emission factors of gasoline.

Annex A5.1 provides explanations on the origin of the Swiss emission factors for road transportation.

Table 3-23 Emission factors for fossil fuels road transport.

| Gas | unit | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| | | **Gasoline** | | | | |
| $CO_2$ | t/TJ | 73.9 | 73.9 | 73.9 | 73.9 | 73.8 |
| $CH_4$ | kg/TJ | 29.99 | 17.88 | 13.75 | 10.53 | 8.31 |
| $N_2O$ | kg/TJ | 3.52 | 5.10 | 4.80 | 1.67 | 1.02 |
| | | **Diesel** | | | | |
| $CO_2$ | t/TJ | 73.6 | 73.6 | 73.6 | 73.5 | 73.4 |
| $CH_4$ | kg/TJ | 2.56 | 2.02 | 1.35 | 0.87 | 0.58 |
| $N_2O$ | kg/TJ | 0.57 | 0.67 | 0.90 | 1.24 | 2.17 |
| | | **Gaseous fuels** | | | | |
| $CO_2$ | t/TJ | NA | NA | NA | NA | NA |
| $CH_4$ | kg/TJ | NA | NA | NA | NA | NA |
| $N_2O$ | kg/TJ | NA | NA | NA | NA | NA |
| | | **Lubricants** | | | | |
| $CO_2$ | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| $CH_4$ | kg/TJ | 29.99 | 17.88 | 13.75 | 10.53 | 8.31 |
| $N_2O$ | kg/TJ | 3.52 | 5.10 | 4.80 | 1.67 | 1.02 |

| Gas | unit | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| | | **Gasoline** | | | | |
| $CO_2$ | t/TJ | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 |
| $CH_4$ | kg/TJ | 6.94 | 6.66 | 6.70 | 6.75 | 6.53 |
| $N_2O$ | kg/TJ | 0.70 | 0.65 | 0.62 | 0.58 | 0.57 |
| | | **Diesel** | | | | |
| $CO_2$ | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| $CH_4$ | kg/TJ | 0.90 | 1.11 | 1.45 | 1.83 | 2.13 |
| $N_2O$ | kg/TJ | 2.65 | 2.76 | 2.90 | 3.09 | 3.25 |
| | | **Gaseous fuels** | | | | |
| $CO_2$ | t/TJ | NA | NA | NA | NA | NA |
| $CH_4$ | kg/TJ | NA | NA | NA | NA | NA |
| $N_2O$ | kg/TJ | NA | NA | NA | NA | NA |
| | | **Lubricants** | | | | |
| $CO_2$ | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| $CH_4$ | kg/TJ | 6.94 | 6.66 | 6.70 | 6.75 | 6.53 |
| $N_2O$ | kg/TJ | 0.70 | 0.65 | 0.62 | 0.58 | 0.57 |

| Gas | unit | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| | | **Gasoline** | | | | |
| $CO_2$ | t/TJ | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 |
| $CH_4$ | kg/TJ | 6.19 | 6.06 | 6.06 | 6.16 | 6.16 |
| $N_2O$ | kg/TJ | 0.57 | 0.70 | 0.66 | 0.56 | 0.56 |
| | | **Diesel** | | | | |
| $CO_2$ | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| $CH_4$ | kg/TJ | 2.32 | 2.37 | 2.51 | 2.62 | 2.62 |
| $N_2O$ | kg/TJ | 3.37 | 3.50 | 3.58 | 3.62 | 3.62 |
| | | **Gaseous fuels** | | | | |
| $CO_2$ | t/TJ | NA | NA | NA | NA | NA |
| $CH_4$ | kg/TJ | NA | NA | NA | NA | NA |
| $N_2O$ | kg/TJ | NA | NA | NA | NA | NA |
| | | **Lubricants** | | | | |
| $CO_2$ | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| $CH_4$ | kg/TJ | 6.19 | 6.06 | 6.06 | 6.16 | 6.16 |
| $N_2O$ | kg/TJ | 0.57 | 0.70 | 0.66 | 0.56 | 0.56 |

Table 3-24 Emission factors for biofuels used in road transport. The $CO_2$ emission factor refers to biogenic emissions. Liquid biofuel from waste vegetable oil was produced from 2007–2009 (not shown in table, see CRT reporting tables for full time series), the corresponding $CO_2$, $CH_4$ and $N_2O$ emission factors are assumed to be identical to those of fossil diesel.

| Gas | unit | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| | | **Bioethanol** | | | | |
| $CO_2$ | t/TJ | 73.9 | 73.9 | 73.9 | 73.9 | 73.8 |
| $CH_4$ | kg/TJ | 29.99 | 17.88 | 13.75 | 10.53 | 8.31 |
| $N_2O$ | kg/TJ | 3.52 | 5.10 | 4.80 | 1.67 | 1.02 |
| | | **Biodiesel** | | | | |
| $CO_2$ | t/TJ | 73.6 | 73.6 | 73.6 | 73.5 | 73.4 |
| $CH_4$ | kg/TJ | 2.56 | 2.02 | 1.35 | 0.87 | 0.58 |
| $N_2O$ | kg/TJ | 0.57 | 0.67 | 0.90 | 1.24 | 2.17 |
| | | **Biogas (since 2013)** | | | | |
| $CO_2$ | t/TJ | NA | NA | NA | NA | NA |
| $CH_4$ | kg/TJ | NA | NA | NA | NA | NA |
| $N_2O$ | kg/TJ | NA | NA | NA | NA | NA |

| Gas | unit | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| | | **Bioethanol** | | | | |
| $CO_2$ | t/TJ | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 |
| $CH_4$ | kg/TJ | 6.94 | 6.66 | 6.70 | 6.75 | 6.53 |
| $N_2O$ | kg/TJ | 0.70 | 0.65 | 0.62 | 0.58 | 0.57 |
| | | **Biodiesel** | | | | |
| $CO_2$ | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| $CH_4$ | kg/TJ | 0.90 | 1.11 | 1.45 | 1.83 | 2.13 |
| $N_2O$ | kg/TJ | 2.65 | 2.76 | 2.90 | 3.09 | 3.25 |
| | | **Biogas (since 2013)** | | | | |
| $CO_2$ | t/TJ | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 |
| $CH_4$ | kg/TJ | 31.14 | 27.36 | 25.71 | 23.80 | 22.72 |
| $N_2O$ | kg/TJ | 3.08 | 3.16 | 3.11 | 3.26 | 3.15 |

| Gas | unit | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| | | **Bioethanol** | | | | |
| $CO_2$ | t/TJ | 73.8 | 73.8 | 73.8 | 73.8 | 73.8 |
| $CH_4$ | kg/TJ | 6.19 | 6.06 | 6.06 | 6.16 | 6.16 |
| $N_2O$ | kg/TJ | 0.57 | 0.70 | 0.66 | 0.56 | 0.56 |
| | | **Biodiesel** | | | | |
| $CO_2$ | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| $CH_4$ | kg/TJ | 2.32 | 2.37 | 2.51 | 2.62 | 2.62 |
| $N_2O$ | kg/TJ | 3.37 | 3.50 | 3.58 | 3.62 | 3.62 |
| | | **Biogas (since 2013)** | | | | |
| $CO_2$ | t/TJ | 56.1 | 56.1 | 56.1 | 56.1 | 56.1 |
| $CH_4$ | kg/TJ | 21.56 | 19.72 | 18.45 | 15.69 | 15.69 |
| $N_2O$ | kg/TJ | 3.14 | 4.26 | 3.59 | 3.12 | 3.12 |

## Activity data

### *Domestic aviation (1A3a)*

The operating company of the helicopter base “Heliport Balzers” provided data on fuel consumption for 1995, 2001–2023 as well as domestic fuel consumption for 2012–2023 (Rotex Helicopter AG 2006 -2024). The fleet consists of three helicopters. Details for the kerosene consumption are described in chp. 3.2.2, the part of domestic consumption is shown in Table 3-25.

Table 3-25 Activity data for 1A3a Domestic aviation: kerosene consumption 1990-2023 in TJ (only domestic consumption without international bunker fuels). See also Table 3-4.

| **Source/fuel** | **1990** | **1995** | **2000** | **2005** | **2010** | |
|---|---|---|---|---|---|---|
| **1A3a Domestic aviation (helicopters only)** | TJ | | | | | |
| Kerosene (domestic) | 1.03 | 1.03 | 1.08 | 1.04 | 0.89 | |
| | | | | | | |
| **Source/fuel** | **2014** | **2015** | **2016** | **2017** | **2018** | |
| **1A3a Domestic aviation (helicopters only)** | TJ | | | | | |
| Kerosene (domestic) | 0.85 | 0.81 | 0.56 | 0.35 | 0.40 | |
| | | | | | | |
| **Source/fuel** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023** |
| **1A3a Domestic aviation (helicopters only)** | TJ | | | | | % |
| Kerosene (domestic) | 1.14 | 0.81 | 0.84 | 0.85 | 1.05 | 2% |

### *Road transportation (1A3b)*

The amount of gasoline and diesel fuel sold in Liechtenstein serve as activity data for the calculation of the $CO_2$ emissions (see Table 3-26).

For gaseous fuels, the amount reported by gasoline stations is used. Since 1997 the imported diesel is blended with a small share of biodiesel and since 2010 the imported gasoline is blended with a small share of bioethanol. The shares are assumed to be equal to the share determined for Switzerland (INFRAS 2024).

The biofuel consumption of vegetable oil produced in Liechtenstein occurred only between 2007 and 2009. Since 2013, Liechtenstein produces biogas from sewage gas treatment and uses a part of this biogas in road transportation.

Table 3-26 Time series of activity data for 1A3b Road transportation. Vegetable oil was used between 2007 and 2009 (not shown in table, see CRT reporting table for full time series) and biogas is used since 2013.

| **Fuel** | **1990** | **1995** | **2000** | **2005** | **2010** |
|---|---|---|---|---|---|
| | TJ | | | | |
| Gasoline | 819 | 903 | 977 | 773 | 593 |
| Diesel | 200 | 184 | 239 | 301 | 407 |
| Natural Gas | NO | NO | NO | 32.4 | 59.4 |
| Lubricants (1A3biv) | 0.0025 | 0.0022 | 0.0018 | 0.0015 | 0.0011 |
| Biogas | NO | NO | NO | NO | NO |
| Bioethanol | NO | NO | NO | 0.10 | 0.24 |
| Biodiesel | NO | NO | 0.3 | 0.9 | 1.5 |
| **Sum** | **1'020** | **1'086** | **1'216** | **1'107** | **1'061** |
| 1990=100% | 100% | 107% | 119% | 109% | 104% |

| **Fuel** | **2014** | **2015** | **2016** | **2017** | **2018** |
|---|---|---|---|---|---|
| | TJ | | | | |
| Gasoline | 508 | 405 | 378 | 369 | 362 |
| Diesel | 470 | 413 | 426 | 442 | 420 |
| Natural Gas | 19.5 | 17.4 | 9.5 | 5.6 | 7.0 |
| Lubricants (1A3biv) | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0014 |
| Biogas | 0.48 | 0.43 | 0.21 | 0.13 | 0.19 |
| Bioethanol | 1.29 | 2.70 | 3.37 | 4.09 | 4.74 |
| Biodiesel | 2.84 | 5.36 | 10.23 | 17.45 | 22.93 |
| **Sum** | **1'002** | **844** | **828** | **839** | **817** |
| 1990=100% | 98% | 83% | 81% | 82% | 80% |

| **Fuel** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023** |
|---|---|---|---|---|---|---|
| | TJ | | | | | % |
| Gasoline | 355 | 317 | 331 | 293 | 404 | -51% |
| Diesel | 408 | 386 | 419 | 379 | 322 | 60% |
| Natural Gas | 5.4 | 2.8 | 2.5 | 2.1 | 1.6 | - |
| Lubricants (1A3biv) | 0.0014 | 0.0011 | 0.0011 | 0.0011 | 0.0012 | -52% |
| Biogas | 0.15 | 0.08 | 0.06 | 0.05 | 0.04 | - |
| Bioethanol | 5.28 | 5.19 | 6.81 | 7.00 | 9.81 | - |
| Biodiesel | 22.65 | 20.80 | 18.18 | 16.24 | 14.74 | - |
| **Sum** | **796** | **732** | **777** | **698** | **752** | **-26%** |
| 1990=100% | 78% | 72% | 76% | 68% | 74% | |

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 $CO_2$ emissions were more than 40% lower in the base year and 30% lower in 2004 than the emissions reported in respective GHG inventories. The differences between this result and the statistics of fuel sales are explained by fuelling of (mainly) 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

The following recalculations lead to changes in $CO_2$, $CH_4$ and $N_2O$ emissions resulting in a decrease of 0.02 kt $CO_2$eq in 2022:

- 1A3b: The activity data for biodiesel and bioethanol 1997-2022 were updated, since updated shares of biofuels are available from the Swiss customs statistics, which is applied in Switzerland's road transportation model (INFRAS 2024).

#### 3.2.7.6 Category-specific planned improvements

In Submission 2025, emission factors for road transportation could not be updated using the latest version of Switzerland's road transportation model. Instead, the emission factors from the 2024 submission (INFRAS 2023) were used. In the next submission, the emission factors will be updated based on the latest available version of Switzerland's road transportation model.

### 3.2.8 Other sectors (commercial/institutional, residential, agriculture/forestry/fishing) (1A4)

#### 3.2.8.1 Category description: Other sectors (1A4)

**Key category information 1A4**

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

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

Table 3-27 Specification of source category 1A4 Other sectors.

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

### 3.2.8.2 Methodological issues: Other sectors (1A4)

#### Methodology

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

For fuel combustion in commercial and institutional buildings (1A4a) as well as in households (1A4b), a Tier 2 method is used and cross-checked with the estimate on the gas oil consumption based on expert judgement (see sub-section 3.2.4.2 energy statistics and contribution to the IPCC source categories). A top-down method based on aggregated fuel consumption data from the energy statistics of Liechtenstein (OS 2024a) 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. Emission factors are taken from the Swiss non-road online database (INFRAS 2015). The activity data is derived from the information provided by the General Directorate of Swiss Customs (refunding institution of fuel levies until 2005) and by OEP census (OEP 2012c). For more details, see section 3.2.4.2, paragraph gasoline/diesel oil.

#### Emission factors

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

$CO_2$ emission factors and NCV values are country-specific (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.

The coal emission factor for $CO_2$ refers to the emission factor of hard coal in Switzerland (Cemsuisse 2010). As Liechtenstein is a small neighbouring country of Switzerland, it is assumed that similar coal is used as in Switzerland. The $N_2O$ emission factor is taken from the IPCC 2006 Guidelines and the $CH_4$ emission factor is taken from Switzerland's National Inventory Document 2024 (FOEN 2024).

The country-specific emission factors for $CO_2$ emissions from gas oil and Liquefied Petroleum Gas (LPG) are taken from Switzerland's National Inventory Document 2024 (FOEN 2024). Emission factors of $CH_4$ and $N_2O$ are taken from the IPCC 2006 Guidelines (Vol. 2, Chp. 2, Table 2.4 and 2.5). For biogas, the same emission factors are used as for natural gas.

The $CO_2$, $CH_4$ and $N_2O$ emission factors for natural gas is taken from IPCC 2006 Guidelines (Vol. 2, Chp. 2, Table 2.4 and 2.5).

The $CO_2$, $CH_4$ and $N_2O$ emission factors for alkylate gasoline is taken from IPCC 2006 Guidelines (Vol. 2, Chp. 3, Table 3.3.1).

The $CO_2$ and $N_2O$ emission factors for combustion of wood are taken from IPCC 2006 Guidelines (Vol. 2, Chp. 2, Table 2.4). The $CH_4$ emission factor for combustion of wood is derived from FOEN 2022a. They are based on air pollution control and laboratory measurements and literature. For small wood combustion installations in 1A4b, a weighted emission factor is applied based on the share of different types of wood firing boilers (Acontec 2018a).

Table 3-28 Emission factors for 1A4a and 1A4b: Commercial/institutional and residential in Other sectors for the year 2023.

| Source/fuel | $CO_2$ fossil [t/TJ] | $CO_2$ biogenic [t/TJ] | $CH_4$ [kg/TJ] | $N_2O$ [kg/TJ] |
|---|---|---|---|---|
| **1A4a/b Other sectors - Commercial/institutional and Residential** | | | | |
| Gas oil | 73.7 | - | 10.0 | 0.6 |
| LPG | 65.5 | - | 5.0 | 0.1 |
| Alkylate gasoline | 69.3 | - | 140.0 | 0.4 |
| Coal | 92.7 | - | 300.0 | 1.5 |
| Natural gas | 56.1 | - | 5.0 | 0.1 |
| Biomass (Biogas from WWTP) | - | 56.1 | 5.0 | 0.1 |
| Biomass (Wood combustion 1A4a) | - | 112.0 | 10.0 | 4.0 |
| Biomass (Wood combustion 1A4b) | - | 112.0 | 73.6 | 4.0 |

### *Agriculture/forestry (1A4c)*

The $CO_2$, $CH_4$ and $N_2O$ emission factors for diesel used in non-road vehicles and machinery (agriculture and forestry) are country-specific and are taken from Switzerland's database of non-road vehicles (INFRAS 2015). 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.

For biodiesel the same emission factors are used as for fossil diesel.

The $CO_2$, $CH_4$ and $N_2O$ emission factors for alkylate gasoline is taken from IPCC 2006 Guidelines (Vol. 2, Chp. 3, Table 3.3.1).

Table 3-29 Emission factors for 1A4c: Other sectors – Agriculture/forestry for the year 2023.

| Source/fuel | $CO_2$ fossil [t/TJ] | $CO_2$ biogenic [t/TJ] | $CH_4$ [kg/TJ] | $N_2O$ [kg/TJ] |
|---|---|---|---|---|
| **1A4c Other sectors - Agriculture/forestry** | | | | |
| Diesel | 73.3 | - | 0.9 | 3.0 |
| Biodiesel | - | 73.3 | 0.9 | 3.0 |
| Alkylate gasoline | 69.3 | - | 140.0 | 0.4 |

## 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 2024a). 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 2024e). 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 3-30 Activity data in 1A4a Commercial/institutional and 1A4b Residential. Biomass consumption comprises consumption of biogas from wastewater treatment plants and consumption of wood.

| Source/fuel | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| | TJ | | | | |
| **1A4a Commercial/institutional** | **938.28** | **877.25** | **901.85** | **1'054.00** | **799.90** |
| Gas oil | 758.40 | 635.05 | 555.03 | 587.93 | 415.84 |
| LPG | 13.29 | 8.14 | 5.52 | 3.68 | 5.34 |
| Natural gas | 140.84 | 212.33 | 288.54 | 408.34 | 268.97 |
| Coal | NO | NO | NO | NO | NO |
| Biomass | 25.75 | 21.73 | 52.75 | 54.05 | 109.76 |
| **1A4b Residential** | **311.19** | **402.65** | **493.19** | **646.14** | **687.34** |
| Gas oil | 252.80 | 211.68 | 185.01 | 195.98 | 138.61 |
| Alkylate gasoline | NO | 0.05 | 0.10 | 0.11 | 0.13 |
| Natural gas | 41.22 | 176.43 | 272.91 | 414.01 | 475.43 |
| Coal | NO | NO | NO | NO | NO |
| Biomass | 17.17 | 14.49 | 35.17 | 36.03 | 73.18 |

| Source/fuel | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| | TJ | | | | |
| **1A4a Commercial/institutional** | **529.41** | **645.60** | **561.29** | **588.32** | **538.53** |
| Gas oil | 282.03 | 341.39 | 271.17 | 292.35 | 236.73 |
| LPG | 3.63 | 3.68 | 3.63 | 3.50 | 3.82 |
| Natural gas | 128.39 | 170.73 | 161.40 | 174.91 | 158.49 |
| Coal | NO | NO | NO | NO | NO |
| Biomass | 115.36 | 129.81 | 125.09 | 117.56 | 139.49 |
| **1A4b Residential** | **565.83** | **639.13** | **620.03** | **640.90** | **604.66** |
| Gas oil | 94.01 | 113.80 | 90.39 | 97.45 | 78.91 |
| Alkylate gasoline | 0.16 | 0.12 | 0.20 | 0.20 | 0.12 |
| Natural gas | 387.37 | 430.90 | 438.68 | 456.84 | 424.07 |
| Coal | NO | NO | NO | NO | NO |
| Biomass | 84.29 | 94.32 | 90.75 | 86.41 | 101.56 |

| Source/fuel | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|
| | TJ | | | | | % |
| **1A4a Commercial/institutional** | **567.10** | **539.98** | **516.01** | **476.05** | **483.93** | **-48%** |
| Gas oil | 294.70 | 285.92 | 244.81 | 219.15 | 241.34 | -68% |
| LPG | 3.59 | 3.68 | 3.36 | 3.04 | 9.02 | -32% |
| Natural gas | 140.78 | 147.81 | 171.06 | 138.54 | 123.38 | -12% |
| Coal | NO | NO | NO | NO | NO | - |
| Biomass | 128.04 | 102.57 | 96.78 | 115.32 | 110.20 | 328% |
| **1A4b Residential** | **656.06** | **637.21** | **670.37** | **580.63** | **554.18** | **78%** |
| Gas oil | 98.23 | 95.31 | 81.60 | 73.05 | 80.45 | -68% |
| Alkylate gasoline | 0.12 | 0.15 | 0.12 | 0.10 | 0.12 | - |
| Natural gas | 462.20 | 462.88 | 513.75 | 422.23 | 391.74 | 850% |
| Coal | NO | NO | NO | NO | | - |
| Biomass | 95.51 | 78.87 | 74.90 | 85.24 | 81.87 | 377% |

Since 1990, gas oil consumption decreased by approximately 68% for 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 $CO_2$ levy on January 1, 2010, induced the commercial consumers to refill their fuel tanks at the end of 2009.

In 2012, the cold winter (high number of heating degree days) led to a small increase of gas oil consumption in these source categories 1A4a and 1A4b. Due to the further increase in the $CO_2$ levy by 1$^{st}$ January 2016, again an increase in sales of gas oil was observed in 2015, which leads to a reduced apparent consumption of gas oil in 2016. The same pattern can be observed again between 2017 and 2019, due to another increase in the $CO_2$ levy on January 1 in 2018. In 2021 gas oil consumption decreased again due to an increase in gas oil prices in 2021.

The total energy consumption in 1A4b decreased slightly from 2022 to 2023.

This shift in fuel mix is a reason for $CO_2$ emissions from the use of gaseous and liquid fuels in category 1A4a and 1A4b being key categories regarding level and trend.

Among other factors, the increase in consumption of harvested wood as fuel (as documented in the wood harvesting statistics of Liechtenstein, OE 2024b) contributes to the strong increase in biomass consumption since 1990.

### *Agriculture/forestry/fishing (1A4c)*

The activity data related non-road machinery is shown in Table 3-31. Besides diesel, the consumption of alkylate gasoline is also accounted for (20% in 1A4b and 80% in 1A4c). The consumption of alkylate gasoline has been derived from an annual census carried out by the Office of Environment (OE 2024e).

Table 3-31 Activity data in 1A4c Agriculture/forestry/fishing.

| Source/fuel | 1990 | 1995 | 2000 | 2005 | 2010 | |
|---|---|---|---|---|---|---|
| 1A4c Other Sectors - Agriculture/forestry | TJ | | | | | |
| Alkylate gasoline | NO | 0.20 | 0.41 | 0.46 | 0.50 | |
| Diesel | 17.91 | 16.84 | 17.49 | 18.18 | 18.45 | |
| Biodiesel | NO | NO | 0.02 | 0.06 | 0.08 | |
| | | | | | | |
| **Source/fuel** | **2014** | **2015** | **2016** | **2017** | **2018** | |
| 1A4c Other Sectors - Agriculture/forestry | TJ | | | | | |
| Alkylate gasoline | 0.62 | 0.47 | 0.80 | 0.82 | 0.49 | |
| Diesel | 16.17 | 15.53 | 14.37 | 15.07 | 21.70 | |
| Biodiesel | 0.11 | 0.23 | 0.40 | 0.69 | 1.34 | |
| | | | | | | |
| **Source/fuel** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023** |
| 1A4c Other Sectors - Agriculture/forestry | TJ | | | | | % |
| Alkylate gasoline | 0.48 | 0.60 | 0.50 | 0.42 | 0.50 | - |
| Diesel | 21.14 | 22.96 | 23.70 | 24.89 | 22.14 | 24% |
| Biodiesel | 1.33 | 1.40 | 1.16 | 1.20 | 1.15 | - |

### 3.2.8.3 Uncertainty assessment 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

The following recalculations lead to changes in $CO_2$, $CH_4$ and $N_2O$ emissions resulting in a decrease of 0.01 kt $CO_2$eq in 2022:

- 1A4a/b: Since 2021, wood biomass is used as a fuel through the wood gasification process in a combined heat and power plant. Until submission 2024, total consumption of wood biomass and the resulting emissions were reported in sectors 1A4a and 1A4b. In the current submission, the allocation of wood biomass consumption to 1A1a and to 1A4a/1A4b was implemented (for more information see section 3.2.4.2), leading to a recalculation of activity data and emissions of $CO_2$, $CH_4$ and $N_2O$ in 1A4a and 1A4b for the years 2021 and 2022.
- 1A4c: The activity data for biodiesel and bioethanol 1997-2022 were updated, since updated shares of biofuels are available from the Swiss customs statistics, which is applied in Switzerland's road transportation model (INFRAS 2024).

#### 3.2.8.6 Category-specific planned improvements

No category specific improvements are planned.

### 3.2.9 Other (1A5)

#### 3.2.9.1 Category description: Other (1A5)

Emissions of category 1A5 do not occur in Liechtenstein.

### 3.2.10 Uncertainties and time-series consistency 1A

#### 3.2.10.1 Uncertainties – Fuel combustion activities (1A)

For the current submission, a simplified uncertainty analysis has been carried out as described in chp. 1.6. Uncertainties were accounted individually for the key categories, whereas the rest of the sources was aggregated by gas and treated as four “rest” categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. The key categories 1A1 gaseous fuels, 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 households as well as different industry and services sectors (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 1.6.3 and 3.2.4.2).

Details about the uncertainty analysis of the activity data (fuel consumption) in 1A are based on expert judgements. Dominant 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 biomass fuels have a relatively high uncertainty of 20%.

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

Liechtenstein and Switzerland form a customs and monetary union governed by a customs treaty. Therefore, all gas oil is supplied by Swiss suppliers and no taxation accrues at the borders for the import to Liechtenstein. It is therefore assumed that fuel has the same properties as the fuels sold on the Swiss market. Therefore, the emission factors and their uncertainties have been taken from Switzerland, and are documented in the Swiss NID (FOEN 2024):

In 2013, a large measurement campaign was carried out in Switzerland to determine the $CO_2$ emission factors of the dominant liquid fuels (SFOE/FOEN 2014). Based on the standard deviation of these measurements relative uncertainties were derived (FOEN 2024). Liechtenstein adopts these uncertainty estimates for the uncertainty analysis. The following uncertainties have been applied for the emission factors:

- Natural gas (1A1, 1A2, 1A4): U(EF $CO_2$) = 0.34%
- Liquid fuels (1A2, 1A4): U(EF $CO_2$) = 0.08%
- Gasoline (1A3b): U(EF $CO_2$) = 0.13%
- Diesel oil (1A3b): U(EF $CO_2$) = 0.07%

Note that 1A3b/$CO_2$ is not differentiated in the KCA of the CRT Reporter by fuel type but is considered as a key category as sum of gasoline and diesel oil. For the uncertainty analysis, the uncertainty of the aggregated category has to be calculated via error propagation from the uncertainty inputs given above: AD 10% and 15% for gasoline and diesel oil respectively and EF ($CO_2$) 0.13% and 0.07%. Annex 2 shows the procedure for uncertainty aggregation. The results are:

1A3b/$CO_2$: U(AD) = 8.7%, U(EF) = 0.08%.

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

1A4 liquid/$CO_2$: U(AD) = 15.9%, U(EF) = 0.06%

1A4 gaseous/$CO_2$: U(AD) = 4.0%, U(EF) = 0.27%

All the non-key categories of 1A (1A1a/$CH_4$, 1A1a/$N_2O$, 1A2e/$CH_4$ etc.) are summed up in the rest categories $CH_4$, $N_2O$ to which medium uncertainties are attributed (see explanation in chapter 1.6).

### 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 1990–2023. The entire time series are therefore consistent.

**Completeness**

The emissions for the entire time series 1990–2023 have been calculated and reported. The data on emissions of $CO_2$, $CH_4$ and $N_2O$ for sector 1 Energy are also complete.

## 3.2.11 Category-specific QA/QC and verification of Fuel combustion activities (1A)

**General QA/QC activities**

The category-specific QA/QC activities have been carried out as mentioned in section 1.5 also including triple checks of Liechtenstein's reporting tables (CRT tables). The triple check includes a detailed comparison of current and last year emissions by two NID authors and by the specialist from the Office of Environment. In addition, the activity data has been cross checked with the data in Liechtenstein's energy statistics (OS 2024a).

**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. Updated emission factors for Switzerland's road transport emissions were published in 2022 (INFRAS 2022a). The same emission factors are used for Liechtenstein. The results have undergone large plausibility checks and comparisons with earlier estimates.

The emission factors for $CH_4$ and $N_2O$ used for the modelling of 1A3b Road transportation are taken from the handbook of emission factors HBEFA 4.2 (INFRAS 2022a), which is also applied in Germany, Austria, the Netherlands and Sweden.

## 3.2.12 Category-specific recalculations

All recalculations carried out for source categories 1A1 – 1A5 are listed in corresponding sub-chapters 3.2.5.5 to 3.2.8.5. No other recalculations have been performed.

## 3.3 Fugitive emissions from solid fuels and oil and natural gas and other emission from energy production (1B)

### 3.3.1 Fugitive emissions from solid fuels (1B1)

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

### 3.3.2 Fugitive emissions from oil and natural gas and other emissions from energy production (1B2)

#### 3.3.2.1 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 $CH_4$ 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 cover 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 3-32 shows the sources for which fugitive emissions are accounted for.

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

Table 3-32 Specification of source category 1B2 Fugitive emissions from oil and natural gas and other emissions from energy production.

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

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

**Methodology**

For source 1B2b Natural gas, the emissions of $CH_4$ leakages from gas pipelines are calculated with a Tier 3 method. The method considers the length, type and pressure of the gas pipelines. The distribution network components (regulators, shut off fittings and gas meters), the losses from maintenance and extension as well as the end user losses are taken into account. NMVOC leakages are not estimated. For the calculation of the fugitive emissions of the transmission pipelines data in Table 3-36 and Table 3-37 are considered. Regarding density, NCV and share of methane within natural gas, the following values are applied for the entire time series:

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

According to expert information of Liechtenstein's gas and heat utility (LW), the losses identified within the NID 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 3-34).

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 (CRT), 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 CRT.

### Emission factors

The emission factors for gas distribution losses (source 1B2b) depend on the type and pressure of the natural gas pipeline (see Table 3-33) and are taken from literature. Batelle (1994) provides specific emission factors for different sources of fugitive emissions based on measurements of 1989 in Germany. Specific data for Switzerland (and Liechtenstein) is provided by a study of Xinmin (2004).

Liechtenstein is a very small country and strongly linked with Switzerland in several aspects. Therefore, the technology providers are mostly the same for both countries and it can be assumed that the technologies used are the same. Therefore, the $CH_4$ emission factors are assumed to be applicable also for Liechtenstein.

Table 3-33 $CH_4$ emission factors for 1B2b Fugitive emissions from natural gas in 2023 (Battelle 1994, Xinmin 2004). For HDPE (polyethylene) 1-5 bar, the upper value shows the assumption for 1993 and previous years while the lower 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<br>*0.0006* | - | - |
| Gas meters | - | - | - | 5.11 |

Table 3-34 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 3-37. The $CH_4$ emissions from gas meters are accounted for by applying an emission factor of 5.11 $m^3$ $CH_4$ per gas meter and year (Batelle 1994). Losses at end users are estimated based on expert assumptions.

Table 3-34 Natural gas losses at end users as additional information (Battelle 1994, S.114).

| Source/fuel | | 1990-2023 |
|---|---|---|
| **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 |

The fugitive emissions of $CO_2$ from natural gas are calculated by using a country-specific emission factor based on measurements of the gas composition in 2016 and 2017 (Acontec 2018b). It amounts to 0.78% of the total volume of natural gas. The emission factor is assumed constant for the entire time series.

Table 3-35 $CO_2$ emission factors for 1B2b Fugitive emissions from natural gas. A constant emission factor is used for the entire time series.

| Source/fuel | | 1990-2023 |
|---|---|---|
| **1B2b Fugitive emissions from natural gas** | Unit | |
| Fugitive $CO_2$ Emissions from natural gas | Vol % | 0.78% |

### 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 Heat (LW 2024, edition 2023 includes data up to 2023, former name until 2021 LGV). 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 3-36 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 | 1995 | 2000 | 2005 | 2010 | |
|---|---|---|---|---|---|---|---|
| **1B2b Fugitive emissions from natural gas** | **Unit** | | | | | | |
| Steel cath. > 5 bar | km | 26.3 | 26.3 | 26.3 | 26.6 | 26.6 | |
| HDPE (Polyethylene) 1-5 bar | km | 28.5 | 29.5 | 37.3 | 45.6 | 51.0 | |
| HDPE (Polyethylene) < 100 mbar | km | 67.0 | 135.9 | 206.0 | 276.3 | 312.8 | |
| Connections | number | 479 | 1’398 | 2’460 | 3’464 | 4’116 | |
| | | | | | | | |
| **Source/fuel** | | **2014** | **2015** | **2016** | **2017** | **2018** | |
| **1B2b Fugitive emissions from natural gas** | **Unit** | | | | | | |
| Steel cath. > 5 bar | km | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | |
| HDPE (Polyethylene) 1-5 bar | km | 52.1 | 52.1 | 52.1 | 52.1 | 52.1 | |
| HDPE (Polyethylene) < 100 mbar | km | 336.1 | 341.2 | 347.0 | 352.0 | 355.6 | |
| Connections | number | 4’411 | 4’486 | 4’491 | 4’571 | 4’651 | |
| | | | | | | | |
| **Source/fuel** | | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023** |
| **1B2b Fugitive emissions from natural gas** | **Unit** | | | | | | % |
| Steel cath. > 5 bar | km | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 1% |
| HDPE (Polyethylene) 1-5 bar | km | 52.1 | 52.1 | 51.6 | 51.6 | 51.4 | 81% |
| HDPE (Polyethylene) < 100 mbar | km | 360.7 | 363.5 | 366.8 | 370.0 | 374.6 | 459% |
| Connections | number | 4’715 | 4’758 | 4’768 | 5’330 | 4’523 | 844% |

Table 3-36 documents the continuous increase of Liechtenstein’s gas supply network since 1990. By 2023, the number of connections installed have increased by about a factor of 9.5 compared 1990.

Table 3-37 Natural gas volumes of Liechtenstein's natural gas distribution network as additional information.

| Source/fuel | Unit | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| **1B2b Fugitive emissions from natural gas** | | | | | | |
| Natural gas volume industry | Mio. $m^3$ | 7.5 | 8.8 | 9.7 | 10.4 | 6.0 |
| Natural gas volume other | Mio. $m^3$ | 5.1 | 11.7 | 16.8 | 25.1 | 23.7 |
| **Sum natural gas volume** | Mio. $m^3$ | **12.6** | **20.5** | **26.5** | **35.4** | **29.8** |

| Source/fuel | Unit | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| **1B2b Fugitive emissions from natural gas** | | | | | | |
| Natural gas volume industry | Mio. $m^3$ | 7.6 | 7.1 | 7.2 | 7.7 | 7.1 |
| Natural gas volume other | Mio. $m^3$ | 16.0 | 18.1 | 17.9 | 18.6 | 17.3 |
| **Sum natural gas volume** | Mio. $m^3$ | **23.6** | **25.2** | **25.1** | **26.3** | **24.4** |

| Source/fuel | Unit | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|---|
| **1B2b Fugitive emissions from natural gas** | | | | | | | % |
| Natural gas volume industry | Mio. $m^3$ | 6.3 | 5.7 | 6.4 | 5.7 | 5.0 | -33% |
| Natural gas volume other | Mio. $m^3$ | 18.5 | 18.1 | 20.2 | 16.7 | 15.7 | 208% |
| **Sum natural gas volume** | Mio. $m^3$ | **24.7** | **23.9** | **26.6** | **22.4** | **20.7** | **65%** |

### 3.3.2.3 Uncertainties and time-series consistency

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

The combined uncertainty of emissions of $CH_4$ from 1B2 (which is a key category regarding trend) is estimated based on expert judgement.

For the current submission, a simplified uncertainty analysis has been carried out as described in chp. 1.6. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. Since emissions of $CO_2$ from 1B2 is not a key category, its uncertainties are accounted in the "rest" categories with mean uncertainty, which is 10% combined uncertainty for $CO_2$ emissions.

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 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

#### 3.3.2.5 Category-specific recalculations

No category-specific recalculations were carried out.

#### 3.3.2.6 Category-specific planned improvements

No category-specific improvements are planned.

## 3.4 $CO_2$ transport and storage (1C)

Category 1C is not occurring in Liechtenstein.

# 4. Industrial processes and product use (IPPU) (CRT sector 2)

## 4.1 Overview of sector

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. 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)
- 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 $N_2O$ emissions from 2G3a Medical applications and 2G3b Other propellant for pressure and aerosol products), are reported under source category 2 IPPU. In addition, SF6 emissions from 2G1 Electrical equipment and $CO_2$ emissions from 2D1 Lubricant use are reported. $NF_3$ emissions are not occurring.

The emissions of source category 2 Industrial processes and product use have increased from 1990 to 2014. Since 2018 they show a decreasing tendency (Table 4-1 and Figure 4-1).

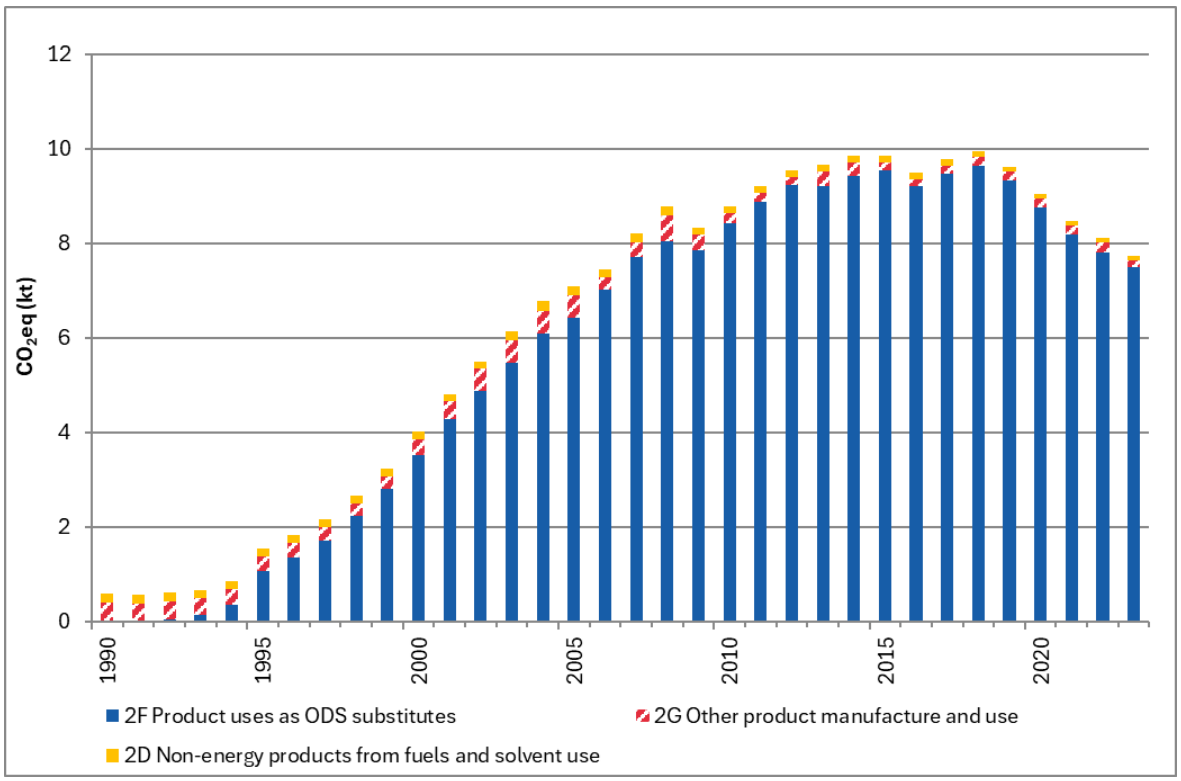



Figure 4-1 Liechtenstein's GHG emissions of sector 2 Industrial processes and product use. Note that there are no emissions in sectors 2A, 2B, 2C, 2E and 2H.

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

The total emissions of sector 2 Industrial processes and other product use (IPPU) account for 7.75 kt $CO_2$ equivalent in 2023. Emissions of the IPPU sector play therefore a minor role in Liechtenstein's inventory and contribute to 4.6% to the total emissions excluding LULUCF. 7.5 kt $CO_2$ equivalent were emitted in sector 2F Product uses as ODS substitutes and another 0.1 kt $CO_2$ equivalent in sector 2G Other product manufacture and use and 0.1 kt $CO_2$ equivalent in sector 2D Non-energy products from fuels and solvent use. The total emissions in the IPPU sector increased by a factor of 12.8 since 1990. This trend is in particular dominated by the increase in HFC emissions. $CO_2$ emissions decreased by 45% and $N_2O$ emissions decreased by 68% between 1990 and 2023.

From 2022 to 2023, the total F-gas emissions decreased by 4.8%, HFC emissions decreased by 4.1%, PFC emissions decreased by 7.8% and $SF_6$ emissions decreased by 76.7%.

Further details on the methodological approach used for the calculation of emissions from source category 2D, 2F and 2G are documented in Annex A5.3.

Table 4-1 GHG emissions of sector 2 Industrial processes and product use by gases in $CO_2$ equivalent (kt) and the relative change (last column).

| Gas | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| | CO2 equivalent (kt) | | | | |
| $CO_2$ | 0.2 | 0.16 | 0.17 | 0.20 | 0.15 |
| $N_2O$ | 0.40 | 0.32 | 0.24 | 0.22 | 0.18 |
| F-Gases | 0.00 | 1.07 | 3.62 | 6.69 | 8.47 |
| **Sum** | **0.60** | **1.55** | **4.03** | **7.11** | **8.80** |

| Gas | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| | CO2 equivalent (kt) | | | | |
| $CO_2$ | 0.14 | 0.14 | 0.14 | 0.13 | 0.12 |
| $N_2O$ | 0.15 | 0.14 | 0.13 | 0.12 | 0.12 |
| F-Gases | 9.56 | 9.59 | 9.23 | 9.53 | 9.71 |
| **Sum** | **9.85** | **9.86** | **9.50** | **9.79** | **9.96** |

| Gas | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|
| | CO2 equivalent (kt) | | | | | % |
| $CO_2$ | 0.12 | 0.11 | 0.11 | 0.12 | 0.11 | -45% |
| $N_2O$ | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | -68% |
| F-Gases | 9.39 | 8.82 | 8.25 | 7.89 | 7.51 | 7821248% |
| **Sum** | **9.64** | **9.05** | **8.49** | **8.13** | **7.75** | **1185%** |

## 4.2 Mineral industry (2A)

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

## 4.3 Chemical industry (2B)

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

## 4.4 Metal industry (2C)

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

## 4.5 Non-energy products from fuels and solvent use (2D)

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

**Key category information 2D**

Source category 2D "Non-energy products from fuels and solvent use" is not a key category.

Source category 2D comprises emissions of $CO_2$ from lubricant use. Other direct greenhouse gas emissions from source category 2D are not occurring in Liechtenstein.

Table 4-2 Specification of source category 2D Non-energy products from fuels and solvent use.

| 2D | Source | Specification |
|---|---|---|
| 2D1 | Lubricant use | Emissions of $CO_2$ from primary usage of lubricants in machinery and vehicles |

### 4.5.2 Methodological issues: Non-energy products from fuels and solvent use (2D)

#### 4.5.2.1 Methodology

**Lubricant use (2D1)**

Lubricants are mostly used in industrial and transportation applications. They can be subdivided into motor oils, industrial oils and greases, which differ in terms of physical characteristics, commercial applications and environmental fate. Lubricants in engines are primarily used for their lubricating properties and associated $CO_2$ emissions are therefore considered as non-combustion emissions reported in 2D1 Lubricant use.

Liechtenstein estimates the emissions from lubricant use in Switzerland by assuming that emissions in Liechtenstein are proportional to the number of inhabitants.

#### 4.5.2.2 Emission factors

**Lubricant use (2D1)**

The emission factors of $CO_2$ from lubricant use in Switzerland are based on default IPCC values for NCV, carbon content and oxidation fraction documented in vol. 2, chp.1 and vol. 3, chp. 5.2 and 5.3, respectively, of IPCC 2006.

Based on $CO_2$ emissions in source category 2D1 in Switzerland and the number of inhabitants in Switzerland the following emission factors per inhabitant for Liechtenstein are derived.

Table 4-3 Emission factors for 2D1 Non-energy products from fuels and solvents.

| Emission factors 2D Non-energy products from fuels and solvents | | 1990 | 1995 | 2000 | 2005 | 2010 | |
|---|---|---|---|---|---|---|---|
| Inhabitants Switzerland | number | 6'712'000 | 7'041'000 | 7'184'000 | 7'437'000 | 7'825'000 | |
| Emissions 2D1 Switzerland | kt | 47.0 | 36.2 | 37.0 | 42.7 | 32.6 | |
| 2D1 EF $CO_2$ from Lubricant use - $CO_2$ | kg/inhabitant | 7.00 | 5.14 | 5.15 | 5.74 | 4.17 | |
| | | | | | | | |
| **Emission factors 2D Non-energy products from fuels and solvents** | | **2014** | **2015** | **2016** | **2017** | **2018** | |
| Inhabitants Switzerland | number | 8'189'000 | 8'282'000 | 8'373'000 | 8'452'000 | 8'514'000 | |
| Emissions 2D1 Switzerland | kt | 31.7 | 30.5 | 30.2 | 29.5 | 27.0 | |
| 2D1 EF $CO_2$ from Lubricant use - $CO_2$ | kg/inhabitant | 3.87 | 3.68 | 3.60 | 3.49 | 3.17 | |
| | | | | | | | |
| **Emission factors 2D Non-energy products from fuels and solvents** | | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023 %** |
| Inhabitants Switzerland | number | 8'575'000 | 8'638'000 | 8'705'000 | 8'739'000 | 8'889'000 | 32% |
| Emissions 2D1 Switzerland | kt | 26.1 | 23.5 | 25.0 | 25.5 | 24.7 | -48% |
| 2D1 EF $CO_2$ from Lubricant use - $CO_2$ | kg/inhabitant | 3.05 | 2.73 | 2.87 | 2.92 | 2.77 | -60% |

## 4.5.2.3 Activity data

### Lubricant use (2D1)

The amount of lubricants used in Liechtenstein is based on import, export and production data from Switzerland (FOEN 2024b). The amount used in Liechtenstein is assumed to be proportional to the number of inhabitants in Switzerland and Liechtenstein respectively.

Table 4-4 Number of inhabitants of Liechtenstein as proxy for activity data calculations of emissions under source category 2D1.

| Number of inhabitants for AD calculation | 1990 | 1995 | 2000 | 2005 | 2010 | |
|---|---|---|---|---|---|---|
| | Number of inhabitants | | | | | |
| Liechtenstein | 29'032 | 30'923 | 32'863 | 34'905 | 36'149 | |
| | | | | | | |
| **Number of inhabitants for AD calculations** | **2014** | **2015** | **2016** | **2017** | **2018** | |
| | Number of inhabitants | | | | | |
| Liechtenstein | 37'366 | 37'623 | 37'810 | 38'114 | 38'380 | |
| | | | | | | |
| **Number of inhabitants for AD calculations** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023 %** |
| | Number of inhabitants | | | | | |
| Liechtenstein | 38'749 | 39'055 | 39'315 | 39'677 | 40'015 | 38% |

### 4.5.3 Uncertainties and time-series consistency

For the current submission, a simplified uncertainty analysis has been carried out as described in chp. 1.6. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. Since 2D1 is not a key category, its uncertainties are accounted in the "rest" categories with mean uncertainty, which is 10% combined uncertainty for $CO_2$ emissions.

The time series are consistent.

### 4.5.4 Category-specific QA/QC and verification

The category-specific QA/QC activities are documented in section 1.5.

### 4.5.5 Category-specific recalculations

No category specific recalculations were carried out.

### 4.5.6 Category-specific planned improvements

No category-specific improvements are planned.

## 4.6 Electronic industry (2E)

### 4.6.1 Category description: Electronic industry (2E)

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

## 4.7 Product uses as ODS substitutes (2F)

### 4.7.1 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 4-5 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 2024a) 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 by the following methodology:

For every single emission source and gas, the contribution to the total GHG emissions of the respective source category at the level of 2F1, 2F2 and 2F4 is calculated. A threshold of 10% is defined and applied per sub-category (2F1, 2F2 and 2F4). Only emission sources and gases that contribute more than 10% to a given sub-category are considered to be relevant for Liechtenstein's GHG inventory under source category 2F. Emissions that account for less than 10% in the Swiss inventory in the respective sub-category are neglected, since they likely originate from an emissions source that does not occur in Liechtenstein.

For the emission sources identified as relevant by applying the 10% threshold in the Swiss GHG inventory, emissions in Liechtenstein are estimated by applying the rule of proportion. They are calculated 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 A5.3.

**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 2024 (FOEN 2024).

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 2024 (FOEN 2024), citations are written in italics. It is considered as valid for Liechtenstein as well, since Liechtenstein's data are based on Switzerland's national inventory database EMIS (FOEN 2024a):

*The inventory under source category 2F1 includes different applications and equipment types. For each individual emission, models are used for calculating actual emissions as per the 2006 IPCC Guideline's 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. For the following applications a bottom-up approach is applied relying on statistics, product information and expert estimations:*

*Domestic refrigeration*

*Mobile air conditioning for different vehicle types (example illustrated in Annex A5.2 in FOEN 2024)*

*Transport refrigeration for different vehicles types*

*Stationary air conditioning (direct and indirect systems)*

*Heat pumps*

*Tumble dryers*

*On the other hand, a top-down approach is applied for the calculation of the stock in commercial and industrial equipment starting with the total imported amount of refrigerant. To determine the portion used for commercial and industrial refrigeration, the refrigerant consumption of other applications is subtracted from the import amount. Consumption for the production and maintenance is based on the bottom-up calculations*

*of stock as given in the example of mobile air conditioning in Annex A5.2 in FOEN 2024. A comparison to neighbouring countries shows higher stock and emissions from mobile air-conditioning in Switzerland. Model parameters were checked and a higher rate of air-conditioning of >95 % in vehicles is assumed plausible and is confirmed by companies dismantling vehicles.*

*Commercial and industrial refrigeration were evaluated together in former years. To obtain separate models, the total bulk refrigerant used for commercial and industrial applications is split based on the typical use of refrigerant blends and the available information on commercial and industrial equipment (Carbotech 2024). Parameters for commercial and industrial applications are given in Table 4 48. Furthermore, HFC-245fa, included under commercial and industrial refrigeration, was found to be used for organic rankine cycles (ORC).*

*The combination of bottom-up with top-down calculations leads to more comprehensive results than using just a single approach. Noteworthy, in the hypothetical but possible case of incomplete bottom-up evaluations, the remaining imported refrigerant would be attributed to the production and maintenance of industrial and commercial refrigeration equipment. This might be the reason why the resulting refrigerant stock of commercial and industrial refrigeration, which serves as the residual, tends to be higher than in neighbouring countries.*

*The import data as reported to FOEN are adjusted for imported substances to be used in Liechtenstein. This is to eliminate double counting with the inventory data of Liechtenstein. The split factor is based on the proportion of employees in the industrial and service sector (share of import for Liechtenstein <1 %). The adjustment does not affect the bottom-up calculations and leads to an adjustment of commercial and industrial refrigeration mainly.*

Table 4-6 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-32<br>HFC-125<br>HFC-134a<br>HFC-143a<br>$C_3F_8$ | Total emissions reported for Switzerland | Number of persons employed in industrial and service sector |
| Transport Refrigeration | HFC-125<br>HFC-134a<br>HFC-143a | Total emissions reported for Switzerland | Number of inhabitants |
| Industrial Refrigeration | Included in commercial refrigeration | | |
| Stationary Air Conditioning | HFC-32<br>HFC-125<br>HFC-134a<br>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 2024 (FOEN 2024), 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 of foam production have been calculated (Tier 1a) as residual balance between FOEN import statistics and consumption in PU spray, PU and XPS foams.*

*Desktop research on HFC-245fa use in neighbouring countries was carried out for the inventory 2019 to identify the relevance of HFC-245fa emissions from the import of foam products. HFC-245fa has not been used for foam blowing in Switzerland, but measurements at the Jungfraujoch site by Empa (see chp. 4.7.4 and Annex A6.1 in FOEN 2024) indicate emissions probably related to the import of foam products. Due to the low*

*relevance, lacking data and the decreasing use in neighbouring countries since 2005 (partly through bans) the model calculations were not extended with HFC-245fa (Carbotech 2024).*

**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 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 2024 (FOEN 2024), given below.

*The Tier 2a emission model for Aerosol / metered dose inhalers is based on a top-down approach using import statistics for HFCs until 2020 (end of Swiss production). The consumption was extrapolated for the time period 2021 to 2022 considering the development of HFC use of former years and the reported consumption of inhalers containing HFC in Switzerland (Carbotech, 2024).*

### 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 2024a). The following explanations are taken from Switzerland's National Inventory Report 2024 (FOEN 2024):

*Emission factors related to 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 and has been used partly for the verification of the quality (confidential data from retailers and other industries). The product life factors and further parameters (i.e. re-filling frequency, handling losses and reuse of refrigerant) are used to allocate imported F-gases to new products and maintenance activities.*

*The following table displays the detailed model parameters used for the present submission and values used in the early period of HFC use (1990 to 1995). For product life emission factors of some equipment types, a dynamic model is applied, which implies that emissions decreased 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 (Carbotech 2024, UBA 2005, UBA 2007, Schwarz 2001, Schwarz and Wartmann 2005). Constant emission factors were assumed from 2015 onwards. The charge at the end of life for different applications has been analysed considering the technical minimal charge of the equipment and the expected frequency of*

*the maintenance (UBA/Ökorecherche 2012). Disposal losses are calculated based on expert assumptions on the portion of broken equipment (100 % loss) and on assumptions on disposal losses for professional recovery on site or waste treatment by specialized companies.*

Table 4-7 Typical values of lifetime, charge and emission factors used in the model calculations for 1990 to 2022 for refrigeration and air conditioning equipment. Changes of model parameters within this time period are indicated giving the initial value considered in the early time period of F-gas use around 1995 and the value used for modelling for 2022 (decrease between 1995 and 2015, steady values from 2015 onwards). The reduction of charge and losses is the result of improvement of technology and handling of equipment (from FOEN 2024).

| | Product life time | HFC Stock 2022 | Composition of stock HFC/PFC | Initial charge of new product | Manufacturing emission factor | Product life emission factor | Disposal loss emission factor ***) | Charge at end of life *) | Export of retiring equipment **) |
|---|---|---|---|---|---|---|---|---|---|
| | [a] | [t] | Main products | [kg] | [% of initial charge] | [% per annum] | [% of remaining charge] | [% of initial charge of new product] | [% of retiring equipment] |
| Domestic refrigeration | 16 | 1 | HFC134a | 0.1 | NO | 0.5 | 19 ****) | 92.0 | <3 |
| Commercial refrigeration | 8 | 1'820 | R404a, R407C, R449a, R410a, R507, R422d, R448a | NR | 0.5 | 1995: 12.5<br>2022: 7.8 | 24 | 80-90 | NE |
| Industrial refrigeration | 15 | 480 | HFC134a, R410a, R407c, R404a, R422d, R507 | NR | 0.5 | 1995: 10<br>2022: 5 | 15 | 75-90 | NE |
| Transport refrigeration: trucks/vans | 10 | 55 | R404a, R134a | 1.8-7.8 | 1.5 | 15.0 | 28 | 86.0 | 90 |
| Transport refrigeration: wagons | 16 | | | NR | NO | 10.0 | 28 | 100.0 | NE |
| Stationary air conditioning: direct cooling systems | 15 | 2'415 | R410a, HFC134a, R407c, R404a, HFC32, R517a | NR | 1995: 3<br>2022: 1 | 1995:10<br>2022:4 | 28 | 74-89 | NE |
| Stationary air conditioning: indirect cooling systems | 15 | | | NR | 1.0 | 1995: 6<br>2022: 4 | 19 | 85-89 | NE |
| Stationary air conditioning: heat pumps | 15 | | | 1995: 4.7-7.5<br>2022: 2.8-4.5 | 1995: 3<br>2022: 1 | 2.0 | 19 | 86.0 | NE |
| Stationary air conditioning: tumble dryers | 15 | | HFC134a, R407c | 0.4 | 0.5 | 2.0 | 19 | 74.0 | NE |
| Mobile air conditioning: cars | 15 | 2'420 | HFC134a | 1995: 0.84<br>2022: 0.55 | NO | 8.5 | 50 | 58.0 | 1995: 31-72<br>2022: 48 |
| Mobile air conditioning: truck/van cabins | 12 | | | 1.1 | NO | 1995: 10<br>2022: 8.5 | 50 | 69-73 | 90 trucks / 50 vans |
| Mobile air conditioning: buses | 12 | | | 7.5 | NO | 1995: 20<br>2022:15 | 45 | 78.0 | 50 |
| Mobile air conditioning: trains | 16 | | | 20 | NO | 5.5 | 20 | 100.0 | 50 |

*) Calculated value taking into account annual loss and portion refilled over the whole product life where applicable.
**) Allocation of disposal losses to export country (export for reselling and secondhand use)
***) Calculated value taking into account share of total refrigerant loss and emission factor of professional disposal. Disposal losses occur from 2000 onwards (introduction of HFCs and PFCs starting 1991 and 8 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)
NE = Not estimated

### 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 2024a). The following explanations are taken from Switzerland's National Inventory Report 2024 (FOEN 2024):

*For the emission factors and the lifetimes of XPS and PU foams, expert estimates and default values according to the 2006 IPCC Guidelines (IPCC 2006, Volume 3, p. 7.37) are used. For PU sprays, 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 4-8 Typical values on lifetime, charge and emission factors used in model calculations for foam blowing (from FOEN 2024).

| **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 in Switzerland has been HFC-free.

** 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 2024a). The following explanations are taken from Switzerland's National Inventory Report 2023 (FOEN 2024):

*A manufacturing emission factor of 1 % is applied. The model then assumes prompt emissions, i.e. 50 % of the remaining substance is emitted in the first year and the rest in the second year, in line with the 2006 IPCC Guidelines (IPCC 2006).*

### 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 4-9 Figures used as indicators for calculation of activity data by applying rule of proportion.

| | 1990 | | 2023 | |
|---|---|---|---|---|
| **Number of households** | | | | |
| Liechtenstein | 10'556 | Source: National census 1990 (OEA 2010) | 18’294 | Source: National census 2010 with trend extrapolation (OEA 2010) |
| Switzerland | 2'841'850 | Source: National census 1990 (SFSO 2005) | 4'019’945 | Source: Population and Households Statistics (SFSO 2024e) |
| Conversion Factor CH→LIE | 0.371% | | 0.455% | |
| **Number of employees in industrial and service sector** | | | | |
| Liechtenstein | 19'554 | Source: Employment statistics Liechtenstein (OS 2024e) | 42’874 | Source: Employment statistics Liechtenstein (OS 2024e) |
| Switzerland | 3'658'406 | Source: Employment statistics Switzerland (SFSO 2024b) | 5'177’084 | Source: Employment statistics Switzerland (SFSO 2024b) |
| Conversion Factor CH→LIE | 0.534% | | 0.828% | |
| **Number of registered passenger cars** | | | | |
| Liechtenstein | 16'891 | Source: Statistical Yearbook Liechtenstein (OS 2024c) | 31’333 | Source: Statistical Yearbook Liechtenstein (OS 2024c) |
| Switzerland | 2'985'397 | Source: National motorcar statistics for Switzerland (SFSO 2024c) | 4'760’948 | Source: National motorcar statistics for Switzerland (SFSO 2024c) |
| Conversion factor CH→LIE | 0.566% | | 0.658% | |

#### 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 4-10 Figures used as indicator for calculation of activity data by applying rule of proportion (see also Table 4-4).

| Number of inhabitants in 2023 | | |
|---|---|---|
| Liechtenstein | 40’015 | Source: OS 2024d |
| Switzerland | 8'889’000 | Source: SFSO 2024d |
| Conversion Factor CHE→LIE | 0.450% | |

Emissions from the foam blowing subcategory from manufacturing and stocks have been declining since 2009.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 the number of inhabitants of Switzerland and Liechtenstein based on the methodology as described above. The figures as shown in Table 4-10 have been used as a proxy.

### 4.7.3 Uncertainties and time-series consistency

There is only one key category as determined by the CRT Reporter from this sector: 2F1/aggregate F-gases. The combined uncertainty is based data from the Swiss GHG inventory 2024 (FOEN 2024) for HFC, which were derived from a Monte Carlo simulation. It amounts to 14.2%. Since 99% of the F-gases emissions are caused by HFC, this value is applied.

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 entire time series.

### 4.7.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in section 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

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 $SF_6$. Therefore, it can be assumed that the notation key NO is correct for Liechtenstein.

### 4.7.5 Category-specific recalculations

Switzerland's GHG inventory 2025 was not yet available for Liechtenstein's submission 2025. For Switzerland, the following recalculations have been carried out in submission 2024, which also influence Liechtenstein's emission time series reported in Submission 2025:

- 2F1: Changes in portion of different refrigerants used for stationary refrigeration; changes in time period required for the complete elimination of HFC/PFC blends. Correction in the disposal amount, remaining charge at end of life. For further details see Carbotech (2024).
- 2F4: Aerosol in asthma spray, revision of activity data based on literature of asthma spray use in Switzerland (inhalers).

In addition, the following recalculations lead to changes in HFC and PFC emissions:

- 2F1 Refrigeration and air conditioning: Since the number of employees in industrial and service sector in Switzerland was updated based on newest available data (SFSO 2024b) the activity data (number of employees) has changed from 2010–2022.

In 2022, these recalculations lead to a decrease in HFC/PFC emissions of <0.01 kt $CO_2$eq.

### 4.7.6 Category-specific planned improvements

There are no category-specific planned improvements for the next submission.

# 4.8 Other product manufacture and use (2G)

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

Liechtenstein emission sources of 2G Other product manufacture and use are given in Table 4-11.

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

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

Source category 2G comprises emissions from SF6 in electrical equipment as well as $N_2O$ emissions from product applications hospitals (anaesthesia) and households (aerosol cans). Other emissions do 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 $SF_6$ emissions in Liechtenstein arise from the transformers operated by the utility Liechtensteinische Kraftwerke (LKW). The LKW reports on activity data and emissions with a Tier 3 method. A complete mass balance analysis is conducted by LKW on installation

level, which was reconfirmed by LKW in 2011. No production of equipment with $SF_6$ is occurring.

**$N_2O$ from product use**

Data availability in Liechtenstein is very limited. In order to 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 $N_2O$ from product use are documented in Annex A5.3.

### 4.8.2.2 Emission factors

**Electrical equipment**

Emission factors for this source category are based on industry information (LKW) and fluctuate over time due to differences in the gas imports per year, installations of F-gas equipment and differences in refill amounts of $SF_6$ gases (see Table 4-12).

**$N_2O$ from product use**

Emission factors for $N_2O$, which correspond to the specific emissions per inhabitant, are taken from Switzerland's national inventory database EMIS (FOEN 2024a). Specific emission factors are derived for 2G3a Medical applications and 2G3b Other propellant for pressure and aerosol products. Table 4-12 illustrates the resulting 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 manufacture and use of electrical equipment 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 2024a) are used as a proxy for Liechtenstein.

Table 4-12 Emission factors of Liechtenstein's $SF_6$ emissions under source category 2G1 and $N_2O$ emissions under 2G3 for the time series 1990–2023.

| Emission factors 2G Other product manufacture and use | 1990 | 1995 | 2000 | 2005 | 2010 | |
|---|---|---|---|---|---|---|
| 2G1 Electrical equipment - $SF_6$ product life factor (% per annum) | NO | NO | 0.360 | 0.403 | 0.033 | |
| 2G3 $N_2O$ from product uses - $N_2O$ (g/inhabitant) | 52.0 | 39.5 | 27.0 | 23.8 | 18.7 | |
| | | | | | | |
| **Emission factors 2G Other product manufacture and use** | **2014** | **2015** | **2016** | **2017** | **2018** | |
| 2G1 Electrical equipment - SF6 product life factor (% per annum) | 0.130 | 0.041 | 0.016 | 0.049 | 0.074 | |
| 2G3 $N_2O$ from product uses - $N_2O$ (g/inhabitant) | 14.8 | 14.0 | 12.8 | 12.3 | 12.3 | |
| | | | | | | |
| **Emission factors 2G Other product manufacture and use** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023 %** |
| 2G1 Electrical equipment - SF6 product life factor (% per annum) | 0.050 | 0.057 | 0.054 | 0.071 | 0.016 | - |
| 2G3 $N_2O$ from product uses - $N_2O$ (g/inhabitant) | 12.2 | 12.2 | 12.2 | 12.3 | 12.2 | -77% |

### 4.8.2.3 Activity data

Table 4-4 illustrates the numbers of inhabitants of Liechtenstein and Switzerland for the entire time series. The number of inhabitants is used to derive Liechtenstein's activity data under source category 2G3.

Table 4-13 Activity data of source category 2G Other product manufacture and use. (Number of inhabitants see also Table 4-4.)

| Activity data 2G Other product manufacture and use | 1990 | 1995 | 2000 | 2005 | 2010 | |
|---|---|---|---|---|---|---|
| 2G1 Electrical equipment - $SF_6$ amount in operating systems (average annual stocks) in kt | NO | NO | 0.0011 | 0.0028 | 0.0031 | |
| 2G3 $N_2O$ from product uses - number of inhabitants | 29'032 | 30'923 | 32'863 | 34'905 | 36'149 | |
| | | | | | | |
| **Emission factors 2G Other product manufacture and use** | **2014** | **2015** | **2016** | **2017** | **2018** | |
| 2G1 Electrical equipment - $SF_6$ amount in operating systems (average annual stocks) in kt | 0.0039 | 0.0040 | 0.0040 | 0.0040 | 0.0041 | |
| 2G3 $N_2O$ from product uses - number of inhabitants | 37'366 | 37'623 | 37'810 | 38'114 | 38'380 | |
| | | | | | | |
| **Emission factors 2G Other product manufacture and use** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023 %** |
| 2G1 Electrical equipment - $SF_6$ amount in operating systems (average annual stocks) in kt | 0.0041 | 0.0041 | 0.0042 | 0.0042 | 0.0043 | - |
| 2G3 $N_2O$ from product uses - number of inhabitants | 38'749 | 39'055 | 39'315 | 39'677 | 40'015 | 38% |

#### Electrical equipment

Activity data is based on industry information. Before 1995/1996 a different technology was applied, which did not use $SF_6$ (see Table 4-13). $SF_6$ emissions show an increasing trend. Since only one company is involved (LKW), individual changes in emissions become evident. Variability could also be a result of changing reporting periods and/or changes (reductions) in actual maintenance and repair interventions.

**$N_2O$ from product use & Other**

The activity data is the number of inhabitants in Liechtenstein and is provided in Table 4-4. The number of inhabitants in Liechtenstein is taken from OS 2024d. Data on the Swiss inhabitants (see Table 4-9) are taken from SFSO 2024d.

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

The time series are consistent.

### 4.8.4 Category-specific QA/QC and verification

The category-specific QA/QC activities have been carried out as mentioned in section 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

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

### 4.8.5 Category-specific recalculations

No category-specific recalculations were carried out.

### 4.8.6 Category-specific planned improvements

No category-specific improvements are planned.

## 4.9 Other (2H)

### 4.9.1 Category description: Other (2H)

Emissions from category 2H are not occurring in Liechtenstein.

# 5. Agriculture (CRT sector 3)

## 5.1 Overview of sector

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

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

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

Liechtenstein's emissions within sector 3 Agriculture are calculated according to the Swiss agriculture model. The ERT 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 of the model are revised at 5-year 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 (see planned improvements in chp. 10.4). The latest update has been conducted for the current submission 2025. Note that the nitrogen flow model AGRAMMON has not been changed. An update of the AGRAMMON model is underway. The new AGRAMMON model will be included in the agriculture model of Liechtenstein's NID when available (within a feasible timespan).

Greenhouse gas emissions from agriculture amount to 24.2 kt $CO_2$ equivalents in 2023, which is a contribution of 14.5% to the total of Liechtenstein's greenhouse gas emissions (excluding LULUCF). Main agricultural sources of greenhouse gases in 2023 were enteric fermentation emitting 15.9 kt $CO_2$eq, followed by agricultural soils with 4.2 kt $CO_2$eq, manure management with 4.1 kt $CO_2$eq and urea application with 0.04 kt $CO_2$eq. Overall emissions from agriculture decreased by 2.4% between 1990 and (see Table 5-1 and Figure 5-1). A period of decreasing emissions between 1990–2000 turned into an increasing trend from 2001–2008. From 2009 on, emissions are fluctuating without showing a clear trend. Compared to the previous reporting year (2022), emissions have remained constant (+0.1%).

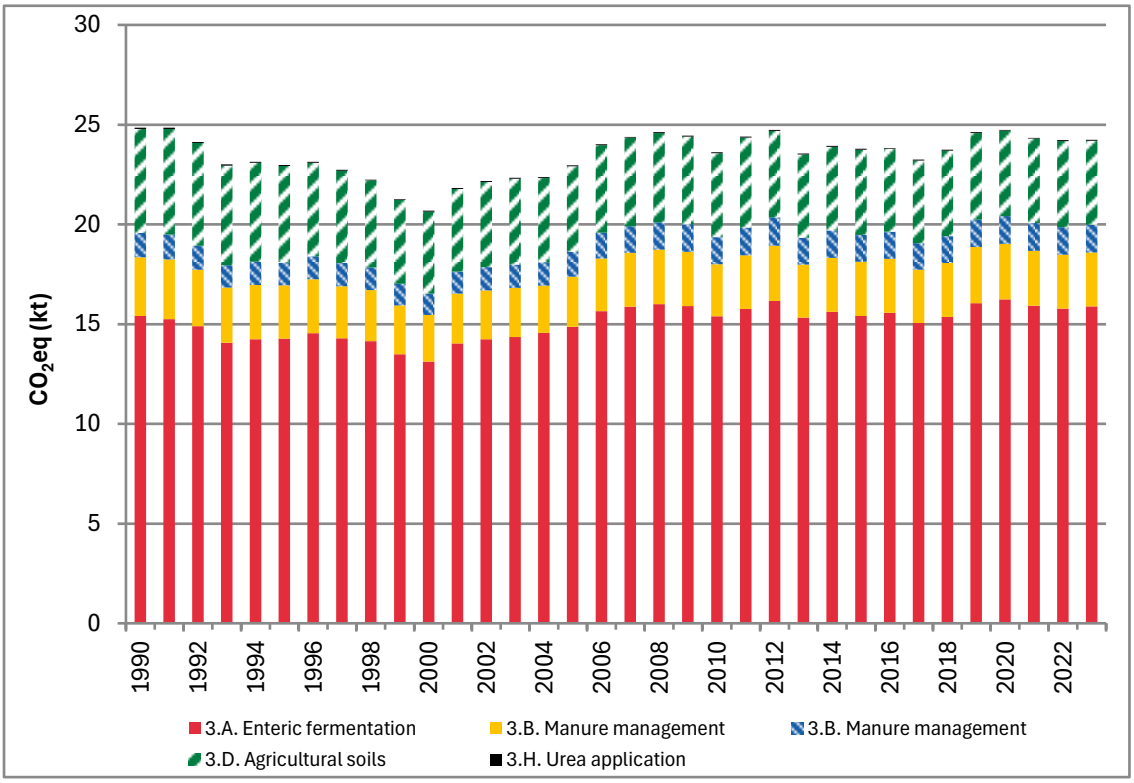



Figure 5-1 Liechtenstein's GHG emissions of the sector 3 Agriculture by sub-sectors. Note that emissions in sub-sectors 3C, 3E, 3F, 3G, 3I are not occurring.

Table 5-1 shows the emission trends for $CO_2$, $CH_4$ and $N_2O$ within sector 3 Agriculture. $CO_2$ emissions, which originate from urea application only, decreased by 27.1% in 2023 compared to 1990. The development of urea application is similar as in Switzerland (see Swiss inventory, FOEN 2024, chp. 5.1). $CH_4$ emissions are slightly above 1990 levels (+1.3%). $N_2O$ emissions decreased by 12.9% between 1990 and 2023. Both, $CH_4$ and $N_2O$ emissions, are highly dependent on the development and the shares of different animal populations (see also Figure 5-5).

Table 5-1 GHG emissions of sector 3 Agriculture by gas in $CO_2$ equivalent (kt) and the relative change since 1990 (last column).

| Gas | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | |
| $CO_2$ | 0.06 | 0.05 | 0.05 | 0.05 | 0.04 |
| $CH_4$ | 18.36 | 16.95 | 15.46 | 17.38 | 18.00 |
| $N_2O$ | 6.43 | 5.98 | 5.18 | 5.54 | 5.58 |
| **Sum** | **24.85** | **22.98** | **20.69** | **22.97** | **23.62** |

| Gas | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | |
| $CO_2$ | 0.04 | 0.05 | 0.04 | 0.04 | 0.05 |
| $CH_4$ | 18.33 | 18.13 | 18.28 | 17.74 | 18.07 |
| $N_2O$ | 5.57 | 5.62 | 5.51 | 5.47 | 5.62 |
| **Sum** | **23.94** | **23.80** | **23.83** | **23.25** | **23.74** |

| Gas | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt) | | | | | % |
| $CO_2$ | 0.05 | 0.04 | 0.04 | 0.05 | 0.04 | -27.1% |
| $CH_4$ | 18.86 | 19.03 | 18.68 | 18.48 | 18.60 | 1.3% |
| $N_2O$ | 5.71 | 5.67 | 5.62 | 5.70 | 5.60 | -12.9% |
| **Sum** | **24.62** | **24.75** | **24.34** | **24.22** | **24.24** | **-2.4%** |

There are three key categories of the inventory belonging to the sector 3 Agriculture (key category analysis excluding LULUCF categories). Those categories are displayed in Figure 5-2, including emission levels for the base year 1990 and the reporting year 2023.

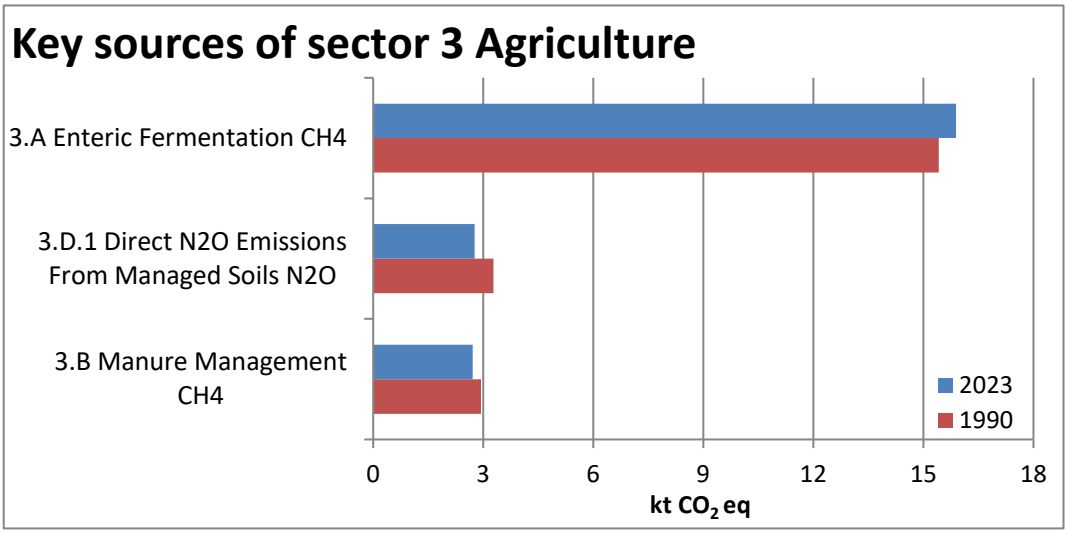



Figure 5-2 Key categories from agriculture (KCA excl. LULUCF). Emissions in $CO_2$ equivalents (kt) per key source category in 2023 and in the base year 1990.

## 5.2 Enteric fermentation (3A)

### 5.2.1 Category description: Enteric fermentation (3A)

**Key category information 3A**

$CH_4$ emissions from 3A Enteric fermentation are a key category by level and trend (KCA excluding LULUCF categories).

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

As illustrated in Figure 5-1, $CH_4$ emissions from source category 3A Enteric fermentation have decreased between 1990 and 2000 and then increased again from 2001 to 2012. From then on, emissions show fluctuations without a clear trend. The emission development is highly correlated with 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 (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<br>Other mature cattle<br>Growing cattle (fattening calves, pre-weaned calves, breeding cattle 1st year, breeding cattle 2nd year, breeding cattle 3rd year, fattening cattle) |
| 3A2 | Sheep | Fattening sheep<br>Milksheep |
| 3A3 | Swine | Swine |
| 3A4a | Goats | Goats |
| 3A4b | Horses | Horses < 3 years<br>Horses > 3 years |
| 3A4c | Mules and Asses | Mules and Asses |
| 3A4d | Poultry | Poultry |

## 5.2.2 Methodological issues: Enteric fermentation (3A)

As for previous submissions, Liechtenstein adopted the methodology of Switzerland (see chp. 5.1) to calculate emissions originating from source category 3A Enteric fermentation.

For mature dairy cattle a detailed Tier 3 model approach is applied, predicting gross energy intake by the means of a feeding model that takes into account animal performance and diet bio-chemical composition. A country-specific methane conversion rate ($Y_m$) was derived from a series of studies representing Swiss specific feeding conditions.

Emission estimation for all other cattle categories follows a Tier 2 approach. This means that detailed country-specific data on nutrient requirements and feed intake were used. $CH_4$ conversion rates were taken from the 2019 IPCC Refinement (IPCC 2019) to the 2006 IPCC Guidelines (IPCC 2006).

Methods for all other animal categories are based on a Tier 2 approach, estimating country-specific energy intake rates. Methane conversion rates were taken from the 2019 IPCC Refinement, the 2006 IPCC Guidelines or from published peer reviewed literature.

Activity data used for estimating emissions from 3A Enteric fermentation is country specific.

### 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 2024 (FOEN 2024, p. 264). The method is based on the IPCC equation 10.21 (IPCC 2019):

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

Where:

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

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

$Y_m$ = methane conversion rate: fraction of gross energy in feed converted to $CH_4$ (%)

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 A5.2.

**Gross energy intake (GE) (compare FOEN 2024, page 264ff)**

For calculating the gross energy intake (GE), country-specific methods based on available data on requirements of net energy, digestible energy and metabolisable energy were used. The different energy levels used for energy conversion from energy required for maintenance and production to GE intake are illustrated in Figure 5-3. 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, requirements for each cattle category were calculated individually following the feeding recommendations for Switzerland provided in RAP (1999) and Morel et al. (2017). 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.

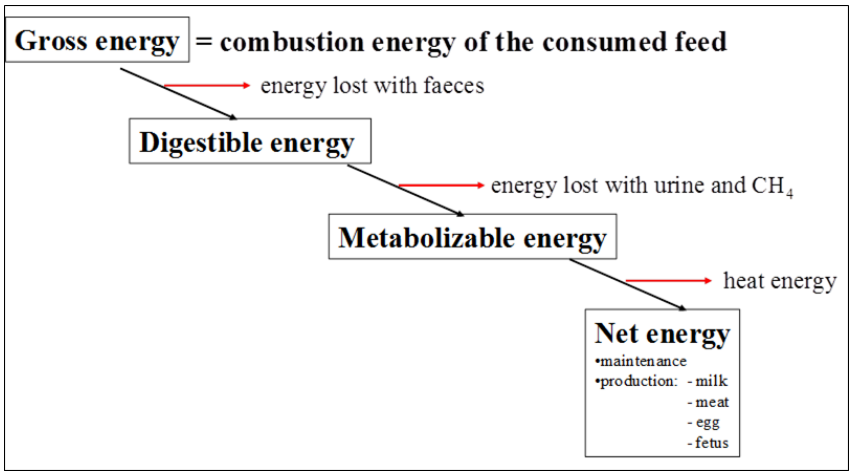



Figure 5-3 Levels of feed energy conversion (Soliva 2006a).

Table 5-3 Conversion factors used for the calculation of energy requirements of individual livestock categories (Soliva 2006). 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 | 0.339 |
| Other Mature Cattle | | NEL to GE | 0.265 |
| Growing Cattle | *Fattening Calves* | *ME to GE* | 0.939 |
| | *Pre-Weaned Calves* | *NEL to GE* | 0.299 |
| | *Breeding Cattle 1st Year* | *NEL to GE* | 0.332 |
| | *Breeding Cattle 2nd Year* | *NEL to GE* | 0.313 |
| | *Breeding Cattle 3rd Year* | *NEV to GE* | 0.313 |
| | *Fattening Cattle* | *NEV to GE* | 0.383 |
| Sheep | *Fattening Sheep* | *NEV to GE* | 0.350 |
| | *Milksheep* | *NEL to GE* | 0.287 |
| Swine | | DE to GE | 0.682 |
| Goats | | NEL to GE | 0.283 |
| Horses | | DE to GE | 0.700 |
| Mules and Asses | | DE to GE | 0.700 |
| Poultry | | ME to GE | 0.700 |

Gross energy intake of **mature dairy cattle** is primarily dependent on animal performance, i.e. body weight and milk yield. Accordingly, the respective GE was assessed with a detailed model within the Swiss GHG inventory (Agroscope 2014c). Using the respective model outputs, a simple linear regression equation was 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 5-4 includes only milk yield as driving parameter:

milk production per head per year:
GE = 0.0236 MJyr/kg/day * Milk + 142.42 MJ/head/day

Where:

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

Milk = amount of milk produced (kg/head/year)

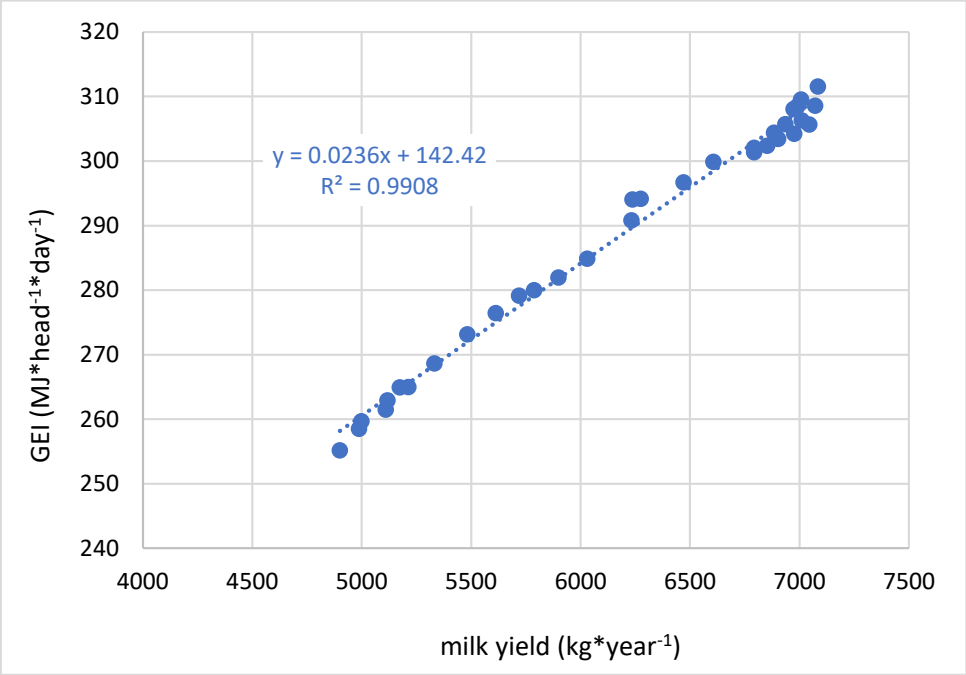



Figure 5-4 Linear regressions relating gross energy intake (GE) to milk yield for mature dairy cattle for Switzerland (based on FOEN 2024).

In Liechtenstein, 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 7’095 kg per head and year in 2023 (23.26 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 of the Office of Environment. 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. 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 the two months when cows are dry).

| **Milk Production Cattle** | | **1990** | **1995** | **2000** | **2005** | **2010** |
|---|---|---|---|---|---|---|
| Population Size Mature Dairy Cattle | head | 2'850 | 2'643 | 2'440 | 2'489 | 2'425 |
| Lactation Period | day | 305 | 305 | 305 | 305 | 305 |
| Milk Yield Mature Dairy Cattle | kg/head/day | 18.99 | 19.19 | 20.72 | 22.24 | 21.87 |
| Milk Yield Other Mature Cattle | kg/head/day | 8.20 | 8.20 | 8.20 | 8.20 | 8.20 |
| | | | | | | |
| **Milk Production Cattle** | | **2014** | **2015** | **2016** | **2017** | **2018** |
| Population Size Mature Dairy Cattle | head | 2'367 | 2'299 | 2'232 | 2'246 | 2'271 |
| Lactation Period | day | 305 | 305 | 305 | 305 | 305 |
| Milk Yield Mature Dairy Cattle | kg/head/day | 22.16 | 22.73 | 23.09 | 23.15 | 23.55 |
| Milk Yield Other Mature Cattle | kg/head/day | 8.20 | 8.20 | 8.20 | 8.20 | 8.20 |
| | | | | | | |
| **Milk Production Cattle** | | **2019** | **2020** | **2021** | **2022** | **2023** |
| Population Size Mature Dairy Cattle | head | 2'332 | 2'311 | 2'231 | 2'194 | 2'187 |
| Lactation Period | day | 305 | 305 | 305 | 305 | 305 |
| Milk Yield Mature Dairy Cattle | kg/head/day | 24.53 | 24.09 | 23.74 | 23.36 | 23.26 |
| Milk Yield Other Mature Cattle | kg/head/day | 8.20 | 8.20 | 8.20 | 8.20 | 8.20 |

For **other mature cattle** and **growing cattle** Liechtenstein determines GE based on the same approach as Switzerland. The method is based on the feeding requirements according to RAP (1999) and Morel et al. (2017). In the calculation of the net energy (NE), 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). See Figure 5-3 and Table 5-3 for more details on NEL and NEV.

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 (Morel et al. 2017).

The gross energy intake of **growing cattle** corresponds to the weighted average GE of all sub-categories displayed in Table 5-5 (in italics). No methane is generated from milk. Energy intake from milk or milk products is still considered when estimating methane emission factors from enteric fermentation of calves. The GE for all six sub-categories are constant over time and based on the respective estimates in the Swiss Inventory (FOEN 2024. 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 5-7), the average gross energy intake for growing cattle also changes slightly.

Table 5-5 Gross energy intake per head of different livestock groups. Disaggregated categories not contained in the CRT-Tables are displayed in italic.

| Gross Energy Intake | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| | MJ/head/day | | | | | | | |
| Cattle | 640.8 | 639.5 | 650.1 | 659.6 | 657.5 | 659.4 | 663.0 | 667.3 |
| Mature Dairy Cattle | 279.1 | 280.5 | 291.6 | 302.5 | 299.8 | 301.9 | 306.0 | 308.6 |
| Other Mature Cattle | 250.6 | 250.6 | 250.6 | 250.6 | 250.6 | 250.6 | 250.6 | 250.6 |
| Growing Cattle (weighted average) | 111.1 | 108.4 | 107.9 | 106.5 | 107.0 | 106.9 | 106.4 | 108.1 |
| *Fattening Calves* | *47.1* | *47.1* | *47.1* | *47.1* | *47.1* | *47.1* | *47.1* | *47.1* |
| *Pre-Weaned Calves* | *60.1* | *60.1* | *60.1* | *60.1* | *60.1* | *60.1* | *60.1* | *60.1* |
| *Breeding Cattle 1st Year* | *75.4* | *75.4* | *75.4* | *75.4* | *75.4* | *75.4* | *75.4* | *75.4* |
| *Breeding Cattle 2nd Year* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* |
| *Breeding Cattle 3rd Year* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* |
| *Fattening Cattle* | *103.7* | *103.7* | *103.7* | *103.7* | *103.7* | *103.7* | *103.7* | *103.7* |
| Sheep | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 |
| Swine | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 |
| Goats | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 |
| Horses (weighted average) | 107.5 | 107.7 | 108.0 | 108.2 | 108.3 | 108.3 | 108.2 | 108.5 |
| *Horses <3 years* | *101.4* | *101.4* | *101.4* | *101.4* | *101.4* | *101.4* | *101.4* | *101.4* |
| *Horses >3 years* | *109.0* | *109.0* | *109.0* | *109.0* | *109.0* | *109.0* | *109.0* | *109.0* |
| Mules and Asses | 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 |

| Gross Energy Intake | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|
| | MJ/head/day | | | | | | |
| Cattle | 666.0 | 668.9 | 675.7 | 673.5 | 670.8 | 668.6 | 667.5 |
| Mature Dairy Cattle | 309.0 | 312.0 | 319.0 | 315.8 | 313.3 | 310.5 | 309.9 |
| Other Mature Cattle | 250.6 | 250.6 | 250.6 | 250.6 | 250.6 | 250.6 | 250.6 |
| Growing Cattle (weighted average) | 106.4 | 106.3 | 106.1 | 107.1 | 106.9 | 107.5 | 107.0 |
| *Fattening Calves* | *47.1* | *47.1* | *47.1* | *47.1* | *47.1* | *47.1* | *47.1* |
| *Pre-Weaned Calves* | *60.1* | *60.1* | *60.1* | *60.1* | *60.1* | *60.1* | *60.1* |
| *Breeding Cattle 1st Year* | *75.4* | *75.4* | *75.4* | *75.4* | *75.4* | *75.4* | *75.4* |
| *Breeding Cattle 2nd Year* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* |
| *Breeding Cattle 3rd Year* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* | *143.6* |
| *Fattening Cattle* | *103.7* | *103.7* | *103.7* | *103.7* | *103.7* | *103.7* | *103.7* |
| Sheep | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 |
| Swine | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 | 28.1 |
| Goats | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 |
| Horses (weighted average) | 108.6 | 108.6 | 108.5 | 108.5 | 108.6 | 108.8 | 108.7 |
| *Horses <3 years* | *101.4* | *101.4* | *101.4* | *101.4* | *101.4* | *101.4* | *101.4* |
| *Horses >3 years* | *109.0* | *109.0* | *109.0* | *109.0* | *109.0* | *109.0* | *109.0* |
| Mules and Asses | 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) Poultry data is not Gross Energy intake (GE) but Metabolizable Energy intake (ME)

Energy requirements and GE intake of **sheep, swine, goats** and **poultry** were obtained from the respective estimates of the Swiss Farmers Union (SBV 2018, Giuliani 2018). 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 2024 page 269)

For the methane conversion rate ($Y_m$), few country-specific data exist. The same approach as in the Swiss inventory was applied for all animal categories. All values for $Y_m$ for the different livestock categories and the corresponding data sources are shown in Table 5-6.

Table 5-6 Methane conversion rates ($Y_m$) for different livestock groups in 2023. Disaggregated categories are displayed in italic.

| Livestock category | Methane conversion rate ($Y_m$) | Sources |
|---|---|---|
| Cattle | | |
| Mature Dairy Cattle | 6.9% | Adopted based on a series of measurements conducted under Swiss specific feeding and husbandry conditions at the Federal Institute of Technology in Zurich (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)) |
| Other Mature Cattle | 6.5% | Table 10.12 in IPCC (2019) |
| Growing Cattle | 6.1% | Weighted average |
| *Fattening Calves* | *0.0%* | *Based on Tables 10.12 and 10A.2 in IPCC (2019) (where suitable, weighted averages)* |
| *Pre-Weaned Calves* | *4.0%* | |
| *Breeding Cattle 1st Year* | *6.3%* | |
| *Breeding Cattle 2nd Year* | *6.3%* | |
| *Breeding Cattle 3rd Year* | *6.3%* | |
| *Fattening Cattle* | *6.4%* | |
| Sheep | 5.8% | Weighted according to the population structure of Switzerland due to missing data on the sheep population structure in Liechtenstein |
| *Lambs < 1 year* | *4.5%* | *Table 10.13 in IPCC (2006)* |
| *Mature sheep* | *6.5%* | *Table 10.13 in IPCC (2019)* |
| Swine | 0.6% | Crutzen et al. (1986) and Minonzio et al. (1998) |
| Goats | 5.5% | Martínez-Fernández et al. (2014) and Fernández et al. (2013) |
| Horses | 2.45% | 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) |
| Mules and Asses | 2.45% | |
| Poultry | 0.16% | Country-specific value (Switzerland) evaluated in an in vivo trial with broilers (Hadorn and Wenk 1996) |

For fattening calves, a methane conversion rate of 0% is applied. According to IPCC (2006), this is suitable for fattening calves which are fully fed with milk. Some small amounts of roughage may be administered towards the end of the fattening period. However, methane production from this roughage is considered minimal as the animals are generally barely capable to digest it. Accordingly, the $CH_4$ conversion rate ($Y_m$) of 0% is adequate.

#### 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 of the Office of Environment. Annual data are available for the livestock categories mature dairy cattle, sheep, goats and swine 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 5-7.

Table 5-7 Activity data for Liechtenstein (data sources: Division of Agriculture).

| **Population size** | **1990** | **1995** | **2000** | **2005** | **2010** | **2014** | **2015** | **2016** |
|---|---|---|---|---|---|---|---|---|
| | 1000 head | | | | | | | |
| Cattle | 6.33 | 5.86 | 4.95 | 5.57 | 5.99 | 6.21 | 6.03 | 6.23 |
| Mature Dairy Cattle | 2.85 | 2.64 | 2.44 | 2.49 | 2.43 | 2.37 | 2.30 | 2.23 |
| Other Mature Cattle | 0.02 | 0.05 | 0.07 | 0.36 | 0.38 | 0.45 | 0.47 | 0.41 |
| Growing Cattle (weighted average) | 3.46 | 3.17 | 2.43 | 2.72 | 3.19 | 3.40 | 3.27 | 3.59 |
| *Fattening Calves* | *0.05* | *0.08* | *0.11* | *0.08* | *0.08* | *0.08* | *0.08* | *0.08* |
| *Pre-Weaned Calves* | *0.02* | *0.04* | *0.01* | *0.27* | *0.28* | *0.33* | *0.34* | *0.30* |
| *Breeding Cattle 1st Year* | *1.14* | *1.06* | *0.65* | *0.60* | *0.81* | *0.88* | *0.83* | *0.98* |
| *Breeding Cattle 2nd Year* | *0.90* | *0.70* | *0.54* | *0.68* | *0.81* | *0.87* | *0.82* | *0.97* |
| *Breeding Cattle 3rd Year* | *0.63* | *0.58* | *0.34* | *0.35* | *0.46* | *0.49* | *0.47* | *0.55* |
| *Fattening Cattle* | *0.72* | *0.73* | *0.77* | *0.74* | *0.74* | *0.75* | *0.73* | *0.70* |
| Sheep | 2.78 | 2.63 | 2.98 | 3.06 | 3.66 | 3.58 | 3.89 | 4.05 |
| Swine | 3.25 | 2.43 | 1.99 | 1.70 | 1.69 | 1.71 | 1.75 | 1.79 |
| Goats | 0.17 | 0.15 | 0.16 | 0.32 | 0.43 | 0.28 | 0.29 | 0.33 |
| Horses (weighted average) | 0.17 | 0.16 | 0.16 | 0.27 | 0.34 | 0.31 | 0.30 | 0.27 |
| *Horses <3 years* | *0.03* | *0.03* | *0.02* | *0.03* | *0.03* | *0.03* | *0.03* | *0.02* |
| *Horses >3 years* | *0.13* | *0.14* | *0.14* | *0.24* | *0.30* | *0.28* | *0.27* | *0.25* |
| Mules and Asses | 0.07 | 0.13 | 0.22 | 0.14 | 0.15 | 0.18 | 0.16 | 0.17 |
| Poultry | 4.44 | 6.25 | 8.06 | 10.45 | 12.92 | 12.68 | 12.50 | 12.83 |

| **Population size** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022** | **2023** | **1990-2023** |
|---|---|---|---|---|---|---|---|---|
| | 1000 head | | | | | | | % |
| Cattle | 5.79 | 5.89 | 6.12 | 6.39 | 6.27 | 6.27 | 6.35 | 0.3% |
| Mature Dairy Cattle | 2.25 | 2.27 | 2.33 | 2.31 | 2.23 | 2.19 | 2.19 | -23% |
| Other Mature Cattle | 0.43 | 0.45 | 0.49 | 0.48 | 0.50 | 0.47 | 0.52 | 2485% |
| Growing Cattle (weighted average) | 3.11 | 3.17 | 3.30 | 3.60 | 3.55 | 3.61 | 3.64 | 5% |
| *Fattening Calves* | *0.08* | *0.08* | *0.08* | *0.08* | *0.08* | *0.07* | *0.07* | 46% |
| *Pre-Weaned Calves* | *0.32* | *0.33* | *0.36* | *0.36* | *0.36* | *0.35* | *0.38* | 2433% |
| *Breeding Cattle 1st Year* | *0.79* | *0.80* | *0.83* | *0.95* | *0.94* | *0.97* | *0.97* | -15% |
| *Breeding Cattle 2nd Year* | *0.78* | *0.79* | *0.82* | *0.94* | *0.93* | *0.96* | *0.96* | 6% |
| *Breeding Cattle 3rd Year* | *0.44* | *0.45* | *0.47* | *0.53* | *0.53* | *0.55* | *0.55* | -14% |
| *Fattening Cattle* | *0.71* | *0.72* | *0.75* | *0.74* | *0.72* | *0.71* | *0.72* | -1% |
| Sheep | 4.12 | 3.99 | 3.88 | 3.83 | 4.23 | 4.44 | 4.46 | 60% |
| Swine | 1.88 | 1.77 | 1.72 | 1.47 | 1.63 | 1.56 | 1.49 | -54% |
| Goats | 0.36 | 0.43 | 0.43 | 0.51 | 0.54 | 0.50 | 0.50 | 189% |
| Horses (weighted average) | 0.26 | 0.24 | 0.25 | 0.24 | 0.23 | 0.24 | 0.24 | 46% |
| *Horses <3 years* | *0.01* | *0.01* | *0.02* | *0.01* | *0.01* | *0.01* | *0.01* | -70% |
| *Horses >3 years* | *0.24* | *0.23* | *0.24* | *0.22* | *0.21* | *0.23* | *0.23* | 74% |
| Mules and Asses | 0.16 | 0.23 | 0.22 | 0.23 | 0.23 | 0.22 | 0.21 | 193% |
| Poultry | 12.46 | 12.92 | 15.01 | 15.44 | 20.64 | 20.70 | 20.66 | 366% |

Total number of cattle decreased by about a fifth between 1990 and the beginning of the new millennium, grew again between 2000 and 2012 and from then on has stabilised with slight fluctuations. Other mature cattle have grown in number due to an increasing meat demand from extensive livestock production. Swine population has decreased with one drastic drop between 2003 and 2004 caused by a disease. The increase in the poultry population between 1990 and 2007 is a result of two new poultry farms that were established in Liechtenstein. Another poultry farm was established in 2020, which explains

the increase of poultry in 2021. Figure 5-5 illustrates the development of the sizes of Liechtenstein's animal populations.

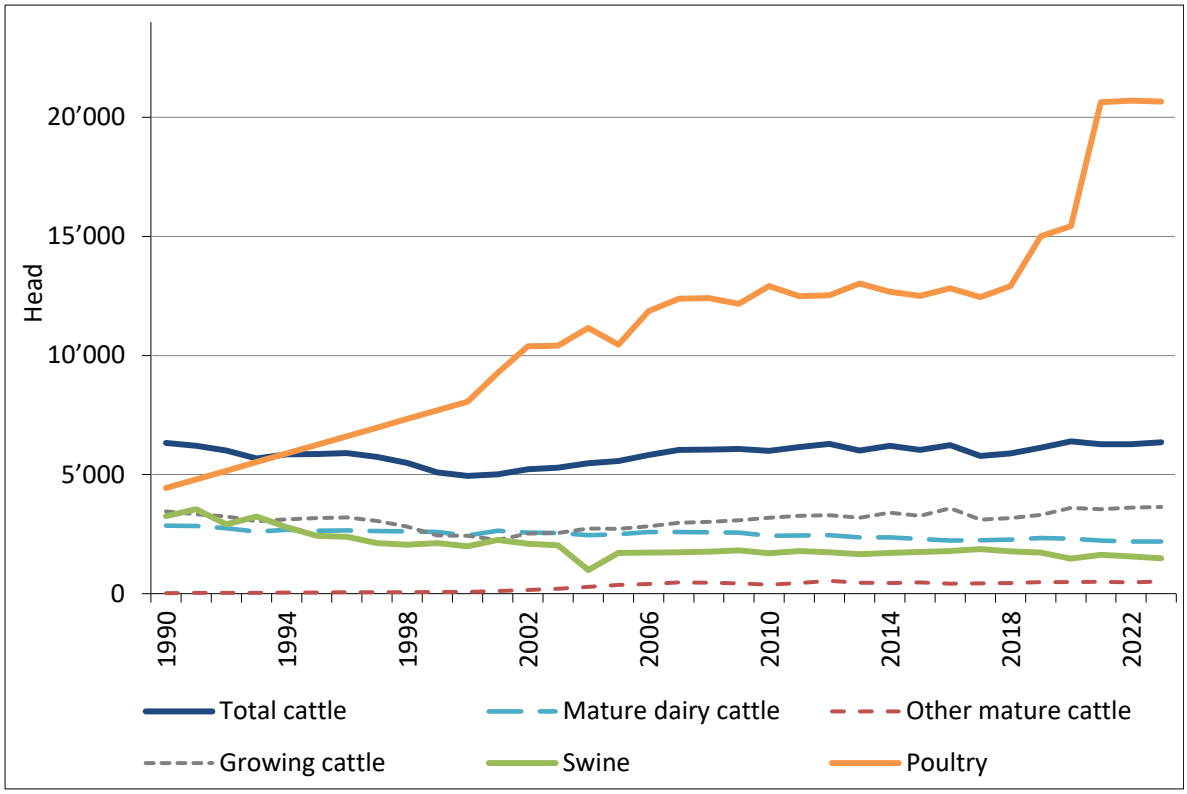



Figure 5-5 Development of population size of main animal categories (Division of Agriculture).

### 5.2.3 Uncertainties and time-series consistency

Uncertainties of emission factors and activity data are taken from ART (2008) and 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 (FOEN 2024) and completed with default uncertainties from the 2019 IPCC Refinement (IPCC 2019). The arithmetic mean of the lower and upper bound uncertainty was used for activity data (6.5%) and for emission factors (19.2%), resulting in a combined uncertainty of 20.3% for Approach 1 analysis.

The time series 1990–2023 are consistent. 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 1.5 including triple checks of Liechtenstein's reporting tables (CRT tables). The triple check includes a detailed comparison of current and previous submission data for the base year 1990 and for the year 2022 as well as an analysis of the increase or decrease of emissions between 2022 and 2023 in the current submission.

In addition to the overall triple check a separate internal technical documentation of Liechtenstein's model is available (Bretscher 2019, in German only). For model updates, separate documentations exist (for the update in Submission 2025: Bretscher 2024). The manual and documentations ensure transparency and traceability 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 2024). The respective conclusions are equally valid for Liechtenstein since the methods used are an adaptation of the Swiss model version. Bottom-up inventory estimates in Switzerland agree well with several atmospherically $CH_4$ measurements, thus verifying the methodological approach applied in the inventory.

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

### 5.2.5 Category-specific recalculations

The following recalculations lead to changes in $CH_4$ emissions, resulting in an increase of 0.03 kt $CO_2$eq in 2022:

- 3A: $CH_4$ emissions from enteric fermentation of growing cattle, other mature cattle and goats were recalculated for the whole time series. New methane conversion rates ($Y_m$) were adopted from the 2019 IPCC Refinement (IPCC 2019). Overall emissions declined by -73.8 t $CO_2$eq on average.
- 3A: $CH_4$ emissions from enteric fermentation of sheep were recalculated for the years 2015–2022 due to an adjustment of the methane conversion rate ($Y_m$, affecting IEF). The weighting of the methane conversion rates for adult and young sheep was adjusted based on new consistent time series of the number of young sheep in Switzerland. The mean impact on overall emissions was -29.1 t $CO_2$eq for the period 2015–2022.
- 3A: The data does not show a difference in milk yields depending on the wight of mature dairy cattle. Accordingly, gross energy intake (GE) was not calculated anymore based on two linear regressions (for mature dairy cattle below or above 6'030 kg weight, respectively). Instead, a single linear regression was used to calculate GE (see chp. 5.2.2.1). This recalculation has no impact on nitrogen excretion.

### 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 latest update has been done for the submission 2025.

## 5.3 Manure management (3B)

### 5.3.1 Category description: Manure management (3B)

**Key category information 3B**

$CH_4$ emissions from 3B Manure Management are a key category by level and trend (KCA excluding LULUCF categories).

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 5-8). Five ($CH_4$) respectively four ($N_2O$) different manure management systems are considered including indirect $N_2O$ emissions from manure management (see Table 5-9). The total emissions from source category 3B Manure management closely follow the development of the cattle population. Most significant contributors to $CH_4$ emissions in 2023 are cattle with approximately 85%. To $N_2O$ emissions, cattle and sheep contribute significant shares of around 70% and 17%, respectively (direct emissions only). Approximately 62% of the total $N_2O$ emissions attributed to source category 3B Manure management originate from indirect $N_2O$ emissions.

Table 5-8 Specification of source category 3B Manure Management according to livestock.

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

Table 5-9 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 in previous submissions, 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 2019 IPCC Refinement ($CH_4$: IPCC 2019 equation 10.23; $N_2O$: IPCC 2019 equation 10.25).

$CH_4$ emissions from Manure management were generally estimated using a Tier 2 methodology. For cattle a more detailed method was applied, estimating volatile solids (VS) excretion based on gross energy intake estimates as used for Enteric fermentation. Methane conversion factors (MCF) are from IPCC (2019; solid storage, pasture range and paddock, anaerobic digesters, poultry manure), from country-specific data sources (deep bedding) or were modelled according to Mangino et al. (2001) (liquid systems, anaerobic digesters).

$N_2O$ emissions from source category 3B Manure management were estimated using a country-specific Tier 3 methodology (adopted from Switzerland). Activity data used for estimating the emissions is collected specifically for Liechtenstein (see Table 5-10, Table 5-7, and additional information below). Detailed country-specific data on nitrogen excretion rates, manure management system distribution and nitrogen volatilisation were applied in accordance with the Swiss inventory. Emission factors for direct $N_2O$ emissions are based on IPCC (2019) and Kupper 2017. The emission factor for indirect emissions from atmospheric deposition is based on Bühlmann et al. (2015) and Bühlmann (2014).

The $N_2O$ emissions from pasture, range and paddock are reported under 3D Agricultural soils, source category 3Da3 (Urine and dung deposited by grazing animals).

For the calculation of $CH_4$ and $N_2O$ emissions, slightly different livestock sub-categories were used (see Table 5-10). The livestock categories reported in the CRT tables are the same, but the respective sub-categories as a basis for the calculation are different. The categorization for the estimation of $CH_4$ emissions had to be adapted to data available for energy requirements, while the categorisation for the estimation of $N_2O$ emissions is

determined by the respective categorisation of the Swiss inventory (AGRAMMON, Kupper et al. 2022, Richner and Sinaj 2017). Nevertheless, there is no inconsistency in the total number of animals as they are the same both for $CH_4$ and $N_2O$ emissions. Note that although not growing cattle in the proper sense, bulls are contained in the categories breeding cattle 3rd year or fattening cattle according to their purposes.

Table 5-10 Livestock categories for estimating $CH_4$ and $N_2O$ emissions from source category 3B Manure management.

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

### 5.3.2.2 Emission factors $CH_4$

Calculation of $CH_4$ emissions from manure management is based on methods described in the 2019 IPCC Refinement (IPCC 2019, equation 10.23):

$$EF_T = VS_T \cdot 365 \frac{days}{year} \cdot B_{0T} \cdot 0.67 \frac{kg}{m^3} \cdot \sum_S MCF_S \cdot MS_{T,S}$$

Where:

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

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

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

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

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

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

**Volatile solids excretion (VS) (compare FOEN 2024 page 280)**

The daily excretions of volatile solids (VS) for all **cattle sub-categories** as well as for **sheep, goats, horses, mules and asses** were estimated based on equation 10.24 in the 2019 Refinement to the IPCC Guidelines (IPCC 2019):

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

Where:

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

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

DE = digestibility of the feed (%)

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. 5.2.2.1. 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 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 percentage points. Resulting feed digestibility was 72.2% on average, gross energy content (EDF) was 18.26 MJ/kg and ash content was 9.0%.

For **other mature cattle, calves and other growing cattle**, IPCC default values were taken for the feed digestibility (IPCC 2019, table 10A.2). For the energy density of the feed (EDF) the IPCC (2019) default value, i.e. 18.45 MJ/kg was adopted. Furthermore, an ash content of 8.0 % was used for all these categories.

For **sheep, goats, horses, mules and asses,** VS excretion was estimated based on equation 10.24 in IPCC 2019 with default values for feed digestibility of 65 % (sheep, goats, IPCC 2019) and 70 % (horses, mules and asses, Stricker 2012). The energy density of the feed

(EDF) was 18.45 MJ/kg. The ash content of manure was 8.0 % for sheep and goats and 4.0 % for horses and mules and asses (IPCC 2006).

For VS excretion of the livestock categories **swine** and **poultry,** default values from IPCC were taken (IPCC 2006, Tables 10A-7, 10A-8, 10A-9).

**Maximum $CH_4$ producing capacity ($B_0$)**

For the methane producing capacity ($B_o$), default values were used (IPCC 2019).

**Methane conversion factor (MCF) (compare FOEN 2024, page 281)**

For estimating $CH_4$ emissions from source category 3B manure management, five different manure management systems are distinguished. Liechtenstein has an average annual temperature below 15°C (MeteoSwiss 2024) 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 2019 Refinement (IPCC 2019) were used (see Table 5-11).

**Liquid/slurry systems** are 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 inventory of Liechtenstein. The respective MCF-values for liquid/slurry systems decrease slightly from 14.8% in 1990 to 13.8% in 2023. The variation of the MCF is due to the increasing share of manure application on pasture, range and paddock which can be observed in Switzerland as well as in Liechtenstein. The higher the share of manure applied on pasture, range and paddock, the lower is the overall MCF for liquid/slurry systems (as livestock is only grazing during summer, the relative share of low methane conversion factors during the cold winter month decreases when summer grazing time increases. Note that in Liechtenstein's inventory the MCF is kept constant since submission 2025 (i.e. 13.8%) until the agriculture model is updated (5-yearly).

Fattening calves, sheep and goats are kept in **deep bedding 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 bedding is supported by the specific feeding and manure management regime in Liechtenstein (especially cold winter temperatures) and confirmed by a number of studies that are representative for the country-specific manure 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). Note that the use of the relatively high MCF of 10% (justified by the literature mentioned) leads to a clearly higher methane emission factor for sheep in Liechtenstein compared to other European countries.

For all poultry categories, a MCF value of 1.5% was used according to the default value for **poultry manure systems** in the 2019 IPCC Refinement (IPCC 2019).

Table 5-11 Manure management systems and methane conversion factors (MCFs) for 2023. 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. | 13.8 |
| 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 2024, page 284)**

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 5-12). Since agricultural structures and practices are basically identical in Liechtenstein, 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 Richner and Sinaj (2017). The estimation is conducted within the framework of the Swiss nitrogen flow model AGRAMMON (Kupper et al. 2022). Values for 1990 and 1995 are based on expert judgement and values from literature, while values for 2002, 2007, 2010, 2015 and 2019 are based on extensive farm surveys in Switzerland. 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).

For cattle, the distribution of animal excreta to the various manure management systems (MS) is different with regard to estimating $N_2O$ emissions from 3B Manure management (for further information refer to chp. 5.3.2.4) compared to estimating $CH_4$ emissions from 3B Manure management. This is because cattle stables usually have simultaneously both liquid and solid manure storage systems. As volatile solids are excreted mainly in dung and nitrogen mainly in urine, the proportion of VS stored as solid manure is higher compared to the proportion of N. For further information regarding the estimation of the distribution of nitrogen and volatile solids to manure management systems for cattle, please refer to Switzerland's greenhouse gas inventory (FOEN 2024, Annex A5.3).

Table 5-12 Manure management system (MS) distribution for Liechtenstein for selected years.

| MS Distribution | | 1990 | | | | | 1995 | | | | | 2002 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | | | % | | | | | % | | | | |
| | | Liquid / Slurry | Solid storage | Pasture range and paddock | Deep bedding | Other (Deep litter, Poultry manure) | Liquid / Slurry | Solid storage | Pasture range and paddock | Deep bedding | Other (Deep litter, Poultry manure) | Liquid / Slurry | Solid storage | Pasture range and paddock | Deep bedding | Other (Deep litter, Poultry manure) |
| Mature Dairy Cattle | | 64.0 | 27.7 | 8.3 | 0.0 | 0.0 | 66.0 | 24.5 | 9.5 | 0.0 | 0.0 | 65.6 | 16.4 | 18.0 | 0.0 | 0.0 |
| Other Mature Cattle | | 41.5 | 32.2 | 26.3 | 0.0 | 0.0 | 39.5 | 34.2 | 26.2 | 0.0 | 0.0 | 40.2 | 20.7 | 39.1 | 0.0 | 0.0 |
| Growing Cattle (weighted average) | | 34.7 | 46.8 | 16.9 | 1.6 | 0.0 | 35.5 | 46.4 | 16.3 | 1.9 | 0.0 | 31.1 | 40.8 | 26.8 | 1.3 | 0.0 |
| | *Fattening Calves* | *14.8* | *0.0* | *0.0* | *85.2* | *0.0* | *15.2* | *0.0* | *0.0* | *84.8* | *0.0* | *22.0* | *0.0* | *0.3* | *77.7* | *0.0* |
| | *Pre-Weaned Calves* | *41.5* | *32.2* | *26.3* | *0.0* | *0.0* | *39.5* | *34.2* | *26.2* | *0.0* | *0.0* | *41.6* | *21.1* | *37.3* | *0.0* | *0.0* |
| | *Breeding Cattle 1st Year* | *37.2* | *48.7* | *14.1* | *0.0* | *0.0* | *38.2* | *47.6* | *14.2* | *0.0* | *0.0* | *34.1* | *38.9* | *27.0* | *0.0* | *0.0* |
| | *Breeding Cattle 2nd Year* | *45.6* | *29.0* | *25.4* | *0.0* | *0.0* | *47.5* | *26.8* | *25.6* | *0.0* | *0.0* | *38.2* | *23.5* | *38.4* | *0.0* | *0.0* |
| | *Breeding Cattle 3rd Year* | *50.8* | *29.2* | *20.0* | *0.0* | *0.0* | *51.7* | *28.0* | *20.3* | *0.0* | *0.0* | *42.6* | *22.6* | *34.8* | *0.0* | *0.0* |
| | *Fattening Cattle* | *70.4* | *24.2* | *0.0* | *5.5* | *0.0* | *66.7* | *27.7* | *0.0* | *5.6* | *0.0* | *67.7* | *26.9* | *2.2* | *3.2* | *0.0* |
| Sheep (weighted average) | | 0.0 | 0.0 | 30.7 | 69.3 | 0.0 | 0.0 | 0.0 | 30.7 | 69.3 | 0.0 | 0.0 | 0.0 | 33.5 | 66.5 | 0.0 |
| Swine (weighted average) | | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 99.5 | 0.3 | 0.1 | 0.0 | 0.0 |
| Goats | | 0.0 | 0.0 | 13.6 | 86.4 | 0.0 | 0.0 | 0.0 | 13.6 | 86.4 | 0.0 | 0.0 | 0.0 | 12.2 | 87.8 | 0.0 |
| Horses (weighted average) | | 0.0 | 93.2 | 6.8 | 0.0 | 0.0 | 0.0 | 93.2 | 6.8 | 0.0 | 0.0 | 0.0 | 78.9 | 21.1 | 0.0 | 0.0 |
| Mules and Asses (weighted average) | | 0.0 | 93.2 | 6.8 | 0.0 | 0.0 | 0.0 | 93.2 | 6.8 | 0.0 | 0.0 | 0.0 | 76.9 | 23.1 | 0.0 | 0.0 |
| Poultry (weighted average) | | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.6 | 0.0 | 99.4 | 0.0 | 0.0 | 5.0 | 0.0 | 95.0 |

| MS Distribution | | 2007 | | | | | 2010 | | | | | 2015 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | | | % | | | | | % | | | | |
| | | Liquid / Slurry | Solid storage | Pasture range and paddock | Deep bedding | Other (Deep litter, Poultry manure) | Liquid / Slurry | Solid storage | Pasture range and paddock | Deep bedding | Other (Deep litter, Poultry manure) | Liquid / Slurry | Solid storage | Pasture range and paddock | Deep bedding | Other (Deep litter, Poultry manure) |
| Mature Dairy Cattle | | 68.4 | 13.9 | 17.7 | 0.0 | 0.0 | 68.4 | 14.8 | 16.9 | 0.0 | 0.0 | 72.3 | 11.7 | 15.9 | 0.0 | 0.0 |
| Other Mature Cattle | | 50.6 | 20.5 | 29.0 | 0.0 | 0.0 | 49.3 | 18.3 | 32.4 | 0.0 | 0.0 | 53.5 | 15.1 | 31.5 | 0.0 | 0.0 |
| Growing Cattle (weighted average) | | 31.8 | 42.6 | 24.1 | 1.4 | 0.0 | 31.1 | 43.6 | 24.0 | 1.3 | 0.0 | 34.9 | 40.2 | 23.9 | 1.0 | 0.0 |
| | *Fattening Calves* | *22.8* | *0.0* | *0.2* | *77.0* | *0.0* | *18.2* | *0.0* | *0.2* | *81.6* | *0.0* | *26.1* | *0.0* | *1.7* | *72.2* | *0.0* |
| | *Pre-Weaned Calves* | *51.0* | *18.8* | *30.1* | *0.0* | *0.0* | *46.0* | *33.2* | *20.9* | *0.0* | *0.0* | *37.8* | *30.2* | *32.0* | *0.0* | *0.0* |
| | *Breeding Cattle 1st Year* | *42.0* | *34.8* | *23.3* | *0.0* | *0.0* | *44.7* | *33.8* | *21.5* | *0.0* | *0.0* | *47.0* | *32.1* | *20.9* | *0.0* | *0.0* |
| | *Breeding Cattle 2nd Year* | *42.4* | *21.1* | *36.5* | *0.0* | *0.0* | *44.5* | *21.2* | *34.3* | *0.0* | *0.0* | *44.8* | *20.4* | *34.8* | *0.0* | *0.0* |
| | *Breeding Cattle 3rd Year* | *46.6* | *21.6* | *31.8* | *0.0* | *0.0* | *47.6* | *21.8* | *30.6* | *0.0* | *0.0* | *56.3* | *18.1* | *25.6* | *0.0* | *0.0* |
| | *Fattening Cattle* | *63.3* | *29.2* | *4.3* | *3.2* | *0.0* | *59.0* | *33.1* | *4.0* | *3.9* | *0.0* | *65.3* | *26.5* | *4.9* | *3.4* | *0.0* |
| Sheep (weighted average) | | 0.0 | 0.0 | 40.2 | 59.8 | 0.0 | 0.0 | 0.0 | 34.5 | 65.5 | 0.0 | 0.0 | 0.0 | 36.7 | 63.3 | 0.0 |
| Swine (weighted average) | | 98.6 | 0.1 | 1.3 | 0.0 | 0.0 | 99.4 | 0.5 | 0.1 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Goats | | 0.0 | 0.0 | 7.1 | 92.9 | 0.0 | 0.0 | 0.0 | 10.0 | 90.0 | 0.0 | 0.0 | 0.0 | 11.6 | 88.4 | 0.0 |
| Horses (weighted average) | | 0.0 | 80.0 | 20.0 | 0.0 | 0.0 | 0.0 | 74.8 | 25.2 | 0.0 | 0.0 | 0.0 | 78.6 | 21.4 | 0.0 | 0.0 |
| Mules and Asses (weighted average) | | 0.0 | 75.2 | 24.8 | 0.0 | 0.0 | 0.0 | 79.3 | 20.7 | 0.0 | 0.0 | 0.0 | 77.6 | 22.4 | 0.0 | 0.0 |
| Poultry (weighted average) | | 0.0 | 0.0 | 6.9 | 0.0 | 93.1 | 0.0 | 0.0 | 5.8 | 0.0 | 94.2 | 0.0 | 0.0 | 6.7 | 0.0 | 93.3 |

#### 5.3.2.3 Activity data $CH_4$

The activity data was obtained from Liechtenstein's Office for Food-control and Veterinary (Amt für Lebensmittelkontrolle und Veterinärwesen) in cooperation with the Division of Agriculture. Annual data for the livestock categories mature dairy cattle, sheep, goats and swine are available for the full 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 5-7 (see chp. 5.2.2.2) shows the time series of 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 $N_2O$

Estimation of direct $N_2O$ emissions from Manure management relies basically on the same manure management systems as the estimation of $CH_4$ emissions (see Table 5-9). The emission factors poultry manure is based on default values given in table 10.21 of IPCC 2019 whereas emissions factors for solid storage and anaerobic digesters are from the respective table in the 2019 IPCC Refinement (IPCC 2019; see also Kupper 2017; see Table 5-13). For liquid/slurry systems an emission factor (EF3) of 0.002 kg $N_2O$-N/kg N as suggested for "Pit storage below animal confinements" was considered appropriate (IPCC 2019, Kupper 2017).

The emission factor for indirect $N_2O$ emissions after volatilisation of $NH_3$ and $NO_x$ from manure management systems was reassessed during a literature review by Bühlmann et al. (2015) and Bühlmann (2014). Due to the fragmented land use in Switzerland and Liechtenstein, where agricultural land use alternates with natural and semi-natural ecosystems over short distances, the 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 2019) 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 2.6%. Note that in Liechtenstein's inventory the emission factor for indirect emissions is kept constant from submission 2025 onwards (i.e. 0.026 kg $N_2O$-N / kg N) until the agriculture model is updated (5-yearly).

Table 5-13 $N_2O$ emission factor for manure management systems in Liechtenstein (2023).

| Animal waste management system | Emission factor |
|---|---|
| | kg $N_2O$-N / kg N |
| Liquid/Slurry: with natural crust cover | 0.002 |
| Liquid/Slurry: without natural crust cover | 0.002 |
| Solid storage | 0.005 |
| Cattle and swine deep bedding: no mixing | 0.010 |
| Poultry manure | 0.001 |
| Indirect emissions due to volatilisation | 0.026 |

Note that the emission factors used above are used in the Swiss GHG inventory. A Swiss expert for the agricultural sector from Agroscope has evaluated the application of these emission factors for Liechtenstein's inventory and considers them suitable (Bretscher 2020).

### 5.3.2.5 Activity data $N_2O$

Activity data for $N_2O$ emissions from source category 3B Manure management was estimated according to equation 10.25 of the 2019 IPCC Refinement:

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

Where:

$N_2O_{D(mm)}$ = direct $N_2O$ emissions from manure management (kg $N_2O$/year)

$N_T$ = number of head of livestock species/category T (head)

$Nex_T$ = annual average N excretion per head of species/category T (kg N/head/year)

$MS_{T,S}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S (-)

$EF_{3(S)}$ = emission factor direct $N_2O$ emissions from manure management system S (kg $N_2O$-N/kg N)

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

**Livestock population**

The activity data was obtained from Liechtenstein's Office for Food-control and Veterinary (Amt für Lebensmittelkontrolle und Veterinärwesen) in cooperation with the Division of Agriculture. Annual data for the livestock categories mature dairy cattle, sheep, goats and swine are available 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 5-14 Sizes of Liechtenstein's animal populations.

| Population sizes Liechtenstein | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 1990 - 2023 (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fattening Calves | 50 | 81 | 112 | 83 | 81 | 79 | 77 | 75 | 75 | 76 | 78 | 77 | 75 | 74 | 73 | 46% |
| Pre-Weaned Calves | 15 | 35 | 11 | 266 | 281 | 330 | 342 | 304 | 318 | 331 | 359 | 356 | 364 | 346 | 380 | 2433% |
| Breeding Cattle 1st Year | 1'136 | 1'057 | 649 | 601 | 814 | 877 | 828 | 982 | 785 | 801 | 828 | 948 | 935 | 971 | 969 | -15% |
| Breeding Cattle 2nd Year | 903 | 699 | 544 | 676 | 808 | 871 | 822 | 974 | 778 | 794 | 822 | 940 | 927 | 964 | 961 | 6% |
| Breeding Cattle 3rd Year | 631 | 575 | 343 | 348 | 459 | 494 | 466 | 553 | 442 | 451 | 467 | 534 | 526 | 547 | 545 | -14% |
| Fattening Cattle | 723 | 725 | 774 | 743 | 743 | 745 | 732 | 700 | 709 | 720 | 747 | 740 | 721 | 705 | 716 | -1% |
| Growing Cattle | 3'458 | 3'172 | 2'433 | 2'717 | 3'186 | 3'396 | 3'267 | 3'588 | 3'107 | 3'173 | 3'301 | 3'595 | 3'548 | 3'607 | 3'644 | 5% |
| Mature Dairy Cattle | 2'850 | 2'643 | 2'440 | 2'489 | 2'425 | 2'367 | 2'299 | 2'232 | 2'246 | 2'271 | 2'332 | 2'311 | 2'231 | 2'194 | 2'187 | -23% |
| Other Mature Cattle | 20 | 47 | 74 | 362 | 382 | 449 | 465 | 413 | 432 | 450 | 489 | 484 | 495 | 471 | 517 | 2485% |
| **Total Cattle** | **6'328** | **5'862** | **4'947** | **5'568** | **5'993** | **6'212** | **6'031** | **6'233** | **5'785** | **5'894** | **6'122** | **6'390** | **6'274** | **6'272** | **6'348** | **0%** |
| Fattening Sheep | 1'636 | 1'079 | 1'522 | 2'005 | 2'061 | 2'105 | 2'094 | 2'087 | 2'168 | 2'165 | 2'225 | 1'992 | 2'176 | 2'245 | 2'243 | 37% |
| Milksheep | 0 | 0 | 0 | 41 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | - |
| **Total Sheep** | **2'781** | **2'632** | **2'983** | **3'063** | **3'656** | **3'581** | **3'892** | **4'050** | **4'123** | **3'989** | **3'884** | **3'829** | **4'228** | **4'436** | **4'457** | **60%** |
| Goat Places | 111 | 100 | 96 | 171 | 253 | 169 | 182 | 217 | 242 | 293 | 267 | 297 | 350 | 385 | 386 | 248% |
| **Total Goats** | **171** | **145** | **164** | **324** | **434** | **283** | **285** | **330** | **361** | **431** | **431** | **511** | **544** | **498** | **495** | **189%** |
| Horses <3 years Agr. | 33 | 27 | 20 | 28 | 31 | 27 | 29 | 17 | 12 | 11 | 16 | 14 | 12 | 5 | 10 | -70% |
| Horses >3 years Agr. | 133 | 135 | 136 | 237 | 304 | 282 | 272 | 249 | 243 | 233 | 236 | 221 | 214 | 234 | 232 | 74% |
| **Total Horses Agr.** | **166** | **162** | **156** | **265** | **335** | **309** | **301** | **266** | **255** | **244** | **252** | **235** | **226** | **239** | **242** | **46%** |
| **Total Mules and Asses Agr.** | **73** | **133** | **223** | **144** | **154** | **178** | **163** | **172** | **157** | **230** | **218** | **230** | **227** | **215** | **214** | **193%** |
| Piglets | 506 | 452 | 398 | 222 | 301 | 114 | 285 | 226 | 197 | 183 | 172 | 291 | 214 | 105 | 189 | -63% |
| Fattening Pig over 25 kg | 1'006 | 1'091 | 1'229 | 1'162 | 1'058 | 1'180 | 1'206 | 1'153 | 1'309 | 1'149 | 1'131 | 901 | 1'106 | 1'047 | 1'021 | 1% |
| Dry Sows | 207 | 191 | 91 | 96 | 101 | 72 | 87 | 77 | 70 | 68 | 73 | 80 | 80 | 85 | 88 | -57% |
| Nursing Sows | 66 | 62 | 22 | 21 | 18 | 26 | 12 | 25 | 25 | 27 | 25 | 13 | 16 | 23 | 13 | -80% |
| Boars | 5 | 5 | 4 | 3 | 3 | 2 | 10 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | -60% |
| **Total Swine** | **3'251** | **2'429** | **1'992** | **1'703** | **1'690** | **1'712** | **1'747** | **1'789** | **1'875** | **1'772** | **1'724** | **1'465** | **1'632** | **1'557** | **1'487** | **-54%** |
| Growers | 105 | 53 | 0 | 0 | 61 | 12 | 246 | 141 | 131 | 95 | 100 | 104 | 162 | 164 | 153 | 46% |
| Layers | 4'145 | 5'506 | 6'866 | 10'112 | 12'175 | 12'509 | 12'056 | 12'438 | 12'141 | 12'371 | 14'322 | 15'143 | 20'337 | 20'242 | 20'222 | 388% |
| Broilers | 0 | 500 | 1'000 | 250 | 390 | 5 | 0 | 100 | 0 | 300 | 400 | 60 | 51 | 71 | 61 | - |
| Turkey | 22 | 55 | 87 | 52 | 103 | 31 | 43 | 44 | 46 | 13 | 37 | 0 | 0 | 0 | 0 | - |
| Other Poultry | 163 | 134 | 106 | 39 | 191 | 123 | 153 | 104 | 137 | 137 | 151 | 129 | 90 | 223 | 226 | 39% |
| **Total Poultry** | **4'435** | **6'248** | **8'059** | **10'453** | **12'920** | **12'680** | **12'498** | **12'827** | **12'455** | **12'916** | **15'010** | **15'436** | **20'640** | **20'700** | **20'662** | **366%** |

### Nitrogen excretion ($N_{ex}$) (compare FOEN 2024 page 287ff)

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. 2022), see Figure 5-6 below. These values are based on the "Principles of Fertilisation in Arable and Forage Crop Production" (Richner and Sinaj 2017). 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 within the Swiss AGRAMMON model (nitrogen flow model) 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.; Kupper et al. 2022). This more disaggregated approach leads to considerably lower calculated nitrogen excretion rates compared to IPCC (2019), 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).

In Liechtenstein, nitrogen excretion of **mature dairy cattle** is not directly adopted from the Swiss 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 regression displays the increase in nitrogen excretion with increasing milk yield.

milk production per head per year:
GE = 0.0236 MJyr/kg/day * Milk + 142.42 MJ/head/day

Where:

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

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. Data on milk yield is contained in Table 5-4.

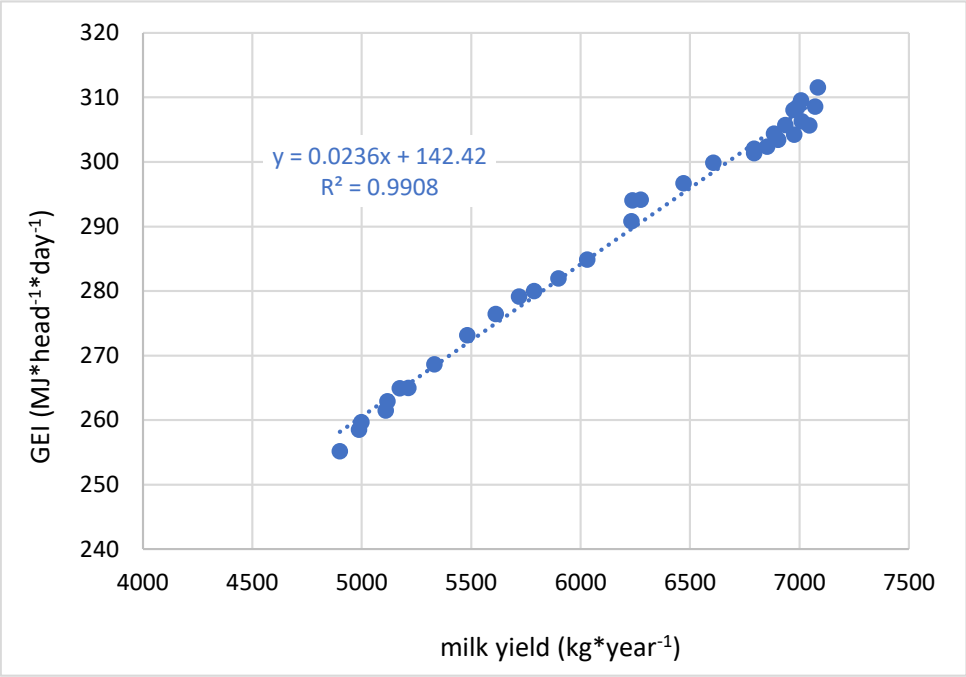



Figure 5-6 Linear regression relating nitrogen excretion (NexDC) of mature dairy cattle to milk yield (based on FOEN 2024).

Table 5-15 Nitrogen excretion rates of Liechtenstein's livestock.

| Nitrogen Excretion | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| | kg N/head/year | | | | | | | |
| Cattle (weighted average) | 66.9 | 66.9 | 71.8 | 71.8 | 68.7 | 67.7 | 68.2 | 66.3 |
| Mature Dairy Cattle | 104.4 | 104.7 | 108.6 | 110.7 | 110.1 | 110.5 | 111.3 | 111.8 |
| Other Mature Cattle | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 |
| Growing Cattle (weighted average) | 35.9 | 35.2 | 34.6 | 34.5 | 35.2 | 35.5 | 35.5 | 35.8 |
| *Fattening Calves* | *13.0* | *13.0* | *13.0* | *14.2* | *16.0* | *17.6* | *18.0* | *18.0* |
| *Pre-Weaned Calves* | *22.0* | *22.0* | *22.0* | *22.0* | *22.0* | *22.0* | *22.0* | *22.0* |
| *Breeding Cattle 1st Year* | *25.0* | *25.0* | *25.0* | *25.0* | *25.0* | *25.0* | *25.0* | *25.0* |
| *Breeding Cattle 2nd Year* | *40.0* | *40.0* | *40.0* | *40.0* | *40.0* | *40.0* | *40.0* | *40.0* |
| *Breeding Cattle 3rd Year* | *55.0* | *55.0* | *55.0* | *55.0* | *55.0* | *55.0* | *55.0* | *55.0* |
| *Fattening Cattle* | *33.0* | *33.0* | *33.0* | *34.2* | *36.0* | *37.6* | *38.0* | *38.0* |
| Sheep (weighted average) | 8.8 | 6.1 | 7.7 | 10.1 | 8.5 | 8.8 | 8.1 | 7.7 |
| Swine (weighted average) | 8.8 | 11.9 | 11.5 | 11.0 | 10.3 | 10.0 | 10.2 | 9.6 |
| Goats | 11.0 | 11.7 | 10.0 | 9.0 | 9.9 | 10.2 | 10.9 | 11.2 |
| Horses (weighted average) | 43.6 | 43.7 | 43.7 | 43.8 | 43.8 | 43.8 | 43.8 | 43.9 |
| Mules and Asses | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 |
| Poultry (weighted average) | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |

| Nitrogen Excretion | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|
| | kg N/head/year | | | | | | |
| Cattle (weighted average) | 68.9 | 68.9 | 69.2 | 67.4 | 66.9 | 66.1 | 65.9 |
| Mature Dairy Cattle | 111.9 | 112.4 | 113.8 | 113.2 | 112.7 | 112.2 | 112.0 |
| Other Mature Cattle | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 |
| Growing Cattle (weighted average) | 35.5 | 35.5 | 35.4 | 35.6 | 35.6 | 35.7 | 35.5 |
| *Fattening Calves* | *18.0* | *18.0* | *18.0* | *18.0* | *18.0* | *18.0* | *18.0* |
| *Pre-Weaned Calves* | *22.0* | *22.0* | *22.0* | *22.0* | *22.0* | *22.0* | *22.0* |
| *Breeding Cattle 1st Year* | *25.0* | *25.0* | *25.0* | *25.0* | *25.0* | *25.0* | *25.0* |
| *Breeding Cattle 2nd Year* | *40.0* | *40.0* | *40.0* | *40.0* | *40.0* | *40.0* | *40.0* |
| *Breeding Cattle 3rd Year* | *55.0* | *55.0* | *55.0* | *55.0* | *55.0* | *55.0* | *55.0* |
| *Fattening Cattle* | *38.0* | *38.0* | *38.0* | *38.0* | *38.0* | *38.0* | *38.0* |
| Sheep (weighted average) | 7.9 | 8.1 | 8.6 | 7.8 | 7.7 | 7.6 | 7.6 |
| Swine (weighted average) | 10.0 | 9.5 | 9.6 | 9.6 | 10.0 | 10.0 | 10.3 |
| Goats | 11.4 | 11.6 | 10.5 | 9.9 | 10.9 | 13.1 | 13.3 |
| Horses (weighted average) | 43.9 | 43.9 | 43.9 | 43.9 | 43.9 | 44.0 | 43.9 |
| Mules and Asses | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 |
| Poultry (weighted average) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |

Note that for sheep, $N_{ex}$ rates for the entire time period were evaluated as a weighted-average based population number of fattening sheep and milksheep. The inter-annual fluctuations in the values of $N_{ex}$ rates (especially in the period of 1994–1996) are due to changes in population structure of sheep.

**Manure management system distribution (MS) (compare FOEN 2024 page 289)**

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. 2022) and on data provided in Richner and Sinaj (2017).

For cattle, the distribution of animal excreta to the various manure management systems (MS) is different with regard to estimating $CH_4$ emissions from 3B Manure management (for further information refer to chp. 5.3.2.2) compared to estimating $N_2O$ emissions from 3B Manure management. This is because cattle stables usually have simultaneously both liquid and solid manure storage systems. As volatile solids are excreted mainly in dung and nitrogen mainly in urine, the proportion of VS stored as solid manure is higher compared to the proportion of N. Data provided in Table 5-12 refers to the distribution of nitrogen while data provided in CRT Table3.B(a) refer to the distribution of VS. A detailed table of the distribution of VS is contained in Annex A5.2. For further information regarding the estimation of the distribution of nitrogen and volatile solids to manure management systems for cattle, please refer to Switzerland's greenhouse gas inventory (FOEN 2024, Annex A5.3).

Note that for all other animal categories, the distribution of animal excreta to the various manure management systems is similar when estimating $CH_4$ emissions compared to $N_2O$ emissions from 3B Manure management. Any differences between the distribution of excreta to manure management systems for superordinate animal categories solely occur due to different weighting of sub-animal categories.

**Volatilisation of $NH_3$ and $NO_x$ from manure management systems (compare FOEN 2024 page 290)**

For indirect $N_2O$ emissions from manure management the deposition of volatilised $NH_3$ and $NO_x$ is considered. Losses of ammonia from stables and manure storage systems to the atmosphere are calculated according to the Swiss AGRAMMON model (Kupper et al. 2022). It is assumed that the same underlying assumptions on agricultural structures and practices in Switzerland are also valid for Liechtenstein. Specific loss-rates for all major livestock categories are estimated based on agricultural structures and techniques (e.g. stable type, manure management system, measures to reduce $NH_3$ emissions). Accordingly, the overall fraction of nitrogen volatilised underlies certain temporal dynamics that can be explained by changes in agricultural management practices (e.g. the transition to more animal friendly housing systems). It ranges from around 14% to 20%.

For the volatilisation of $NO_x$, values from van Bruggen et al. (2014) were used. Accordingly, it is estimated that 0.2%, 0.5%, 1.0% and 0.1% of the total nitrogen in liquid/slurry, solid storage, deep bedding and poultry manure systems are lost to the atmosphere.

### 5.3.3 Uncertainties and time-series consistency

Uncertainties of emission factors and activity data are taken from ART (2008). These 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 2019 IPCC Refinement (IPCC 2019). The arithmetic mean of the lower and upper bound was used for activity data and for emission factors in the Approach 1 analysis (only for key categories, see Table 3-16).

Table 5-16 Uncertainties for source category 3B Manure management 2023. AD: Activity data; EF: Emission factor; comb.: Combined.

| **Uncertainty 3B** | | **Approach 1** | | |
|---|---|---|---|---|
| | | **AD** | **EF** | **comb.** |
| | | **%** | | |
| $CH_4$ | | 6.5 | 54.6 | 55.0 |

The time series 1990–2023 is consistent. 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, 2010 and 2018 (extensive surveys on approximatively 3'000 farms). Values in-between the assessment years were interpolated linearly, whereas values beyond 2018 are kept constant and will be updated as new survey results become available in parallel with an update of the whole agriculture model.
- Since Liechtenstein has only small animal populations the proportion of the sub-animal categories to each other are highly variable. For that reason, the weighted N-excretions also fluctuate from year to year (e.g. swine and goat). The fluctuation can be fully explained with the underlying data structure in the model for Liechtenstein.
- The emission factor for indirect $N_2O$ emissions after volatilisation of $NH_3$ and $NO_x$ from manure management systems varies according to varying land use as described in Bühlmann (2014).

### 5.3.4 Category-specific QA/QC and verification

The category-specific QA/QC activities were carried out as mentioned in section 1.5 including triple checks of Liechtenstein's reporting tables (CRT tables). The triple check includes a detailed comparison of current and previous submission data for the base year 1990 and for the year 2022 as well as an analysis of the increase or decrease of emissions between 2022 and 2023 in the current submission.

In addition to the overall triple check a separate internal technical documentation of Liechtenstein's model is available (Bretscher 2019, in German only). For model updates, separate documentations exist (for the update in Submission 2025: Bretscher 2024). The manual and documentations ensure transparency and traceability 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 2024). The respective conclusions are equally valid for Liechtenstein since the methods used are an adaptation of the Swiss model version. Bottom-up inventory estimates in Switzerland agree well with several atmospherically $CH_4$ measurements, thus verifying the methodological approach applied in the inventory.

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

### 5.3.5 Category-specific recalculations

The following recalculations lead to changes in $CH_4$ emissions, resulting in a decrease of 0.3 kt $CO_2$eq in 2022:

- 3B: $CH_4$ emissions from manure management of growing cattle and other mature cattle were recalculated for the whole time series. Emission factors were revised in the course of the adoption of the 2019 Refinement to the 2006 IPCC Guidelines (IPCC 2019) by adjusting the values for feed digestibility when calculating excretion of volatile solids (VS). New values for feed digestibility are higher for all animal categories concerned leading to lower estimates of excretion of VS and a reduction of overall emissions of -75.5 t $CO_2$eq on average.
- 3B: $CH_4$ emissions from manure management of sheep, goats, horses and mules and asses were recalculated for the whole time series. Excretion of volatile solids of these livestock categories is now estimated based on equation 10.24 of the 2019 IPCC Refinement (IPCC 2019). New values of VS are lower for sheep, horses and mules and asses and higher for goats leading to an average decrease of emissions of -1.3 t $CO_2$eq.
- 3B: $CH_4$ emissions from liquid manure management were recalculated for the whole time series. Emission factors were revised due to new, slightly higher monthly norm temperature values from MeteoSwiss (2024) for estimating the methane conversion factor (MCF) for liquid systems. The impact on overall emissions ranges from +51.0 to +93.5 t $CO_2$eq.
- 3B: $CH_4$ emissions from manure management of cattle were revised for the whole time series. When estimating VS excretion based on equation 10.24 of the IPCC Guidelines, urea energy is no more accounted for (affecting EF). According to Dämmgen et al. (2011) there is no indication for methane formation from urine energy. The mean impact on overall emissions is -304.3 t $CO_2$eq.

### 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 latest update has been done for the submission 2025.

## 5.4 Rice cultivation (3C)

Rice cultivation does not occur in Liechtenstein.

## 5.5 Agricultural soils (3D)

### 5.5.1 Category description: Agricultural soils (3D)

**Key category information 3D**

Direct $N_2O$ emissions from agricultural soils (3D1) are a key category by level (KCA excluding LULUCF categories).

The source category 3D includes direct and indirect $N_2O$ emissions from managed soils with a subdivision given in Table 5-17.

The most significant $N_2O$ emission sources in 2023 were animal manure applied to soils (31.2%), nitrogen input from atmospheric deposition (20.5%), inorganic nitrogen fertilisers (16.1%), nitrogen leaching and run-off (13.7%) and nitrogen in crop residues returned to soils (12.2%).

Furthermore, $NO_x$ emissions from managed soils as well as NMVOC emissions are estimated.

Table 5-17 Specification of source category 3D Agricultural soils. AD: Activity data; EF: Emission factors.

| 3D | Source | Specification |
|---|---|---|
| 3Da | Direct $N_2O$ emissions from managed soils | 1. Inorganic N fertilisers<br>2. Organic N fertilisers (animal manure applied to soils, sewage sludge applied to soils, other organic fertilisers applied to soils)<br>3. Urine and dung deposited by grazing animals<br>4. Crop residues (inc. residues from meadows and pasture)<br>5. Mineralisation/immobilisation associated with loss/gain of soil organic matter<br>6. Cultivation of organic soils (i.e. histosols)<br>7. Other (Domestic synthetic fertiliser) |
| 3Db | Indirect $N_2O$ emissions from managed soils | 1. Atmospheric deposition<br>2. Nitrogen leaching and run-off |

Direct and indirect $N_2O$ emissions have decreased by 15.7% and 25.3% in 2023 compared to 1990 levels, respectively. The lowest $N_2O$ emission level was in the year 2000. Since then, total emissions are slightly increasing, reflecting a similar increase of cattle numbers (see Figure 5-5).

## 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 2019 IPCC Refinement.

For the calculation of most $N_2O$ emissions from source category 3D Agricultural soils a Tier 1 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 $N_2O$ emissions from agriculture that basically uses the same emission factors but adjusts the activity data to the particular situation of Switzerland. IULIA is continuously updated. New values for nitrogen excretion rates, manure management system distribution and ammonium emission factors from the Swiss AGRAMMON model were adopted (Kupper et al. 2022). Furthermore, the updated version of the "Principles of Fertilisation in Arable and Forage Crop Production" (GRUD; Richner and Sinaj 2017) was used. Most recently, the N-flow model was extended to include all gaseous N-species (including $N_2$) and new $NO_x$ emission factors were implemented (Kupper 2017). Emission factors for $N_2O$ are all IPCC default with the exception of the emission factor for indirect $N_2O$ emissions from atmospheric deposition of N volatilised from managed soils ($EF_4$) which is country-specific.

The modelling of the $N_2O$ emissions is done by Agroscope, the Swiss centre of excellence for agricultural research (Agroscope 2019) and is consistent with source category 3B $N_2O$ emissions from manure management. The model structure is displayed in Figure 5-7 and the corresponding amounts of nitrogen are given in Table 5-18.

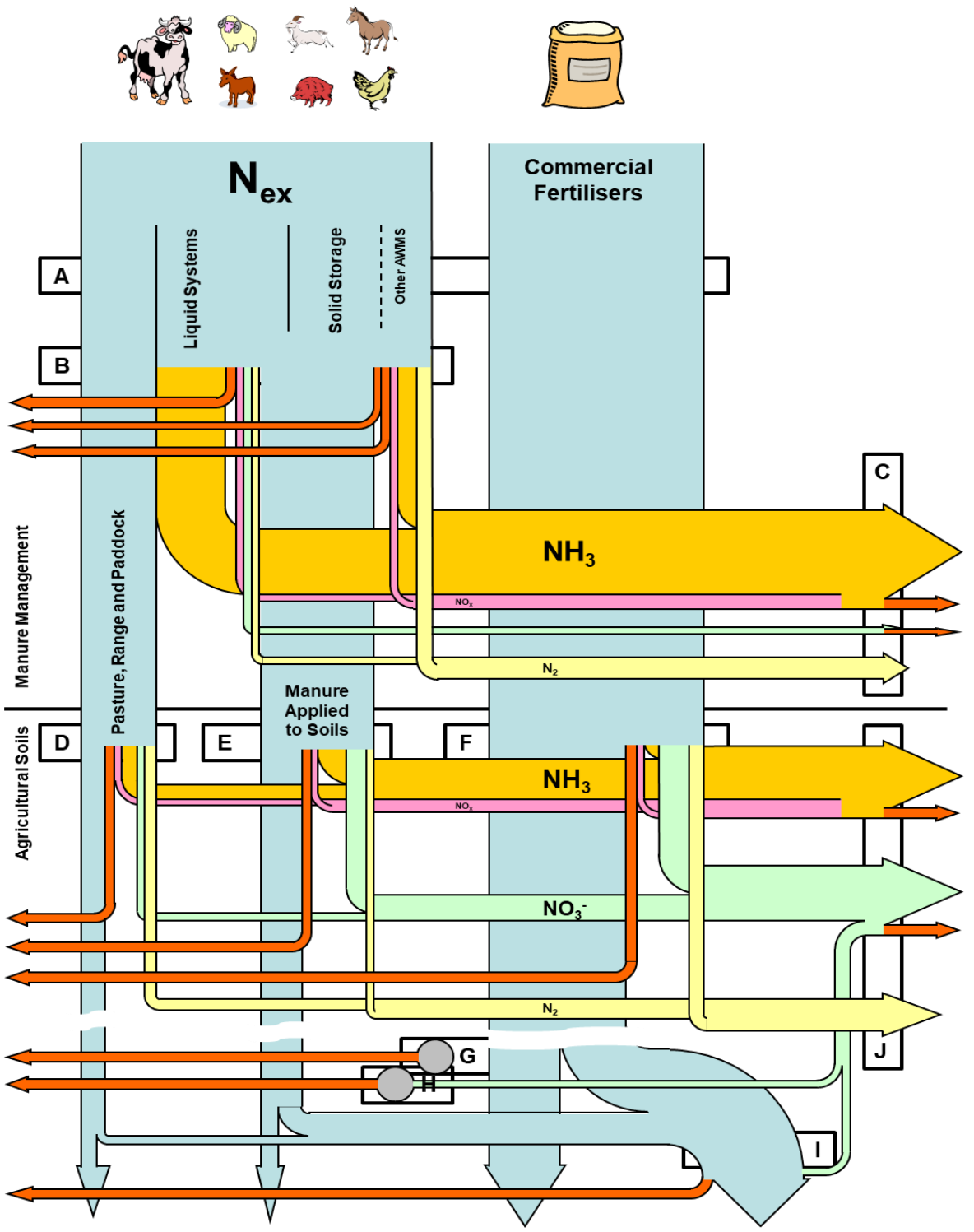



Figure 5-7 Diagram depicting the methodology of the approach to calculate the $N_2O$ emissions in agriculture (red arrows). Black frames and the respective letters refer to the nitrogen flows in Table 5-18. Note that the figure shows explicitly the methodology of the approach and not necessarily the physical nitrogen flows. Commercial fertilisers refer to the sum of urea, other mineral fertilisers, sewage sludge, other organic fertilisers and domestic use of fertilisers. Blue: nitrogen; orange: ammonia ($NH_3$); pink: nitrogen oxides ($NO_x$); green: nitrate ($NO_3^-$); yellow: dinitrogen ($N_2$).

Table 5-18 Nitrogen flows of the N-flow model for Liechtenstein's agriculture. Letters refer to the letters in Figure 5-7. Processes refer to the nitrogen flows in the black frames in Figure 5-7 from left to right or from top to bottom.

| | Process | Amount of N | | | CRF table |
|---|---|---|---|---|---|
| | | 1990 | 2023 | | |
| | | tN | | *equals* | |
| A | 1 Pasture, range and paddock | 53.58 | 98.93 | | 3.Da3 |
| | 2 Liquid/slurry systems | 281.62 | 281.41 | = B | 3.B(b) |
| | 3 Solid storage | 131.11 | 76.39 | | 3.B(b) |
| | 4 Other AWMS | 23.60 | 44.24 | | 3.B(b) |
| | 5 Commercial fertiliser | 278.07 | 192.37 | = F | 3.Da1,2,7 |
| B | 1 Pasture, range and paddock | 53.58 | 98.93 | | 3.Da3 |
| | 2 $NH_3$ volatilisation housing | 28.57 | 50.22 | | 3.B(b)5 |
| | 3 $N_2O$ emission liquid/slurry | 0.56 | 0.56 | | 3.B(b) |
| | 4 $NO_x$ volatilisation liquid/slurry and digester | 0.56 | 0.56 | | 3.B(b)5 |
| | 5 Leaching manure management | 0.00 | 0.00 | | 3.B(b)5 |
| | 6 N2 volatilization liquid/slurry and digester | 5.63 | 5.63 | = A1-A4 | |
| | 7 Manure applied to soils | 364.49 | 312.96 | | 3.Da2 |
| | 8 N2O emission solid storage | 0.66 | 0.38 | | 3.B(b) |
| | 9 N2O emission other AWMS | 0.21 | 0.30 | | 3.B(b) |
| | 10 NOx volatilisation solid storage and deep litter | 0.86 | 0.69 | | 3.B(b)5 |
| | 11 NH3 volatilisation storage | 30.41 | 26.99 | | 3.B(b)5 |
| | 12 N2 volatilization solid storage and deep litter | 4.38 | 3.74 | | |
| C | 1 $NH_3$ deposition manure management | 58.98 | 77.22 | = B2+B10 | |
| | 2 $NO_x$ deposition manure management | 1.43 | 1.25 | = B4+B9 | 3.B(b)5 |
| | 3 Leaching manure management | 0.00 | 0.00 | = B5 | |
| D | 1 Available N PR&P | 39.44 | 75.18 | | |
| | 2 $N_2O$ emission PR&P | 0.30 | 0.55 | | 3.Da3 |
| | 3 $NO_x$ volatilisation PR&P | 0.29 | 0.54 | = B1 | |
| | 4 $NH_3$ volatilisation PR&P | 2.51 | 5.01 | | |
| | 5 Leaching and run-off PR&P | 11.04 | 17.65 | | |
| E | 1 Available N animal manure | 193.89 | 190.01 | | |
| | 2 $N_2O$ emission application animal manure | 3.64 | 3.13 | | 3.Da2 |
| | 3 $NO_x$ volatilisation application animal manure | 2.00 | 1.72 | = B6 | |
| | 4 $NH_3$ volatilisation application animal manure | 89.83 | 62.27 | | |
| | 5 Leaching and run-off application animal manure | 75.11 | 55.83 | | |
| F | 1 Available N com. fertiliser | 199.77 | 146.69 | | |
| | 2 $N_2O$ emission application com. fertiliser | 2.78 | 1.92 | | 3.Da1,2,7 |
| | 3 $NO_x$ volatilisation application com. fertiliser | 1.53 | 1.06 | = A5 | |
| | 4 $NH_3$ volatilisation application com. fertiliser | 16.68 | 8.39 | | |
| | 5 Leaching and run-off application com. fertiliser | 57.31 | 34.32 | | |
| G | 1 Cultivation of organic soils (ha) | 1.77 | 1.33 | | 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 | 79.59 | 90.40 | | 3.Da4 |
| | 2 N in crop residues arable crops | 34.11 | 33.03 | | |
| J | 1 $NH_3$ deposition fertiliser appl. and PR&P | 109.02 | 75.67 | = D4+E4+F4 | 3.Db1 |
| | 2 $NO_x$ deposition fertiliser appl. and PR&P | 3.83 | 3.32 | = D3+E3+F3 | |
| | 3 Leaching and run-off fertiliser appl. and PR&P | 143.46 | 107.80 | = D5+E5+F5 | 3.Db2 |
| | 4 Leaching and run-off mineralisation SOM | 0.00 | 0.00 | | |
| | 5 Leaching and run-off crop residues | 23.43 | 22.02 | | |

### 5.5.2.2 Direct $N_2O$ emissions from managed soils (3Da)

Calculation of Direct $N_2O$ emissions from managed soils is based on IPCC 2006 equation 11.2 including six terms for activity data and three different emission factors:

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

Where:

$N_2O_{Direct}$ = annual direct $N_2O$ emissions produced from managed soils (kg $N_2O$–N/year)

$F_{SN}$ = annual amount of synthetic fertiliser N applied to soils (kg N/year)

$F_{ON}$ = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (kg N/year)

$F_{CR}$ = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

$F_{SOM}$ = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes of land use or management (kg N/year)

$F_{OS}$ = annual area of managed/drained organic soils (ha)

$F_{PRP}$ = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (kg N/year)

$EF_1$ = emission factor for $N_2O$ emissions from N inputs (kg $N_2O$–N/kg N input)

$EF_2$ = emission factor for $N_2O$ emissions from drained/managed organic soils (kg $N_2O$–N/ha/year)

$EF_3$ = emission factor for $N_2O$ emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (kg $N_2O$–N/kg N input)

**Emission factors for direct $N_2O$ emissions**

Emission factors for calculating 3Da Direct $N_2O$ emissions from managed soils are based on default values as provided in the 2019 IPCC Refinement (see Table 5-19). Due to the lack of data, no fertiliser specific emission factors were applied for $EF_1$. The $N_2O$ emission factor for cultivated organic soils ($EF_2$) is the area weighted mean of the IPCC default emission factors for $N_2O$ emissions from cultivated organic soils under cropland (drained 13.0 kg $N_2O$-N/ha/year, IPCC 2014a) and grassland (deep-drained, nutrient rich 8.2 kg $N_2O$-N/ha/year; IPCC 2014). 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 in wet climates ($EF_{3PRP,CPP}$ = 0.006 kg $N_2O$–N/kg N) and the emission factor for sheep and “other animals” ($EF_{3PRP,SO}$ = 0.003 kg $N_2O$–N/kg N) according to the shares of nitrogen excreted by the respective animals (IPCC 2019).

Table 5-19 Emission factors for calculating direct $N_2O$ emissions from managed soils (based on IPCC 2019 and IPCC 2014).

| Emission Source | Emission factor |
|---|---|
| $EF_1$ Inorganic N fertilisers (kg $N_2O$-N/kg) | 0.01 |
| $EF_1$ Organic N fertilisers (kg $N_2O$-N/kg) | 0.01 |
| $EF_1$ Crop residue (kg $N_2O$-N/kg) | 0.01 |
| $EF_1$ Mineralisation/immobilisation soil organic matter (kg $N_2O$-N/kg) | 0.01 |
| $EF_1$ Other (domestic synthetic fertilisers) (kg N2O-N/kg) | 0.01 |
| $EF_2$ Cultivation of organic soils (kg $N_2O$-N/ha) | 10.931 |
| $EF_3$ Urine and dung deposited by grazing animals (kg $N_2O$-N/kg) | 0.0055 |

### Activity data for direct $N_2O$ emissions

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 2024) 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 1990–2017 in the Swiss inventory (see internal technical documentation in Bretscher (2019). 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 (i.e. domestic use of inorganic fertilisers; Kupper et al. 2022). These fertilisers are used in public green areas, sports grounds and home gardens. In the CRT-tables they are reported under 3Da7 Other (Domestic synthetic fertilisers) while emission calculation is conducted together with 3Da1. In certain occasions, as for instance for the estimation of indirect $N_2O$ emissions from managed soils, the sum of urea, other mineral fertilisers, sewage sludge (1990–2003 only), other organic fertilisers and domestic fertilisers is referred to as “commercial fertilisers” (see also Figure 5-7 and Table 5-18).

**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 IPCC (2019), 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 5-7 and Table 5-21). $Frac_{GASM}$ in CRT Table3.D represents the amount of nitrogen volatilised as $NH_3$, $NO_x$, $N_2O$ and $N_2$ from housing and manure storage divided by the manure excreted in the stable (liquid/slurry, solid storage, digesters, deep litter and poultry manure). The nitrogen input from manure applied to soils under 3D.1.b.i in CRT Table3.D can thus be

calculated with the numbers given in CRT Table3.B(b) and Table3.D. Nitrogen from bedding material was not accounted for under animal manure applied to soils. The respective nitrogen is included in the nitrogen returned to soils as crop residues.

The amount of **sewage sludge** applied to agricultural soils is provided by the annual report "Rechenschaftsbericht" (CG 2023). Since 2003, the use of sewage sludge as fertiliser is prohibited in Liechtenstein (see Annex A5.4). From then on, the entire sewage sludge is treated in one centralized Municipal Wastewater 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 (EZV 2024).

**Other organic fertilisers** contain compost. Compost data are provided by the Office of Environment. 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 2019 IPCC Refinement (IPCC 2019). Estimation of total livestock nitrogen excretion is 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. 2022). For each livestock category, the share of animals that have access to grazing, the number of days per year they are actually grazing as well as the number of hours per day grazing takes place was assessed. The estimates are based on values from the literature and expert judgement (1990, 1995) and on surveys on approximatively 3000 Swiss farms (2000, 2007, 2010, 2015, 2019).

$N_2O$ emissions from **crop residues** are based on the amount of nitrogen in crop residues returned to soil. For **arable crops** data were calculated based on standard values for nitrogen in crop residues per hectare from GRUD (Richner and Sinaj 2017) 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 as suggested in the 2019 Refinement (IPCC 2019, other forages including perennial grasses and grass/clover pastures). The main part of the agricultural land use consists of grassland which underscores the importance of this source for Liechtenstein. Input data on the managed

area of meadows and pastures are taken from the Office of the Environment, Division of Agriculture (OE 2015a). Note that this input data shows an increase of the area of natural meadows for the year 2011, which leads to the increase of PR&P residues visible in Table 5-20 in the year 2011. The method for meadows and pastures is similar to Switzerland (see FOEN 2024). Estimated values of total crop production, nitrogen incorporated with crop residues $F_{(CR)}$, residue/crop ratio, dry matter fraction of residues and nitrogen content of residues are provided in Annex A5.2.

$N_2O$ 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 factors for $N_2O$ emissions from cultivated organic soils under cropland (drained 13.0 kg $N_2O$-N/ha/year, IPCC 2014) and grassland (deep-drained, nutrient rich 8.2 kg $N_2O$-N/ha/year; IPCC 2014). 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).

The relevant activity data for calculating $N_2O$ emissions from managed soils are displayed in Table 5-20. Additional information is given in Annex A5.2.

Table 5-20 Activity data for calculating direct $N_2O$ emissions from managed soils.

| Activity Data | | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|
| | | t N/yr | | | | | | | |
| 1. Inorganic N fertilisers | Urea | 37 | 31 | 29 | 29 | 27 | 26 | 30 | 27 |
| | Other mineral fertilisers | 200 | 169 | 155 | 158 | 147 | 142 | 162 | 145 |
| 2. Organic N fertilisers | a. Animal manure | 364 | 333 | 279 | 297 | 308 | 312 | 307 | 307 |
| | b. Sewage sludge | 30.4 | 31.3 | 10.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | c. Other organic fertilisers | 0.3 | 0.3 | 0.4 | 0.5 | 0.4 | 0.5 | 0.4 | 0.5 |
| 3. Urine and dung deposited by grazing animals | | 54 | 51 | 71 | 98 | 97 | 98 | 95 | 96 |
| 4. Crop residues | Arable crops | 34 | 44 | 32 | 30 | 27 | 31 | 30 | 30 |
| | Residues PR&P | 80 | 84 | 86 | 93 | 86 | 85 | 85 | 85 |
| 5. Min./imm. associated with loss/gain of SOM | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6. Cultivation of organic soils (ha) | | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 7. Other (domestic inorganic fertilisers) | | 9.9 | 8.4 | 7.6 | 7.8 | 7.3 | 7.0 | 8.0 | 7.2 |

| Activity Data | | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 1990 -2023 |
|---|---|---|---|---|---|---|---|---|---|
| | | t N/yr | | | | | | | % |
| 1. Inorganic N fertilisers | Urea | 28 | 31 | 29 | 26 | 26 | 29 | 27 | -27% |
| | Other mineral fertilisers | 152 | 166 | 155 | 138 | 142 | 156 | 135 | -32% |
| 2. Organic N fertilisers | a. Animal manure | 300 | 305 | 317 | 317 | 316 | 313 | 315 | -14% |
| | b. Sewage sludge | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - |
| | c. Other organic fertilisers | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.2 | 0.4 | 49% |
| 3. Urine and dung deposited by grazing animals | | 92 | 94 | 98 | 99 | 99 | 99 | 100 | 87% |
| 4. Crop residues | Arable crops | 32 | 32 | 33 | 35 | 31 | 33 | 33 | -4% |
| | Residues PR&P | 86 | 86 | 86 | 98 | 89 | 90 | 90 | 13% |
| 5. Min./imm. associated with loss/gain of SOM | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - |
| 6. Cultivation of organic soils (ha) | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | -26% |
| 7. Other (domestic inorganic fertilisers) | | 7.5 | 8.2 | 7.7 | 6.8 | 7.0 | 7.7 | 6.8 | -32% |

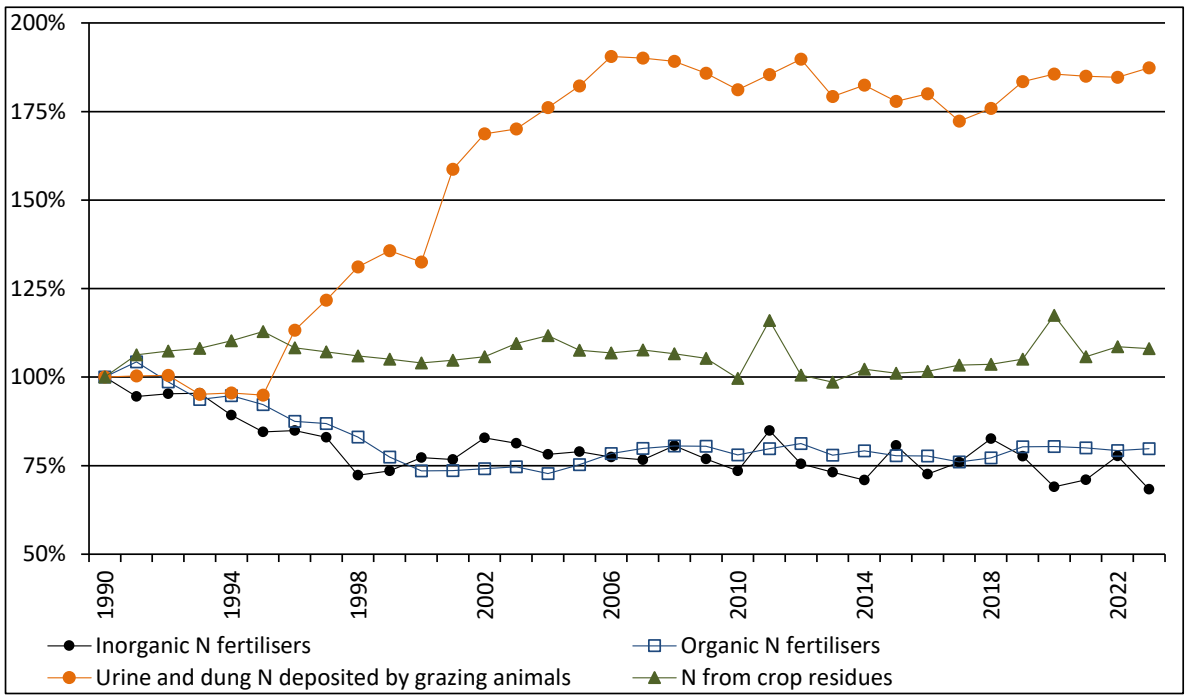



Figure 5-8 Relative development of the most important activity data for source category 3Da direct $N_2O$ emissions from managed soils

Figure 5-8 depicts the development of the most important activity data for direct $N_2O$ emissions from managed soils. The use of inorganic N-fertiliser declined mainly during the 1990s due to structural changes: Between 1996 and 2011, the share of the area of farms certified by the production label BIO (organic production) grew from 28% in 2005 to 41% in 2020 (OS 2014d, OS 2021d). 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.

### 5.5.2.3 Indirect $N_2O$ emissions from atmospheric deposition of N volatilised from managed soils (3Db1)

$N_2O$ emissions from atmospheric deposition of N volatilised from managed soil were estimated based on equations 11.9 and 11.11 of the 2019 IPCC Refinement (IPCC 2019), which were adapted to the more detailed approach applied in Switzerland as follows:

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

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)

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

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

$F_{AMT}$ = annual amount of managed animal manure N of livestock category T applied to soils (kg N/year)

$Frac_{GASMT}$ = fraction of applied animal manure N of livestock category T that volatilises as $NH_3$ (kg N/kg N)

$F_{PRPT}$ = annual amount of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category T (kg N/year)

$Frac_{GASPT}$ = fraction of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category T that volatilises as $NH_3$ (kg N/kg N)

$F_{CN}$ = total amount of commercial fertiliser N applied to soils (kg N/year)

$F_{CN}$ = 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 2.6%. For further information, see chp. 5.3.2.4.

**Activity data for indirect $N_2O$ emissions from atmospheric deposition (compare FOEN 2024 page 305)**

The estimation of volatilisation of ammonia and $NO_x$ was harmonized with the Swiss AGRAMMON model using the same emission factors and basic parameters (see Table 5-21). Losses of commercial fertiliser nitrogen, animal manure N applied to soils, urine and dung N deposited on pasture, range and paddock by grazing animals as well as ammonia losses from agricultural soils due to processes in the vegetation cover were considered. For the calculation of $NH_3$ emissions, changes of agricultural structures (e.g. changes to more animal friendly housing systems) and techniques (manure management, measures to reduce $NH_3$ emissions) are considered and explain temporal dynamics.

Ammonia volatilisation from **commercial fertiliser N** was estimated separately for urea and other synthetic fertilisers, sewage sludge (1990–2003), and other organic fertilisers (compost). Ammonia volatilisation of nitrogen in synthetic fertilisers was assessed separately for individual fertiliser types based on (EMEP/EEA 2019). The weighted mean value for synthetic fertilisers excluding urea is 2.8% (mean 1990–2022). Furthermore, 13.1% of urea-nitrogen is lost as ammonia. Ammonia emission factors for sewage sludge range from 20% to 26% depending on the composition of the sludge (Kupper et al. 2022) and is NO from 2004 onwards. Other organic fertilisers include compost as well as liquid and solid digestates. Ammonia emission factors are 3.4% for compost (Kupper et al. 2022).

Total $Frac_{GASF}$ (including $NO_x$ emissions) as reported in reporting table 3.D declined considerably from 6.0% in 1990 to 4.5% in 2023 due to a change in the shares of the different commercial fertilisers: the use of urea and sewage sludge (sewage sludge only 1990–2003), which both have high $NH_3$ emission factors, has declined since 1990.

Different ammonia loss factors were used for **animal manure N applied to soils** from different livestock categories according to the detailed approach of the AGRAMMON model (Kupper et al. 2022). Overall weighted $Frac_{GASMT}$ for animal manure applied to soils slightly decreased from 24.6% in 1990 to 19.9% in 2023.

Ammonia volatilisation from **urine and dung N deposited on pasture, range and paddock by grazing animals** was also assessed individually for each livestock category. Weighted mean loss rates ($Frac_{GASPT}$) range between 4.7% and 5.1%.

Nitrogen pools and flows for calculating 3Db Indirect $N_2O$ emissions from managed soils are displayed in Table 5-22. Additional information is given in Annex A5.2.

Table 5-21 Overview of $NH_3$ and $NO_x$ emission factors used for the assessment of emissions from source category 3Db1 Indirect $N_2O$ emissions from atmospheric deposition.

| Emission Factors Volatilisation | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | |
| $NH_3$ from commercial fertiliser N ($Frac_{GASFi}$) | 6.00 | 6.84 | 5.27 | 4.31 | 4.57 | 4.55 | 4.83 | 4.36 |
| Urea | 13.42 | 11.04 | 8.73 | 3.21 | 15.73 | 10.13 | 12.60 | 8.56 |
| Other Mineral Fertilisers | 3.06 | 2.58 | 2.36 | 2.41 | 2.25 | 2.17 | 2.47 | 2.22 |
| Recycling Fertilisers (weighted average) | 14.45 | 12.52 | 11.37 | 11.51 | 10.72 | 10.34 | 11.77 | 10.59 |
| Sewage Sludge | 16.50 | 13.94 | 12.75 | NO | NO | NO | NO | NO |
| Compost | 3.43 | 3.43 | 3.43 | 3.43 | 3.43 | 3.43 | 3.43 | 3.43 |
| $NH_3$ from application of animal manure N ($Frac_{GASMT}$) | 24.65 | 24.76 | 22.96 | 22.61 | 21.24 | 20.35 | 20.10 | 20.11 |
| Mature Dairy Cattle | 26.69 | 26.78 | 25.38 | 25.30 | 23.76 | 22.50 | 22.19 | 22.19 |
| Other Mature Cattle | 24.16 | 23.68 | 21.76 | 22.65 | 22.45 | 21.77 | 21.61 | 21.61 |
| Growing Cattle (weighted average) | 24.84 | 24.75 | 22.72 | 22.86 | 21.99 | 21.28 | 21.07 | 21.12 |
| Sheep (weighted average) | 3.72 | 4.38 | 4.14 | 5.23 | 5.50 | 5.04 | 4.92 | 4.92 |
| Swine (weighted average) | 21.52 | 21.02 | 19.79 | 20.02 | 18.82 | 18.21 | 18.05 | 18.04 |
| Other Livestock (weighted average) | 5.73 | 7.32 | 7.32 | 7.70 | 8.26 | 8.58 | 8.59 | 8.74 |
| $NH_3$ from urine and dung N deposited on PR&P ($Frac_{GASPT}$) | 4.68 | 4.68 | 4.78 | 4.86 | 4.88 | 4.90 | 4.91 | 4.91 |
| Mature Dairy Cattle | 4.67 | 4.65 | 4.65 | 4.61 | 4.59 | 4.59 | 4.59 | 4.59 |
| Other Mature Cattle | 4.57 | 4.57 | 4.57 | 4.57 | 4.57 | 4.56 | 4.57 | 4.57 |
| Growing Cattle (weighted average) | 4.57 | 4.57 | 4.57 | 4.56 | 4.57 | 4.57 | 4.57 | 4.57 |
| Sheep (weighted average) | 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 |
| Other Livestock (weighted average) | 5.00 | 6.01 | 8.11 | 9.96 | 9.22 | 10.42 | 10.58 | 11.10 |
| $NH_3$ from Agricultural Soils (kg/ha/year) | 0.24 | 0.25 | 0.35 | 0.45 | 0.35 | 0.41 | 0.36 | 0.38 |
| $NO_x$ from applied fertilisers ($Frac_{NOXA}$) | 4.96 | 4.08 | 3.23 | 1.19 | 5.81 | 3.74 | 4.66 | 3.17 |
| $NO_x$ 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 |

| Emission Factors Volatilisation | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 1990 -2023 |
|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | % |
| $NH_3$ from commercial fertiliser N ($Frac_{GASFi}$) | 4.36 | 4.36 | 4.36 | 4.36 | 4.36 | 4.36 | 4.46 | -26% |
| Urea | 11.28 | 11.28 | 12.44 | 10.62 | 7.41 | 18.36 | 18.61 | 39% |
| Other Mineral Fertilisers | 2.32 | 2.52 | 2.37 | 2.11 | 2.17 | 2.37 | 2.23 | -27% |
| Recycling Fertilisers (weighted average) | 11.08 | 12.05 | 11.32 | 10.06 | 10.35 | 11.33 | 9.84 | -32% |
| Sewage Sludge | NO | NO | NO | NO | NO | NO | NO | - |
| Compost | 3.43 | 3.43 | 3.43 | 3.43 | 3.43 | 3.43 | 3.43 | 0% |
| $NH_3$ from application of animal manure N ($Frac_{GASMT}$) | 20.05 | 20.04 | 20.07 | 20.16 | 19.97 | 19.90 | 19.90 | -19% |
| Mature Dairy Cattle | 22.19 | 22.19 | 22.19 | 22.19 | 22.19 | 22.19 | 22.19 | -17% |
| Other Mature Cattle | 21.61 | 21.61 | 21.61 | 21.61 | 21.61 | 21.61 | 21.61 | -11% |
| Growing Cattle (weighted average) | 21.07 | 21.07 | 21.07 | 21.10 | 21.10 | 21.11 | 21.11 | -15% |
| Sheep (weighted average) | 4.92 | 4.92 | 4.92 | 4.92 | 4.92 | 4.92 | 4.90 | 32% |
| Swine (weighted average) | 18.05 | 18.03 | 18.03 | 18.05 | 18.04 | 18.01 | 18.03 | -16% |
| Other Livestock (weighted average) | 8.73 | 8.60 | 8.94 | 9.04 | 9.64 | 9.53 | 9.52 | 66% |
| $NH_3$ from urine and dung N deposited on PR&P ($Frac_{GASPT}$) | 4.92 | 4.92 | 4.95 | 4.95 | 5.07 | 5.07 | 5.06 | 8% |
| Mature Dairy Cattle | 4.59 | 4.59 | 4.59 | 4.59 | 4.59 | 4.59 | 4.59 | -2% |
| Other Mature Cattle | 4.57 | 4.57 | 4.57 | 4.57 | 4.57 | 4.57 | 4.57 | 0% |
| Growing Cattle (weighted average) | 4.57 | 4.57 | 4.57 | 4.57 | 4.57 | 4.57 | 4.57 | 0% |
| Sheep (weighted average) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 0% |
| Swine (weighted average) | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | - |
| Other Livestock (weighted average) | 11.17 | 10.88 | 11.65 | 12.03 | 13.85 | 13.64 | 13.55 | 171% |
| $NH_3$ from Agricultural Soils (kg/ha/year) | 0.38 | 0.31 | 0.40 | 0.44 | 0.45 | 0.12 | 0.36 | 49% |
| $NO_x$ from applied fertilisers ($Frac_{NOXA}$) | 4.17 | 4.17 | 4.60 | 3.93 | 2.74 | 6.79 | 6.88 | 39% |
| $NO_x$ 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% |

Note: The notation key of emission factors for sewage sludge is automatically set “NO” by the CRT reporter from 2004 on.

Table 5-22 Overview of N pools and flows for calculating indirect $N_2O$ emissions from managed soils.

| Nitrogen Pools and Flows | | 1990 | 1995 | 2000 | 2005 | 2010 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|
| | | t N/yr | | | | | | | |
| | Animals manure N applied to soils | 364 | 333.0 | 279.2 | 296.8 | 307.8 | 312.5 | 307.1 | 306.6 |
| | Commercial fertiliser | 509.8 | 557.7 | 578.3 | 584.3 | 591.9 | 591.1 | 599.1 | 585.7 |
| | Area of agricultural soils (ha) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Deposition | Sum volatised N ($NH_3$ and $NO_x$) | 112.8 | 104.7 | 81.2 | 83.5 | 81.7 | 79.6 | 79.4 | 77.4 |
| | $NH_3$ emissions from commercial fertilisers | 16.7 | 16.5 | 10.7 | 8.4 | 8.3 | 8.0 | 9.7 | 7.8 |
| | $NH_3$ emissions from applied animal manure | 89.8 | 82.4 | 64.1 | 67.1 | 65.4 | 63.6 | 61.7 | 61.7 |
| | $NH_3$ emissions from pasture, range and paddock | 2.51 | 2.38 | 3.39 | 4.75 | 4.73 | 4.79 | 4.68 | 4.73 |
| | $NH_3$ emissions from agricultural soils | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | $NO_x$ emissions from commercial fertilisers | 1.53 | 1.32 | 1.11 | 1.08 | 1.00 | 0.97 | 1.10 | 0.99 |
| | $NO_x$ emissions from applied animal manure | 2.00 | 1.83 | 1.54 | 1.63 | 1.69 | 1.72 | 1.69 | 1.69 |
| | $NO_x$ emissions from PR&P | 0.29 | 0.28 | 0.39 | 0.54 | 0.53 | 0.54 | 0.52 | 0.53 |
| Leaching and run-off | Sum leaching and run-off | 166.9 | 155.1 | 132.0 | 133.7 | 124.9 | 125.3 | 128.0 | 124.6 |
| | Leaching and run-off from commercial fertilisers | 57.3 | 49.6 | 39.8 | 36.7 | 32.5 | 31.4 | 35.7 | 32.1 |
| | Leaching and run-off from applied animal manure | 75.1 | 68.6 | 55.0 | 55.7 | 54.9 | 55.7 | 54.8 | 54.7 |
| | Leaching and run-off from pasture, range and paddock | 11.0 | 10.5 | 14.0 | 18.3 | 17.3 | 17.4 | 17.0 | 17.2 |
| | Leaching and run-off from crop residues | 23.4 | 26.4 | 23.3 | 22.9 | 20.2 | 20.7 | 20.5 | 20.6 |
| | Leaching and run-off from mineralisation of SOM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| Nitrogen Pools and Flows | | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 1990 -2023 |
|---|---|---|---|---|---|---|---|---|---|
| | | t N/yr | | | | | | | % |
| | Animals manure N applied to soils | 300 | 305 | 316.8 | 317.0 | 315.6 | 313.0 | 314.7 | -14% |
| | Commercial fertiliser | 585.7 | 585.7 | 585.7 | 585.7 | 585.7 | 585.7 | 585.7 | 15% |
| | Area of agricultural soils (ha) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| Deposition | Sum volatised N ($NH_3$ and $NO_x$) | 76.1 | 77.9 | 80.2 | 79.5 | 79.0 | 79.0 | 78.5 | -30% |
| | $NH_3$ emissions from commercial fertilisers | 8.2 | 8.9 | 8.4 | 7.5 | 7.7 | 8.4 | 7.6 | -55% |
| | $NH_3$ emissions from applied animal manure | 60.1 | 61.0 | 63.6 | 63.9 | 63.0 | 62.3 | 62.6 | -30% |
| | $NH_3$ emissions from pasture, range and paddock | 4.54 | 4.63 | 4.86 | 4.93 | 5.02 | 5.01 | 5.08 | 103% |
| | $NH_3$ emissions from agricultural soils | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - |
| | $NO_x$ emissions from commercial fertilisers | 1.04 | 1.13 | 1.06 | 0.94 | 0.97 | 1.06 | 0.93 | -39% |
| | $NO_x$ emissions from applied animal manure | 1.65 | 1.68 | 1.74 | 1.74 | 1.74 | 1.72 | 1.73 | -14% |
| | $NO_x$ emissions from PR&P | 0.51 | 0.52 | 0.54 | 0.55 | 0.55 | 0.54 | 0.55 | 87% |
| Leaching and run-off | Sum leaching and run-off | 124.6 | 128.7 | 129.7 | 128.7 | 126.8 | 129.8 | 126.2 | -24% |
| | Leaching and run-off from commercial fertilisers | 33.6 | 36.5 | 34.3 | 30.5 | 31.4 | 34.3 | 30.2 | -47% |
| | Leaching and run-off from applied animal manure | 53.5 | 54.3 | 56.5 | 56.6 | 56.3 | 55.8 | 56.1 | -25% |
| | Leaching and run-off from pasture, range and paddock | 16.5 | 16.8 | 17.5 | 17.7 | 17.7 | 17.6 | 17.9 | 62% |
| | Leaching and run-off from crop residues | 21.0 | 21.0 | 21.3 | 23.8 | 21.4 | 22.0 | 21.9 | -7% |
| | Leaching and run-off from mineralisation of SOM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - |

Figure 5-9 depicts the development of the most important activity data for indirect $N_2O$ emissions from managed soils. Ammonia emissions from application of commercial fertilisers declined mainly due to reduced fertiliser use and due to the decreasing share of fertilisers with high ammonia emission rates (i.e. urea and sewage sludge) (see chapter 5.5.2.2). Ammonia emissions from applied animal manure declined mainly due to declining livestock populations and hence due to the reductions of available manure N. The fraction of applied animal manure N that volatilises as $NH_3$ ($Frac_{GASMT}$) declined slightly and also contributed to the decreasing trend.

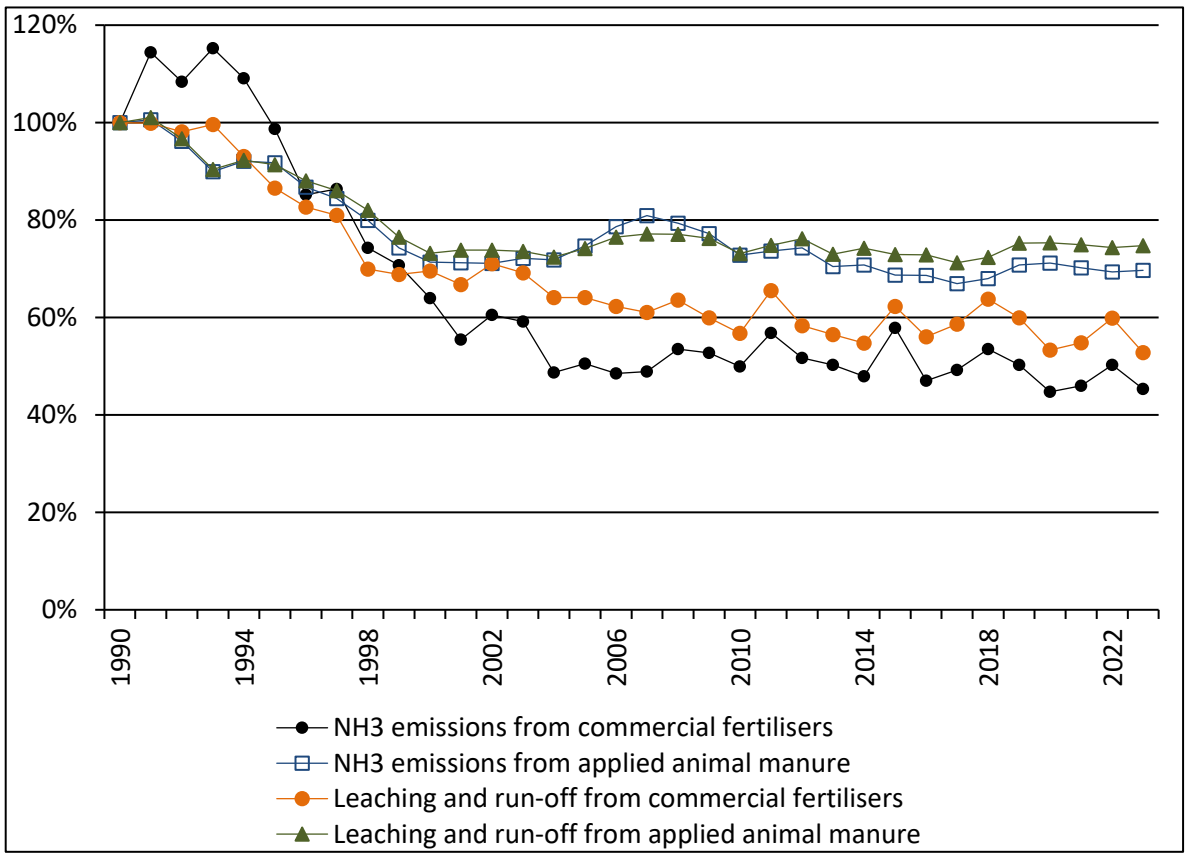



Figure 5-9 Relative development of the most important activity data for source category 3Db indirect $N_2O$ emissions from managed soils.

### 5.5.2.4 Indirect $N_2O$ emissions from leaching and run-off from managed soils (3Db2)

$N_2O$ emissions from leaching and run-off from managed soils were estimated based on equation 11.10 of the 2019 IPCC Refinement (IPCC 2019):

$$N_2O_{(L)} - N = (F_{CN} + F_{AM} + F_{PRP} + F_{CR} + F_{SOM}) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

Where:

$N_2O_{(L)}$–N = annual amount of $N_2O$–N produced from leaching and run-off of N additions to managed soils (kg $N_2O$–N/year)

$F_{CN}$ = annual amount of commercial fertiliser N applied to soils (kg N/year)

$F_{AM}$ = annual amount of managed animal manure N applied to soils (kg N/year)

$F_{PRP}$ = annual amount of urine and dung N deposited by grazing animals (kg N/year)

$F_{CR}$ = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

$F_{SOM}$ = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes of land use or management (kg N/year)

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

$EF_5$ = emission factor for $N_2O$ emissions from N leaching and run-off (kg $N_2O$–N/kg N leached and run-off)

**Emission factor for indirect $N_2O$ emissions from nitrogen leaching and run-off**

The emission factor for indirect $N_2O$ emissions from leaching and run-off from managed soils is 0.011 kg $N_2O$–N/kg N according to the 2019 IPCC Refinement (IPCC 2019).

**Activity data for indirect $N_2O$ emissions from nitrogen leaching and run-off (compare FOEN 2024 page 310)**

For the calculation of $N_2O$ emissions from leaching and run-off from managed soils, N-leaching from commercial fertilisers (including synthetic fertilisers, sewage sludge and compost), managed animal manure N applied to soils ($F_{AM}$), urine and dung N deposited by grazing animals ($F_{PRP}$) and N in crop residues returned to soils ($F_{CR}$) were accounted for. It is assumed that no nitrogen is mineralised in agricultural soils of Liechtenstein. The method for the assessment of the respective amounts of nitrogen is described in chp. 5.5.2.2 and numbers are shown in Table 5-20.

$Frac_{LEACH}$ was taken from the Swiss GHG inventory. It was estimated for the years 1990 and 2010 by dividing the available amount of nitrogen by the amount of nitrogen that is lost due to leaching and run-off in Switzerland according to model estimates of Prasuhn (2016). The respective loss rates are 20.6% for 1990 and 17.8% for 2010. According to Spiess and Prasuhn (2006), it can be assumed that loss rates were somewhat higher in the early 1990s and then declined due to agricultural policy reforms. Accordingly, the reduction in the nitrate loss rate was implemented between 1995 and 2010 with constant loss rates after 2010. The same loss rates were 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 5-22.

Figure 5-9 depicts the development of the most important activity data for indirect $N_2O$ emissions from managed soils. Both leaching and run-off from commercial fertiliser and animal manure N declined during the inventory time period due to the reduced nitrogen inputs and the decreasing nitrate loss rates ($Frac_{LEACH}$).

### 5.5.3 Uncertainties and time-series consistency

Uncertainties of emission factors and activity data are taken from ART (2008). These 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 2019 IPCC Refinement (IPCC 2019). 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 5-23. For 3Da (Direct $N_2O$ emissions – Fertilisers) the sub-positions 3Da 1, 2, 4, and 7 were combined according to Approach 1 error propagation.

Since there are two aggregate categories 3D direct/$N_2O$ and 3D indirect/$N_2O$, the uncertainties of fertilisers, organic soils, urine and dung deposited on pasture range and paddock are aggregated (via error propagation) and similar for 3D indirect/$N_2O$ atmospheric deposition and leaching /runoff. The results of the aggregations are given in Table 5-23 and are used in chp. 1.6.

Table 5-23 Approach 1 uncertainties for 3D Agricultural soils in 2023. AD: Activity data; EF: Emission factor; CO: Combined.

| **Uncertainty 3D** | | **Approach 1** | | |
|---|---|---|---|---|
| | | **AD** | **EF** | **comb.** |
| | | % | | |
| 3D1 Direct soil emissions | Fertilisers | 13.8 | 85.0 | 86.1 |
| | Organic soils | 33.3 | 137.5 | 141.5 |
| | Urine and dung deposited on PR&P | 66.8 | 216.7 | 226.7 |
| | 3D1 aggregate | 13.9 | 80.5 | 81.7 |
| 3D2 Indirect soil emissions | Atmospheric deposition | 42.0 | 80.0 | 90.4 |
| | Leaching and run-off | 22.3 | 90.9 | 93.6 |
| | 3D2 aggregate | 26.8 | 60.3 | 66.0 |

For further uncertainty results also consult chp. 1.6.

The time series 1990–2023 are consistent. 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, 2010 and 2015 (extensive surveys on approximatively 3000 farms). Values in-between the assessment years were interpolated linearly, whereas values beyond 2015 are kept constant and will be updated as new survey results become available.
- The emission factor for indirect $N_2O$ emissions following volatilization of $NH_3$ and $NO_x$ varies according to varying land use as described in 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 were carried out as mentioned in section 1.5 including triple checks of Liechtenstein's reporting tables (CRT tables). The triple check includes a detailed comparison of current and previous submission data for the base year 1990 and for the year 2022 as well as an analysis of the increase or decrease of emissions between 2022 and 2023 in the current submission.

In addition to the overall triple check a separate internal technical documentation of Liechtenstein's model is available (Bretscher 2019, in German only). For model updates, separate documentations exist (for the update in Submission 2025: Bretscher 2024). The manual and documentations ensure 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 2024). The respective conclusions are equally valid for Liechtenstein since the methods used are an adaptation of the Swiss model version. Bottom-up inventory estimates in Switzerland agree well with several atmospherically $CH_4$ measurements, thus verifying the methodological approach applied in the inventory.

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

### 5.5.5 Category-specific recalculations

The following recalculations lead to changes in $CH_4$ an $N_2O$ emissions, resulting in a decrease of 0.3 kt $CO_2$eq in 2022:

- 3D: $N_2O$ emissions from cultivated organic soils were recalculated for the whole time series. New disaggregated emission factors for grassland and cropland were adopted from the IPCC Wetland Supplement. The impact on overall emissions was +2.3 t $CO_2$eq on average.
- 3D: $N_2O$ emissions from urine and dung de-posited by grazing animals were recalculated for the whole time series. New emission factors for pasture, range and paddocks (EF3's) from the 2019 IPCC Refinement were adopted. The impact on overall emissions ranges from -272.1 to -549.7 t $CO_2$eq.
- 3D: $N_2O$ emissions from nitrogen leaching and run-off were recalculated for the whole time series. The respective emission factor (EF5) from the 2019 IPCC Refinement was adopted. The impact on overall emissions ranges from +181.2 to +246.5 t $CO_2$eq.

### 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 latest update has been done for the submission 2025.

## 5.6 Prescribed burning of savannas (3E)

Burning of savannas does not occur (NO) as this is not an agricultural practice in Liechtenstein.

## 5.7 Field burning of agricultural residues (3F)

Field burning of agricultural residues is not occurring (NO) in Liechtenstein.

## 5.8 Liming (3G)

According to a research of the OE, liming is not occurring (NO) in Liechtenstein (OE 2015b).

## 5.9 Urea application (3H)

### 5.9.1 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 $CO_2$ that was fixed during the industrial production process of the fertiliser. Emissions in Liechtenstein have decreased between 1990 and 2023, ranging between 0.06 and 0.04 kt $CO_2$.

### 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 holds a share of 15% of all synthetic fertilisers. Further information regarding the methods for estimating commercial fertilisers see chp. 5.2.2.2. Note that the amount of urea ammonium nitrate (UAN) is not quantified. It is estimated to be <1% in Switzerland (Agricura 2016) and therefore negligible in Liechtenstein.

### 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. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. Since 3H is not a key category its uncertainties are accounted in the "rest" categories with mean uncertainty.

Consistency: Time series for source category 3H Urea application are all considered consistent.

### 5.9.4 Category-specific QA/QC and verification

General QA/QC measures are described in NID chp. 1.5. 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

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 latest update has been done for the submission 2025.

## 5.10 Other carbon-containing fertilisers (3I)

The use of other carbon-containing fertilisers was not estimated (NE) for Liechtenstein. Urea ammonium nitrate (UAN) is used in Switzerland. On average, the share of UAN applied in Switzerland is <1% of total urea (Agricura 2016). The share of UAN used in Liechtenstein cannot be determined. However, it is very likely <1% as well. Accordingly, the emissions from UAN application are very likely <0.005 kt $CO_2$ in the year 2023 (1% of emissions of source category 3H Urea application), which means that it accounts for less

than 0.001% of total GHG emissions (excl. LULUCF). Accordingly, the application of UAN contributes less than 0.05% of the national total GHG emissions and does not exceed 500 kt $CO_2$ eq. It is considered below the threshold of significance pursuant to decision 24/CP.19, annex I, paragraph 37(b).

# 6. Land Use, Land-Use Change and Forestry (LULUCF) (CRT sector 4)

## 6.1 Overview of sector

### 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. In general, carbon stocks and stock changes based on studies and surveys carried out in Switzerland are 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 (Thürig et al. 2004). Region 3 is situated adjacently along the Western border of Liechtenstein. In submission 2024, a new calculation model was implemented allowing for more differentiated applications of calculation methods, conversion times and time series; it corresponds widely to the model applied in the Swiss GHGI (FOEN 2024).

The land areas in the period 1990–2023 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, 2014 and 2019. 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 Inventories (LWI 2012 and LWI 2025), which had been recorded in 2010 and 2022, respectively. The inventory comprehended ca. 400 terrestrial sampling plots, where biomass stock, growth, harvesting and mortality had been measured.

For cropland and grassland, partially country-specific emission factors and carbon stock values were applied. For other land use categories, IPCC default values or expert estimates from Switzerland are used.

### 6.1.2 Emissions and removals

Table 6-1 and Figure 6-1 summarize the $CO_2$ equivalent emissions and removals in consequence of carbon losses and gains for the years 1990–2023. The total net emissions of $CO_2$ equivalent vary between -12.66 kt (1991) and 25.71 kt (2000). Three components of the $CO_2$ balance are shown separately:

- Gain of living biomass on forest land: this is the growth of biomass on forest land remaining forest land; it is the largest sink of carbon.
- Loss of living biomass on forest land: decrease of carbon in living biomass (by harvest and mortality) on forest land remaining forest land; it is the largest source of carbon.
- Land-use change, soil and HWP: this is all the rest including carbon removals/emissions due to land-use changes and use of soils, especially of organic soils, as well as the carbon stock changes in harvested wood products (HWP). It also includes the $N_2O$ emissions from organic soils (CRT Table4(II)), direct $N_2O$ emissions due to N mineralization in soils (up to 0.59 $CO_2$eq) associated with land-conversions and indirect $N_2O$ emissions due to nitrogen leaching and run-off on non-agricultural soils (CRT Table4(III)).

Table 6-1 $CO_2$ equivalent emissions/removals [kt] of the source category LULUCF. Positive values refer to emissions; negative values refer to removals from the atmosphere. A GWP of 265 was used for $N_2O$.

| **LULUCF** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** |
|---|---|---|---|---|---|---|---|---|---|---|
| | kt CO2 eq | | | | | | | | | |
| Gain of living biomass in forest | -49.50 | -49.57 | -49.64 | -49.71 | -49.78 | -49.85 | -49.92 | -49.88 | -49.84 | -49.80 |
| Loss of living biomass in forest | 50.78 | 34.43 | 45.55 | 42.05 | 61.78 | 47.84 | 39.18 | 50.35 | 41.83 | 40.11 |
| Land-use change, soil and HWP | 2.28 | 2.47 | 2.66 | 2.85 | 3.04 | 3.22 | 3.39 | 8.52 | 8.89 | 9.25 |
| **Sector 4 LULUCF (total)** | **3.56** | **-12.66** | **-1.43** | **-4.81** | **15.03** | **1.21** | **-7.35** | **8.99** | **0.87** | **-0.44** |

| **LULUCF** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** |
|---|---|---|---|---|---|---|---|---|---|---|
| | kt CO2 eq | | | | | | | | | |
| Gain of living biomass in forest | -49.76 | -49.72 | -49.68 | -49.68 | -49.68 | -49.67 | -49.67 | -49.67 | -49.66 | -49.76 |
| Loss of living biomass in forest | 65.86 | 41.68 | 42.14 | 45.99 | 47.96 | 47.76 | 52.42 | 61.47 | 63.37 | 60.33 |
| Land-use change, soil and HWP | 9.61 | 9.90 | 10.19 | 7.68 | 7.90 | 8.12 | 8.34 | 8.55 | 8.76 | 8.32 |
| **Sector 4 LULUCF (total)** | **25.71** | **1.86** | **2.65** | **3.99** | **6.19** | **6.20** | **11.09** | **20.35** | **22.47** | **18.89** |

| **LULUCF** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** |
|---|---|---|---|---|---|---|---|---|---|---|
| | kt CO2 eq | | | | | | | | | |
| Gain of living biomass in forest | -49.86 | -40.54 | -40.61 | -40.68 | -40.75 | -40.74 | -40.73 | -40.72 | -40.72 | -40.71 |
| Loss of living biomass in forest | 58.85 | 40.83 | 41.06 | 36.09 | 36.07 | 32.54 | 31.36 | 32.45 | 39.84 | 33.36 |
| Land-use change, soil and HWP | 8.27 | 8.13 | 7.99 | 7.85 | 7.71 | 9.39 | 9.10 | 8.61 | 10.33 | 9.77 |
| **Sector 4 LULUCF (total)** | **17.27** | **8.42** | **8.44** | **3.26** | **3.04** | **1.19** | **-0.27** | **0.34** | **9.45** | **2.43** |

| **LULUCF** | **2020** | **2021** | **2022** | **2023** | **Mean** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kt CO2 eq | | | | | | | | | |
| Gain of living biomass in forest | -40.74 | -40.77 | -40.81 | -40.84 | -46.28 | | | | | |
| Loss of living biomass in forest | 28.54 | 25.75 | 27.26 | 27.59 | 43.37 | | | | | |
| Land-use change, soil and HWP | 7.04 | 6.65 | 6.25 | 5.95 | 7.26 | | | | | |
| **Sector 4 LULUCF (total)** | **-5.16** | **-8.38** | **-7.29** | **-7.30** | **4.35** | | | | | |

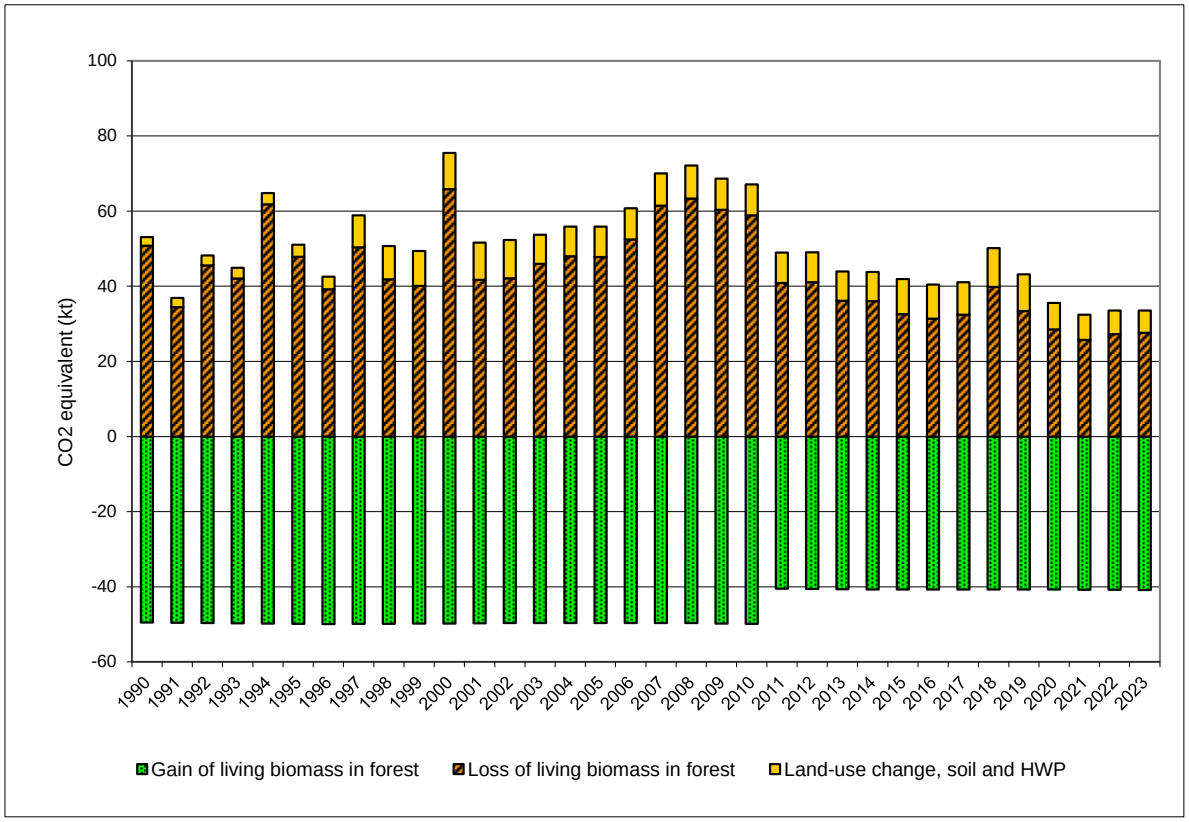



Figure 6-1 Liechtenstein's $CO_2$ removals due to the increase (growth) of living biomass on forest land, the $CO_2$ emissions due to the decrease (harvest and mortality) of living biomass on forest land and the net $CO_2$ equivalent emissions due to land-use changes and from use of soils.

Gain and loss of living biomass in forests are the dominant categories when looking at the $CO_2$ emissions and removals. There is a considerable annual variation of loss of living biomass in forests dependent on the wood harvesting rate. In 1990, 1994, 1997 and 2000 the loss of living biomass in forests was larger than the gain (Table 6-1). After 2010, the gain in living biomass decreased according to LWI 2025 (Figure 6-1). However, harvest and mortality decreased even stronger causing net sinks of $CO_2$ in the LULUCF sector from 2020 onwards. The resulting $CO_2$ emissions are visible in the total emissions/removals of the LULUCF sector (see Figure 6-2). Further explanatory notes on variations and trends can be found in chp. 2.2.2 "Sector 4 LULUCF".

Compared to these biomass changes in forests, the net $CO_2$ equivalent emissions arising from land-use changes, from soils and HWP are relatively small (see Figure 6-1). It can be observed that land-use conversions to grassland increase significantly after 1996: higher conversion rates from forest land to grassland leads to increased $CO_2$ emissions (see Table 6-2). 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. Since 2008 HWP is a net source as the production of sawnwood was decreasing strongly.

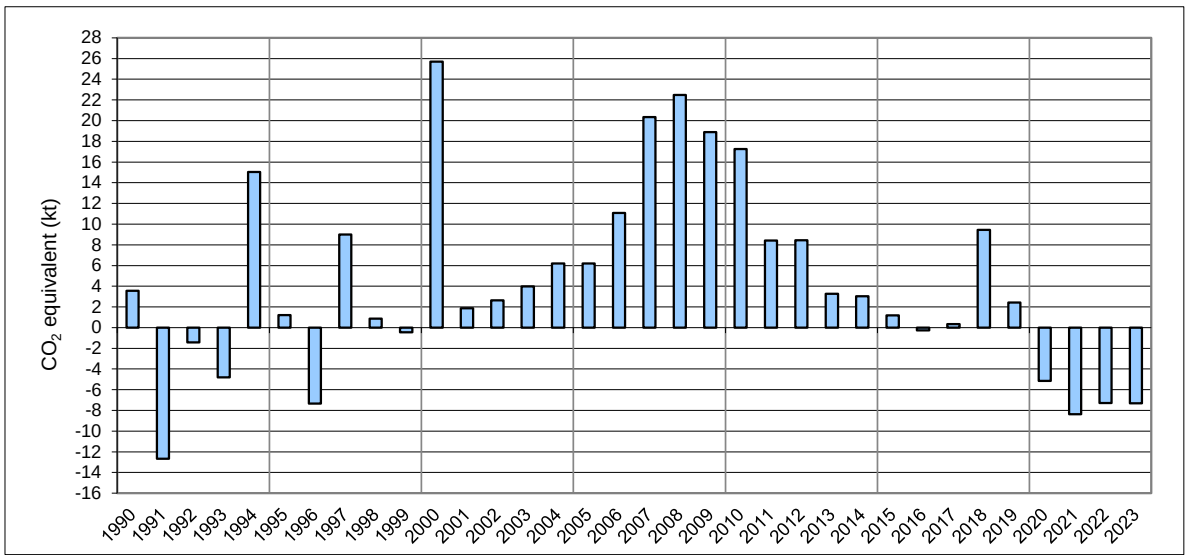



Figure 6-2 Liechtenstein's CO2 emissions/removals of sector 4 LULUCF.

Table 6-2 Net $CO_2$ removals and emissions per land-use category in kt $CO_2$.

| Net $CO_2$ emissions/removals | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total Land-Use Categories** | **3.28** | **-12.95** | **-1.71** | **-5.09** | **14.75** | **0.92** | **-7.63** | **8.62** | **0.49** | **-0.84** |
| **A. Forest Land** | **-5.19** | **-21.61** | **-10.57** | **-14.13** | **5.53** | **-8.48** | **-17.21** | **-5.97** | **-14.41** | **-16.05** |
| 1. Forest Land remaining Forest Land | -0.11 | -15.89 | -5.27 | -8.70 | 10.20 | -3.26 | -11.66 | -0.88 | -9.04 | -10.66 |
| 2. Land converted to Forest Land | -5.08 | -5.72 | -5.29 | -5.43 | -4.67 | -5.21 | -5.55 | -5.08 | -5.37 | -5.39 |
| **B. Cropland** | **4.44** | **4.43** | **4.42** | **4.42** | **4.41** | **4.40** | **4.39** | **4.39** | **4.38** | **4.38** |
| 1. Cropland remaining Cropland | 4.18 | 4.17 | 4.17 | 4.16 | 4.15 | 4.14 | 4.13 | 4.12 | 4.12 | 4.11 |
| 2. Land converted to Cropland | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 |
| **C. Grassland** | **2.13** | **2.12** | **2.11** | **2.10** | **2.09** | **2.08** | **2.08** | **5.63** | **5.72** | **5.80** |
| 1. Grassland remaining Grassland | 1.61 | 1.60 | 1.59 | 1.58 | 1.58 | 1.57 | 1.56 | 1.71 | 1.70 | 1.70 |
| 2. Land converted to Grassland | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 3.93 | 4.01 | 4.10 |
| **D. Wetlands** | **2.30** | **2.30** | **2.30** | **2.31** | **2.31** | **2.31** | **2.32** | **2.52** | **2.53** | **2.55** |
| 1. Wetlands remaining Wetlands | 2.01 | 2.02 | 2.02 | 2.02 | 2.03 | 2.03 | 2.03 | 2.04 | 2.05 | 2.06 |
| 2. Land converted to Wetlands | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.47 | 0.48 | 0.49 |
| **E. Settlements** | **1.88** | **1.88** | **1.87** | **1.87** | **1.86** | **1.86** | **1.85** | **2.21** | **2.21** | **2.20** |
| 1. Settlements remaining Settlements | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | -0.11 | -0.12 | -0.12 |
| 2. Land converted to Settlements | 1.86 | 1.86 | 1.86 | 1.86 | 1.85 | 1.85 | 1.85 | 2.32 | 2.32 | 2.33 |
| **F. Land converted to Other Land** | **0.41** | **0.41** | **0.41** | **0.42** | **0.42** | **0.42** | **0.43** | **1.13** | **1.17** | **1.21** |
| **G. Harvested wood products** | **-2.69** | **-2.48** | **-2.27** | **-2.07** | **-1.87** | **-1.67** | **-1.48** | **-1.29** | **-1.11** | **-0.93** |

| Net $CO_2$- emissions/removals | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total Land-Use Categories** | **25.29** | **1.43** | **2.20** | **3.52** | **5.71** | **5.71** | **10.59** | **19.84** | **21.95** | **18.39** |
| **A. Forest Land** | **9.78** | **-14.33** | **-13.79** | **-9.89** | **-7.87** | **-8.03** | **-3.32** | **5.78** | **7.73** | **4.48** |
| 1. Forest Land remaining Forest Land | 14.18 | -9.07 | -8.59 | -4.88 | -2.97 | -3.17 | 1.34 | 10.10 | 11.95 | 8.90 |
| 2. Land converted to Forest Land | -4.40 | -5.26 | -5.20 | -5.01 | -4.90 | -4.86 | -4.66 | -4.32 | -4.22 | -4.43 |
| **B. Cropland** | **4.37** | **4.36** | **4.36** | **4.41** | **4.38** | **4.35** | **4.33** | **4.30** | **4.28** | **4.18** |
| 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 | 0.26 | 0.26 | 0.26 | 0.32 | 0.31 | 0.29 | 0.28 | 0.26 | 0.25 | 0.15 |
| **C. Grassland** | **5.89** | **5.97** | **6.06** | **4.43** | **4.48** | **4.53** | **4.58** | **4.63** | **4.68** | **4.41** |
| 1. Grassland remaining Grassland | 1.70 | 1.69 | 1.69 | 1.21 | 1.22 | 1.23 | 1.25 | 1.26 | 1.27 | 1.75 |
| 2. Land converted to Grassland | 4.19 | 4.28 | 4.37 | 3.22 | 3.26 | 3.30 | 3.34 | 3.38 | 3.41 | 2.66 |
| **D. Wetlands** | **2.57** | **2.58** | **2.60** | **2.56** | **2.56** | **2.57** | **2.57** | **2.58** | **2.58** | **2.67** |
| 1. Wetlands remaining Wetlands | 2.07 | 2.07 | 2.08 | 2.08 | 2.09 | 2.09 | 2.09 | 2.09 | 2.09 | 2.10 |
| 2. Land converted to Wetlands | 0.50 | 0.51 | 0.52 | 0.48 | 0.48 | 0.48 | 0.48 | 0.49 | 0.49 | 0.57 |
| **E. Settlements** | **2.21** | **2.21** | **2.21** | **1.59** | **1.60** | **1.61** | **1.61** | **1.62** | **1.63** | **1.70** |
| 1. Settlements remaining Settlements | -0.12 | -0.12 | -0.12 | -0.23 | -0.23 | -0.23 | -0.23 | -0.23 | -0.23 | -0.01 |
| 2. Land converted to Settlements | 2.33 | 2.33 | 2.33 | 1.82 | 1.83 | 1.83 | 1.84 | 1.85 | 1.85 | 1.72 |
| **F. Land converted to Other Land** | **1.24** | **1.28** | **1.31** | **0.87** | **0.90** | **0.93** | **0.96** | **0.99** | **1.02** | **0.82** |
| **G. Harvested wood products** | **-0.75** | **-0.65** | **-0.54** | **-0.44** | **-0.34** | **-0.25** | **-0.15** | **-0.06** | **0.04** | **0.13** |

| Net $CO_2$- emissions/removals | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total Land-Use Categories** | **16.76** | **7.91** | **7.93** | **2.74** | **2.52** | **0.63** | **-0.86** | **-0.24** | **8.86** | **1.84** |
| **A. Forest Land** | **2.80** | **-6.02** | **-5.97** | **-11.13** | **-11.32** | **-15.19** | **-16.72** | **-16.00** | **-8.99** | **-15.84** |
| 1. Forest Land remaining Forest Land | 7.37 | -1.06 | -0.92 | -5.81 | -5.90 | -9.29 | -10.42 | -9.33 | -2.19 | -8.40 |
| 2. Land converted to Forest Land | -4.58 | -4.96 | -5.05 | -5.32 | -5.42 | -5.90 | -6.30 | -6.66 | -6.80 | -7.44 |
| **B. Cropland** | **4.17** | **4.17** | **4.17** | **4.17** | **4.16** | **4.06** | **3.98** | **3.89** | **3.80** | **3.72** |
| 1. Cropland remaining Cropland | 4.03 | 4.03 | 4.03 | 4.03 | 4.03 | 3.95 | 3.88 | 3.81 | 3.74 | 3.67 |
| 2. Land converted to Cropland | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.11 | 0.10 | 0.08 | 0.07 | 0.05 |
| **C. Grassland** | **4.39** | **4.37** | **4.35** | **4.32** | **4.30** | **6.27** | **6.36** | **6.36** | **6.34** | **6.32** |
| 1. Grassland remaining Grassland | 1.75 | 1.75 | 1.76 | 1.76 | 1.76 | 1.06 | 1.08 | 1.10 | 1.12 | 1.14 |
| 2. Land converted to Grassland | 2.64 | 2.61 | 2.59 | 2.57 | 2.54 | 5.21 | 5.28 | 5.26 | 5.22 | 5.19 |
| **D. Wetlands** | **2.68** | **2.68** | **2.69** | **2.70** | **2.70** | **2.50** | **2.49** | **2.47** | **2.45** | **2.43** |
| 1. Wetlands remaining Wetlands | 2.11 | 2.11 | 2.12 | 2.12 | 2.13 | 2.11 | 2.10 | 2.08 | 2.07 | 2.05 |
| 2. Land converted to Wetlands | 0.57 | 0.57 | 0.57 | 0.57 | 0.58 | 0.39 | 0.39 | 0.39 | 0.38 | 0.38 |
| **E. Settlements** | **1.69** | **1.69** | **1.68** | **1.67** | **1.66** | **1.58** | **1.60** | **1.61** | **1.63** | **1.64** |
| 1. Settlements remaining Settlements | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | -1.87 | -1.87 | -1.87 | -1.87 | -1.87 |
| 2. Land converted to Settlements | 1.71 | 1.70 | 1.69 | 1.68 | 1.67 | 3.46 | 3.47 | 3.49 | 3.50 | 3.52 |
| **F. Land converted to Other Land** | **0.81** | **0.81** | **0.81** | **0.81** | **0.81** | **1.21** | **1.24** | **1.23** | **1.22** | **1.21** |
| **G. Harvested wood products** | **0.21** | **0.21** | **0.21** | **0.20** | **0.20** | **0.19** | **0.19** | **0.19** | **2.41** | **2.36** |

| Net $CO_2$- emissions/removals | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|
| **Total Land-Use Categories** | **-5.68** | **-8.89** | **-7.79** | **-7.79** |
| **A. Forest Land** | **-20.87** | **-23.87** | **-22.56** | **-22.44** |
| 1. Forest Land remaining Forest Land | -13.07 | -15.78 | -14.35 | -14.05 |
| 2. Land converted to Forest Land | -7.80 | -8.09 | -8.21 | -8.39 |
| **B. Cropland** | **3.69** | **3.66** | **3.62** | **3.59** |
| 1. Cropland remaining Cropland | 3.64 | 3.62 | 3.60 | 3.56 |
| 2. Land converted to Cropland | 0.05 | 0.04 | 0.03 | 0.03 |
| **C. Grassland** | **4.31** | **4.24** | **4.18** | **4.17** |
| 1. Grassland remaining Grassland | 1.55 | 1.57 | 1.59 | 1.61 |
| 2. Land converted to Grassland | 2.76 | 2.67 | 2.59 | 2.55 |
| **D. Wetlands** | **2.36** | **2.35** | **2.33** | **2.32** |
| 1. Wetlands remaining Wetlands | 2.05 | 2.05 | 2.04 | 2.04 |
| 2. Land converted to Wetlands | 0.31 | 0.30 | 0.29 | 0.28 |
| **E. Settlements** | **1.75** | **1.75** | **1.74** | **1.74** |
| 1. Settlements remaining Settlements | -0.57 | -0.57 | -0.57 | -0.57 |
| 2. Land converted to Settlements | 2.32 | 2.31 | 2.31 | 2.31 |
| **F. Land converted to Other Land** | **0.76** | **0.72** | **0.68** | **0.65** |
| **G. Harvested wood products** | **2.31** | **2.27** | **2.22** | **2.18** |

### 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 2024). 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 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 inventories (LWI 2012, LWI 2025). For other categories, carbon stocks and carbon stock changes were taken from Swiss data based on measurements and estimations.
- The land use and the land-use change matrix were calculated in each spatial stratum.
- Carbon stock changes in living biomass (deltaC$_l$), in dead organic matter (deltaC$_d$) and in soil (deltaC$_s$) were calculated for all cells of the land-use change matrix.
- Calculate $N_2O$ emissions due to mineralisation of soil organic matter.
- 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 reporting tables.
- Calculate $CO_2$ emissions and removals of the carbon pool in Harvested wood products (HWP).

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 cannot be cultivated, are classified as unmanaged. This holds for stony grassland (CC36), unproductive grassland (CC37), surface waters (CC41), unproductive wetland (CC42) and other land (rocks, sand, glaciers; CC61).

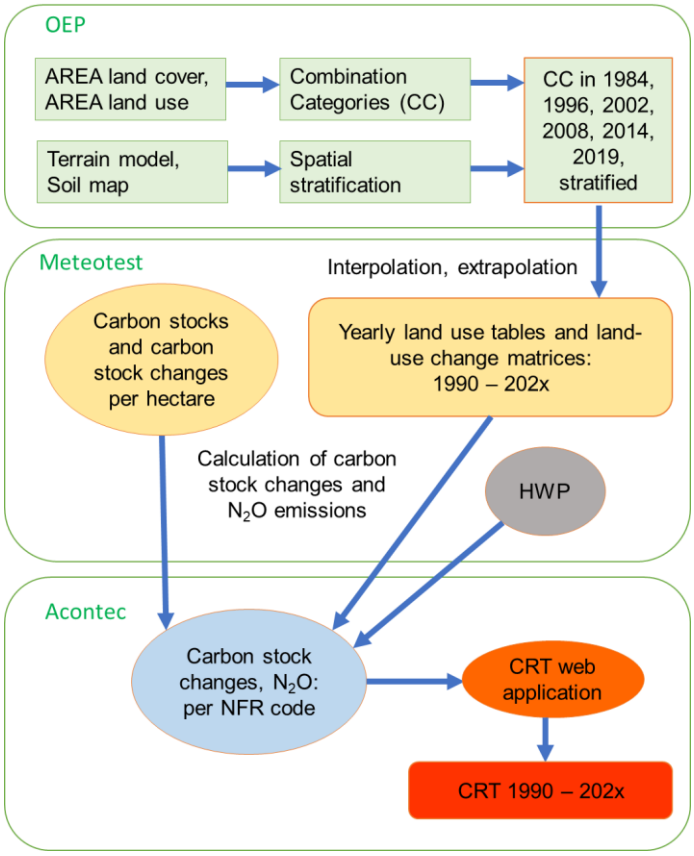



Figure 6-3 Procedure of calculating emissions and removals from LULUCF and producing Common Reporting Tables (CRT) in Liechtenstein.

Table 6-3 Land-use categories used in this report (so-called combination categories CC): 6 main categories and the 16 land-use categories. For a detailed definition of the CC categories see chp. 6.2.1.

| Main category | Land-use category | Remarks | Managed or unmanaged | CC code |
|---|---|---|---|---|
| A. Forest land | productive 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 | 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 |
| | vineyard, low-stem orchard, tree nursery | perennial agricultural plants with woody biomass and grass understorey | managed | 33 |
| | copse | agricultural and unproductive areas covered by perennial woody biomass including trees | managed | 34 |
| | stony grassland | grass, herbs and shrubs on stony surfaces | unmanaged | 36 |
| | unproductive grassland | unmanaged grass vegetation | unmanaged | 37 |
| D. Wetlands | surface water | 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 | other land | areas without soil and vegetation: rocks, sand, scree, glaciers | unmanaged | 61 |

### 6.1.3.2 Calculating carbon stock changes

The method is based largely on the Swiss procedure according to FOEN (2024).

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

$stockC_{l,i,CC}$: carbon stock in living biomass

$stockC_{d,i,CC}$: carbon stock in dead organic matter (sum of dead wood and litter)

$stockC_{s,i,CC}$: carbon stock in soil

$gainC_{l,i,CC}$: annual gain (growth) of carbon in living biomass

$lossC_{l,i,CC}$: annual loss (cut & mortality) of carbon in living biomass

$changeC_{d,i,CC}$: annual net carbon stock change in dead organic matter (sum of dead wood and litter)

$changeC_{s,i,CC}$: annual net carbon stock change in soil

On this basis, the carbon stock changes in living biomass ($deltaC_l$), in dead organic matter ($deltaC_d$) and in soil ($deltaC_s$) are calculated for all cells of the land-use change matrix. Each cell is characterized by a land-use category before the conversion (b), a land-use category after the conversion (a) and the area of converted land within the spatial stratum (i).

Equations 6.1-6.6 show according to the IPCC Guidelines (IPCC 2006, Volume 4), two approaches and their application for calculating carbon gains and losses: (1) the gain-loss approach (Equation 2.4; IPCC 2006, Volume 4) and (2) the stock-difference approach (Equation 2.5; IPCC 2006, Volume 4).

The gain-loss approach for calculating (net) carbon stock changes is defined as:

$$deltaC_{l,i,ba} = (gainC_{l,i,a} - lossC_{l,i,b}) * A_{i,ba} \quad (6.1)$$

$$deltaC_{d,i,ba} = changeC_{d,i,a} * A_{i,ba} \quad (6.2)$$

$$deltaC_{s,i,ba} = changeC_{s,i,a} * Ai,ba \quad (6.3)$$

The stock-difference approach for calculating carbon stock changes is defined as:

$$deltaC_{l,i,ba} = [\ (stockC_{l,i,a} - stockC_{l,i,b}) / CT\ ] * A_{i,ba} \quad (6.4)$$

$$deltaC_{d,i,ba} = [\ (stockC_{d,i,a} - stockC_{d,i,b}\ ) / CT\ ] * A_{i,ba} \quad (6.5)$$

$$deltaC_{s,i,ba} = [\ (stockC_{s,i,a} - stockC_{s,i,b}\ ) / CT\ ] * A_{i,ba} \quad (6.6)$$

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

i: spatial stratum

$A_{i,ba}$: area of land converted from b to a in the spatial stratum i, activity data from the land-use change matrix (area converted in the inventory year if CT=1 year, or the sum of the areas converted within the last 20 years if CT=20 years)

CT: conversion time (yr)

Table 6-4 defines the calculation approaches. The gain-loss approach was used in cases of no change in land use and generally for continuous transitions, e.g. the growth of living biomass on land converted to forest land. The stock-difference approach was used for

abrupt changes following discrete events (e.g. loss of biomass by deforestation, CT = 1 year) as well as for slow processes such as the change in soil carbon content (CT = 20 years, see chp. 6.1.3.3).

For conversions between the two forest land-use categories the approach was chosen in such a way that potential carbon losses of living biomass cannot be underestimated: e.g. for CC12 to CC13 stock-difference is used, and for CC13 to CC12 gain-loss is used, respectively (see Table 6-4).

In case of a land-use change to "Buildings and constructions" (CC51) a loss of 20% of the initial soil carbon stock was reported (for a detailed documentation see chp. 6.8.2.2). In case of land-use changes from CC51 to other categories the regular stock-difference approach according to equation 6.6 and Table 6-4), respectively, were applied.

Table 6-4 Calculation approaches (gain-loss or stock-difference with conversion time in years) applied for different land-use changes and carbon pools. Combination category codes CC12–CC61 were introduced in Table 6-3.

| Change in land-use category | Living biomass | Dead wood, litter (dead organic matter) | Mineral soil | Organic soil | Remarks |
|---|---|---|---|---|---|
| no change in category | gain-loss | gain-loss | gain-loss | gain-loss | |
| 4A1: CC13 to CC12 | gain-loss | stock-diff., 20 | stock-diff., 20 | gain-loss | forest land internal changes |
| 4A1: CC12 to CC13 | stock-diff., 20 | stock-diff., 20 | stock-diff., 20 | gain-loss | forest land internal changes |
| 4A2: non-forest land-use category to CC12/CC13 | gain-loss | stock-diff., 20 | stock-diff., 20 | gain-loss | change to forest land |
| 4B2: change to CC21 | stock-diff., 1 | stock-diff., 1 | stock-diff., 20 | gain-loss | change to cropland |
| 4C1: change among CC31-37 | stock-diff., 1 | stock-diff., 1 | stock-diff., 1 | gain-loss | grassland internal changes |
| 4C2: change to CC31-CC37 | stock-diff., 1 | stock-diff., 1 | stock-diff., 20 | gain-loss | change to grassland |
| 4D1: change among CC41-42 | stock-diff., 1 | stock-diff., 1 | stock-diff., 1 | gain-loss | wetlands internal changes |
| 4D2: change to CC41 | stock-diff., 1 | stock-diff., 1 | stock-diff., 1 | gain-loss | change to surface water |
| 4D2: change to CC42 | stock-diff., 1 | stock-diff., 1 | stock-diff., 20 | gain-loss | change to unproductive wetland |
| 4E1: change among CC51-54 | stock-diff., 1 | stock-diff., 1 | stock-diff., 1 | gain-loss | settlements internal changes |
| 4E2: change to CC51 | stock-diff., 1 | stock-diff., 1 | stock-diff., 20 (20%) | stock-diff., 20 (20%) | change to sealed settlement areas; soil carbon stock reduced by 20% |
| 4E2: change to CC52-54 | stock-diff., 1 | stock-diff., 1 | stock-diff., 20 | gain-loss | change to unsealed settlement areas |
| 4F2: change to CC61 | stock-diff., 1 | stock-diff., 1 | stock-diff., 20 | stock-diff., 20 | change to other land |

#### 6.1.3.3 Conversion time in the stock-difference approach

Table 6-4 shows the conversion times applied in the stock-difference approach to carbon stock changes in living biomass, dead organic matter (dead wood, litter), and soil for different land-use changes.

Changes in the soil carbon stock, and this is also true for the increase of woody biomass, as a result of land-use changes are slow processes that might take decades. Therefore, IPCC (2006, Volume 4, chp. 2) suggests implementing a conversion time (CT). Following the IPCC default value (CT = 20 years), carbon emissions or removals due to a soil carbon stock difference ($stockC_{s,i,a}$ – $stockC_{s,i,b}$) do not occur in one year but are distributed evenly over the 20 years following the land-use change.

A conversion time of 20 years was applied to all mineral soil carbon stock changes except for land converted to surface water and for internal changes in Grassland, Wetlands and Settlements. Accordingly, the area of mineral soil of each category 2 in reporting tables Table4.A to Table4.F contains 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 6-5 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 1990–2023 except for the loss in living biomass of productive forest (CC12) where annual values are used (see chp. 6.4.2).

Table 6-5 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 1990–2023, except the cells highlighted in green and orange (see main text). Values in purple-coloured cells were recalculated in Submission 2025.

| land-use code CC | altitude zone z | carbon stock in living biomass (stockCl,i) | 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 drained organic soil (changeCs,i) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Strata | Stocks (t C ha-1) | | | | | Changes (t C ha-1 yr-1) | | | | | |
| 12 Productive forest | 1 | 103.73 | 11.69 | 16.99 | 63.42 | 155 | 3.12 | -3.19 | 0.131 | -0.005 | 0 | -2.6 |
| | 2 | 101.44 | 12.29 | 16.99 | 80.18 | 155 | 2.77 | -2.83 | 0.131 | -0.005 | 0 | -2.6 |
| | 3 | 102.33 | 13.37 | 18.03 | 103.28 | 155 | 2.27 | -2.32 | -0.006 | 0.006 | 0 | -2.6 |
| 13 Unproductive forest | 1 | 20.45 | 0 | 7.51 | 61.82 | NO | 0 | 0 | 0 | 0 | 0 | NO |
| | 2 | 47.53 | 0 | 16.29 | 80.81 | NO | 0 | 0 | 0 | 0 | 0 | NO |
| | 3 | 42.36 | 0 | 26.21 | 103.24 | NO | 0 | 0 | 0 | 0 | 0 | NO |
| 21 Cropland | all | 6.82 | 0 | 0 | 57.06 | 155 | 0 | 0 | 0 | 0 | 0 | -9.52 |
| 31 Permanent Grassland | 1 | 5.61 | 0 | 0 | 60.93 | 155 | 0 | 0 | 0 | 0 | 0 | -9.52 |
| | 2 | 5.26 | 0 | 0 | 59.08 | 155 | 0 | 0 | 0 | 0 | 0 | -9.52 |
| | 3 | 3.30 | 0 | 0 | 51.68 | 155 | 0 | 0 | 0 | 0 | 0 | -9.52 |
| 32 Shrub Vegetation | 1 | 20.45 | 0 | 0 | 55.5 | NO | 0 | 0 | 0 | 0 | 0 | NO |
| | 2 | 20.45 | 0 | 0 | 43.3 | NO | 0 | 0 | 0 | 0 | 0 | NO |
| | 3 | 20.45 | 0 | 0 | 36.7 | NO | 0 | 0 | 0 | 0 | 0 | NO |
| 33 Vineyards et al. | all | 5.58 | 0 | 0 | 50.8 | NO | 0 | 0 | 0 | 0 | 0 | NO |
| 34 Copse | 1 | 20.45 | 0 | 0 | 62.6 | 155 | 0 | 0 | 0 | 0 | 0 | -5.3 |
| | 2 | 20.45 | 0 | 0 | 57.4 | 155 | 0 | 0 | 0 | 0 | 0 | -5.3 |
| | 3 | 20.45 | 0 | 0 | 37.6 | 155 | 0 | 0 | 0 | 0 | 0 | -5.3 |
| 36 Stony Grassland | all | 7.16 | 0 | 0 | 13.5 | NO | 0 | 0 | 0 | 0 | 0 | NO |
| 37 Unproductive Grassland | all | 3.45 | 0 | 0 | 37.5 | 155 | 0 | 0 | 0 | 0 | 0 | -5.3 |
| 41 Surface Waters | all | 0 | 0 | 0 | 0 | 155 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 Unproductive Wetland | all | 6.50 | 0 | 0 | 56.9 | 155 | 0 | 0 | 0 | 0 | 0 | -5.3 |
| 51 Buildings, Constructions | all | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 52 Herbaceous Biomass in S. | all | 9.54 | 0 | 0 | 57.2 | 155 | 0 | 0 | 0 | 0 | 0 | -9.52 |
| 53 Shrubs in Settlements | all | 15.43 | 0 | 0 | 52.0 | 155 | 0 | 0 | 0 | 0 | 0 | -5.3 |
| 54 Trees in Settlements | all | 20.72 | 0 | 0 | 56.5 | 155 | 0 | 0 | 0 | 0 | 0 | -5.3 |
| 61 Other Land | all | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Legend**

*altitude zones:*
1 < 600 m
2 601 - 1200 m
3 > 1200 m

NO: land-use type does not occur on organic soil

On organic soils, a value of 155 t C $ha^{-1}$ for stock Cs was assumed for all land-use categories that occur on organic soils (based on Oechslin et al. 2021). 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, LWI 2025). The cells highlighted in orange in Table 6-5 include annual losses of biomass based on harvesting statistics. The data for 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 6-6 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. 6.3.1.3); in the Table 6-6 these values are highlighted in orange. For categories 4B, 4(III) 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 6-6 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 | Combined uncertainty | Key category |
|---|---|---|---|---|---|---|
| | | | % | % | % | |
| 4A1 | Forest Land remaining Forest Land | $CO_2$ | 2.7 | 34.9 | 35.0 | yes |
| 4A2 | Land converted to Forest Land | $CO_2$ | 17.2 | 34.9 | 38.9 | yes |
| 4B1 | Cropland remaining Cropland | $CO_2$ | 30.8 | 23.0 | 38.4 | yes |
| 4B2 | Land converted to Cropland | $CO_2$ | 26.9 | 52.2 | 58.7 | |
| 4C1 | Grassland remaining Grassland | $CO_2$ | 6.0 | 47.0 | 47.4 | yes |
| 4C2 | Land converted to Grassland | $CO_2$ | 13.6 | 32.4 | 35.1 | yes |
| 4D1 | Wetlands remaining Wetlands | $CO_2$ | 10.5 | 50.0 | 51.1 | yes |
| 4D2 | Land converted to Wetlands | $CO_2$ | 40.9 | 36.2 | 54.6 | |
| 4E1 | Settlements remaining Settlements | $CO_2$ | 6.4 | 57.1 | 57.5 | yes |
| 4E2 | Land converted to Settlements | $CO_2$ | 19.4 | 31.6 | 37.0 | yes |
| 4F1 | Other Land remaining Other Land | $CO_2$ | NA | NA | NA | |
| 4F2 | Land converted to Other Land | $CO_2$ | 40.9 | 40.1 | 57.3 | |
| 4III | Direct emissions | $N_2O$ | 85.6 | 100.0 | 131.6 | |
| 4III | Indirect emissions (Leaching) | $N_2O$ | 87.9 | 100.0 | 133.1 | |
| 4G | Harvested Wood Products | $CO_2$ | 50.0 | 54.8 | 74.2 | yes |

## 6.2 Land-use definitions and classification systems

### 6.2.1 Combination Categories (CC) as derived from AREA 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 16 combination categories (CC) implementing the main categories proposed by IPCC as well as by country-specific sub-divisions (see Table 6-7). 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 6-7. 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.

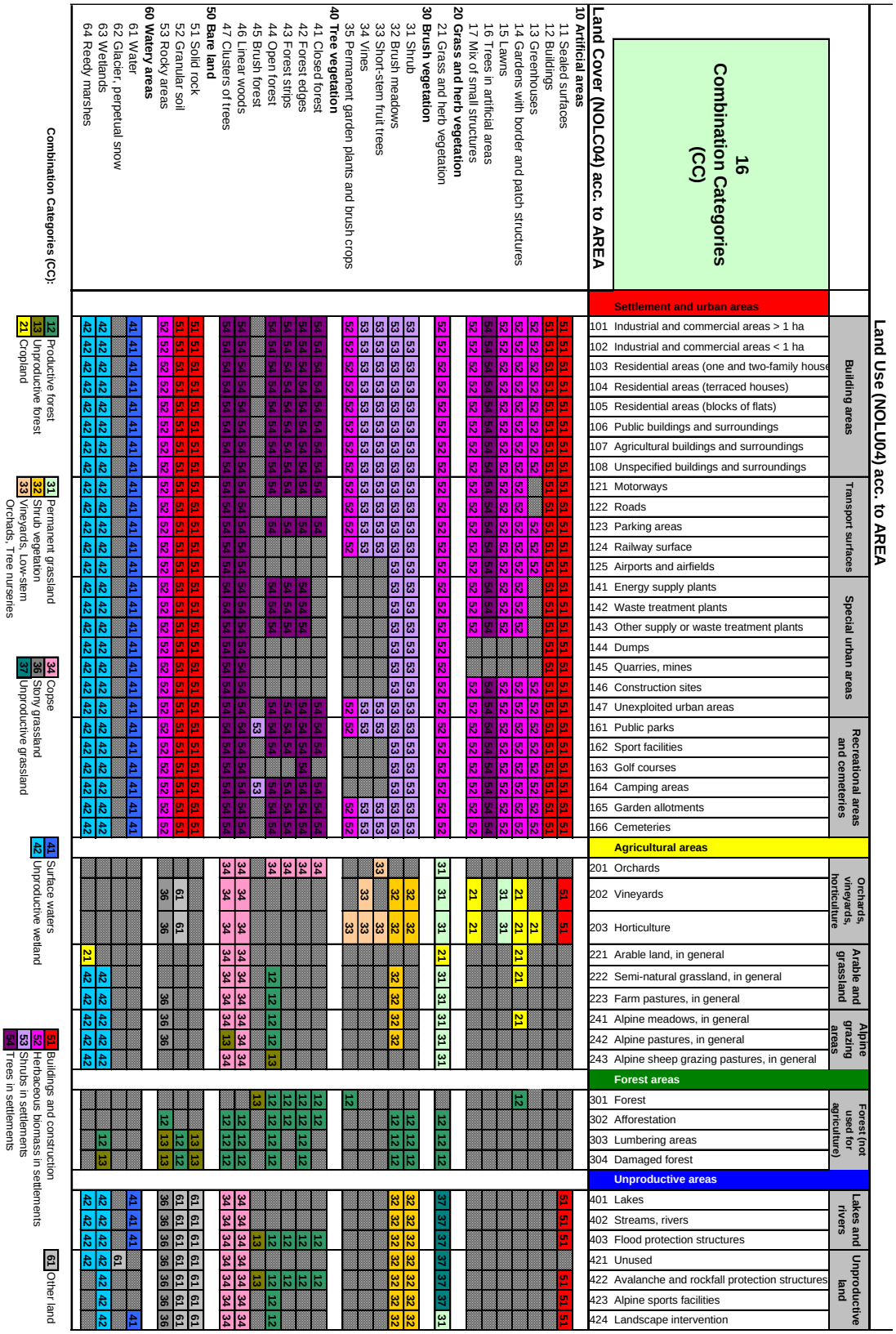
With regard to carbon content in biomass, there is a strong relation to the vegetation type (i.e. land cover in most cases). This is exemplarily reflected by the mainly horizontal arrangement of the individual CCs in Table 6-7. With regard to carbon turnover and soil organic carbon the CC definition 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. 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 and Copse (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.

Regarding the applicability of the combined categories (CC) for Liechtenstein, we can conclude that the basic land-use and land-cover categories (NOLC04/NOLU04 as shown in Table 6-7) are an integrated part of the AREA methodology and it was important to adopt them for Liechtenstein's AREA surveys. However, the CC derived from NOLC04/NOLU04 are not always essential in Liechtenstein: for example, CC35 (orchards) occurs very sparely and was therefore included in CC34.

Table 6-7 Relation between the land-use (NOLU04) and land-cover (NOLC04) categories of the AREA survey and the derived 16 combination categories (CC).



### 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, which is one of the five main regions used in the Swiss National Forest Inventory (Thürig et al. 2004).

Altitude data were supplied on a hectare-grid from the Office of Environment (Eberle 2023) 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). Two soil types (organic and mineral soils) were additionally differentiated. The organic soils had been mapped in digital form for Liechtenstein's concept of environmental and agricultural development (Büchel et al. 2006). That map contains the following groups and categories:

- Organic soils ('Moorböden, Alluvial überschüttetes Moor');
- Mineral soils (*'Fahlgley, Fahlgley mit z.T. Torfunterlage, Buntgley, Buntgley mit z.T. Torfunterlage, Braunerde, Fluvisol'*);
- Other (recultivated areas).

The first group (organic soils) was selected for defining the respective stratum as shown in Figure 6-4. Organic soils only occur on the ground of the Rhine valley. In the regions where organic soils occur, mainly agricultural areas (CC21, CC31) and wetlands (CC42) can be found.

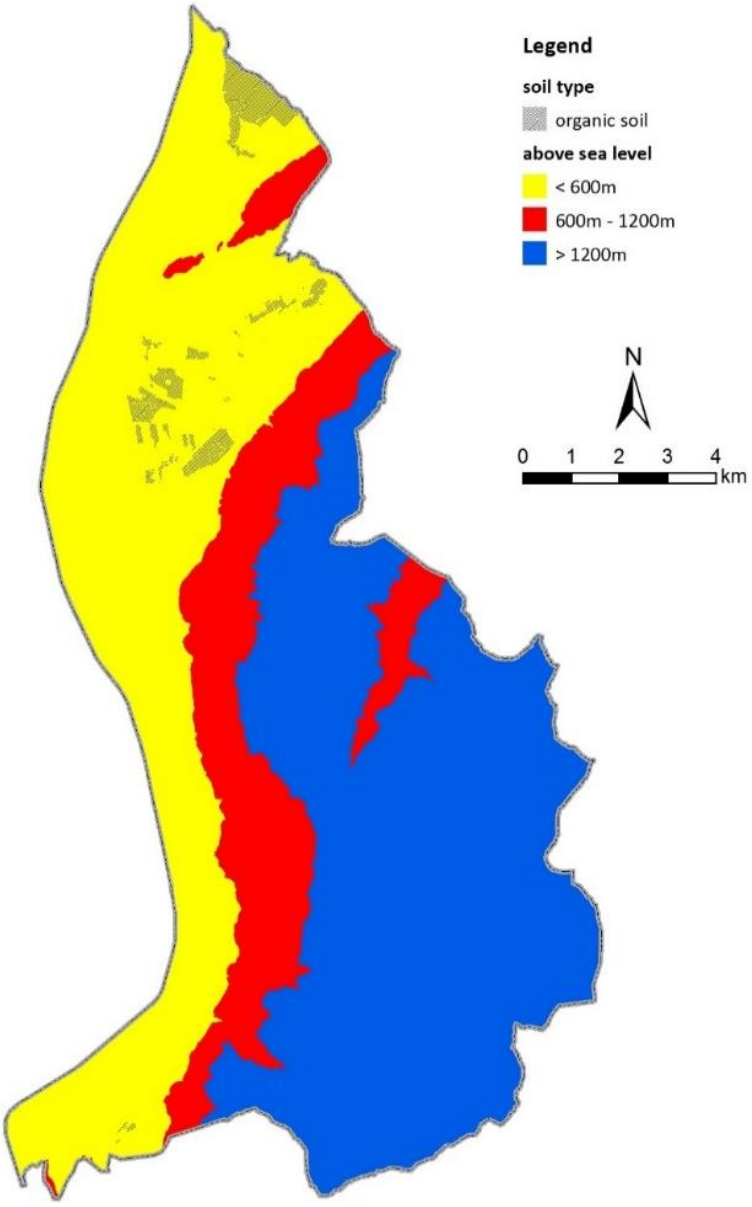



Figure 6-4 Map of Liechtenstein showing the altitude classes and soil types. Reference: OEP 2006d.

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

Table 6-8 shows the trend of land-use changes at the level of the disaggregated land-use categories (CC). The data results from interpolation and extrapolation in time. For example, areas of managed forests (CC12) increase by 3% from 1990 to 2023, while the area of cropland (CC21) decreases by 21% since 1990. The most significant land-use changes in absolute terms since 1990 can be observed in the categories cropland CC21 (decrease by 403 ha), grassland CC31-CC37 (decrease by 327 ha) and settlements CC51-CC54 (increase by 506 ha).

In Table 6-9 the land-use statistics resulting from spatial stratification (chp. 6.2.2) and interpolation in time (chp. 6.3.1.2) are exemplarily shown for the year 1990. The table gives also the area size of the individual spatial strata (column "Sum").

Table 6-8 Statistics of land use (CC = combination categories) for the period 1990–2023 (in ha) and changes (in hectares and in %, see bottom lines) between 1990 and 2023.

| | Forest Land | | Cropl. | Grassland | | | | | | Wetlands | | Settlements | | | | Other L. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC | 12 | 13 | 21 | 31 | 32 | 33 | 34 | 36 | 37 | 41 | 42 | 51 | 52 | 53 | 54 | 61 | Sum |
| Year | | | | | | | | | | | | | | | | | |
| 1990 | 5'148 | 885 | 1'953 | 3'227 | 594 | 31 | 719 | 345 | 398 | 201 | 159 | 903 | 305 | 15 | 144 | 1'024 | 16'046 |
| 1991 | 5'156 | 889 | 1'948 | 3'214 | 586 | 31 | 717 | 343 | 396 | 197 | 159 | 916 | 307 | 14 | 146 | 1'026 | 16'046 |
| 1992 | 5'164 | 894 | 1'943 | 3'201 | 579 | 31 | 715 | 342 | 394 | 194 | 159 | 929 | 309 | 14 | 149 | 1'029 | 16'046 |
| 1993 | 5'172 | 899 | 1'938 | 3'188 | 572 | 31 | 713 | 341 | 392 | 191 | 160 | 943 | 311 | 13 | 152 | 1'032 | 16'046 |
| 1994 | 5'180 | 904 | 1'933 | 3'174 | 565 | 32 | 711 | 340 | 390 | 188 | 160 | 956 | 312 | 12 | 155 | 1'035 | 16'046 |
| 1995 | 5'188 | 909 | 1'928 | 3'161 | 558 | 32 | 709 | 339 | 388 | 184 | 160 | 969 | 314 | 12 | 158 | 1'037 | 16'046 |
| 1996 | 5'196 | 914 | 1'923 | 3'148 | 551 | 32 | 707 | 338 | 386 | 181 | 160 | 982 | 316 | 11 | 161 | 1'040 | 16'046 |
| 1997 | 5'192 | 917 | 1'916 | 3'144 | 550 | 32 | 699 | 339 | 385 | 187 | 160 | 997 | 319 | 12 | 160 | 1'036 | 16'046 |
| 1998 | 5'188 | 920 | 1'909 | 3'141 | 549 | 32 | 690 | 341 | 383 | 194 | 161 | 1'013 | 322 | 13 | 159 | 1'031 | 16'046 |
| 1999 | 5'185 | 923 | 1'902 | 3'137 | 548 | 33 | 682 | 342 | 382 | 200 | 161 | 1'028 | 325 | 15 | 159 | 1'027 | 16'046 |
| 2000 | 5'181 | 925 | 1'895 | 3'133 | 547 | 33 | 674 | 343 | 381 | 206 | 161 | 1'043 | 327 | 16 | 158 | 1'023 | 16'046 |
| 2001 | 5'177 | 928 | 1'888 | 3'130 | 546 | 33 | 665 | 345 | 379 | 213 | 162 | 1'059 | 330 | 17 | 157 | 1'018 | 16'046 |
| 2002 | 5'173 | 931 | 1'881 | 3'126 | 545 | 33 | 657 | 346 | 378 | 219 | 162 | 1'074 | 333 | 18 | 156 | 1'014 | 16'046 |
| 2003 | 5'173 | 934 | 1'864 | 3'130 | 546 | 33 | 652 | 344 | 377 | 217 | 162 | 1'088 | 339 | 18 | 153 | 1'015 | 16'046 |
| 2004 | 5'174 | 937 | 1'846 | 3'134 | 548 | 33 | 647 | 342 | 376 | 215 | 161 | 1'103 | 345 | 19 | 151 | 1'017 | 16'046 |
| 2005 | 5'174 | 940 | 1'829 | 3'138 | 549 | 33 | 642 | 340 | 375 | 214 | 161 | 1'117 | 352 | 19 | 148 | 1'018 | 16'046 |
| 2006 | 5'174 | 942 | 1'812 | 3'141 | 550 | 33 | 636 | 337 | 374 | 212 | 161 | 1'131 | 358 | 19 | 145 | 1'019 | 16'046 |
| 2007 | 5'175 | 945 | 1'794 | 3'145 | 552 | 33 | 631 | 335 | 373 | 210 | 160 | 1'146 | 364 | 20 | 143 | 1'021 | 16'046 |
| 2008 | 5'175 | 948 | 1'777 | 3'149 | 553 | 33 | 626 | 333 | 372 | 208 | 160 | 1'160 | 370 | 20 | 140 | 1'022 | 16'046 |
| 2009 | 5'187 | 949 | 1'765 | 3'152 | 545 | 34 | 620 | 332 | 372 | 207 | 161 | 1'172 | 372 | 19 | 140 | 1'020 | 16'046 |
| 2010 | 5'199 | 950 | 1'754 | 3'154 | 537 | 34 | 614 | 331 | 373 | 205 | 162 | 1'185 | 374 | 19 | 139 | 1'017 | 16'046 |
| 2011 | 5'212 | 951 | 1'742 | 3'157 | 529 | 35 | 608 | 330 | 373 | 204 | 163 | 1'197 | 376 | 18 | 139 | 1'015 | 16'046 |
| 2012 | 5'224 | 952 | 1'730 | 3'160 | 520 | 35 | 602 | 328 | 373 | 203 | 164 | 1'209 | 377 | 17 | 139 | 1'012 | 16'046 |
| 2013 | 5'236 | 953 | 1'719 | 3'162 | 512 | 36 | 596 | 327 | 374 | 201 | 165 | 1'222 | 379 | 17 | 138 | 1'010 | 16'046 |
| 2014 | 5'248 | 954 | 1'707 | 3'165 | 504 | 36 | 590 | 326 | 374 | 200 | 166 | 1'234 | 381 | 16 | 138 | 1'007 | 16'046 |
| 2015 | 5'250 | 969 | 1'687 | 3'177 | 493 | 36 | 593 | 326 | 376 | 196 | 164 | 1'239 | 388 | 16 | 136 | 999 | 16'046 |
| 2016 | 5'252 | 983 | 1'667 | 3'190 | 481 | 37 | 595 | 326 | 379 | 192 | 161 | 1'244 | 396 | 17 | 135 | 991 | 16'046 |
| 2017 | 5'254 | 998 | 1'646 | 3'202 | 470 | 37 | 598 | 326 | 381 | 189 | 159 | 1'250 | 403 | 17 | 133 | 983 | 16'046 |
| 2018 | 5'256 | 1'012 | 1'626 | 3'215 | 458 | 38 | 600 | 326 | 384 | 185 | 156 | 1'255 | 411 | 18 | 132 | 975 | 16'046 |
| 2019 | 5'258 | 1'027 | 1'606 | 3'227 | 447 | 38 | 603 | 326 | 386 | 181 | 154 | 1'260 | 418 | 18 | 130 | 967 | 16'046 |
| 2020 | 5'265 | 1'034 | 1'592 | 3'233 | 439 | 38 | 601 | 325 | 387 | 179 | 154 | 1'269 | 422 | 18 | 129 | 962 | 16'046 |
| 2021 | 5'272 | 1'040 | 1'578 | 3'238 | 431 | 38 | 599 | 325 | 388 | 177 | 153 | 1'277 | 426 | 18 | 128 | 956 | 16'046 |
| 2022 | 5'279 | 1'047 | 1'564 | 3'244 | 423 | 38 | 597 | 324 | 389 | 175 | 153 | 1'286 | 430 | 18 | 127 | 951 | 16'046 |
| 2023 | 5'286 | 1'053 | 1'550 | 3'250 | 416 | 39 | 596 | 324 | 389 | 172 | 153 | 1'294 | 433 | 19 | 127 | 946 | 16'046 |
| Change ha | 138 | 169 | -403 | 23 | -178 | 8 | -123 | -21 | -8 | -28 | -6 | 391 | 128 | 4 | -17 | -78 | 0 |
| Change % | 3 | 19 | -21 | 1 | -30 | 26 | -17 | -6 | -2 | -14 | -4 | 43 | 42 | 24 | -12 | -8 | 0 |

Table 6-9 Statistics of land use (CC = combination categories) by the end of 1990 (in ha), stratified separately for elevation zones and soil type. The country's total area is 16'046 ha.

| CC | 12 | 13 | 21 | 31 | 32 | 33 | 34 | 36 | 37 | 41 | 42 | 51 | 52 | 53 | 54 | 61 | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation | | | | | | | | | | | | | | | | | |
| Z1: < 601 m | 973 | 1 | 1'953 | 1'193 | 20 | 30 | 383 | 15 | 90 | 162 | 136 | 753 | 273 | 12 | 126 | 53 | 6'169 |
| Z2: 601-1200 m | 1'976 | 9 | - | 364 | 10 | 1 | 81 | 10 | 6 | 15 | - | 84 | 24 | 2 | 14 | 72 | 2'663 |
| Z3: >1200 m | 2'200 | 876 | - | 1'671 | 564 | - | 255 | 321 | 302 | 24 | 24 | 67 | 8 | 2 | 4 | 899 | 7'214 |
| | 5'148 | 885 | 1'953 | 3'227 | 594 | 31 | 719 | 345 | 398 | 201 | 159 | 903 | 305 | 15 | 144 | 1'024 | 16'046 |
| Soil | | | | | | | | | | | | | | | | | |
| mineral | 5'142 | 885 | 1'826 | 3'164 | 594 | 31 | 716 | 345 | 395 | 199 | 47 | 900 | 305 | 15 | 144 | 1'024 | 15'727 |
| organic | 6 | - | 127 | 64 | - | - | 3 | - | 3 | 2 | 112 | 4 | 1 | - | - | - | 319 |
| | 5'148 | 885 | 1'953 | 3'227 | 594 | 31 | 719 | 345 | 398 | 201 | 159 | 903 | 305 | 15 | 144 | 1'024 | 16'046 |

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 6-10 shows an overview of the mean annual changes of all CC in 2010 as an example. The totals of the columns equal the total increase of one specific category. The totals of the rows equal 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 the reporting table 4.1 for each year 1990–2023.

Table 6-10 Land-use change in 2010 (change matrix). Units: ha/year.

| | | | To | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | main category | | Forest Land | | Cropl. | Grassland | | | | | | Wetlands | | Settlement | | | | Other L. | |
| | | CC | 12 | 13 | 21 | 31 | 32 | 33 | 34 | 36 | 37 | 41 | 42 | 51 | 52 | 53 | 54 | 61 | Decrease |
| From | Forest Land | 12 | | 1.0 | - | 1.2 | 0.7 | - | 1.0 | - | 0.3 | - | 0.7 | 1.3 | 0.3 | - | - | 0.3 | 6.8 |
| | | 13 | 7.0 | | - | 1.3 | 0.8 | - | 0.3 | - | 0.2 | - | - | - | - | - | - | 0.2 | 9.8 |
| | Cropland | 21 | - | - | | 16.3 | - | 0.5 | 0.3 | - | - | 0.2 | - | 2.8 | 1.0 | - | - | - | 21.2 |
| | Grassland | 31 | 0.7 | 2.2 | 8.3 | | 2.5 | - | 2.5 | 1.0 | 0.2 | - | 0.5 | 6.3 | 3.0 | 0.2 | 0.2 | 0.2 | 27.7 |
| | | 32 | 5.0 | 7.2 | - | 1.7 | | - | 2.2 | 0.5 | 0.3 | - | - | 0.2 | - | - | - | - | 17.0 |
| | | 33 | - | - | - | 0.2 | - | | - | - | - | - | - | 0.2 | - | - | - | - | 0.3 |
| | | 34 | 5.2 | 0.2 | 0.3 | 4.0 | 0.5 | 0.3 | | 0.3 | 0.7 | 0.3 | - | 0.7 | 1.0 | - | 0.3 | - | 13.8 |
| | | 36 | 0.5 | 0.3 | 0.2 | 2.0 | 1.5 | - | 0.3 | | 0.7 | - | - | - | - | - | - | 0.5 | 6.0 |
| | | 37 | - | - | - | 0.2 | 1.7 | - | 0.2 | 0.3 | | 0.2 | - | - | - | - | - | 0.2 | 2.7 |
| | Wetlands | 41 | - | - | - | - | - | - | - | - | - | | - | 0.2 | - | - | - | 3.7 | 3.8 |
| | | 42 | - | - | - | - | - | - | - | - | - | 0.2 | | 0.2 | - | - | - | - | 0.3 |
| | Settlement | 51 | - | - | 0.5 | 2.2 | - | - | 0.2 | - | 0.2 | - | - | | 1.5 | 0.2 | 0.2 | - | 4.8 |
| | | 52 | - | - | 0.2 | 0.7 | 0.2 | - | 0.2 | - | - | - | - | 3.7 | | 0.5 | 2.5 | - | 7.8 |
| | | 53 | 0.5 | - | - | - | - | - | - | - | - | - | - | 0.7 | 0.3 | | - | - | 1.5 |
| | | 54 | - | - | - | - | - | - | 0.2 | - | - | - | - | 0.8 | 2.5 | - | | - | 3.5 |
| | Other Land | 61 | 0.2 | - | - | 0.7 | 1.0 | - | 0.5 | 2.7 | 0.5 | 1.7 | 0.2 | 0.2 | - | - | - | | 7.5 |
| | | Increase | 19.0 | 10.8 | 9.5 | 30.3 | 8.8 | 0.8 | 7.8 | 4.8 | 3.0 | 2.5 | 1.3 | 17.2 | 9.7 | 0.8 | 3.2 | 5.0 | 134.7 |

## 6.3 Country-specific approaches

### 6.3.1 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

#### 6.3.1.1 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 $m^2$ 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 1990–2023 six 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 2019

Land-use statistics from the years 1984 and 1996 were originally evaluated according to a set of different land-use categories. For this purpose, 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, 2014 and 2019 data the new land-use and land-cover categories were used directly (EDI/BFS 2009).

### 6.3.1.2 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, 2008 to 2014 and 2014 to 2019 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 2019 is estimated by linear extrapolation, assuming that the average trend observed between 2008–2019 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.

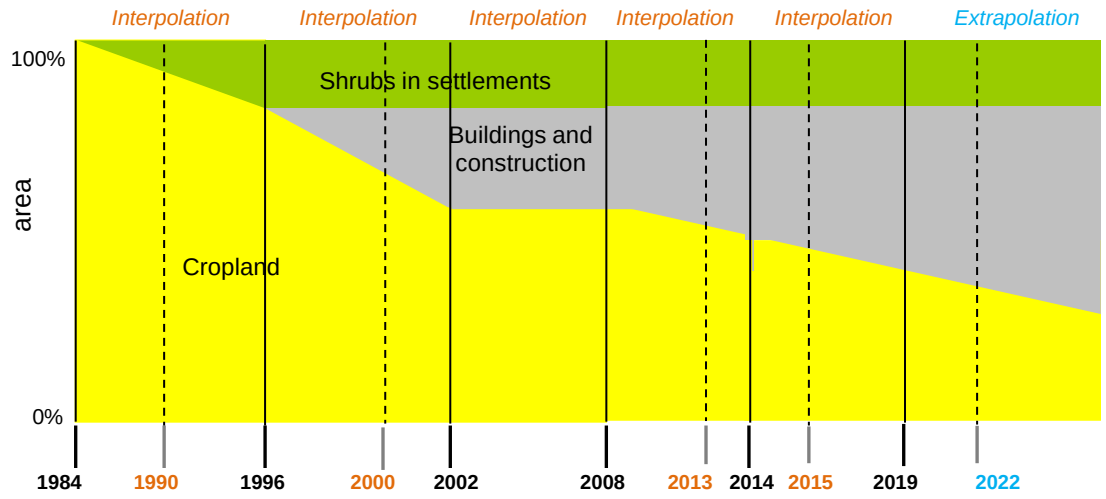



Figure 6-5 Hypothetical linear development of land-use changes between the six Land-use surveys (1984, 1996, 2002, 2008, 2014, 2019) with the example of areas changing 1984-1996 from “cropland” to “shrubs in settlements” and then 1996–2002 and again 2008–2014 to “buildings and constructions". The dotted lines show how the share of the different land use categories is determined in years between land use statistics and extrapolated after 2019.

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 2019 is done by taking the average trend of the time period 2008 to 2019. The ‘status’ for each individual year in the period 1990–2023 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 6-8).

#### 6.3.1.3 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 6-6. Details related to uncertainties of AREA data are presented in this chapter, while uncertainties of other AD (such as consumption of harvested wood products) and emission factors are presented in the respective chapters (6.x.3) of the LULUCF categories.

Uncertainties of the AREA-based activity data are presented in Table 6-11. 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

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

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:

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

Table 6-11 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.

### 6.3.1.4 QA/QC and verification of activity data

The general QA/QC measures are described in chp. 1.5.

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.

### 6.3.1.5 Recalculations of activity data

No recalculations were implemented in submission 2025.

### 6.3.1.6 Planned improvements for activity data

There are no planned improvements.

### 6.3.2 Information on approaches used for natural disturbances

Presently, Liechtenstein intends to apply, in the case of significant magnitude events, the provision of natural disturbances for units of Forest land. Natural disturbances were not mentioned in the Intended Nationally Determined Contribution (Government 2015a). It is planned to include them in future contributions.

For non-Forest land, no provisions for natural disturbances will be applied.

### 6.3.3 Information on approaches used for harvested wood products

For accounting harvested wood products (HWP), the approach B (production approach) as described in chp. 12, Volume 4 of IPCC (2006) is applied. The wood products pool contains only products made from wood harvested in Liechtenstein. The wood products pool possibly includes products made from domestic harvest that are exported to other countries. More details and results are presented in chp. 6.11.

## 6.4 Forest Land (4A)

### 6.4.1 Description

**Key category information 4A**

The $CO_2$ emission from 4A1 Forest Land remaining Forest Land is key source by level and trend.
4A2 Land Converted to Forest Land is a key source by level and trend.

40% of the total area of Liechtenstein is forest land. The total forest area increased by 5% between 1990 and 2023. The annual net $CO_2$ emissions/removals are in the range -23.9 kt $CO_2$ (2021) to 9.8 kt $CO_2$ (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 as well as on the growth and mortality rates measured in the national forest inventories (see also chapters 2.2.2 and 6.1.2). The source category 4A2 “Land converted to Forest Land” is a net sink in all years.

All of the forest land is temperate forest. Forest land is defined as follows (Government 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 managed forest (CC12) and unproductive forest (CC13) 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. 6.3.1. Carbon stocks and carbon stock changes are taken partly from Switzerland and partly from Liechtenstein's NFIs as well as from Liechtenstein's wood harvesting statistics. Details are described in the following paragraphs.

#### 6.4.2.1 National Forest Inventories (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 Inventories. The NFI are based on over 400 terrestrial sampling points situated in accessible forest stands (without brush forest) representing a mesh of 354 x 354 $m^2$. They were conducted in 2010 (LWI 2012) and 2022 (LWI 2025), respectively. Thus, the carbon fluxes induced by growth, cut and mortality are an average of two 12-year periods: 1998-2010, 2011-2022. Table 6-12 shows important results of the NFI.

- The average annual rates in LWI 2012 were 7.9 $m^3$ $ha^{-1}$ for growth, 5.7 $m^3$ $ha^{-1}$ for cut and 2.7 $m^3$ $ha^{-1}$ for mortality; overall, the growing stock was decreasing during this period.
- In LWI 2025, the annual rates were 6.4 $m^3$ $ha^{-1}$ for growth, 3.3 $m^3$ $ha^{-1}$ for cut and 2.2 $m^3$ $ha^{-1}$ for mortality; overall, the growing stock was increasing 2011-2022.

In order to simplify the calculation of annual gains and growing stocks, it is assumed that gross growth are constant over the respective time periods, i.e. the average rates 1998–2010 are applied for all years between 1990 and 2010, and the average rates 2011-2022 are applied for the years 2011 onwards. Due to methodological issues, the stocks measured in LWI 2012 and LWI 2025 are not comparable. Therefore, only the newest results concerning stocks from LWI 2025 are used for all years (Table 6-12).

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

Table 6-12 Results of Liechtenstein's forest inventories 2010 (LWI 2012) and 2022 (LWI 2025).

| | Elevation ≤ 1000 m | Elevation > 1000 m | Liechtenstein |
|---|---|---|---|
| | **Growth 1998-2010** [$m^3$ $ha^{-1}$ $yr^{-1}$] | | |
| Coniferous | 4.9 | 6.4 | 5.8 |
| Deciduous | 4.3 | 0.7 | 2.1 |
| Total | 9.2 | 7.1 | 7.9 |
| | **Stocks 2010** [$m^3$ $ha^{-1}$], not used any more | | |
| Growing stock | *374* | *383* | *379* |
| Dead wood | *24* | *34* | *30* |

| | | | |
|---|---|---|---|
| | **Growth 2011-2022** [$m^3$ $ha^{-1}$ $yr^{-1}$] | | |
| Coniferous | 4.0 | 5.0 | 4.6 |
| Deciduous | 3.9 | 0.4 | 1.8 |
| Total | 7.9 | 5.4 | 6.4 |
| | **Stocks 2022** [$m^3$ $ha^{-1}$] | | |
| Growing stock | 308 | 323 | 317 |
| Dead wood | 36 | 41 | 39 |

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-reports (LWI 2012 and 2025) present 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 reports present 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 6-5 were produced.

### 6.4.2.2 Biomass Conversion and Expansion Factors (BCEF)

BCEFs for Liechtenstein were derived from results of the 4th National Forest Inventory (NFI4, 2017) of Switzerland. As shown by Thürig et al. (2004), Liechtenstein's forest has similar growing conditions as the forest area in the Swiss NFI region 3 (Pre-Alps).

Therefore, published data on stocks and biomass from the NFI region 3 were used to calculate BCEFs for Liechtenstein as shown in Table 6-13. The necessary NFI result-tables were downloaded from www.lfi.ch/resultate (Abegg et al. 2020). In the Swiss NFI as well as in Liechtenstein's NFI, growing stock, gross growth, cut (harvesting) and mortality are expressed as round wood over bark.

In previous Swiss NIRs (FOEN 2008) 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 second Swiss NFI and other functions for twigs, branches, bark, coarse roots and foliages; BCEFs were then calculated for each spatial stratum as the ratio between round wood over bark ($m^3$ $ha^{-1}$) and the total above- and belowground biomass (t $ha^{-1}$) (as documented by Thürig and Schmid 2008). For comparison, Table 6-14 shows the new and the previously used BCEFs for coniferous and deciduous species stratified for altitude.

The new BCEFs for living biomass derived from NFI4 were initially not stratified for altitude (Table 6-13). Stratified values for the three altitude zones were calculated in accordance with the previous values, maintaining the overall area-weighted average (see Table 6-14). The new values are 2-4% lower than the previous version. They lie in the default range given by IPCC 2006. The BCEF for dead wood was not stratified.

Table 6-13 BCEFs to convert growing stock (round-wood over bark, $m^3$ $ha^{-1}$) to total biomass (t $ha^{-1}$) for conifers and deciduous species as well as BCEF for dead wood, derived from results of the Swiss NFI4, region 3 (Abegg et al. 2020).

| Swiss NFI 4 (2017) | Units | Region 3 (Pre-Alps) | | |
|---|---|---|---|---|
| | | Coniferous | Deciduous | Total |
| Living biomass: | | | | |
| Growing stock | $m^3$/ha | 331.7 | 106.8 | 438.5 |
| Biomass of living trees | t/ha | 200.4 | 85.9 | 286.3 |
| BCEF living biomass | t/$m^3$ | **0.60** | **0.80** | **0.65** |
| default BCEF | t/$m^3$ | 0.7 (0.4-1.0) | 0.8 (0.55-1.1) | |
| Dead wood: | | | | |
| Stock of dead wood | $m^3$/ha | | | 31.2 |
| Biomass of dead wood | t/ha | | | 20.2 |
| BCEF dead wood | t/$m^3$ | | | **0.65** |

Table 6-14 BCEFs from NFI4 stratified for altitude according to previous BCEFs from NFI2 (FOEN 2008).

| BCEFs Living biomass | Units | New values (NFI4 2009/2017) | | Previous values 2008 | |
|---|---|---|---|---|---|
| | | Coniferous | Deciduous | Coniferous | Deciduous |
| Altitude: | | | | | |
| < 601 m | t/$m^3$ | 0.59 | 0.78 | *0.59* | *0.82* |
| 601 - 1200 m | t/$m^3$ | 0.59 | 0.78 | *0.59* | *0.82* |
| > 1200 m | t/$m^3$ | 0.62 | 0.82 | *0.64* | *0.86* |
| weighted mean | t/$m^3$ | **0.60** | **0.80** | ***0.61*** | ***0.83*** |

In the Swiss GHG inventories after 2012, single-tree allometric functions were used instead of BCEFs. Therefore, BCEFs are no longer published in the Swiss NIDs.

The IPCC default carbon content of solid wood of 50% was applied (IPCC 2006 Table 4.3: mean value from Lamlom and Savidge (2003) for conifers and broadleaved trees in temperate forests).

BCEFs and carbon contents were used to calculate carbon stocks and fluxes from the volumes measured in Liechtenstein's 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 Inventories (NFI, LWI 2012 and 2025); they represent the average of the respective periods 1998–2010 and 2011-2022 (see Table 6-5 and Table 6-16).

For calculating the loss, annual harvesting statistics (Table 6-15) 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 periods (see Table 6-15).
- According to the NFI 2010 (LWI 2012, period 1999–2010), the average cut is 5.65 $m^3$ $ha^{-1}$ $yr^{-1}$ and the average mortality is 2.70 $m^3$ $ha^{-1}$ $yr^{-1}$. The total loss is 8.35 $m^3$ $ha^{-1}$ $yr^{-1}$. With this information the carbon stock losses were calculated and split in the two parts cut and mortality 1990-2010 as shown in Table 6-16.
- According to the NFI 2022 (LWI 2025, period 2011-2022), the average cut is 3.3 $m^3$ $ha^{-1}$ $yr^{-1}$ and the average mortality is 2.2 $m^3$ $ha^{-1}$ $yr^{-1}$. The total loss is 5.5 $m^3$ $ha^{-1}$ $yr^{-1}$. With this information the carbon stock losses were calculated and split in the two parts cut and mortality 2011-2023 as shown in Table 6-16
- The annual losses per altitude zone were calculated assuming that the annual cut is proportional to the relative harvesting factor (see Table 6-15) 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 6-16.

Table 6-15 Wood harvesting statistics for Liechtenstein's forest 1986–2023 and the annual harvesting relative to the reference period of the two NFI (1999–2010, 2011-2022). Source: OE 2024b.

| 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 | 1.321 |
| 2012 | 26'813 | 1.328 |
| 2013 | 22'316 | 1.106 |
| 2014 | 22'259 | 1.103 |
| 2015 | 19'089 | 0.946 |
| 2016 | 18'012 | 0.892 |
| 2017 | 18'986 | 0.941 |
| 2018 | 25'573 | 1.267 |
| 2019 | 19'790 | 0.980 |
| 2020 | 15'468 | 0.766 |
| 2021 | 12'958 | 0.642 |
| 2022 | 14'292 | 0.708 |
| 2023 | 14'566 | 0.722 |
| Mean 1999-2010 | 20'714 | 1.000 |
| Mean 2011-2022 | 20'185 | 1.000 |

Table 6-16 Splitting total carbon stock loss of living biomass (NFIs, averages (a) 1999–2010 and (b) 2011–2022) into cut and mortality and (c) calculated annual losses 1990–2023 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 | 3.12 | -3.27 | -1.06 | -2.21 | Results of NFI 2010 are used for the period 1990-2010 |
| zone 2 | 2.77 | -2.90 | -0.94 | -1.96 | |
| zone 3 | 2.27 | -2.38 | -0.77 | -1.61 | |

(b) Average 2011-2022:

| Altitude | Gain | Total loss | Mortality | Cut | |
|---|---|---|---|---|---|
| zone 1 | 2.70 | -2.22 | -0.72 | -1.50 | Results of NFI 2022 are used for the period 2011-2023 |
| zone 2 | 2.32 | -1.90 | -0.61 | -1.29 | |
| zone 3 | 1.71 | -1.41 | -0.45 | -0.95 | |

(c) Annual loss:

| Altitude | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| zone 1 | -3.19 | -2.16 | -2.85 | -2.63 | -3.86 | -2.99 | -2.44 | -3.14 | -2.61 | -2.50 |
| zone 2 | -2.83 | -1.91 | -2.53 | -2.33 | -3.43 | -2.65 | -2.16 | -2.78 | -2.31 | -2.22 |
| zone 3 | -2.32 | -1.57 | -2.08 | -1.91 | -2.81 | -2.17 | -1.78 | -2.28 | -1.90 | -1.82 |

| Altitude | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| zone 1 | -4.12 | -2.60 | -2.63 | -2.87 | -3.00 | -2.98 | -3.27 | -3.84 | -3.96 | -3.76 |
| zone 2 | -3.65 | -2.31 | -2.33 | -2.55 | -2.66 | -2.64 | -2.90 | -3.41 | -3.51 | -3.34 |
| zone 3 | -2.99 | -1.89 | -1.91 | -2.09 | -2.18 | -2.17 | -2.38 | -2.79 | -2.88 | -2.74 |

| Altitude | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| zone 1 | -3.66 | -2.70 | -2.71 | -2.38 | -2.37 | -2.14 | -2.06 | -2.13 | -2.62 | -2.19 |
| zone 2 | -3.25 | -2.31 | -2.32 | -2.04 | -2.03 | -1.83 | -1.76 | -1.82 | -2.24 | -1.88 |
| zone 3 | -2.67 | -1.71 | -1.72 | -1.51 | -1.50 | -1.36 | -1.30 | -1.35 | -1.66 | -1.39 |

| Altitude | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|
| zone 1 | -1.87 | -1.68 | -1.78 | -1.80 |
| zone 2 | -1.60 | -1.44 | -1.53 | -1.54 |
| zone 3 | -1.18 | -1.07 | -1.13 | -1.14 |

### 6.4.2.4 Growing 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 trails) 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. Therefore, the same carbon stocks per hectare as in Switzerland are assumed (see Table 6-5).

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 2024, Chapter 6.4.2.4), see Table 6-17. 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 (2024) 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 6-7).

"Unproductive forests not covered by NFI are mainly associated with extensively pastured land where sparse tree vegetation (land cover 44 and 47 in Table 6-7) is found. As those forests are assumed to grow preferably on bad site conditions, an average growing stock (> 7 cm diameter) of 150 $m^3$ $ha^{-1}$ is assumed. Multiplied by the mean BCEF of 0.69 (see Thürig and Herold 2013), an average biomass for these forests of 102.75 t $ha^{-1}$ was estimated, which translates to 51.38 t C $ha^{-1}$ (using the IPCC default carbon content of 50%)."

Table 6-17 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 (from FOEN 2024).

| 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 and litter

Stock data from Liechtenstein's NFI (see Table 6-12) and the BCEF derived from the Swiss NFI4 (Table 6-13) were used to calculate carbon contents in dead wood for productive forest (CC12) per spatial stratum (see Table 6-5).

For unproductive forests (CC13) there is no information available on stocks of dead wood and therefore, the Swiss value of 0 t C $ha^{-1}$ (FOEN 2025) is used.

As there are no specific data in Liechtenstein, data from Switzerland (FOEN 2025) are used for carbon contents in litter: Didion (2024) modelled yearly values 1990-2023; for Liechtenstein, the average of that period is used. The data for litter are stratified by the five NFI production regions and three elevation levels.

In Liechtenstein, the carbon stocks in litter of the Swiss NFI-region 3 (Pre-Alps) are used as shown in Table 6-5 for productive forest (CC12); for unproductive forest (CC13) the results from FOEN 2019 are still used.

Applying a Tier 2 approach, changes in carbon contents in deadwood and litter were derived from results of the model Yasso20 applied in Switzerland. Figure 6-6 shows the results of the model Yasso20 applied in Switzerland (FOEN 2025) in NFI-region 3 for productive forests.

- Overall, a clear carbon increase is visible in deadwood in most years of the period 1990–2023; this is also confirmed by Liechtenstein's NFI where the average stock of deadwood increased from 20 to 39 $m^3$/ha between 1998 and 2022.
- Carbon stock changes in litter have a very high inter-annual variability. However, there is no clear trend.

Based on these results (Figure 6-6), the carbon stock changes in deadwood and litter for Liechtenstein were calculated as the average in the period 1990–2023:

- Deadwood: 0.131 t C $ha^{-1}yr^{-1}$ below 1200 m altitude (Z1 and Z2), -0.006 t C $ha^{-1}yr^{-1}$ above 1200 m altitude (Z3)
- Litter: -0.005 t C $ha^{-1}yr^{-1}$ below 1200 m altitude (Z1 and Z2), 0.006 t C $ha^{-1}yr^{-1}$ above 1200 m altitude (Z3)

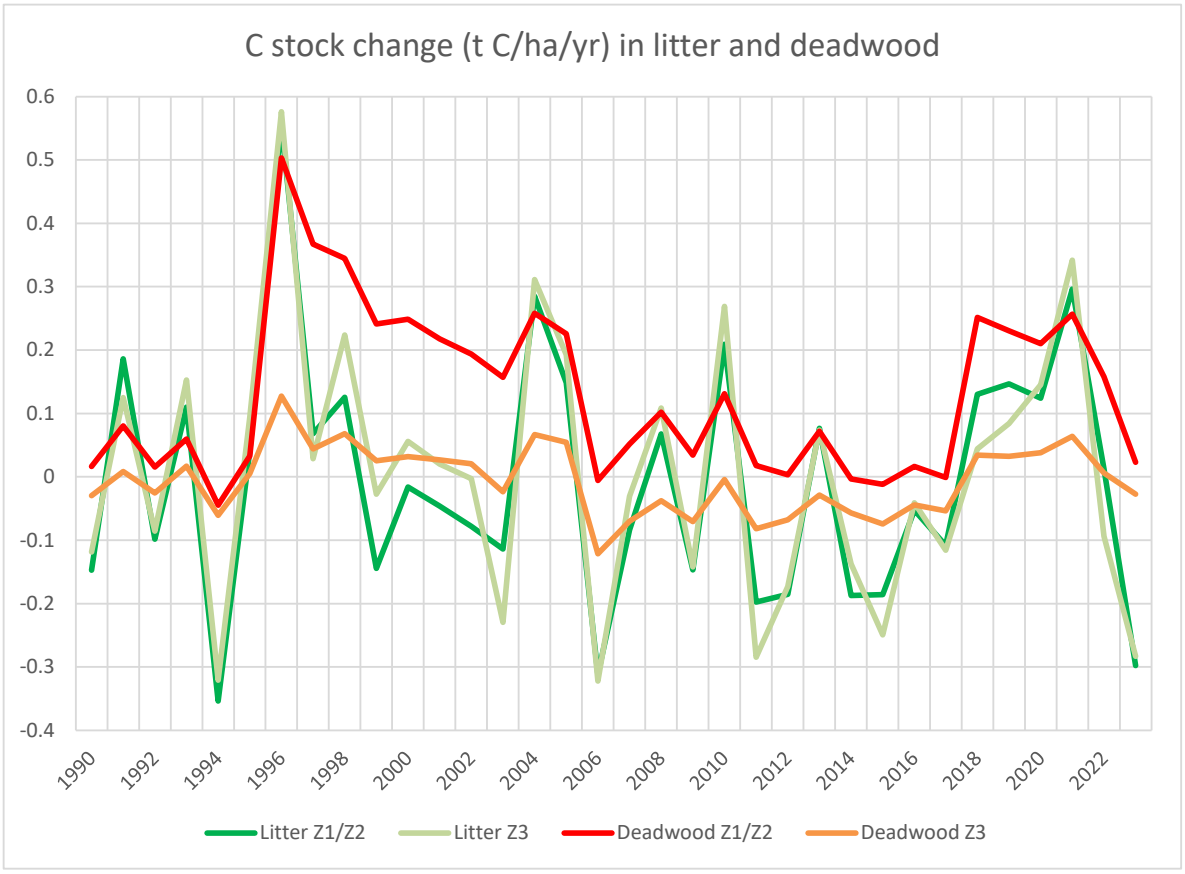



Figure 6-6 Carbon stock changes in deadwood and litter modelled with Yasso20 for different elevation zones (Z1/Z2: ≤1'200m, Z3: >1'200 m) in the NFI-region 3. Data source: FOEN 2025.

### 6.4.2.6 Soil carbon in all forest categories (CC12, CC13)

As there are no data on mineral forest soils in Liechtenstein, data from Switzerland are used for soil carbon contents. As described in FOEN (2025), Nussbaum and Burgos (2021) provided updated data for carbon stocks of soil organic carbon in Swiss forests. The data for soil carbon stocks are stratified by the five NFI production regions and three elevation levels as well as for productive and unproductive forest.

For Liechtenstein, the carbon stocks in mineral soils of the Swiss NFI-region 3 (Pre-Alps) are used as shown in Table 6-5 for productive forest (CC12) and unproductive forest (CC13). Applying a Tier 1 approach, no carbon stock changes are assumed for mineral soils.

Due to following reasons, it is assumed that in the years 1990 to 2023 mineral forest soils 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.
- The results of the model Yasso21 applied in Switzerland (FOEN 2025) in NFI-region 3 show only very small carbon stock changes in mineral soils for CC12 (average +0.014 t C $ha^{-1}yr^{-1}$).

For productive forests on organic soils, a carbon stock of 155 t C $ha^{-1}$ (0–30 cm) was applied in Liechtenstein. This value is based on measurements in the Ruggeller Riet, the most important area with fens and organic soils in Liechtenstein, by Oechslin et al. 2021. A mean total carbon content of 312 t C $ha^{-1}$ was measured, which corresponds to 155 t C $ha^{-1}$ in the upper 30 cm of the soil. Unproductive forests (CC13) do not occur on organic soils.

For the calculation of carbon stock changes in organic soil, the default emission factor of 2.6 t C $ha^{-1}$ $yr^{-1}$ was applied according to the Wetlands Supplement (IPCC 2014a: Table 2.1). Based on study in Switzerland (FOEN 2025), it was assumed that only 3% of organic soil on Forest land is subject to drainage and the effective emission factor was reduced accordingly.

### 6.4.2.7 Land converted to Forest Land

According to the land-use statistics, the areas switching to forest land (CC12 or CC13) are mainly abandoned areas of grassland with woody biomass (CC32 and CC34), see Table 6-10. The carbon stock changes in case of land-use change to forest land (4A2) are calculated as specified in Table 6-4 (see also chp. 6.1.3.2).

For internal conversions in 4A1 between the two forest land-use categories, the approach was chosen in such a way that potential carbon losses of living biomass cannot be underestimated: e.g. for CC12 to CC13 stock-difference is used, and for CC13 to CC12 gain-loss is used, respectively (see Table 6-4).

For land-use changes in 4A2, the calculation approaches are as follows:

**a) Carbon in biomass**

For living biomass, the gain-loss approach was applied. I.e., the annual gain of biomass on these areas was calculated by the annual gross growth rate of the respective forest type (CC12 or CC13), and the loss of biomass was calculated by the rate of cut and mortality according to chp. 6.4.2.3.

**b) Carbon in dead organic matter (DOM)**

For dead wood and litter, the stock-difference approach with 20 years conversion time was applied.

**c) Carbon in soils**

For mineral soils, the stock-difference approach with 20 years conversion time was applied.

For organic soils, the gain-loss approach was applied.

### 6.4.2.8 $N_2O$ emissions from N fertilization and drainage of soils

Fertilization of forests is prohibited by law in Liechtenstein. Therefore, no emissions are reported in CRT Table 4(I).

$N_2O$ emissions from drainage of organic soil was calculated for Forest land with an emission factor of 2.8 kg $N_2O$-N $ha^{-1}$ $yr^{-1}$ and reported in category 4A in CRT Table4(II). The emission factor used is the default value given in the Wetlands Supplement (IPCC 2014a: Table 2.5) for temperate forest land. It is assumed that all forest areas on organic soils are drained.

Remark for submission 2025: Due to technical problems in the CRT reporter, the $N_2O$ emissions of 4(II)D1c are included in the emissions of 4(II)A1 in CRT Table4(II).

### 6.4.2.9 Emissions from wildfires

Controlled burning of forests is not allowed in Liechtenstein. Wildfires affecting forest did not occur in Liechtenstein since 1990 as confirmed by Nägele (2022). Therefore, no emissions are reported for forest land in CRT Table4(IV).

## 6.4.3 Uncertainties and time-series consistency

An overview of uncertainties in the LULUCF sector is shown in Table 6-6. The uncertainty of the AD (areas) for categories 4A1 and 4A2 are presented in chp. 6.3.1.3.

The EF uncertainty for categories 4A1 and 4A2 was estimated to 34.9%. This value was adopted from Switzerland (FOEN 2025) as the methods of the national forest inventories of the two countries are similar). This value includes the uncertainties of all processes.

Gain and loss in living biomass are by far the dominant processes for 4A1 and 4A2 as shown in CRT Table 4.A.

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 section 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

The LULUCF expert, the NIC and the NID author report their QC activities in a checklist (see Annex 4).

### 6.4.5 Category-specific recalculations

In 2022, the following recalculations lead to a decrease of $CO_2$ emissions by 9.17 kt $CO_2$eq.

- 4A, 2011-2022: New values for gains and losses of living biomass were adopted from Liechtenstein's latest NFI (LWI 2025). Both, gains and losses decreased in this period. However, the decrease in losses was stronger resulting in clearly lower $CO_2$ emissions.
- 4A, 1990-2022: For productive forest (CC12), new values for carbon stocks in living biomass and dead wood were derived from Liechtenstein's latest NFI (LWI 2025).
- 4A, 1990-2022: For productive forest (CC12), new values for carbon stock changes in dead wood and litter as well as for carbon stocks in litter were adopted from Yasso model results of Switzerland (FOEN 2025, Didion 2024). Now, there is a stronger increase in dead wood leading to lower $CO_2$ emissions.
- 4A, 1990-2022: For productive and unproductive forests, new values for carbon stocks in mineral soils were adopted from Switzerland (FOEN 2025, Nussbaum and Burgos 2021).
- 4(II)A, 1990-2022: On forest land, $N_2O$ emissions from drained organic soils are reported for the first time. Remark: Due to technical problems with the CRT tables, the $N_2O$ emission of 4(II)D wetlands is included in the number of 4(II)A.

### 6.4.6 Category-specific planned improvements

It is planned to update the carbon stocks in litter for unproductive forests (CC13) according to the Swiss method.

# 6.5 Cropland (4B)

## 6.5.1 Description

**Key category information 4B**

$CO_2$ emissions from 4B1 Cropland remaining Cropland is a key source by level and trend. 4B2 Land Converted to Cropland is not a key source.

10% 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 2023 by 21%.

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 (CC21) 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 6.3.1.

**a) Carbon in living biomass**

The carbon stock value given in Table 6-5 (6.82 t C $ha^{-1}$) represents the average 1990–2020 of Swiss crops. It is based on area-weighted means of standing stocks at harvest (including root biomass) for the 19 most important annual crops (see FOEN 2022, chapter 6.5.2.1).

**b) Carbon in soils**

The Swiss mean carbon stocks for cropland on mineral soils in altitude zone 1 (57.06 t C $ha^{-1}$) was applied. It represents the average 1990–2022 of Swiss crops calculated with the model RothC (FOEN 2024, Wüst-Galley et al. 2019).

For cultivated, drained organic soils 155 t C $ha^{-1}$ (0–30 cm) were applied in Liechtenstein. This value is based on measurements in the Ruggeller Riet, the most important area with fens in Liechtenstein, by Oechslin et al. 2021. A mean total carbon content of 312 t C $ha^{-1}$ was measured, which corresponds to 155 t C $ha^{-1}$ in the upper 30 cm of the soil.

**c) Changes in carbon stocks**

The annual net carbon stock change in organic soils was estimated to -9.52 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 and in living biomass of crops are assumed to be zero for cropland if there is no land-use change (Tier 1 approach).

#### 6.5.2.2 Land converted to Cropland (4B2)

The activity data collection follows the methods described in chapter 6.3.1.

**a) Carbon in living biomass**

When a conversion of a land to cropland occurs, the stock-difference approach is applied for living biomass according to equation 6.4 in chp. 6.1.3.2, with CT=1 year (see Table 6-4).

**b) Carbon in dead organic matter (DOM)**

When a conversion of a land to cropland occurs, the stock-difference approach is applied for DOM carbon according to equations 6.5 in chp. 6.1.3.2, with CT=1 year (see Table 6-4).

**c) Carbon in soils**

When a conversion of a land to cropland occurs, the stock-difference approach is applied for mineral soil carbon according to equations 6.6 in chp. 6.1.3.2, with CT=20 years (see Table 6-4).

On organic soils, the gain-loss approach is used.

**d) $N_2O$ Emissions from Cropland**

$N_2O$ emissions from drainage of organic soils on cropland are reported in the agriculture sector (3D).

The calculation of emissions for categories 4III ($N_2O$ from Nitrogen Mineralization in mineral soils) is described in chp. 6.10.

### 6.5.3 Uncertainties and time-series consistency

The dominant process determining the uncertainty of categories 4B1 is the carbon loss on organic soils, for 4B2 also the carbon stock change in mineral soils is relevant (see Annex A2.2 for more information).

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 6-11) combined with the uncertainty of the soil map used to identify organic soils (chp. 6.2.2), which is assumed to be 30%. The uncertainty of 30% is an expert judgement by Eberle (2018) and the NID authors considering the scale and quality of the soil map produced by Büchel et al. (2006). As shown in Table 6-6 and Annex A2.2, the resulting AD uncertainties are 30.8% for 4B1 and 26.9% for 4B2.

The uncertainty of the emission factor on organic soils is 23% according to Leifeld et al. (2003). It can be used directly for 4B1.

For 4B2 the carbon stock changes in mineral soils are assumed to have a mean uncertainty of 50.0% which results in a combined EF-uncertainty of 52.2% for the sum of the pools in organic and mineral soils (Annex A2.2).

For the current submission, a simplified uncertainty analysis has been carried out as described in chp. 1.6.2. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. Emissions and sinks of the category 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 section 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

The LULUCF expert, the NIC and the NID author report their QC activities in a checklist (see Annex 4). No additional category-specific QA/QC activities have been carried out.

### 6.5.5 Category-specific recalculations

In 2022, the following recalculations lead to a decrease of $CO_2$ emissions by 0.11 kt $CO_2$eq and to minor changes (<0.05 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4B: The carbon stock in mineral soil was updated based on recent results of the RothC model in Switzerland (FOEN 2024). It is now 57.06 instead of 50.65 t C $ha^{-1}$.

### 6.5.6 Category-specific planned improvements

No category-specific improvements are planned.

## 6.6 Grassland (4C)

### 6.6.1 Description

**Key category information 4C**

4C1 Grassland remaining Grassland isa key source concerning level. $CO_2$ emissions from 4C2 Land converted to Grassland are a key category concerning level and trend.

31% of Liechtenstein's total surface is grassland, whereof 86% is managed and 14% is unmanaged grassland. Conversion to grassland occurs mainly from cropland to grassland and from forest to grassland. These changes are however less important than the reverse conversion from grassland to forest (mainly by the raising timber line) and from grassland to cropland. The total area of grassland decreased by 6% in 2023 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 ('Niederstamm-obst') 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 chp. 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 chp.6.3.1. Carbon stocks are based on data from Switzerland (FOEN 2022, 2024 and 2025) as shown in Table 6-5. Details are described in the following paragraphs.

**a) Carbon in living biomass**

***Permanent Grassland (CC31)***

Permanent grasslands range in altitude from 400 m to 2'500 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 (see chp. 6.2.2).

Swiss values for carbon stock in living biomass of permanent grassland are applied. They were calculated as the annual cumulative yield of six differentially managed grasslands for three altitude zones (FOEN 2022). Root biomass was estimated based on allometric function as described in Wüst-Galley et al. (2020).

***Shrub Vegetation (CC32) and Copse (CC34)***

Swiss values for living biomass in shrub vegetation and copse were applied (FOEN 2022). 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 chp. 6.4.2.4. 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 2022). Cl of vineyards is 5.43 t C $ha^{-1}$, Cl of low-stem orchards is 15.06 t C $ha^{-1}$. For tree nurseries no stand densities are available. The weighted mean carbon stock of this combination category is 5.58 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 2022). 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 rockslides, 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 area-weighted mean of permanent grasslands in the three altitude zones, 3.45 t C $ha^{-1}$ (cf. Table 6-5), was assumed to be representative for the biomass on unproductive grassland CC37 (FOEN 2022).

## b) Carbon in soils

### *Permanent Grassland (CC31)*

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

The Swiss mean values for carbon stocks in mineral soils are applied (FOEN 2025). They represent the average 1990–2022 of Swiss permanent grassland calculated with the model RothC (FOEN 2024, Wüst-Galley et al. 2020). Six differently managed permanent grassland types were considered. Plant carbon inputs into the soil from grasslands were assumed to be constant. The resulting carbon stock values for mineral soils on CC31 are displayed in Table 6-5.

The mean soil organic carbon stock (0–30 cm) for organic soils is 155 t C $ha^{-1}$ (0–30 cm). This value is based on measurements in the Ruggeller Riet, the most important area with fens in Liechtenstein, by Oechslin et al. 2021. A mean total carbon content of 312 t C $ha^{-1}$ was measured, which corresponds to 155 t C $ha^{-1}$ in the upper 30 cm of the soil. This value was used for all grassland categories occurring on organic soils: CC31, CC34, CC37 (see Table 6-5).

### *Shrub Vegetation (CC32) and Copse (CC34)*

For mineral soil in land-use categories CC32 and CC34 the carbon stocks of the digital soil maps for Switzerland (Stumpf et al. 2023) were adopted (see Table 6-5). The maps

represent the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories in Switzerland (which are defined identically to Liechtenstein), mean carbon stocks were calculated for each elevation zone:

- Elevation zone 1 (<601 m a.s.l.)
  CC32: 55.5 t C $ha^{-1}$
  CC34: 62.6 t C $ha^{-1}$
- Elevation zone 2 (601-1200 m a.s.l.)
  CC32: 43.3 t C $ha^{-1}$
  CC34: 57.4 t C $ha^{-1}$
- Elevation zone 3 (>1200 m a.s.l.)
  CC32: 36.7 t C $ha^{-1}$
  CC34: 37.6 t C $ha^{-1}$

The carbon stock (0–30 cm) for organic soils is 155 t C $ha^{-1}$ (see CC31).

***Vineyards, Low-stem Orchards and Tree Nurseries (CC33)***

For mineral soil, the carbon stocks of the digital soil maps (Stumpf et al. 2023) were used. The maps represent the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories in Switzerland (which are defined identically to Liechtenstein), a mean carbon stock was calculated for land-use category CC33: 50.8 t C $ha^{-1}$.

The mean soil organic carbon stock (0–30 cm) for organic soils is 155 t C $ha^{-1}$ (see CC31).

***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.

The soil carbon stock was retrieved from the digital soil maps (Stumpf et al. 2023). The maps represent the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories in Switzerland (which are defined identically to Liechtenstein), and considering a 35 % coverage, a mean carbon stock was calculated for CC36: 13.5 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 rockslides, and alpine infrastructure.

The carbon stock in mineral soil was retrieved from the digital soil maps (Stumpf et al. 2023). The maps represent the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories in Switzerland (which are defined identically to Liechtenstein), a mean carbon stock was calculated: 37.5 t C $ha^{-1}$.

**c) Changes in carbon stocks**

Applying a Tier 1 approach, changes of carbon stocks in biomass and in mineral soils are assumed to be zero if there is no land-use change.

The annual net carbon stock change in organic soils on managed permanent grassland (CC31) 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).

For extensively managed or unmanaged grasslands (CC34, CC37) the emission from organic soil was estimated as -5.3 t C $ha^{-1}$ $yr^{-1}$ according to available data from Switzerland (ART 2011b; Paul and Alewell 2018; Paul et al. 2021).

### 6.6.2.2 Land converted to Grassland (4C2)

The activity data collection follows the methods described in chp. 6.3.1.

The carbon stocks in living biomass and in soil are reported in detail under “Grassland remaining grassland” (chp. 6.6.2.1) and are summarized in Table 6-5.

**a) Carbon in living biomass**

When a conversion of a land to grassland occurs, the stock-difference approach is applied for living biomass according to equation 6.4 in chp. 6.1.3.2, with CT=1 year (see Table 6-4).

**b) Carbon in dead organic matter (DOM)**

When a conversion of a land to grassland occurs, the stock-difference approach is applied for dead biomass according to equation 6.5 in chp. 6.1.3.2, with CT=1 year.

**c) Carbon in soils**

When a conversion of a land to grassland occurs, the stock-difference approach is applied for mineral soils according to equation 6.6 in chp. 6.1.3.2, with CT=20 years.

On organic soils, the gain-loss approach is used.

**d) $N_2O$ emissions from Grassland**

$N_2O$ emissions from drainage of organic soils on grassland are reported in the agriculture sector.

The calculation of emissions for CRT category 4(III) ($N_2O$ from Nitrogen Mineralization in mineral soils) is described in chp. 6.10.

## 6.6.3 Uncertainties and time-series consistency

For category 4C1, the dominant processes determining the uncertainty are the carbon stock change on organic and mineral soils. For 4C2 also the carbon stock change in living biomass is relevant (see Annex A2.2 for more information).

The uncertainty of the area of organic soils (AD) is determined by the uncertainty of the AREA survey (4C1 6.0%, and 4C2 13.6% from Table 6-11) combined with the uncertainty of the soil map used to identify organic soils (chp. 6.2.2), which is assumed to be 30%. The

uncertainty of 30% is an expert judgement by Eberle (2018) and the NID authors considering the scale and quality of the soil map produced by Büchel et al. (2006). As shown in Annex A2.2, the resulting AD uncertainty on organic soils is 30.6% for 4C1 and 32.9% for 4C2.

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

The carbon stock changes in mineral soils are assumed to have a mean uncertainty of 50.0% which results in a combined EF-uncertainty of 47.0% for the sum of the pools in organic and mineral soils of category 4C1 (Annex A2.2).

For category 4C2, land converted to grassland, the relevant emissions from living biomass, mineral soils and organic soils were considered:

- Living biomass: the dominant process is the carbon loss in (living) biomass calculated by the stock-difference approach for conversions from forest land to grassland (4C2a). Therefore, the uncertainty of the carbon stock of forest was used as EF-uncertainty (40.3%, see below). The resulting absolute uncertainty in living biomass is 0.222 t C $ha^{-1}$ $yr^{-1}$.
- Mineral soils: Carbon stock change in mineral soils is assumed to have a mean uncertainty of 50.0%. Thus, in 2023, the absolute uncertainty for 4C2 is 0.029 t C $ha^{-1}$ $yr^{-1}$.
- Organic soils: The uncertainty of the carbon stock change (emission factor) in organic soils is 23% as reported by Leifeld et al. (2003: 56) and the uncertainty of the activity data (area of organic soil form soil map by Büchel et al., 2006) is 30% (see above), resulting in a combined uncertainty of 32.9%. Thus, the absolute uncertainty of the total organic soil emissions in 2023 is 0.104 t C $ha^{-1}$ $yr^{-1}$ (related to the total area of 4C2) as shown in Annex A2.2.

The root sum squares of those three absolute uncertainties are 0.209 t C $ha^{-1}$ $yr^{-1}$ for 4C2. This absolute uncertainty was used to calculate a relative emission factor uncertainty for 4C2 by dividing with the mean net carbon stock change per hectare of 4C2. In 2023, the mean net carbon stock changes were -0.64 t C $ha^{-1}$ for 4C2 (calculated from CRT Table4.C). The resulting relative EF-uncertainty is 32.4% for 4C2 (see Table 6-6).

The AD uncertainty (13.6%) for 4C2 comes from the AREA survey as shown in Table 6-11.

The uncertainty of the carbon stock of forest was used as EF-uncertainty for living biomass in 4C2 (40.3%, see above). 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 geographic extent and the topographic situation in Liechtenstein (http://www.lfi.ch/resultate/anleitung-en.php?lang=en).
- Carbon content: 2% (FOEN 2025, chapter 6.4.3)
- Biomass expansion functions, sampling uncertainty: 21.2% (see FOEN 2025, chapter 6.4.3)
- Biomass expansion functions, model uncertainty: 22.2% (FOEN 2025, chapter 6.4.3)

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 section 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

The LULUCF expert, the NIC and the NID author report their QC activities in a checklist (see Annex 4). No additional category-specific QA/QC activities have been carried out.

### 6.6.5 Category-specific recalculations

In 2022, the following recalculations lead to an increase of $CO_2$ emissions by 1.33 kt $CO_2$eq and to minor changes (<0.05 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4C, Permanent grassland (CC31): The carbon stocks in mineral soils were updated based on recent results of the RothC model in Switzerland (FOEN 2024). In general, the new stocks are lower.
- 4C: Carbon stocks in mineral soils were updated for the land-use categories CC32–CC37 based on a digital soil map (Stumpf et al. 2023). In general, the new stocks are lower.

### 6.6.6 Category-specific planned improvements

No category-specific improvements are planned.

## 6.7 Wetlands (4D)

### 6.7.1 Description

| **Key category information 4D** |
| --- |
| Source categories 4D1 Wetlands remaining Wetlands is a key category by level and trend.<br>4D2 Land converted to Wetlands is not a key category. |

2.0% of the total surface of Liechtenstein are wetlands. Wetlands consist of surface waters (CC41) and unproductive wet areas such as shore vegetation, reed and fens (CC42) (Table 6-3). Both types of wetlands are categorized as unmanaged. 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 waters).

## 6.7.2 Methodological issues

### 6.7.2.1 Wetlands remaining Wetlands (4D1)

The activity data collection follows the methods described in chp. 6.3.1. Carbon stocks are taken from Switzerland (FOEN 2025). Details are described in the following paragraphs.

**a) Carbon in living biomass**

Surface waters (CC41) have no carbon stocks by definition.

Unproductive Wetland (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 on mineral soils. However, for CC41 situated in areas with organic soil, a soil carbon stock of 155 t C $ha^{-1}$ (0–30 cm) was assumed. These surface waters were assumed to be shallow ponds as integrated parts of fens or bogs.

Currently, no specific data for mineral soils are available for CC42 in Liechtenstein. Therefore, the carbon stocks of the digital soil maps (Stumpf et al. 2023) were used. The maps represent the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories in Switzerland (which are defined identically to Liechtenstein), a mean carbon stock was calculated for land-use category CC42: 56.9 t C $ha^{-1}$.

**c) Changes in carbon stocks**

Applying a Tier 1 approach, changes of carbon stocks in mineral soils and in biomass are assumed to be zero if there is no land-use change.

For extensively managed unproductive wetlands (CC42) the emission from organic soil was estimated as -5.3 t C $ha^{-1}$ $yr^{-1}$ according to available data from Switzerland (ART 2011b; Paul and Alewell 2018; Paul et al. 2021).

**d) $N_2O$ emissions from N fertilization and drainage of soils**

No emissions were reported in category 4D in CRT Table4(I) (notation key “NO”). Input of nitrogen fertilisers to land-use category unproductive wetlands (CC42) is very unlikely as these areas represent mostly nature conservation areas (fens) in regard to biodiversity.

$N_2O$ emissions from drainage of organic soil was calculated for unproductive wetland (CC42) and reported in category 4(II)D1c Other wetlands remaining other wetlands in CRT Table4(II). Activity data correspond to the total area of organic soil for all subdivisions "Unproductive wetland" (CC42) in CRT Table4.D. The emission factor of 1.6 kg $N_2O$-N $ha^{-1}$ used is the default value given in the IPCC Wetlands Supplement (IPCC 2014a: Table 2.5) for shallow-drained, nutrient-rich grassland. It is assumed that all wetland areas on organic soils are drained.

Remark for submission 2025: Due to technical problems in the CRT reporter, the $N_2O$ emissions of 4(II)D1c are included in the emissions of 4(II)A1 in CRT Table4(II).

#### 6.7.2.2 Land converted to Wetlands (4D2)

The activity data collection follows the methods described in chp. 6.3.1.

The carbon stocks in living biomass and in soil are reported in detail under 4D1 (chp. 6.7.2.1) and are summarized in Table 6-5.

**a) Carbon in living biomass**

When a conversion of a land to wetlands occurs, the stock-difference approach is applied for living biomass according to equation 6.4 in chp. 6.1.3.2, with CT=1 year (see Table 6-4).

**b) Carbon in dead organic matter (DOM)**

When a conversion of a land to wetlands occurs, the stock-difference approach is applied for dead biomass according to equation 6.5 in chp. 6.1.3.2, with CT=1 year.

**c) Carbon in soils**

When a conversion of a land to wetlands occurs, the stock-difference approach is applied for mineral soils according to equation 6.6 in chp. 6.1.3.2, with CT=1 year for CC41 and CT=20 years for CC42.

On organic soils, the gain-loss approach is used.

The calculation of emissions for category 4(III) ($N_2O$ from Nitrogen Mineralization in mineral soils) is described in chp. 6.10.

### 6.7.3 Uncertainties and time-series consistency

Category 4D1 has only emissions from organic soils. Table 6-6 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 processes determining the EF uncertainty are the carbon loss in (living) biomass and in mineral soils calculated by the stock-difference approach for conversions from forest land to wetlands. Therefore, the uncertainty of the carbon stock of forest was used (40.3%, see chp. 6.6.3) for living biomass, and the carbon stock changes in mineral soils are assumed to have a mean uncertainty of 50.0% (see Annex A2.2). The resulting relative EF uncertainty for 4D2 is 36.2% (see Table 6-6).

The AD uncertainty (40.9%) for 4D2 comes from the AREA survey as shown in Table 6-11.

For the current submission, a simplified uncertainty analysis has been carried out as described in chp. 1.6.2. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four “rest” categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. Emissions and sinks of the category 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 section 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

The LULUCF expert, the NIC and the NID author report their QC activities in a checklist (see Annex 4). No additional category-specific QA/QC activities have been carried out.

### 6.7.5 Category-specific recalculations

In 2022, the following recalculations lead to an increase of $CO_2$ emissions by 0.01 kt $CO_2$eq and to minor changes (<0.05 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4D: Carbon stocks in mineral soils were updated for the land-use category CC42 (unproductive wetland) based on a digital soil map (Stumpf et al. 2023). The new stock is 10% lower.
- 4(II)D, 1990-2022: On wetlands, $N_2O$ emissions from drained organic soils are reported for the first time. Remark: Due to technical problems with the CRT tables, the $N_2O$ emission of 4(II)D wetlands is included in the number of 4(II)A.

### 6.7.6 Category-specific planned improvements

No category-specific improvements are planned.

## 6.8 Settlements (4E)

### 6.8.1 Description

**Key category information 4E**

$CO_2$ emissions from Category 4E1 Settlements remaining Settlements is a key category by trend. 4E2 Land converted to Settlements is a key category by level and trend.

12% of Liechtenstein's total surface are settlements. Between 1990 and 2023, 506 net hectares were converted to settlements, which is an increase of 37%. 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 6.3.1. Carbon stocks are taken from Switzerland. As structure and density of Liechtenstein's settlements are very similar to the settlements in Switzerland (FOEN 2025), Liechtenstein adopted the Swiss data on vegetation and mineral soils 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 mineral and organic soil for the combination category "Buildings and Construction" (CC51) was set to zero.

For mineral soil in land-use categories CC52, CC53 and CC54 the carbon stocks of the digital soil maps for Switzerland (Stumpf et al. 2023) were adopted (see Table 6-5). The maps represent the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories in Switzerland (which are defined identically to Liechtenstein), mean carbon stocks were calculated for each category:

- CC52: 57.2 t C $ha^{-1}$
- CC53: 52.0 t C $ha^{-1}$
- CC54: 56.5 t C $ha^{-1}$

The carbon stock (0–30 cm) for organic soils is 155 t C $ha^{-1}$ (0–30 cm) for CC52-54. This value is based on measurements in the Ruggeller Riet, the most important area with fens in Liechtenstein, by Oechslin et al. 2021. A mean total carbon content of 312 t C $ha^{-1}$ was measured, which corresponds to 155 t C $ha^{-1}$ in the upper 30 cm of the soil.

**c) Changes in carbon stocks**

Applying a Tier 1 approach, changes of carbon stocks in mineral soils and in biomass are assumed to be zero if there is no land-use change.

For CC52, areas with herbaceous biomass in settlements, a carbon stock change of -9.52 t C $ha^{-1}$ $yr^{-1}$ is calculated in organic soils. This corresponds to the value used for CC21 Cropland because CC52 areas are managed (gardens, parks) (Leifeld et al. 2003, 2005 and verified by ART 2009b and Paul and Alewell 2018).

For CC53 and CC54, areas with shrubs and trees in settlements, a carbon stock change of -5.3 t C $ha^{-1}$ $yr^{-1}$ is calculated in organic soils according to available data from Switzerland. This corresponds to the value used for extensively managed grasslands (ART 2011b; Paul and Alewell 2018).

For internal changes of land-use categories of settlements (CC51-54) the calculation approaches according to Table 6-4 (chp. 6.1.3.2) are applied. The stock-difference approach for living biomass, DOM and mineral soil is used with CT=1 year.

### 6.8.2.2 Land converted to Settlements (4E2)

The activity data collection follows the methods described in chapter 6.3.1.

The carbon stocks in living biomass and in soil are described under 4E1 (chp. 6.8.2.1) and are summarized in Table 6-5.

**a) Carbon in living biomass**

When a conversion of a land to settlements occurs, the stock-difference approach is applied for living biomass according to equation 6.4 in chp. 6.1.3.2, with CT=1 year (see Table 6-4).

**b) Carbon in dead organic matter (DOM)**

When a conversion of a land to settlements occurs, the stock-difference approach is applied for dead biomass according to equation 6.5 in chp. 6.1.3.2, with CT=1 year.

**c) Carbon in soils**

When a conversion of a land to settlements occurs, the stock-difference approach is applied for mineral soils according to equation 6.6 in chp. 6.1.3.2, with CT=20 years.

In case of land-use changes from non-CC51 to CC51 on mineral and on organic soil a loss of 20% of the initial carbon stock was reported following IPCC 2006 (Volume 4, chp. 8.3.3.2). The reason for this is that 20% of the soil organic matter is assumed to be lost as a result of disturbance, removal or relocation on these areas being sealed. Thus, equation 6.6 presented in chp. 6.1.3.2 was adjusted as follows if a=CC51:

$$deltaC_{s,i,b51} = [\ 0.2 * (0 - stockC_{s,i,b}\ ) / CT\ ] * A_{i,b51}$$

where:

| | |
|---|---|
| $stockC_{s,i,b}$ | carbon stock in soil (t C $ha^{-1}$ ) |
| b | land-use category before conversion (CC = b ≠ 51) |
| b51 | land use conversion from b to CC51 |
| i | spatial stratum |
| $A_{i,b51}$ | area of land (ha) converted from b to CC51 in the spatial stratum i (the sum of the areas converted within the last 20 years) |
| CT | conversion time (20 years; see Table 6-3). |

On organic soils, the gain-loss approach is used in the case of CC52, CC53 and CC54. For CC51, carbon stock changes are calculated the same way as on minerals soils (stock-difference, CT=20 years, 20% loss).

The calculation of emissions for category 4(III) ($N_2O$ from Nitrogen Mineralization in mineral soils) is described in chp. 6.10.

### 6.8.3 Uncertainties and time-series consistency

The dominant processes determining the uncertainty of categories 4E1 and 4E2 are the carbon loss on mineral soils and in living biomass (see Annex A2.2).

Thus, the uncertainty of the area (AD) is determined by the uncertainty of the AREA survey (4E1 6.4%, 4E2 19.4% from Table 6-11).

In accordance with the Swiss National Inventory Report (FOEN 2025) the EF uncertainty for carbon stock changes in mineral soils are 50%.

For category 4E2, the dominant process determining the EF uncertainty in living biomass is the stock-difference in conversions from forest land to settlements. Therefore, the uncertainty of the carbon stock of forest was used (40.3%, see chp. 6.6.3) for living biomass. The same value is used for 4E1.

The resulting relative EF uncertainty for 4E1 and 4E2 are 57.1% and 31.6%, respectively (see Table 6-6 and Annex A2.2).

For the current submission, a simplified uncertainty analysis has been carried out as described in chp. 1.6.2. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7.

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 section 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

The LULUCF expert, the NIC and the NID author report their QC activities in a checklist (see Annex 4). No additional category-specific QA/QC activities have been carried out.

### 6.8.5 Category-specific recalculations

In 2022, the following recalculations lead to a decrease of $CO_2$ emissions by 1.05 kt $CO_2$eq and of $N_2O$ emissions by 0.06 kt $CO_2$eq.

- 4E: Carbon stocks in mineral soils were updated for the land-use categories CC52-54 based on a digital soil map (Stumpf et al. 2023). The new stocks are higher.

### 6.8.6 Category-specific planned improvements

No category-specific improvements are planned.

## 6.9 Other Land (4F)

### 6.9.1 Description

**Key category information 4F2**

Category 4F2 Land converted to Other Land $CO_2$ is not a key category.

6% of Liechtenstein's total surface are summarized in "Other Land". Between 1990 and 2023 the area of "Other Land" has declined by 8%. 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 removals).

### 6.9.2 Methodological issues

By definition, other land has no carbon stocks. In the case of land-use change (4F2), the net changes in biomass and soil are calculated by the stock-difference approach according to equations 6.4, 6.5 and 6.6 in chp. 6.1.3.2, with CT=1 year for biomass and CT=20 years for soil organic carbon (see Table 6-4).

### 6.9.3 Uncertainties and time-series consistency

For category 4F2, land converted to other land, the dominant processes determining the EF uncertainty are the carbon loss in (living) biomass and in mineral soils calculated by the stock-difference approach for conversions from forest land or grassland to other land. As a best guess, the uncertainty of the carbon stock of forest was used (40.3%, see chp. 6.6.3) for living biomass, and the carbon stock changes in mineral soils are assumed to have a mean uncertainty of 50.0%. The resulting relative EF uncertainty for 4F2 is 40.1% (see Annex A2.2).

The AD uncertainty (40.9%) for 4F2 comes from the AREA survey as shown in Table 6-11.

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 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

The LULUCF expert, the NIC and the NID author report their QC activities in a checklist (see Annex 4). No additional category-specific QA/QC activities have been carried out.

### 6.9.5 Category-specific recalculations

In 2022, the following recalculations lead to a decrease of $CO_2$ emissions by 0.11 kt $CO_2$eq and to minor changes (<0.05 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4F2: Carbon losses on areas converted to other land have changed due to recalculations of carbon stocks in biomass for forests and in mineral soils for forest land, cropland, grassland, wetlands and settlements.

### 6.9.6 Category-specific planned improvements

No category-specific improvements are planned.

## 6.10 $N_2O$ from nitrogen mineralization (Category 4(III))

### 6.10.1 Description

This chapter presents the methods for calculating direct and indirect $N_2O$ emissions from nitrogen (N) mineralization in mineral soils. The source of nitrogen is N mineralization associated with loss of soil organic matter resulting from land-use change. These $N_2O$ emissions are not key categories. They include:

- Direct $N_2O$ emissions due to changes of the land-use category are reported for forest land, cropland, grassland, wetlands, settlements and other land.
- Indirect emissions of $N_2O$ due to nitrogen leaching and run-off are reported.

The following $N_2O$ emissions were included in the agriculture sector and not in the LULUCF sector:

- $N_2O$ emissions associated with inputs from N fertilisers (CRT Table4(I)).
- $N_2O$ emissions on 4B1 Cropland remaining cropland and on 4C1 Grassland remaining grassland (CRT Table4(III)). However, for 4C1 the emissions due to changes of the land-use categories among grassland are reported in 4(III). In Liechtenstein, managed grassland also belongs to the agricultural area.
- Indirect $N_2O$ emissions due to atmospheric deposition.

### 6.10.2 Methodological issues

Direct $N_2O$ emissions (4(III)) as a result of the disturbance of mineral soils associated with land-use change are calculated according to IPCC (2019, Volume 4, chp. 11, equation 11.1):

Emission($N_2O$) = – deltaCs * 1 / (C:N) * EF1 * 44 / 28, if deltaCs < 0 [kt $N_2O$]

where:

deltaCs: soil carbon change induced by land-use change [kt C]

C:N: C to N ratio of the soil before the land-use change

EF1: default emission factor = 0.01 kg $N_2O$-N (kg N)$^{-1}$, IPCC 2019 (Volume 4, Table 11.1)

deltaCs is calculated according to the methodology described in chp. 6.1.3.2. If deltaCs is zero or positive (carbon gain) there are no $N_2O$ emissions provoked by a land-use change.

The value of the C:N ratio is related to the land-use category before the change. For cropland and grassland, the ratio is 9.8 according to Leifeld et al. (2007). This value was also used for the mineral soils in wetlands (CC42) and unsealed settlement areas (CC52, CC53, CC54). For forest land, the default value of C:N = 15 was used (IPCC 2019, Volume 4, equation 11.8).

The indirect $N_2O$ emissions (4(III)) as a result of N leaching and run-off are calculated as follows using default emission factors (IPCC 2006, Table 4_11.3):

Emission($N_2O$) = – deltaCs * Frac / (C:N) * EF5 * 44 / 28, if deltaCs < 0 [kt $N_2O$]

where:

Frac: default fraction of mineralized N lost by leaching or run-off =24%, IPCC 2019 (chapter 4_11)

EF5: default emission factor = 0.011 kg $N_2O$-N (kg N)$^{-1}$, IPCC 2019 (Table 4_11.3)

If deltaCs is zero or positive (carbon gain) there are no $N_2O$ emissions provoked by a land-use change. As the approach applied is not tier 3, no $N_2O$ immobilization is reported.

For calculating deltaCs, all land-use changes and conversions between land-use subcategories were taken into account. Cropland remaining cropland is reported in the agriculture sector as prescribed in CRT Table4(III) in footnote 2.

### 6.10.3 Uncertainties and time-series consistency

The uncertainty of the activity data for category 4(III) corresponds to the uncertainty of the amount of mineralized N. It was calculated as the combined uncertainty of:

- Uncertainty of the carbon stock losses in mineral soils: Land converted to settlements (4E2) is a main source in category 4(III). Therefore, the uncertainty of the area converted to settlements (19.4%; Table 6-11) and the uncertainty of the $CO_2$ emission factor (50.0%) were combined to estimate the uncertainty of the carbon stock loss: 53.6%.
- Uncertainty of the C:N ratio: The uncertainty of the C:N ratio for Forest land is used here. With a value of 15 and a 95%-range between 10 and 30 (IPCC 2006, Volume 4, equation 11.8) the mean uncertainty results in 66.7%.

The resulting uncertainty for AD of category 4(III), direct emissions, is 85.6%, calculated as $(53.6^2 + 66.7^2)^{0.5}$.

The uncertainty of the activity data for indirect emissions is 87.9%. It is the combined uncertainty of the amount of leached N, which is calculated from the amount of mineralized N (uncertainty 85.6%, see direct emissions) and Frac (uncertainty 20%, adopted from ART 2008).

A relative uncertainty for the emission factors of direct and indirect emissions 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 6-6) as the EF is a non-negative quantity.

For the current submission, a simplified uncertainty analysis has been carried out as described in chp. 1.6.2. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. Since 4(III) is not a key category their uncertainties are accounted in the "rest" categories with mean uncertainty of $N_2O$.

Consistency: Time series for Nitrogen Mineralization are all considered consistent; they are calculated based on consistent methods and homogenous databases.

### 6.10.4 Category-specific QA/QC and verification

The general QA/QC measures are described in Chapter 1.5.

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

### 6.10.5 Category-specific recalculations

In 2022, the following recalculations lead to an increase (<0.2 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4(III): The emission factor EF5 was updated based on the refined Guidelines (IPCC 2019): 0.011 kg $N_2O$-N (kg N)$^{-1}$ (former value 0.0075).
- 4(III): The fraction of mineralized N lost by leaching or run-off (Frac) was updated based on the default value of the refined Guidelines (IPCC 2019): 24%. The former value (30%) was only a rough estimate.
- 4(III): Carbon losses and nitrogen losses have changed due to recalculations of carbon stocks in mineral soils for forest land, cropland, grassland, wetlands and settlements.

### 6.10.6 Category-specific planned improvements

No category-specific improvements are planned.

# 6.11 Harvested Wood Products (HWP) (4G)

## 6.11.1 Description

**Key category information 4G**

Category 4G Harvested Wood Products (HWP) $CO_2$ is a key category by level and trend.

The data presented in this chapter are estimates of net emissions and removals from HWP due to changes in the HWP carbon pool. The applied approach to HWP accounting is a production approach (see chp. 6.3.3). The estimate uses the product categories, half-lives, and methodologies as described in IPCC (2006) and IPCC (2014).

## 6.11.2 Methodological issues

For the estimation of carbon stocks and carbon stock change, the equations described in IPCC (2014) and IPCC Guidelines 2006 were used.

In Liechtenstein, the enterprise register does not show any enterprises producing paper/paperboard (NOGA code 171200, see https://www.kubb-tool.bfs.admin.ch/en) or wood-based panels (NOGA code 162100). Thus, 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) as follows:

- 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 2022) and of data resulting from two brief surveys in Liechtenstein and data related to the development of the population (see below).
- Instantaneous oxidation was assumed to wood originating from deforestations. This wood is regarded unsuitable for sawnwood production as it originates mostly from natural hazards (such as avalanches and floodings) and from management of forest edges at higher altitudes.

Liechtenstein's sawnwood production between 1900 and 1960 was calculated with the default Tier 1 method provided in Equation 12.6 of the 2006 IPCC Guidelines using the annual rate of increase for Europe (0.0151) from Table 12.3. Equation 12.6 requires the sawnwood production in 1961 ($V_{1961}$) as an input. For Liechtenstein, there are no country-specific statistical data available for calculating the feedstock from domestic harvest. Therefore, feedstock data from Switzerland related to sawnwood for the year 1961 ($V_{swiss,1961}$) was adopted for Liechtenstein. Those Swiss data (FOEN 2022) were calculated with equation 2.8.1 and 2.8.4 in IPCC (2014) on the basis of national statistics, FAO-data. The conversion factors correspond to the default values given by IPCC (2014; table 2.8.1): density 0.5 t/$m^3$, carbon fraction 0.5. Emission factors were calculated with the default half-live of 35 years for sawn wood.

The Swiss feedstock data were adapted to Liechtenstein using the population ratio as follows:

$V_{1961} = V_{swiss,1961} * Population_{1961} / Population_{swiss,1961} = 3'671\ m^3$

where:

$V_{swiss,1961} = 1'181'000\ m^3$ (FOEN 2022)

$Population_{1961} = 16'894$ in Liechtenstein (https://databank.worldbank.org/source/population-estimates-and-projections)

$Population_{swiss,1961} = 5'434'294$ in Switzerland.

Liechtenstein's sawnwood production between 1962 and 1990 was calculated based on the assumption that the development is proportional to the development of the population in Liechtenstein (increase from 17'298 inhabitants in 1962 to 28'745 inhabitants in 1990). This results in a sawnwood production of 6'247 $m^3$ in 1990 (see Figure 6-7).

In 2017, a brief survey was made in Liechtenstein in order to estimate the sawnwood production after 1990 (Rihm 2017). The main results were:

- Since 2017, two enterprises produce totally 3'500 $m^3$ of sawnwood per year.
- Their products are mainly produced for own demand on construction sites. It can be assumed that there is no export of HWP.
- Around the year 2000 a relevant sawmill was shut down. It is estimated that the total production before 2000 was approximately twice as much as today's production. This is in line with the calculated amount for 1990 (6'247 $m^3$).

In 2024, a second brief survey was made in Liechtenstein (OE 2024h) in order to estimate the sawnwood production after 2017. The main result was:

- After an event of fire, the production capacity in the larger sawmill was reduced by 70%. Thus, the total sawnwood production from 2018 onwards is assumed to be 1'050 $m^3$ (30% of 3'500 $m^3$).

With this information the time-series of sawnwood production in Liechtenstein was constructed as follows: 1990–2000 decline from 6'247 $m^3$ to 4'500 $m^3$, 2001–2010 decline from 4'500 $m^3$ to 3'500 $m^3$, 2011–2017 a constant value of 3'500 $m^3$, after 2017 a constant value of 1'050 $m^3$.

Production, gains and losses from sawnwood are listed in Table 6-18 and Figure 6-7 shows the resulting sawnwood production, net emissions and removals.

Table 6-18 Emissions (positive sign) and removals (negative sign) from HWP (sawnwood) between 1990 and 2023, in kt $CO_2$. Wood panels and paper/paperboard are not produced in Liechtenstein.

| **Harvested wood products** | **1990** | **1995** | **2000** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** |
|---|---|---|---|---|---|---|---|---|---|---|
| Sawnwood production, 1000 $m^3$ | 6.25 | 5.37 | 4.50 | 4.20 | 4.10 | 4.00 | 3.90 | 3.80 | 3.70 | 3.60 |
| Gains sawnwood, kt C | 1.56 | 1.34 | 1.13 | 1.05 | 1.03 | 1.00 | 0.98 | 0.95 | 0.93 | 0.90 |
| Losses sawnwood, kt C | -0.83 | -0.89 | -0.92 | -0.93 | -0.93 | -0.93 | -0.93 | -0.93 | -0.93 | -0.93 |
| **Net emissions/removals, kt $CO_2$** | **-2.69** | **-1.67** | **-0.75** | **-0.44** | **-0.34** | **-0.25** | **-0.15** | **-0.06** | **0.04** | **0.13** |

| **Harvested wood products** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** |
|---|---|---|---|---|---|---|---|---|---|---|
| Sawnwood production, 1000 $m^3$ | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 1.05 | 1.05 |
| Gains sawnwood, kt C | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 | 0.26 | 0.26 |
| Losses sawnwood, kt C | -0.93 | -0.93 | -0.93 | -0.93 | -0.93 | -0.93 | -0.93 | -0.93 | -0.92 | -0.91 |
| **Net emissions/removals, kt $CO_2$** | **0.21** | **0.21** | **0.21** | **0.20** | **0.20** | **0.19** | **0.19** | **0.19** | **2.41** | **2.36** |

| **Harvested wood products** | **2020** | **2021** | **2022** | **2023** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sawnwood production, 1000 $m^3$ | 1.05 | 1.05 | 1.05 | 1.05 | | | | | | |
| Gains sawnwood, kt C | 0.26 | 0.26 | 0.26 | 0.26 | | | | | | |
| Losses sawnwood, kt C | -0.89 | -0.88 | -0.87 | -0.86 | | | | | | |
| **Net emissions/removals, kt $CO_2$** | **2.31** | **2.27** | **2.22** | **2.18** | | | | | | |

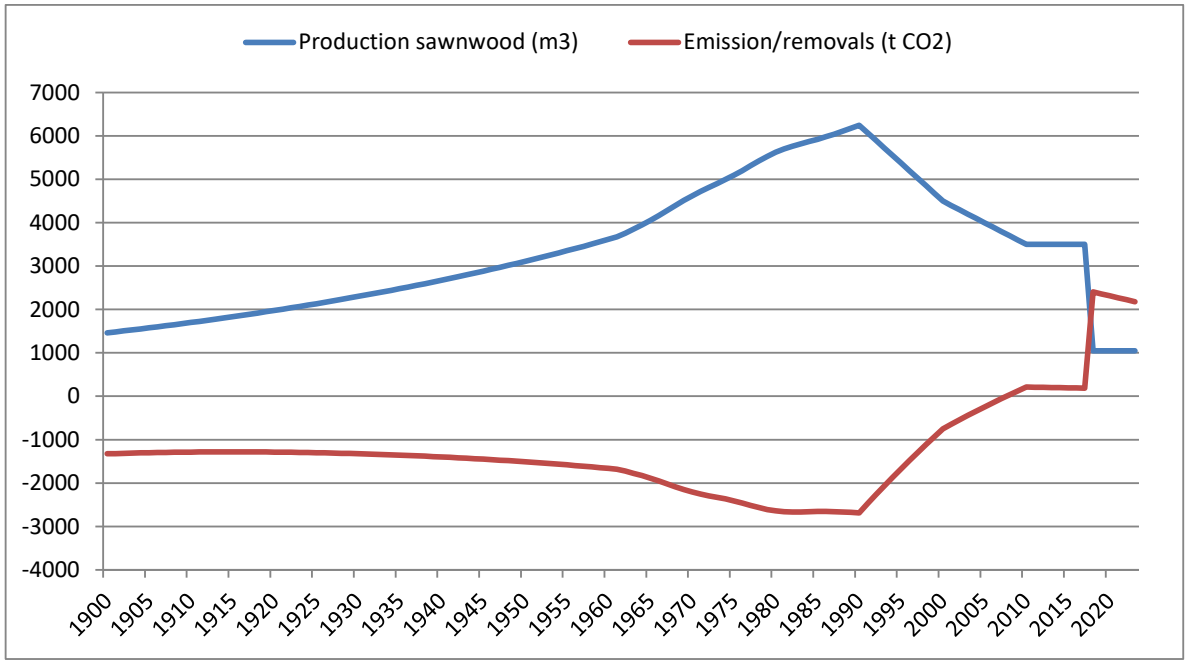



Figure 6-7 Liechtenstein's sawnwood production ($m^3$) and net emissions (positive sign) and removals (negative sign) of $CO_2$ (tons) from Harvested Wood Products between 1900 and 2023.

Import and export of sawnwood from 1990 to 2023 are reported in CRT Table4.Gs2. They were estimated on the basis of Swiss import and export data published in the Swiss NID (FOEN 2024) as Liechtenstein lacks own customs statistics (Customs Union with Switzerland, see chp. 1.1.1). Imports were calculated as a fraction of 0.0045 (ratio of Liechtenstein's and Switzerland's population in 2016) of Swiss sawnwood imports.

Exports of sawnwood were calculated as fraction of 0.0045 of Swiss exports until the year 2000. Between 2001 and 2009 a linear decline of the exports was assumed, concurrently with the drop of domestic sawnwood production. After 2009, the exports of sawnwood are zero according to the survey by Rihm (2017). After 2021, import values are kept constant.

### 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 judgement.)
- Emission factor, including conversion factors:
  - Wood density: 20% (Swiss expert judgement, see FOEN 2025);
  - Carbon contents in wood products: 10% (Lamlom and Savidge 2003);
  - 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:

$U_{HWP}$EmissionFactor = $\sqrt{20\%^2 + 10\%^2 + 50\%^2} = 54.8\%$

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 section 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

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

### 6.11.5 Category-specific recalculations

In 2022, the following recalculation leads to an increase of $CO_2$ emissions by 2.05 kt $CO_2$.

- 4G, 2018–2022: The production of sawnwood was reduced from 3'500 m3 to 1'050 m3 based on a new survey to the two sawmills in Liechtenstein.

### 6.11.6 Category-specific planned improvements

No category-specific improvements are planned.

# 7. Waste (CRT sector 5)

## 7.1 Overview of sector

Within the waste sector, emissions from four 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

Category 5E Other is not occurring in Liechtenstein.

Figure 7-1 depicts Liechtenstein's greenhouse gas emissions in sector 5 Waste between 1990 and 2023 according to the four categories 5A - 5D. Additionally, Table 7-1 lists the GHG emissions of this sector by gas in $CO_2$ equivalent (kt) for the years 1990 - 2023.

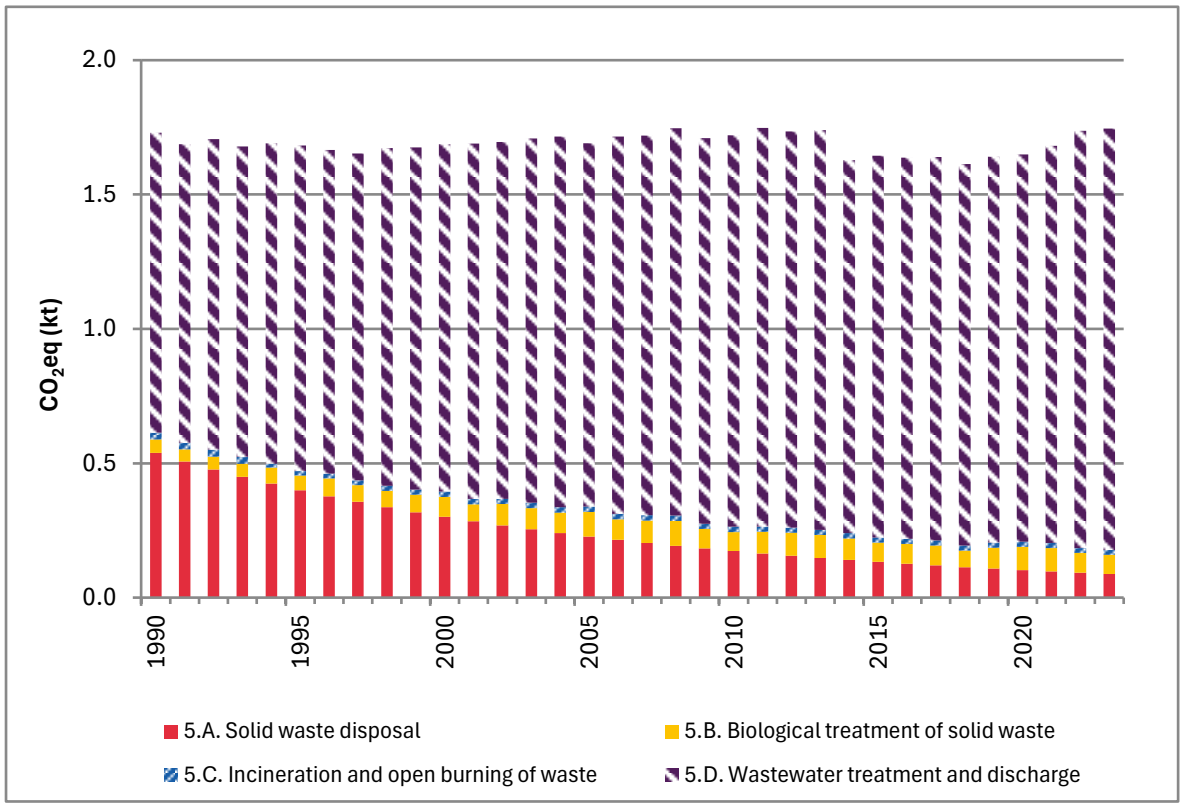



Figure 7-1 Liechtenstein's GHG emissions of sector 5 Waste. Note that there are no emissions in category 5E Other.

Table 7-1 GHG emissions of sector 5 Waste by gas in $CO_2$ equivalent (kt), and the relative change (last column bottom right).

| Gas | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| | CO2 equivalent (kt) | | | | |
| $CO_2$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| $CH_4$ | 1.24 | 1.17 | 1.17 | 1.17 | 1.13 |
| $N_2O$ | 0.48 | 0.50 | 0.51 | 0.51 | 0.58 |
| **Sum** | **1.73** | **1.68** | **1.69** | **1.69** | **1.72** |

| Gas | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| | CO2 equivalent (kt) | | | | |
| $CO_2$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| $CH_4$ | 1.04 | 1.03 | 1.04 | 1.04 | 1.03 |
| $N_2O$ | 0.57 | 0.60 | 0.59 | 0.59 | 0.57 |
| **Sum** | **1.63** | **1.64** | **1.64** | **1.64** | **1.61** |

| Gas | 2019 | 2020 | 2021 | 2022 | 2023 | 1990-2023 |
|---|---|---|---|---|---|---|
| | CO2 equivalent (kt) | | | | | % |
| $CO_2$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | -29% |
| $CH_4$ | 1.04 | 1.05 | 1.06 | 1.10 | 1.11 | -11% |
| $N_2O$ | 0.59 | 0.59 | 0.61 | 0.63 | 0.63 | 32% |
| **Sum** | **1.64** | **1.65** | **1.68** | **1.74** | **1.75** | **1%** |

In sector 5 Waste a total of 1.75 kt $CO_2$ equivalents of greenhouse gases were emitted in 2023. 5.0% of the total emissions origin from 5A Solid waste disposal, 4.1% from 5B Biological treatment of solid waste, 1.0% from 5C Incineration and open burning of waste and 89.8% from source category 5D Wastewater treatment and discharge. Emissions from 5E Other are not occurring in Liechtenstein.

The total greenhouse gas emissions show a slight increase from 1990 to 2023 by 1%. The development of the greenhouse gas emissions is determined by category 5D Wastewater treatment and discharge and to a lesser and decreasing extend by category 5A Solid waste disposal. In category 5D Wastewater treatment and discharge since 2014 sewage gas is not used any more as fuel for boilers or co-generation, all sewage gas is up-graded and supplied to the gas grid. In category 5A Solid waste disposal a steady decrease of greenhouse gas emissions can be observed, due to cease landfilling in 1974.

General methodological remark for sector 5 Waste: As living standards, infrastructure as well as regulatory frameworks, technical standards and legal principles 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 $CH_4$ from wastewater treatment.

Waste management in Switzerland and Liechtenstein is governed by the same legal regulations and principles, e.g. waste avoidance, waste recycling and sound treatment of the remaining waste are guiding principles. As an example, both countries introduced the polluter-pays-principle at the beginning of the 1990ies. The very same effect in both countries could be observed, that the amount of MSW incinerated dropped significantly due to a better segregation with a slight increase of incinerated quantities afterwards.

As examples for the same regulatory framework in Liechtenstein (left) and Switzerland (right) may serve environmental law and clean air law (see Table 7-2).

Table 7-2 Environmental Law (Government 2008a) and Clean Air Law (Government 2008b) in Liechtenstein and Switzerland.

| **Liechtenstein** | **Switzerland** |
|---|---|
| 814.01 2008.199 Umweltschutzgesetz (USG) vom 29. Mai 2008 (Fassung vom 1. Februar 2022) | 814.01 Bundesgesetz über den Umweltschutz (Umweltschutzgesetz, USG) vom 7. Oktober 1983 (Stand am 1. Januar 2022) |
| 814.301.1 2008.245 Luftreinhalteverordnung (LRV) vom 30. September 2008 (Fassung vom 13. Januar 2023) | 814.318.142.1 Luftreinhalte-Verordnung (LRV) vom 16. Dezember 1985 (Stand am 1. Januar 2023) |

Furthermore, in 1960 Vaduz was one of the three communities which established 'Verein für Abfallentsorgung', a cooperation to jointly organize and finance the sound solid waste management in Switzerland and Liechtenstein in this region. Since 1974 every community in Liechtenstein is member and participating in this joint effort between Switzerland and Liechtenstein.

## 7.2 Solid waste disposal (5A)

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

| **Key category information 5A** |
|---|
| Category 5A Solid waste disposal is not a key category. |

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 category 5A1 Managed waste disposal sites are not occurring.

### 5A2 Unmanaged waste disposal sites

100% of the collected municipal solid waste (and the combustible industrial waste) is being exported to Switzerland for incineration to a Swiss municipal solid waste incinerator nearby (MSWIP Buchs). Incineration plants in Switzerland co-generate heat and electricity in a highly efficient manner. Heat is generally fed in a district heating system, which allows replacing large amounts of fossils fuels such as oil and gas. The heat imported by Liechtenstein from the MSWIP Buchs is reported in 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 others) 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 7-3 Specification of 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 7-3).

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

**Methodology**

The $CH_4$ 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 Liechtenstein's conditions.

The following equation is applied to calculate the $CH_4$ generation in the year t:

$CH_4$ generated in the year t [kt/year] = $\sum x$ [A • k • M(x) • L0(x) • e-k(t-x)] • (1-OX)

where

| | |
|---|---|
| t = | current year |
| x = | the year of waste input, x ≤ 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) • DOC(x) • DOCF • F • 16/12) [kt $CH_4$ / kt waste] |
| MCF(x) = | methane correction factor (fraction) |
| DOC(x) = | degradable organic carbon [kt C/ kt waste] |
| $DOC_F$ = | fraction of DOC, that is converted to landfill gas (fraction) |
| F = | fraction of $CH_4$ in landfill gas (fraction) |
| 16/12 = | factor to convert C to $CH_4$. |
| OX = | oxidation factor (fraction) |

The 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 7-4).

Table 7-4 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 7-5).

Table 7-5 Amount of municipal solid waste (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)

For the current submission a simplified uncertainty analysis has been carried out as described in chapter 1.6. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. Since 5A is not a key category, its emissions are part of the "rest" categories with mean uncertainty of $CH_4$. The combined uncertainty for $CH_4$ is estimated 30% (see Table 1-7).

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 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

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

No category-specific recalculations have been carried out.

### 7.2.6 Category-specific planned improvements: Solid Waste Disposal (5A)

Switzerland has recalculated its waste composition landfilled (FOEN 2020). The shares of kitchen waste and garden waste within the deposited amounts of organic waste on solid waste disposal sites from 1950–1979 have been recalculated according to BUS 1978.

Liechtenstein is planning to align its activity data at the time when the FOD model is going to be updated.

## 7.3 Biological treatment of solid waste (5B)

### 7.3.1 Category description: Biological treatment of solid waste (5B)

| **Key category information 5B** |
| --- |
| Category 5B Biological treatment of solid waste is not a key category. |

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 door-to-door collected organic waste from households (generally food waste) is taken to a composting plant in Switzerland.

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

Table 7-6 Specification of category 5B Biological treatment of solid waste.

| 5B | Source | Specification |
|---|---|---|
| | Composting | Emissions from composting of organic waste<br>- centralized composting plants<br>- backyard composting |

## 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.

Activity data and emission factors for centralized and backyard composting in Switzerland have been thoroughly reassessed in 2017 (Schleiss 2017). New data were gained and EMIS 2024/5B1 Kompostierung, which serves as basis for greenhouse gas emission estimates, has been revised accordingly. Liechtenstein's greenhouse gas emission estimates are based on these latest results from Switzerland.

$CH_4$ and $N_2O$ emissions from centralized composting plants are calculated by multiplying the quantity of composted waste fractions by the emission factors.

$CH_4$ and $N_2O$ emissions from backyard composting are calculated by multiplying the quantity of composted waste per inhabitant by the population and the emission factors.

$N_2O$ emissions from the product of composting that arise after their application in agriculture are reported under source category 3Da2c.

### Emission Factors

Emission factors for composting have been adopted from the Swiss NIR (FOEN 2021): 1.0 kg $CH_4$/t of composted waste and 0.05 kg $N_2O$/t of composted waste. They are based on measurements and expert estimates, documented in the Swiss EMIS database (EMIS 2024/5B1 Kompostierung).

For all years the same constant country-specific emission factors have been applied.

**Activity data**

The Office of Environment provides data on the amount of waste treated in centralized composting plants (OE 2024c).

Activity data for backyard composting were reassessed in Switzerland in 2017 (Schleiss 2017). Amounts of organic waste composted in backyards are based on expert assessments as well as on data from a small number of cities and villages. The experts considered different parameters affecting the waste amounts composted in backyards over the time, i.e. urban, rural situation, communication and incentive programs, and services for separate door-to-door collection of organic wastes. Liechtenstein takes these latest data and specific information into account.

A gradually increase of organic waste treated in centralized composting plants can be observed, starting from 1993. This is most probable directly linked to the introduction of the polluter-pays-principle for mixed municipal solid waste management. A peak has been reached in 2008. A slight decreasing development can be noticed since.

Table 7-7 Activity data of 5B Biological treatment of solid waste composted centrally (kilotons as dry matter).

| Waste composting | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Composted centrally | kt dm/a | 1.07 | 1.12 | 1.56 | 1.98 | 1.55 |

| Waste composting | | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Composted centrally | kt dm/a | 1.81 | 1.60 | 1.67 | 1.67 | 1.35 |

| Waste composting | | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| Composted centrally | kt dm/a | 1.76 | 1.96 | 1.97 | 1.65 | 1.59 |

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 $CH_4$ and $N_2O$ emission in 2009 compared to 2008.

Table 7-8 Activity data of 5B Biological treatment of solid waste backyard composting (kilotons as dry matter).

| Waste composting | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| organic waste | kg wet/inhabitant | 16.2 | 21.9 | 25.0 | 22.7 | 15.2 |
| Population | inhabitants | 29'032 | 30'923 | 32'863 | 34'905 | 36'149 |
| Composted backyard | kt dm/a | 0.14 | 0.20 | 0.25 | 0.24 | 0.17 |

| Waste composting | | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Backyard composting | kg wet/inhabitant | 12.2 | 12.1 | 11.9 | 11.9 | 11.9 |
| Population | inhabitants | 37'366 | 37'623 | 37'810 | 38'114 | 38'380 |
| Composted backyard | kt dm/a | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |

| Waste composting | | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| Backyard composting | kg wet/inhabitant | 11.9 | 11.9 | 11.9 | 11.9 | 11.9 |
| Population | inhabitants | 38'749 | 39'055 | 39'315 | 39'677 | 40'015 |
| Composted backyard | kt dm/a | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |

### 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. Uncertainties were accounted for individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. 5B is not a key category and therefore its uncertainties are part of the "rest" categories with mean uncertainty for $CH_4$ and $N_2O$. The combined uncertainty for $CH_4$ is estimated 30% and for $N_2O$ 80% (see Table 1-7).

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 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

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

The following recalculations lead to changes in $CH_4$ and $N_2O$ emissions, resulting in an increase of 0.05 kt $CO_2$eq in 2022:

The activity data of the year 2022 concerning centralized composting in the last submission was wrong. The mistake has been corrected.

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

No category-specific improvements are planned.

## 7.4 Incineration and open burning of waste (5C)

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

**Key category information 5C**

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 7-9 Specification of 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.<br>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 2024).

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

#### Emission Factors

Country-specific emission factors for $CO_2$, $N_2O$ and $CH_4$ are adopted from the Swiss NIR (FOEN 2024, EMIS 2024/5C1 Abfallverbrennung illegal). The $CO_2$ emission factor in municipal solid waste fluctuates over the reporting period because of gradual changes in the net calorific values of the waste.

The following tables present the emission factors used in source category 5C2. Emission factors are referring to kg wet matter.

Table 7-10 Emission Factors $CH_4$ and $N_2O$ for 5C Incineration and open burning of waste (FOEN 2024).

| **5C Waste Incineration** | | |
|---|---|---|
| **Source** | $CH_4$ (kg/t) | $N_2O$ (kg/t) |
| Illegal waste incineration | 6.0 | 0.150 |

Table 7-11 Emission Factor $CO_2$ for 5C Incineration and open burning of waste (FOEN 2024).

| **5C Open burning of waste** | unit | **1990** | **1995** | **2000** | **2005** | **2010** |
|---|---|---|---|---|---|---|
| EF $CO_2$ fossil | kg/t waste | 525.79 | 552.94 | 578.49 | 560.55 | 523.14 |

| **5C Open burning of waste** | unit | **2014** | **2015** | **2016** | **2017** | **2018** |
|---|---|---|---|---|---|---|
| EF $CO_2$ fossil | kg/t waste | 512.49 | 515.28 | 520.35 | 522.22 | 522.59 |

| **5C Open burning of waste** | unit | **2019** | **2020** | **2021** | **2022** | **2023** |
|---|---|---|---|---|---|---|
| EF $CO_2$ fossil | kg/t waste | 523.51 | 523.31 | 519.87 | 521.30 | 516.06 |

## Activity Data

The activity data for waste incineration is the fossil share of waste quantities 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 2018d) and taking into account its fossil share.

The MSW generated (t wet matter/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 2024c).

The fossil fraction of waste incinerated is assumed to be the same as in Switzerland. Data used are based on a study conducted in year 2014 (Rytec 2014, FOEN 2024).

Table 7-12 Activity data for category 5C Incineration and open burning of waste (OS 2024c, OE 2018d, FOEN 2024).

| **5C Open burning of waste** | unit | **1990** | **1995** | **2000** | **2005** | **2010** |
|---|---|---|---|---|---|---|
| MSW generated | kt | 10.64 | 6.73 | 7.79 | 8.04 | 8.66 |
| Fraction incinerated illegally | | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| Waste incinerated illegally | kt | 0.053 | 0.034 | 0.039 | 0.040 | 0.043 |
| Fossil share of MSW | | 49.7% | 51.3% | 50.5% | 50.5% | 48.6% |
| fossil waste incinerated illegaly | kt | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 |

| **5C Open burning of waste** | unit | **2014** | **2015** | **2016** | **2017** | **2018** |
|---|---|---|---|---|---|---|
| MSW generated | kt | 8.58 | 8.50 | 8.27 | 8.32 | 8.26 |
| Fraction incinerated illegally | | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| Waste incinerated illegally | kt | 0.043 | 0.043 | 0.041 | 0.042 | 0.041 |
| Fossil share of MSW | | 47.8% | 47.8% | 47.8% | 47.8% | 47.8% |
| fossil waste incinerated illegaly | kt | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |

| **5C Open burning of waste** | unit | **2019** | **2020** | **2021** | **2022** | **2023** |
|---|---|---|---|---|---|---|
| MSW generated | kt | 7.98 | 8.20 | 8.11 | 7.87 | 8.03 |
| Fraction incinerated illegally | | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| Waste incinerated illegally | kt | 0.040 | 0.041 | 0.041 | 0.039 | 0.040 |
| Fossil share of MSW | | 47.8% | 47.8% | 47.8% | 47.8% | 47.8% |
| Fossil waste incinerated illegaly | kt | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |

### 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. Uncertainties were accounted individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. 5C is not a key category and therefore its uncertainties are part of the "rest" categories with mean uncertainty for $CO_2$, $CH_4$ and $N_2O$. The combined uncertainty for $CO_2$ is estimated 10%, for $CH_4$ 30%, and for $N_2O$ 80% (see Table 1-7).

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 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

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

No category-specific recalculations have been carried out.

### 7.4.6 Category-specific planned improvements: Incineration and open burning of waste (5C)

No category-specific improvements are planned.

## 7.5 Wastewater treatment and discharge (5D)

### 7.5.1 Category Description: Wastewater treatment and discharge (5D)

**Key category information 5D**

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

Category 5D1 Domestic wastewater comprises all emissions from handling of liquid wastes and sludge from housing and commercial sources (including grey water and night soil).

Source category 5D contains all direct emissions from wastewater handling, including direct emissions of sewage gas (leakage), torching and upgrading of sewage gas to natural gas quality (to be fed into the natural gas network and/or used as fuel). Emissions from

the usage of sewage gas in combined heat and power (CHP) units and boilers (only heat production) are also reported in 5D, since the energy is used on site for the wastewater treatment process.

Wastewater deriving from public sewer systems is treated in the Municipal Wastewater 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 sewage gas 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 (EZV 2024).

Source category 5D2 Industrial wastewater comprises all emissions from handling liquid wastes and sludge from industrial processes such as food processing and metal processing industry. 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. Two metal processing companies have polluted wastewater which is pre-treated on-site by a mechanical and a chemical process. These effluents are then further processed in the MWWTP in Bendern as well. Contaminated wastewater from pre-treatment activities is disposed of in Switzerland.

As all industrial wastewater is processed in the MWWTP in Bendern after a pre-treatment, emissions from source category 5D2 Industrial wastewater are included in 5D1 Domestic wastewater.

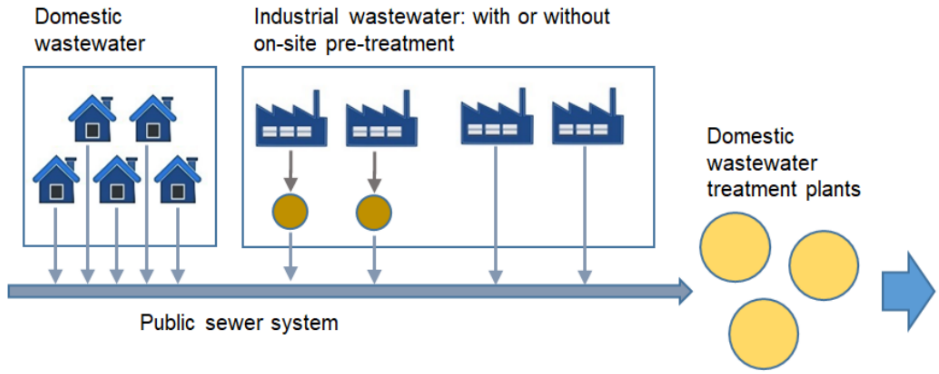



Figure 7-2 Graphical representation of domestic and industrial wastewater streams and treatment.

Table 7-13 Specification of 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 $CH_4$ 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 upgraded.

Subsequent general parameters have been applied (default values according to IPCC 2006):

- BOD (BOD5), biochemical oxygen demand = 60 g/inhabitant/day
- I, correction factor for additional industrial BOD = 1.25
- B0, maximum $CH_4$ producing potential = 0.60 kg $CH_4$/kg BOD
- MCF, methane correction factor = 0.05

#### 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 2024/5D1 Wastewater treatment plants).

Table 7-14 $CH_4$ emission factors of category 5D Wastewater treatment and discharge.

| **5D Waste Water Treatment** | |
|---|---|
| **Source** | kg CH4/TJ |
| Boiler | 6.0 |
| CHP generation | 25.0 |
| Torches | 6.0 |

Emissions from sewage gas upgrading are estimated separately. Based on a SVGW analysis (SVGW 2016) $CH_4$ emissions are estimated as a constant share of 0.062%-Vol. of $CO_2$ stripped.

#### Activity Data

Activity data for $CH_4$ emissions from sewage gas treatment are the amount of gas treated, from losses and leakage from upgrading. In 1990 three wastewater treatment plants had been operational. In 2004, two plants remained, and since 2005 all wastewater of the principality is treated in the MWWTP in Bendern.

Sewage gas is used in boilers, in co-generation plants, flared and up-graded (EZV 2024). These sewage gas amounts are measured.

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 (SVGW 2016).

Table 7-15 Activity data for $CH_4$ emission calculation from sewage gas treatment in 5D Wastewater treatment and discharge (EZV 2024, SFOE 2002, SVGW 2016).

| Sewage gas treatment | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Sewage gas for boilers | TJ | 5.82 | 6.34 | 8.10 | 0.59 | 9.79 |
| Sewage gas for CHP generation | TJ | 6.27 | 7.72 | 11.00 | 18.85 | 10.97 |
| Sewage gas flared | TJ | 2.46 | 1.79 | 1.15 | 0.02 | 0.04 |
| Sewage gas losses | t CH4 | 1.81 | 2.10 | 2.86 | 2.91 | 3.11 |
| Sewage gas for upgrading | t CH4 | 0 | 0 | 0 | 0 | 0 |

| Sewage gas treatment | | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Sewage gas for boilers | TJ | 0.33 | 0.06 | 0.53 | 0.74 | 0.32 |
| Sewage gas for CHP generation | TJ | 0.64 | 0.39 | 1.11 | 1.56 | 1.35 |
| Sewage gas flared | TJ | 0.00 | 0.02 | 0.03 | 0.03 | 0.02 |
| Sewage gas losses | t CH4 | 0.07 | 0.24 | 0.34 | 0.34 | 0.25 |
| Sewage gas for upgrading | t CH4 | 448 | 457 | 418 | 462 | 482 |

| Sewage gas treatment | | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| Sewage gas for boilers | TJ | 0.52 | 0.10 | 0.19 | 0.25 | 0.03 |
| Sewage gas for CHP generation | TJ | 0.78 | 0.38 | 0.64 | 1.45 | 0.47 |
| Sewage gas flared | TJ | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 |
| Sewage gas losses | t CH4 | 0.19 | 0.07 | 0.12 | 0.26 | 0.07 |
| Sewage gas for upgrading | t CH4 | 508 | 548 | 533 | 438 | 445 |

### 7.5.2.2 $N_2O$ Emissions

#### Methodology

$N_2O$ emissions from centralized WWT plants are calculated with a Tier 3 method in accordance with the 2006 IPCC Guidelines (IPCC 2006).

Subsequent general parameters have been applied (default values according to IPCC 2006):

- $F_{IND-COM}$ (correction for commercial/industrial N) = 1.25
- $EF_{PLANT}$ = 3.2 g $N_2O$/inhabitant/yr
- $EF_{EFFLUENT}$ = 0.005 kg $N_2O$-N/kgN
- $F_{NPR}$, fraction of nitrogen in protein = 0.16 kg N/kg protein

#### Activity Data

The time-dependent data on population, degree of utilization and annual per capita protein consumption are summarized in Table 7-16.

Specific numbers for yearly protein consumption are adopted from Switzerland. It is assumed that similar conditions prevail in Liechtenstein. Total protein consumption in

Liechtenstein fluctuates around 37 kg/inhabitant and year. The values are taken from "Nahrungsmittelbilanz der Schweiz" (AGRISTAT 2023). ). The value for year 2023 is assumed to be the same as last year.

Table 7-16 Activity data for $N_2O$ emission calculation in 5D Wastewater treatment and discharge (OS 2024d, AGRISTAT 2023).

| 5D Wastewater treatment and discharge | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Population | inhabitants | 29'032 | 30'923 | 32'863 | 34'905 | 36'149 |
| Degree of Utilization | % | 90.0 | 93.5 | 95.4 | 96.8 | 97.0 |
| Protein Consumption | kg/capita/a | 38.1 | 37.1 | 37.2 | 36.3 | 38.0 |

| 5D Wastewater treatment and discharge | | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Population | inhabitants | 37'366 | 37'623 | 37'810 | 38'114 | 38'380 |
| Degree of Utilization | % | 97.0 | 97.0 | 97.0 | 97.0 | 97.0 |
| Protein Consumption | kg/capita/yr | 36.5 | 37.2 | 36.1 | 36.1 | 35.4 |

| 5D Wastewater treatment and discharge | | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| Population | inhabitants | 38'749 | 39'055 | 39'315 | 39'677 | 40'015 |
| Degree of Utilization | % | 97.0 | 97.0 | 97.0 | 97.0 | 97.0 |
| Protein Consumption | kg/capita/yr | 35.4 | 35.8 | 36.5 | 36.5 | 36.5 |

### 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. Uncertainties were accounted for individually only for the key categories, whereas the rest of the sources was aggregated by gas and treated as four "rest" categories ($CO_2$, $CH_4$, $N_2O$, F-gases) with mean uncertainties according to Table 1-7. 5B is not a key category and therefore its uncertainties are part of the "rest" categories with mean uncertainty for $CH_4$ and $N_2O$. The combined uncertainty for $CH_4$ is estimated 30%, and for $N_2O$ 80% (see Table 1-7).

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 1.5 including also the triple check of the CRT table Summary2 (detailed comparison of latest with previous data for the base year, for 2022 and for the changing rates 2022/2023).

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

The following recalculations lead to changes in $N_2O$ emissions, resulting in an increase of 0.02 kt $CO_2$eq in 2022:

- Data for per capita protein consumption were taken from “Nahrungsmittelbilanz der Schweiz” Agristat, instead from NID CHE Submissions. Agristat is the original data source. As a result for the years 2011-2017 and 2020-2022 the data changed slightly.

### 7.5.6 Category-specific planned improvements: Wastewater treatment and discharge (5D)

No category-specific improvements are planned.

## 7.6 Other (5E)

No emissions are occurring in Liechtenstein under this category.

# 8. Other

No other sources or sinks are occurring in Liechtenstein.

# 9. Indirect $CO_2$ and $N_2O$ emissions

Based on the UNFCCC reporting guidelines (UNFCCC 2014) it is not mandatory to take into account indirect $CO_2$ emissions. Liechtenstein decided not to report indirect $CO_2$ and nitrous oxide emissions. The emissions are therefore not estimated – NE. For that reason, precursor substances such as NMVOC are only reported under 2D3 Other (Solvent use, road paving and asphalt roofing).

# 10. Recalculations and improvements

## 10.1 Explanations and justifications for recalculations, including in response to the review

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 CRT Table8.s1, 8s2)

**1 Energy**

***Recalculation in the Reference Approach***

- The activity data for biodiesel and bioethanol 1997-2022 were updated, since updated shares of biofuels are available from the Swiss customs statistics, which is applied in Switzerland's road transportation model (INFRAS 2024).

***Recalculation in 1A1***

The following recalculations lead to changes in $CO_2$, $CH_4$ and $N_2O$ emissions resulting in an increase of 0.02 kt $CO_2$eq in 2022:

- 1A1a: Since 2021, wood biomass is used as a fuel through the wood gasification process in a combined heat and power plant. Until submission 2024, total consumption of wood biomass and the resulting emissions were reported in categories 1A4a and 1A4b. In the current submission, the allocation of wood biomass consumption to 1A1a and to 1A4a/1A4b was implemented (for more information see section 3.2.4.2), leading to a recalculation of activity data and emissions of $CO_2$, $CH_4$ and $N_2O$ in 1A1a for the years 2021 and 2022.

***Recalculation in 1A2***

In 2022, the following recalculations lead to minor changes (<0.001 kt $CO_2$eq) in $CO_2$, $CH_4$ and $N_2O$ emissions.

- 1A2g: The activity data for biodiesel and bioethanol 1997-2022 were updated, since updated shares of biofuels are available from the Swiss customs statistics, which is applied in Switzerland's road transportation model (INFRAS 2024).

***Recalculation in 1A3***

The following recalculations lead to changes in $CO_2$, $CH_4$ and $N_2O$ emissions resulting in a decrease of 0.02 kt $CO_2$eq in 2022:

1A3b: The activity data for biodiesel and bioethanol 1997-2022 were updated, since updated shares of biofuels are available from the Swiss customs statistics, which is applied in Switzerland's road transportation model (INFRAS 2024).

***Recalculation in 1A4***

The following recalculations lead to changes in $CO_2$, $CH_4$ and $N_2O$ emissions resulting in a decrease of 0.01 kt $CO_2$eq in 2022:

- 1A4a/b: Since 2021, wood biomass is used as a fuel through the wood gasification process in a combined heat and power plant. Until submission 2024, total consumption of wood biomass and the resulting emissions were reported in sectors 1A4a and 1A4b. In the current submission, the allocation of wood biomass consumption to 1A1a and to 1A4a/1A4b was implemented (for more information see section 3.2.4.2), leading to a recalculation of activity data and emissions of $CO_2$, $CH_4$ and $N_2O$ in 1A4a and 1A4b for the years 2021 and 2022.
- 1A4c: The activity data for biodiesel and bioethanol 1997-2022 were updated, since updated shares of biofuels are available from the Swiss customs statistics, which is applied in Switzerland's road transportation model (INFRAS 2024).

***Recalculation in 1B2***

There were no category-specific recalculations.

**2 IPPU**

***Recalculation in 2D***

No category specific recalculations were carried out.

***Recalculation in 2F***

Switzerland's GHG inventory 2025 was not yet available for Liechtenstein's submission 2025. For Switzerland, the following recalculations have been carried out in submission 2024, which also influence Liechtenstein's emission time series reported in Submission 2025:

- 2F1: Changes in portion of different refrigerants used for stationary refrigeration; changes in time period required for the complete elimination of HFC/PFC blends. Correction in the disposal amount, remaining charge at end of life. For further details see Carbotech (2024).
- 2F4: Aerosol in asthma spray, revision of activity data based on literature of asthma spray use in Switzerland (inhalers).

In addition, the following recalculations lead to changes in HFC and PFC emissions:

- 2F1 Refrigeration and air conditioning: Since the number of employees in industrial and service sector in Switzerland was updated based on newest available data (SFSO 2024b) the activity data (number of employees) has changed from 2010–2022.

In 2022, these recalculations lead to a decrease in HFC/PFC emissions of <0.01 kt $CO_2$eq.

***Recalculation in 2G***

No category-specific recalculations were carried out.

**3 Agriculture**

General: It is planned that Liechtenstein's agriculture model is 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 latest update has been done for the submission 2025.

***Recalculation in 3A***

The following recalculations lead to changes in $CH_4$ emissions, resulting in an increase of 0.03 kt $CO_2$eq in 2022:

- 3A: $CH_4$ emissions from enteric fermentation of growing cattle, other mature cattle and goats were recalculated for the whole time series. New methane conversion rates ($Y_m$) were adopted from the 2019 IPCC Refinement (IPCC 2019). Overall emissions declined by -73.8 t $CO_2$eq on average.
- 3A: $CH_4$ emissions from enteric fermentation of sheep were recalculated for the years 2015–2022 due to an adjustment of the methane conversion rate ($Y_m$, affecting IEF). The weighting of the methane conversion rates for adult and young sheep was adjusted based on new consistent time series of the number of young sheep in Switzerland. The mean impact on overall emissions was -29.1 t $CO_2$eq for the period 2015–2022.
- 3A: The data does not show a difference in milk yields depending on the wight of mature dairy cattle. Accordingly, gross energy intake (GE) was not calculated anymore based on two linear regressions (for mature dairy cattle below or above 6'030 kg weight, respectively). Instead, a single linear regression was used to calculate GE (see chp. 5.2.2.1). This recalculation has no impact on nitrogen excretion.

***Recalculation in 3B***

The following recalculations lead to changes in $CH_4$ emissions, resulting in a decrease of 0.3 kt $CO_2$eq in 2022:

- 3B: $CH_4$ emissions from manure management of growing cattle and other mature cattle were recalculated for the whole time series. Emission factors were revised in the course of the adoption of the 2019 Refinement to the 2006 IPCC Guidelines (IPCC 2019) by adjusting the values for feed digestibility when calculating excretion of volatile solids (VS). New values for feed digestibility are higher for all animal categories concerned leading to lower estimates of excretion of VS and a reduction of overall emissions of -75.5 t $CO_2$eq on average.

- 3B: $CH_4$ emissions from manure management of sheep, goats, horses and mules and asses were recalculated for the whole time series. Excretion of volatile solids of these livestock categories is now estimated based on equation 10.24 of the 2019 IPCC Refinement (IPCC 2019). New values of VS are lower for sheep, horses and mules and asses and higher for goats leading to an average decrease of emissions of -1.3 t $CO_2$eq.
- 3B: $CH_4$ emissions from liquid manure management were recalculated for the whole time series. Emission factors were revised due to new, slightly higher monthly norm temperature values from MeteoSwiss (2024) for estimating the methane conversion factor (MCF) for liquid systems. The impact on overall emissions ranges from +51.0 to +93.5 t $CO_2$eq.
- 3B: $CH_4$ emissions from manure management of cattle were revised for the whole time series. When estimating VS excretion based on equation 10.24 of the IPCC Guidelines, urea energy is no more accounted for (affecting EF). According to Dämmgen et al. (2011) there is no indication for methane formation from urine energy. The mean impact on overall emissions is -304.3 t $CO_2$eq.

***Recalculation in 3D***

The following recalculations lead to changes in $CH_4$ an $N_2O$ emissions, resulting in a decrease of 0.3 kt $CO_2$eq in 2022:

- 3D: $N_2O$ emissions from cultivated organic soils were recalculated for the whole time series. New disaggregated emission factors for grassland and cropland were adopted from the IPCC Wetland Supplement. The impact on overall emissions was +2.3 t $CO_2$eq on average.
- 3D: $N_2O$ emissions from urine and dung de-posited by grazing animals were recalculated for the whole time series. New emission factors for pasture, range and paddocks (EF3's) from the 2019 IPCC Refinement were adopted. The impact on overall emissions ranges from -272.1 to -549.7 t $CO_2$eq.
- 3D: $N_2O$ emissions from nitrogen leaching and run-off were recalculated for the whole time series. The respective emission factor (EF5) from the 2019 IPCC Refinement was adopted. The impact on overall emissions ranges from +181.2 to +246.5 t $CO_2$eq.

***Recalculation in 3H***

No category-specific recalculations were carried out.

**4 LULUCF**

***Recalculation in 4A***

In 2022, the following recalculations lead to a decrease of $CO_2$ emissions by 9.17 kt $CO_2$eq.

- 4A, 2011-2022: New values for gains and losses of living biomass were adopted from Liechtenstein's latest NFI (LWI 2025). Both, gains and losses decreased in this period. However, the decrease in losses was stronger resulting in clearly lower $CO_2$ emissions.

- 4A, 1990-2022: For productive forest (CC12), new values for carbon stocks in living biomass and dead wood were derived from Liechtenstein's latest NFI (LWI 2025).
- 4A, 1990-2022: For productive forest (CC12), new values for carbon stock changes in dead wood and litter as well as for carbon stocks in litter were adopted from Yasso model results of Switzerland (FOEN 2025, Didion 2024). Now, there is a stronger increase in dead wood leading to lower $CO_2$ emissions.
- 4A, 1990-2022: For productive and unproductive forests, new values for carbon stocks in mineral soils were adopted from Switzerland (FOEN 2025, Nussbaum and Burgos 2021).
- 4(II)A, 1990-2022: On forest land, $N_2O$ emissions from drained organic soils are reported for the first time. Remark: Due to technical problems with the CRT tables, the $N_2O$ emission of 4(II)D wetlands is included in the number of 4(II)A.

***Recalculation in 4B***

In 2022, the following recalculations lead to a decrease of $CO_2$ emissions by 0.11 kt $CO_2$eq and to minor changes (<0.05 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4B: The carbon stock in mineral soil was updated based on recent results of the RothC model in Switzerland (FOEN 2024). It is now 57.06 instead of 50.65 t C $ha^{-1}$.

***Recalculation in 4C***

In 2022, the following recalculations lead to a increase of $CO_2$ emissions by 1.33 kt $CO_2$eq and to minor changes (<0.05 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4C, Permanent grassland (CC31): The carbon stocks in mineral soils were updated based on recent results of the RothC model in Switzerland (FOEN 2024). In general, the new stocks are lower.
- 4C: Carbon stocks in mineral soils were updated for the land-use categories CC32–CC37 based on a digital soil map (Stumpf et al. 2023). In general, the new stocks are lower.

***Recalculation in 4D***

In 2022, the following recalculations lead to an increase of $CO_2$ emissions by 0.01 kt $CO_2$eq and to minor changes (<0.05 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4D: Carbon stocks in mineral soils were updated for the land-use category CC42 (unproductive wetland) based on a digital soil map (Stumpf et al. 2023). The new stock is 10% lower.
- 4(II)D, 1990-2022: On wetlands, $N_2O$ emissions from drained organic soils are reported for the first time. Remark: Due to technical problems with the CRT tables, the $N_2O$ emission of 4(II)D wetlands is included in the number of 4(II)A.

***Recalculation in 4E***

In 2022, the following recalculations lead to a decrease of $CO_2$ emissions by 1.05 kt $CO_2$eq and of $N_2O$ emissions by 0.06 kt $CO_2$eq.

- 4E: Carbon stocks in mineral soils were updated for the land-use categories CC52-54 based on a digital soil map (Stumpf et al. 2023). The new stocks are higher.

***Recalculation in 4F***

In 2022, the following recalculations lead to a decrease of $CO_2$ emissions by 0.11 kt $CO_2$eq and to minor changes (<0.05 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4F2: Carbon losses on areas converted to other land have changed due to recalculations of carbon stocks in biomass for forests and in mineral soils for forest land, cropland, grassland, wetlands and settlements.

***Recalculation in 4(III)***

In 2022, the following recalculations lead to a increase (<0.2 kt $CO_2$eq) regarding the emissions of $N_2O$.

- 4(III): The emission factor EF5 was updated based on the refined Guidelines (IPCC 2019): 0.011 kg $N_2O$-N (kg N)$^{-1}$ (former value 0.0075).
- 4(III): The fraction of mineralized N lost by leaching or run-off (Frac) was updated based on the default value of the refined Guidelines (IPCC 2019): 24%. The former value (30%) was only a rough estimate.
- 4(III): Carbon losses and nitrogen losses have changed due to recalculations of carbon stocks in mineral soils for forest land, cropland, grassland, wetlands and settlements.

***Recalculation in 4G***

In 2022, the following recalculation leads to an increase of $CO_2$ emissions by 2.05 kt $CO_2$.

- 4G, 2018–2022: The production of sawnwood was reduced from 3'500 m3 to 1'050 m3 based on a new survey to the two sawmills in Liechtenstein.

**5 Waste**

***Recalculation in 5A***

There were no category-specific recalculations.

***Recalculation in 5B***

The following recalculations lead to changes in $CH_4$ and $N_2O$ emissions, resulting in an increase of 0.05 kt $CO_2$eq in 2022:

- The activity data of the year 2022 concerning centralized composting was wrong. The mistake has been corrected in this submission.

***Recalculation in 5C***

There were no category-specific recalculations.

***Recalculation in 5D***

The following recalculations lead to changes in $N_2O$ emissions, resulting in an increase of 0.02 kt $CO_2$eq in 2022:

- Data for per capita protein consumption were taken from “Nahrungsmittelbilanz der Schweiz” Agristat, instead from NID CHE Submissions. Agristat is the original data source. As a result for the years 2011-2017 and 2020-2022 the data changed slightly.

## 10.2 Implications for emission and removal levels 1990 and 2022

Table 10-1 shows the recalculation results for the base year 2022. The recalculations have the following effect on the emissions in 2022 in comparison with the submitted emissions of the previous year:

- The difference in national total emissions 2022 amounts to a total decrease of 0.58 kt $CO_2$eq (-0.35%) without emissions/removals from LULUCF.
- Including LULUCF, the difference in national total emissions 2022 amounts to a total decrease of 6.73 kt $CO_2$eq (-4.1%).

The following recalculations contributed substantially to the differences in emissions in 2022 between the current submission and the previous submission:

- There are major recalculations in the LULUCF sector, as new data from the National Forest Inventory 2022 (LWI 2025) were included in the calculations. Relevant changes occurred in the following source categories:
  - 4A Forest land (-9.1 kt $CO_2$eq; recalculations see chapter 6.4.5)
  - 4C Grassland (+1.4 kt $CO_2$eq; recalculations see chapter6.6.5)
  - 4G Harvested Wood Products (+2.1 kt $CO_2$eq; recalculations see chapter6.11.5)
- In addition, the model used to calculate agricultural emissions was updated and leads to relevant recalculations in the following source categories:
  - 3B Manure Management (-0.3 kt $CO_2$eq; recalculations see chapter 5.3.5
  - 3D Agricultural soils (-0.3 kt $CO_2$eq; recalculations see chapter 5.5.5)

Table 10-1 Overview of implications of recalculations on 2022 data. Emissions are shown before the recalculation according to the previous submission in 2024 “Prev.” (OE 2024) and after the recalculation according to the present submission 2025 “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** | **$CO_2$** | | | **$CH_4$** | | | **$N_2O$** | | | **Sum ($CO_2$, $CH_4$ and $N_2O$)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Emissions for 2022** | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. |
| Source and sink categories | $CO_2$ equivalent (kt) | | | | | | | | | $CO_2$ equivalent (kt) | | |
| 1 Energy | 128.2 | 128.2 | *-0.02* | 1.8 | 1.8 | *-0.01* | 0.8 | 0.9 | *0.01* | 130.9 | 130.8 | *-0.01* |
| 2 IPPU (without F-gases) | 0.1 | 0.1 | - | NO | NO | *NO* | 0.1 | 0.1 | - | 0.2 | 0.2 | - |
| 3 Agriculture | 0.0 | 0.0 | - | 18.8 | 18.5 | *-0.28* | 6.0 | 5.7 | *-0.34* | 24.8 | 24.2 | *-0.62* |
| 4 LULUCF | -1.5 | -7.8 | *-6.30* | NO | NO | *NO* | 0.4 | 0.5 | *0.15* | -1.1 | -7.3 | *-6.15* |
| 5 Waste | 0.0 | 0.0 | *0.00* | 1.1 | 1.1 | *0.03* | 0.6 | 0.6 | *0.03* | 1.7 | 1.7 | *0.07* |
| Sum (without F-gases) | 126.9 | 120.5 | *-6.31* | 21.7 | 21.4 | *-0.26* | 8.0 | 7.8 | *-0.15* | 156.5 | 149.8 | *-6.72* |

| **Recalculation** | **HFC** | | | **PFC** | | | **$SF_6$** | | | **Sum (F-gases)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Emissions for 2022** | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. |
| Source and sink categories | $CO_2$ equivalent (kt) | | | | | | | | | $CO_2$ equivalent (kt) | | |
| 2 IPPU (F-gases only) | 7.8 | 7.8 | *-0.01* | 0 | 0 | *0.00* | 0.1 | 0.1 | *0.00* | 7.9 | 7.9 | *-0.01* |

| **Recalculation** | **Sum (all gases)** | | |
|---|---|---|---|
| **Emissions for 2022** | Prev. | Latest | Differ. |
| Source and sink categories | $CO_2$ equivalent (kt) | | |
| **Total $CO_2$ eq Em. with LULUCF** | **164.4** | **157.7** | ***-6.73*** |
| | 100.0% | 95.9% | *-4.09%* |
| **Total $CO_2$ eq Em. without LULUCF** | **165.5** | **164.9** | ***-0.58*** |
| | 100.0% | 99.7% | *-0.35%* |

Table 10-2 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 1990 amounts to a total decrease of 0.56 kt $CO_2$eq (-0.24%) without emissions/removals from LULUCF.
- Including LULUCF, the difference in national total emissions 1990 amounts to a total decrease of 3.80 kt $CO_2$eq (-1.61%).

The main reason for differences in emissions in 1990 between the current submission and the previous submission are recalculations in sector LULUCF (e.g. new data from the National Forest Inventory 2022 (LWI 2025)) and in sector Agriculture (model update).

Table 10-2 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submission in 2024 "Prev." (OE 2024) and after the recalculation according to the present submission 2025 "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** | **$CO_2$** | | | **$CH_4$** | | | **$N_2O$** | | | **Sum ($CO_2$, $CH_4$ and $N_2O$)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Emissions for 1990** | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. |
| Source and sink categories | $CO_2$ equivalent (kt) | | | | | | | | | $CO_2$ equivalent (kt) | | |
| 1 Energy | 198.7 | 198.7 | - | 1.4 | 1.4 | - | 1.1 | 1.1 | - | 201.3 | 201.3 | - |
| 2 IPPU (without F-gases) | 0.2 | 0.2 | - | NO | NO | *NO* | 0.4 | 0.4 | - | 0.6 | 0.6 | - |
| 3 Agriculture | 0.1 | 0.1 | - | 18.9 | 18.4 | *-0.52* | 6.5 | 6.4 | *-0.04* | 25.4 | 24.8 | *-0.56* |
| 4 LULUCF | 6.6 | 3.3 | *-3.34* | NO | NO | *NO* | 0.2 | 0.3 | *0.10* | 6.8 | 3.6 | *-3.24* |
| 5 Waste | 0.0 | 0.0 | - | 1.2 | 1.2 | - | 0.5 | 0.5 | - | 1.7 | 1.7 | - |
| Sum (without F-gases) | 205.6 | 202.2 | *-3.34* | 21.5 | 21.0 | *-0.52* | 8.7 | 8.7 | *0.05* | 235.8 | 232.0 | *-3.80* |

| **Recalculation** | **HFC** | | | **PFC** | | | **$SF_6$** | | | **Sum (F-gases)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Emissions for 1990** | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. | Prev. | Latest | Differ. |
| Source and sink categories | $CO_2$ equivalent (kt) | | | | | | | | | $CO_2$ equivalent (kt) | | |
| 2 IPPU (F-gases only) | 0.0 | 0.0 | - | NA,NO | NA,NO | *NO* | NA,NO | NA,NO | *NO* | 0.0 | 0.0 | - |

| **Recalculation** | **Sum (all gases)** | | |
|---|---|---|---|
| **Emissions for 1990** | Prev. | Latest | Differ. |
| Source and sink categories | $CO_2$ equivalent (kt) | | |
| **Total $CO_2$ eq Em. with LULUCF** | **235.8** | **232.0** | ***-3.80*** |
| | 100.0% | 98.4% | *-1.61%* |
| **Total $CO_2$ eq Em. without LULUCF** | **229.0** | **228.5** | ***-0.56*** |
| | 100.0% | 99.8% | *-0.24%* |

## 10.3 Implications for emission and removal trends, including time series consistency

Due to recalculations, the emission trend 1990–2022 reported in submission 2024 has changed. The emission trend showed a decrease by 27.72% before the recalculations (previous submission, national total without emissions/removals from LULUCF). After the recalculations in the latest submission 2025, the decreasing trend is slightly higher (-27.80%).

Table 10-3 Change of the emission trend 1990–2022 due to recalculations carried out in the latest submission 2025. "Previous" refers to the values from submission 2024 (OE 2024).

| **Recalculation** | **1990** | | **2022** | | **change 1990/2022** | |
|---|---|---|---|---|---|---|
| Submission | previous | latest | previous | latest | previous | latest |
| | $CO_2$ eq (kt) | | | | % | |
| Total excl. LULUCF | 229.01 | 228.45 | 165.52 | 164.95 | -27.72% | -27.80% |

All time series in the present submission are consistent.

## 10.4 Recalculations in response to the review process and planned improvements

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 Document (NID). The IDP summarises all issues detected from internal and external QA/QC activities. It is updated regularly based on the recommendations of the expert review teams of the UNFCCC (ERT).

The latest review of Liechtenstein's greenhouse gas inventory took place in September 2022. The findings of the ERT were published in February 2023 in the report of the individual review of the annual submission of Liechtenstein submitted in 2022 (FCCC/ARR 2023).

Liechtenstein prioritises the implementation of planned improvements based on the results of the key category analysis (see chp. 1.4) and the uncertainty analysis (see chp. 1.6). High priority is assigned to improvements that concern key categories and/or sectors with high uncertainty, such as:

- 1A3b Road transport: The emission factors are usually updated annually to the newest version of the handbook of emission factors (HBEFA).
- 3 Agriculture: The model is fully revised every 5 years. The last update has been done for submission 2025 .
- 4 LULUCF: A new computing framework for the LULUCF sector was developed and implemented in submission 2024.
- 4A Forest land: Results of the National Forest Inventory 2022 were implemented in submission 2025.

The IDP summarises the recommendations and planned improvements and illustrates the implementation status of those. Table 10-4 shows all planned improvements of the IDP that were implemented in the current submission, planned improvements for future submissions and improvements that will not be implemented.

A description of the IDP headers is provided here:

**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 2022/#G.1 refers to ID G.1 of the report on the inventory submitted in 2022, FCCC/ARR/2022/LIE.

**Recommendations/Planned improvement**

The recommendations of the ERT or planned improvements are described in detail in the second column.

### Status

The status provides information about the state of development of each specific point ("implemented in submission 20XX" or "planned improvement for submission 20XX").

### 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 10-4 Inventory development plan for Liechtenstein's greenhouse gas inventory 2025.

| Reference | Identified Issues, e.g. recommendations or planned improvements | Status | Comment/Reason NID | Sector |
|---|---|---|---|---|
| Review 2013 | Conduct internal review complemented with systematic external review. | 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. | 0 General |
| ARR 2013 / 21;81;87;89; Table 3; ARR 2016, ID#G.6 | Review and strengthen its QC procedures to eliminate errors and improve the accuracy of its emission estimates. | 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. | 0 General |
| ARR 2013 / 16c;21;24;35; Table 3, ARR 2018, ID#G.6, PMF 2020, ID#G.5 | Implement additional QC procedures to avoid mistakes or discrepancies between the CRF tables and the NIR. | 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. | 0 General |
| ARR 2022 ID#G.6 | In several of the CRF tables submitted by the Party, some cells were left blank. Blank cells were found for several categories of many sectors across the time series in CRF tables 1.A(a), 2(I)A–H, 3.A, 3.B(a–b), 4(I–III), 4.G, 6, 8 (sheet 4) and 4(KP-II)2–4.. The ERT confirms that no underestimation related with the incorrect use of the notation key was done. The ERT recommends that the Party fill any blank cells in the CRF tables with values or appropriate notation keys. | Ongoing implementation | The party will include the missing notation keys in the CRF reporter application where this is possible. | 0 General |

| Reference | Identified Issues, e.g. recommendations or planned improvements | Status | Comment/Reason NID | Sector |
|---|---|---|---|---|
| ARR 2013 / 21 | Implement additional QC procedures to avoid mistakes or discrepancies between the CRF tables and the NIR. | 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. | 1 Energy |
| ARR 2020, ID#E.10, ARR 2022 ID#E.2 | 1.A.3.b Road transportation - Gasoline, Diesel oil, Gaseous fuels, Biomass - CO2, CH4, N2O: The ERT recommends that the Party provide emission estimates in the sub categories 1A3bii, 1A3biii, 1A3biv in the next CRF and NIR, or provide information on the notation key “IE”.<br><br>The ERT notes that the Party could consider applying approximate data and drivers (e.g. number of vehicles, information from the Swiss inventory, etc) and / or expert judgement to allocate the AD and corresponding emissions. Make efforts to disaggregate AD and report emission estimates for gasoline, diesel oil, gaseous fuels and biomass under categories 1.A.3.b.ii (light-duty trucks), 1.A.3.b.iii (heavy-duty trucks and buses) and 1.A.3.b.iv (motorcycles); where this is not possible, provide information on the use of the notation key “IE” in CRF table 9. | Planned improvement for 2026 | A more detailed explanation was added in the NIR of submission 2021 on how the data is aggregated under source category 1A3bi – Cars and that vehicle categories except passenger cars are therefore IE (see chp. 3.2.7.2 - Methodology - Road transportation). Unfortunately, Liechtenstein does not have sufficiently detailed activity data (e.g. distances travelled and fuel consumption per vehicle category), which would allow to disaggregate the emission data for the different vehicle categories under 1A3b. Liechtenstein is of the opinion that the effort needed to implement this improvement is not justified. Liechtenstein is elaborating a simplified method to further disaggregate the emission data for the different vehicle categories under source category 1A3b and will implement it in the submission 2026. Information on the use of the notation key "IE" is provided in NID chapter 1.7. | 1 Energy |
| ARR 2022 ID#E.7 | 1.A.3.b Road transportation – biodiesel – CO2<br>Estimate and report CO2 emissions associated with the fossil part of the carbon content of biofuels or, if these emissions are considered insignificant, report them as “NE” and provide a quantitative estimate of the likely level of the emissions in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines. | Planned improvement for 2026 | The party will examine how to report the emissions as “NE” in the CTF-tables in submission 2026 and provide an estimate of the likely level. | 1 Energy |

| Reference | Identified Issues, e.g. recommendations or planned improvements | Status | Comment/Reason NID | Sector |
|---|---|---|---|---|
| ARR 2022 ID#A.3 | 3A2: The Party reported in its NIR ( section 5.2.5, p.161) that a weighted-average value of Ym was used to estimate CH4 emissions from enteric fermentation of sheep (e.g. 5.68 per cent for 1990 and 5.94 per cent for 2018). However, the ERT noted that CRF table 3.As1 provides a constant GE of 22.52 MJ/head/day for sheep for the entire time series. As GE is a function of Ym, according to equation 10.21 of the 2006 IPCC Guideline (vol. 4), it can not be constant, as Ym is not constant. Therefore, it was not clear to the ERT how EF for the two subcategory of sheep (lambs <1 year old and mature sheep) were developed. The ERT recommends that the Party evaluate the CH4 enteric fermentation EF for each subcategory of sheep (i.e. for lambs <1 year old and mature sheep), taking into account the GEI and Ym values that are relevant for each subcategory, and use the country-specific data on sheep population by subcategory for the entire reporting period. | Will not be implemented | The Party believes that this recommendation imposes a disproportionate effort compared to the improvement in the estimation of the EF. Furthermore, in the ARR 2022, the ERT notes that the issue does not lead to a potential underestimation of emissions. | 3 Agriculture |
| ARR 2022 ID#L.7 | The ERT, noting that use of the Wetlands Supplement is not mandatory, recommends that if the Party chooses not to estimate CH4 and indirect DOC-CO2 emissions from drained organic soils on cropland and grassland, it report these emissions as “NE” in CRF table 4(II), provide a related explanation in CRF table 9 and report the areas identical to those reported as organic soils in CRF tables 4.B and 4.C. Furthermore, the ERT encourages Liechtenstein to use the Wetlands Supplement in preparing its inventory for future annual submissions and report estimated CH4 and indirect DOC-CO2 emissions from drained | Planned improvement for 2026 | The party will improve table 4(II) as recommended. | 4 LULUCF |

| Reference | Identified Issues, e.g. recommendations or planned improvements | Status | Comment/Reason NID | Sector |
|---|---|---|---|---|
| | organic soils on cropland and grassland. | | | |
| ARR 2022 ID#L.9 | The ERT encourages the Party to report in CRF table 4.Gs2 the additional information items of factors used to convert from product units to carbon for HWP. | Planned improvement for 2026 | The party will improve table 4Gs2 accordingly. | 4 LULUCF |
| ARR 2018, ID#W.2 | Provide quantitative uncertainty estimates for all waste categories and discuss the reasons for the uncertainty estimates in the appropriate section of the waste chapter of the NIR, following the outline for the NIR in the UNFCCC Annex I inventory reporting guidelines. | Ongoing implementation | All waste categories aren't key sources. Therefore, a simplified uncertainty analysis has been carried out.<br>However, NIR submission 2020 CH4 emissions from 5D1 Wastewater Treatment and discharge was a key category. | 5 Waste |
| internal decision | 5A: Switzerland has recalculated its waste composition landfilled. No category-specific improvements are planned. The shares of kitchen waste and garden waste within the deposited amounts of organic waste on solid waste disposal sites from 1950–1979 have been recalculated according to BUS 1978.<br>Lichtenstein is planning to align its activity data at the time when the FOD model is going to be up-dated. | Ongoing implementation | This planned improvement will be implemented during the next update of the FOD-model of Liechtenstein. | 5 Waste |

# Annexes to the National Inventory Document

## Annex 1 Key categories

All relevant information regarding the key category analysis is given in chp. 1.4.

## Annex 2 Uncertainty assessment

### A2.1 Aggregation of categories for application of uncertainty analyses to key categories

In the automatic KCA of the CRT Reporter, the aggregation level of the categories is not identical to the data available for Liechtenstein. That means that uncertainties 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 - 1.

Table A - 1 Aggregation with Gaussian error propagation for the three relevant key categories.

| **1A3b $CO_2$** | (Sub)Categories | | **Aggr. Uncertainties** |
|---|---|---|---|
| | *gasoline* | *diesel* | *total/implied* |
| $U_{\%}$ Emissions | 10.0% | 15.0% | **8.7%** |
| $U_{\%}$ Activity Data | 10.0% | 15.0% | **8.7%** |
| $U_{\%}$ Emission Factor | 0.1% | 0.1% | **0.1%** |
| **1A4 Liquid fuels $CO_2$** | (Sub)Categories | | **Aggr. Uncertainties** |
| | *1A4a* | *1A4b* | *total/implied* |
| $U_{\%}$ Emissions | 20.0% | 20.0% | **15.9%** |
| $U_{\%}$ Activity Data | 20.0% | 20.0% | **15.9%** |
| $U_{\%}$ Emission Factor | 0.1% | 0.1% | **0.1%** |
| **1A4 Gaseous fuels $CO_2$** | (Sub)Categories | | **Aggr. Uncertainties** |
| | *1A4a* | *1A4b* | *total/implied* |
| $U_{\%}$ Emissions | 5.0% | 5.0% | **4.0%** |
| $U_{\%}$ Activity Data | 5.0% | 5.0% | **4.0%** |
| $U_{\%}$ Emission Factor | 0.4% | 0.4% | **0.3%** |

## A2.2 Aggregation of carbon pools in the sector LULUCF

The following table shows the relevant carbon pools that were considered in the uncertainty analysis as well their share in the total carbon stock change (CSC) per main category. "AD_Unc combined" is the uncertainty arising from the AREA survey combined with the uncertainty of the share of organic soils taken from the soil map (30%). If more than one pool was considered the calculation of the uncertainty of the sum of the pools using absolute uncertainties (EF_absUnc) is documented.

Table A - 2 Derivation of EF uncertainties from the relevant processes/pools in sector 4 (2023).

| Cate-gory | Process, pool | CSC t C/ha (1) | Process share | AD_Unc AREA survey % | AD_Unc organic soil % | AD_Unc combined % | EF_Unc % | EF_absUnc t C/ha |
|---|---|---|---|---|---|---|---|---|
| 4A1 | total | 0.65 | 1.00 | 2.7 | | | 34.9 | |
| 4A2 | total | 4.80 | 1.00 | 17.2 | | | 34.9 | |
| 4B1 | organic soil | -0.69 | 1.00 | 6.9 | 30.0 | 30.8 | 23.0 | |
| | total | -0.69 | 1.00 | 6.9 | | | 23.0 | |
| 4B2 | organic soil | -0.13 | 0.63 | 26.9 | 30.0 | 40.3 | 23.0 | 0.061 |
| | mineral soil | 0.01 | 0.07 | 26.9 | | | 50.0 | 0.007 |
| | total | -0.12 | 0.69 | 26.9 | | | 52.2 | 0.061 |
| 4C1 | organic soil | -0.14 | 0.81 | 6.0 | 30.0 | 30.6 | 23.0 | 0.052 |
| | mineral soil | 0.02 | 0.13 | 6.0 | | | 50.0 | 0.011 |
| | total | -0.11 | 0.94 | 6.0 | | | 47.0 | 0.053 |
| 4C2 | organic soil | -0.26 | 0.34 | 13.6 | 30.0 | 32.9 | 23.0 | 0.104 |
| | mineral soil | 0.06 | 0.08 | 13.6 | | | 50.0 | 0.029 |
| | living biom. | -0.44 | 0.58 | 13.6 | | | 40.3 | 0.178 |
| | total | -0.64 | 0.66 | 13.6 | | | 32.4 | 0.209 |
| 4D1 | total | 0.00 | 1.00 | 10.5 | | | 50.0 | |
| 4D2 | mineral soil | -0.81 | 0.63 | 40.9 | | | 50.0 | 0.406 |
| | living biom. | -0.39 | 0.30 | 40.9 | | | 40.3 | 0.157 |
| | total | -1.20 | 0.94 | 40.9 | | | 36.2 | 0.435 |
| 4E1 | mineral soil | 0.12 | 0.89 | 6.4 | | | 50.0 | 0.059 |
| | living biom. | -0.01 | 0.11 | 6.4 | | | 40.3 | 0.006 |
| | total | 0.10 | 1.00 | 6.4 | | | 57.1 | 0.060 |
| 4E2 | mineral soil | -0.46 | 0.34 | 19.4 | | | 50.0 | 0.231 |
| | living biom. | -0.91 | 0.66 | 19.4 | | | 40.3 | 0.366 |
| | total | -1.37 | 1.00 | 19.4 | | | 31.6 | 0.433 |
| 4F2 | mineral soil | -1.02 | 0.61 | 40.9 | | | 50.0 | 0.508 |
| | living biom. | -0.28 | 0.30 | 40.9 | | | 40.3 | 0.113 |
| | total | -1.30 | 0.91 | 40.9 | | | 40.1 | 0.521 |
| 4G | total | -0.05 | 1.00 | 50.0 | | | 57.0 | |

(1) related to total area (sum of organic and mineral soils) in 2022.

# Annex 3 Detailed description of reference approach

No supplementary information to the statements given in Chapter 3.2.1 Comparison of Sectoral Approach with Reference Approach.

# Annex 4 QA/QC plan

## A4.1 QA/QC plan

### A.4.1.1 Quality assurance (QA) activities

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 NID 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 NID 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 NID authors (see A4.3).
- 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 insufficient transparency, which has been solved in recent years. Concerning Industrial Processes of Liechtenstein, emissions in 2F1 and 2F7 were

affected from the findings above. Other industrial processes are not occurring in Liechtenstein. The consequences for the main findings were evaluated for Liechtenstein's GHG inventory and for the NIR for submission December 2006.

- The Swiss Federal Institute of Technology (ETH) was mandated to review the methane emissions of agriculture with respect to methods, activity data and emission factors. The results were documented in two reports (Soliva 2006, 2006a) and communicated to Liechtenstein's Inventory Group. The consequences for the main findings have been evaluated for Liechtenstein's GHG inventory and for the NIR for submission December 2006.
- The waste sector of Switzerland was reviewed by a peer expert group in 2009. The reviewers concluded that waste related emissions are calculated in a plausible way and that results from the report are plausible. The emission factors as well as activity data are based on reliable and solid sources. For details see Rytec (2010). 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 NID, an annual internal review takes place shortly before the submission. Every chapter of the NID is being proofread by specialists not involved in the emission modelling or in the NID 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 NID (NID author F. Weber 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, May 2016 and April 2017–2023). 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.

### A.4.1.2 Quality control (QC) activities

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 Karin Jehle (project manager) and Regula Imhof Director of the Office of Environment/quality manager) take place. Beside technical issues also political topics are discussed. As needed, important information is referred to the department or ministry.

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

- The NID 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 NID, the correct transcription of CRT data into NID data tables and figures, the consistency between data tables and text in the NID as well as the completeness of references in the NID. 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 NID. 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 CRT Reporter. A final data check is done by comparison of random data fields with the provided 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 NID: monitoring of the GHG emission modelling and key category analysis. The project manager checks the NID for correctness, completeness, transparency and quality, checks for the complete archiving of documents and the completeness of the CRT submission documents.
- 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 CRT Reporting Tables for the current submission, exported from the CRT Reporter software, underwent an iterative quality control in a triple check:
  - The emissions of the year 2023 were compared with those of the year 2022 within the current Reporting Table Summary2.
  - The emissions of the year 2022 were compared between the current Reporting Table Summary2 of submission 2025 and the Reporting Table Summary2 of submission 2024.
  - The emissions of the base year 1990 were compared between the current Reporting Table Summary2 of submission 2025 and the Reporting Table Summary2 of the submission 2024.
- In the first step, the CRT 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. In the second step, anomalies in data were investigated within more detailed CRT 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 NID passed several quality controls. Table 1-1 illustrates the official quality control procedure of Liechtenstein's NID. The first internal NID draft is cross-checked by the NID authors in terms of correctness, completeness, consistency and layout. The Office of environment (OE) and the emission modeller review the entire NID as external experts because experts of the OE and the emission modeller are not directly involved in updating the NID. They check the first draft of the NID 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. The review forms for the OE experts and the emission modeller are attached in Annex 4. Afterwards, the NID authors improve the NID considering the revisions made by the OE experts and prepare the second internal draft, which also undergoes an internal cross-check. This second NID draft again is reviewed by the OE and the emission modeller. Their inputs are implemented within the NID, too. The NID authors complete the final NID version including last internal cross-checks. The Office of Environment (OE) carries out a last check and then submits the official National Inventory Document (NID). This process guarantees the compliance of the QA/QC requirements according to the IPCC guidelines (IPCC 2006).

### A.4.1.3 Switzerland's QC-plan with implications for Liechtenstein

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

## A4.2 Checklists for QC activities

- Checklist for project manager (PM), staff member climate unit (SC), sectoral experts (SE)
- Checklist for national inventory compiler (NIC)
- Checklist for NID authors (NA)

Table A - 3 Checklist for QC activities[4] 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 NID authors, NIC national inventory compiler, PM project manager, DFP designated focal point, SC staff member climate unit, SE sectoral experts. Member codes: ANE Anna Ehrler, BES Bettina Schäppi, BRI Beat Rihm, DAG David Giger FEW Felix Weber, HE Hanspeter Eberle, JB Jürgen Beckbissinger, KJ Karin Jehle, MSM Markus Sommerhalder, RI Regula Imhof.

| **Quality Control System for Climate Reporting Liechtenstein Submission 2025** | | **Respon-sible** | **Date** | **Visa** |
|---|---|---|---|---|
| **Checklist for sectoral experts and NID authors**<br>Contact person: Bettina Schäppi, INFRAS<br>Telephone, e-mail: +41 44 205 95 47, bettina.schaeppi@infras.ch | | | | |
| **QC general activities** ***(table 6.1 IPCC 2006 Guidelines)*** | **Procedure** ***(description of checks that were carried out)*** | **Respon-sible** | **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 | 06.11.2024 | JB, KJ |
| | INFRAS-internal checks, comparison with methods chosen | NA | 09.11.2024 | BES |
| 2. Check for transcription errors in data input and reference | plausibility check of the basic input data for Solvent and Ind calculation | SE | 13.11.2024 | JB |
| | plausibility check of the basic input data from the LWA | SE | 20.11.2024 | JB |
| | check input Data for SF6 Emission calculation | SE | 27.11.2024 | JB |
| | check stationary Energy | NA | 04.12.2024 | BES |
| | check IPPU | NA | 11.12.2024 | BES |
| | check Waste | NA | 11.12.2024 | MSM |
| | Agriculture: Plausibility check of data in background tables Acontec. Issues identified and discussed with Acontec | SE | 12.12.2024 | FEW, JB |
| 3. Check that emissions are calculated correctly | Ongoing checks of the calculated emissions in all sectors | SE | 27.11.2024 | JB |
| | Clarification of data/figures | PM | 18.12.2024 | BES |

[4] In Submission 2024, at the time of the inventory preparation the new CTF reporter software was not yet available. Therefore, the CRF Reporter and CRF Tables were used to prepare the NID (e.g. for QA/QC activities, for the KCA, for preparation of NID data tables).

| Quality Control System for Climate Reporting Liechtenstein Submission 2025 | | Respon-sible | Date | Visa |
|---|---|---|---|---|
| | INFRAS-internal control: Plausibility checks, "Delta-Analysis" combined with KCA, INFRAS-internal control of time series | NA | 29.01.2025 | BES, FEW |
| | INFRAS-internal checks during generation of tables/figure in Chapter. 2 Trends (independent control by second person BES) | SE | 29.01.2025 | ANE |
| 4. Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used | check energy-activity-data (reference approach) | SE | 06.11.2024 | JB |
| | check energy-activity-data (reference approach) | NA | 11.12.2024 | BES |
| | check Energy | SE | 06.11.2024 | JB |
| | check Energy | NA | 14.12.2024 | ANE |
| | check IPPU | SE | 06.11.2024 | JB |
| | check IPPU | NA | 12.12.2024 | ANE |
| | check Agriculture | SE | 06.11.2024 | JB |
| | check Agriculture | NA | 14.12.2024 | FEW |
| | check LULUCF | SE | 07.11.2024 | JB |
| | check LULUCF | NA | 16.01.2025 | BRI |
| | check Waste | SE | 07.11.2024 | JB |
| | check Waste | NA | 05.12.2024 | MSM |
| 5. Check the integrity of database files | integrity checked | SE | 20.11.2024 | JB |
| 6. Check for consistency in data between source categories | check general data consistency | SE | 20.11.2024 | JB |
| | check Energy (stationary) | NA | 11.12.2024 | ANE |
| | check Energy (mobile) | NA | 11.12.2024 | ANE |
| | check IPPU | NA | 12.12.2024 | ANE |
| | check Agriculture | NA | 11.01.2025 | FEW |
| | check LULUCF | NA | 20.12.2024 | BRI |
| | check Waste | NA | 16.01.2025 | MSM |
| 7. Check that the movement of inventory data among processing steps is correct | Processing checked | NIC | 12.12.2024 | KJ |
| | Data transfer from the land-use statistics to the LULUCF tables and clarification of comprehensive questions with JB | SE | 07.11.2024 | KJ |
| | check Agriculture | SE | 13.11.2024 | JB |
| | plausibility check / control of overall emissions from agriculture in CO2 equivalents, in total and for the source categories for all years | SE | 13.11.2024 | JB |
| | check LULUCF | SE | 16.01.2025 | KJ |
| 8. Check that uncertainties in emissions and removals are estimated or calculated correctly | check Energy | NA | 29.01.2025 | FEW |
| | check IPPU | NA | 29.01.2025 | FEW |
| | check Agriculture | NA | 29.01.2025 | FEW |
| | check Waste | NA | 29.01.2025 | MSM, FEW |
| 9. Check time series consistency | check for temporal consistency in time series input data for each category. | NIC | 29.01.2025 | KJ |
| | check in the algorithm/method used for calculations throughout the time series. | NIC | 29.01.2025 | KJ |
| | check methodological and data changes resulting in recalculations. | NA | 12.12.2024 | BES |
| | check that the effects of mitigation activities have been appropriately reflected in time series calculations. | NIC | 29.01.2025 | KJ |
| 10. Check completeness | Completeness check for all sectors | SE | 27.11.2024 | JB |

| **Quality Control System for Climate Reporting Liechtenstein Submission 2025** | | **Respon-sible** | **Date** | **Visa** |
|---|---|---|---|---|
| | Completeness check for all sectors | NA | 26.01.2025 | BES |
| 11. Trend checks | For each category, current inventory estimates should be compared to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain any differences. Significant changes in emissions or removals from previous years may indicate possible input or calculation errors. | NIC/SE/NA | 18.12.2024 | KJ, JB, FEW, BES, ANE, MSM, BRI, DAG |
| | Check value of implied emission factors across time series. | NIC | 22.01.2025 | KJ |
| | Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series. | NIC/SE | 8.12.2024 | KJ, JB, FEW, BES, ANE, MSM, BRI, DAG |
| 12. Review of internal documentation | Internal OE check of documentation; Clarification of open questions with SE | PM | 13.12.2024 | KJ |
| **Further activities** | **Procedure** ***(description of checks that were carried out)*** | **Respon-sibles** | **Date** | **Visa** |
| 13. Compare estimates for key categories to previous estimates | check of KCA previous/latest key categories | SE | 29.01.2025 | DAG, ANE |
| 14. Compare CRT tables with previous year | check Energy | NA | 04.12.2024 | ANE, DAG |
| | check IPPU | NA | 05.12.2024 | ANE |
| | check Agriculture | NA | 15.12.2024 | FEW |
| | check Waste | NA | 18.12.2024 | MSM |
| | check LULUCF | NA | 12.12.2024 | 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 | 7.11.2024 | KJ |
| | check: Energy (stationary) | NA | 05.12.2024 | ANE |
| | check: Solvents | NA | 05.12.2024 | ANE |
| | Clarification of comprehensive questions in different sectors with SE | PM/NA | 11.12.2024 | KJ |
| | Two independent checks of Energy (mobile) | SE | 05.12.2024 | ANE |
| | check waste | NA | 16.01.2025 | MSM |
| | check Agriculture | SE | 15.12.2024 | FEW |
| | check LULUCF | SE | 10.06.2024 | BRI |
| 16. Where LIE uses Swiss-specific EF: Where changes in the Swiss EFoccur, check whether the changes are also adequate for LIE or not | Clarify the changes of emission factors in IPPU and Agriculture | SE | 11.12.2024 | ANE, FEW |
| 17. Check correctness of KCA, comparison with previous results | Plausibility checks of KCA | PM | 05.02.2025 | KJ |
| | cross-check within KCA with/without LULUCF 1990 and reporting year: Emissions correct, thresholds correct. Comparison with KCA of previous Submission. Plausibility checks of KCA | NA | 29.01.2025 | DAG, ANE |
| 18. Check correctness of uncertainty analysis, comparison with previous results | internal plausibility checks for all sectors | NA | 29.01.2025 | FEW |

| Quality Control System for Climate Reporting Liechtenstein Submission 2025 | | Respon-sible | Date | Visa |
|---|---|---|---|---|
| Check of transcription errors CRT --> NID (numbers, tables, figures) | INFRAS internal plausibility checks | NA | 29.01.2025 | BES |
| | check waste | NA | 30.01.2025 | MSM |
| | INFRAS-internal control. Comparison of data in CRT tables and NID. 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 NID and adjusts the text correspondingly. These working steps are afterwards checked by another collaborator of INFRAS. | NA | 29.01.2025 | BES, FEW |
| 20. Check AD in NID and CRT and compare data with reference data sources | check waste | NA | 12.02.2025 | MSM |
| 21. Check for complete and correct references in NID | INFRAS-internal checks | NA | 26.02.2025 | BES |
| 22. Check for correctness, completeness, transparency and quality of NID | Proofread of complete draft NID | NA | 26.02.2025 | BES |
| | final proofread Executive Summary, feedback to KJ | NFP | 01.04.2025 | KJ |
| | final proofread inventory/NID, feedback and discussion with KJ | QM | 03.04.2025 | KJ |
| | final proofread inventory/NID, discussion with BES and JB | PM | 02.04.2025 | BES, KJ |
| | final proofread inventory/NID, feedback to KJ | SE | 04.04.2025 | HE |
| | Internal OE discussions on the inventory/NID draft with RI HE and KJ | PM | 07.04.2025 | KJ |
| | Feedback from OE internal discussions | PM | 07.04.2025 | KJ |
| | Final proofreading inventory/NID | PM | 08.04.2025 | KJ |
| 23. Check for completeness of submission documents | Final check and Submission | PM/NIC NFP | 11.04.2025 | RI, KJ |
| 24. Archiving activities | Archiving: INFRAS, Meteotest, save internally all data individually. NID 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 | 15.04.2025 | BES, BRI |
| | Internal Review of documents submitted in April; all relevant documents archived | NIC | 15.04.2025 | KJ |

## A4.3 Checklists for QA activities (internal review)

Table A - 4 Checklists for QA activity internal review.

**Liechtenstein's National Inventory Document**
**Review form for internal review of NID submission 2024**

| | |
|---|---|
| Reviewer | **Karin Jehle (KJ)** |
| Institution | Office of Environment |
| phone | +423 236 61 96 |
| e-mail | karin.jehle@llv.li |
| Chapter(s) reviewed | all |

| | |
|---|---|
| NID authors | Bettina Schaeppi (BES) |
| Institution | INFRAS |
| phone | +41 44 205 95 47 |
| e-mail | bettina.schaeppi@infras.ch |

| **Reviewer's comments (yellow) and answers of authors (green)** |
|---|
| Consistency checks were made. Checks between CRT data and NID were made.<br>Questions sent as comments. |
| Comments in the text were addressed. |

| | |
|---|---|
| **Reviewers comments performed** | |
| Date / Signum | 02.04.2025 / KJ |

| | |
|---|---|
| **Taken note of review** | |
| Date / Signum | 08.04.2025 / BES |

**If necessary: Additional comments of reviewer (yellow) and author's answers (green)**

| |
|---|
| none |
| |
| |

| | |
|---|---|
| Datum / Signum | 11.04.2025 / KJ |

**Liechtenstein's National Inventory Document**
**Review form for internal review of NID submission 2024**

| | |
|---|---|
| Reviewer | **Regula Imhof (RI)** |
| Institution | Office of Environment |
| phone | +423 236 61 97 |
| e-mail | regula.imhof@llv.li |
| Chapter(s) reviewed | ES, chp. 1 |

| | |
|---|---|
| NID author | Bettina Schäppi |
| Institution | INFRAS |
| phone | +41 44 205 95 47 |
| phone, e-mail | bettina.schaeppi@infras.ch |

| **Reviewer's comments (yellow) and answers of authors (green)** | |
|---|---|
| Double check consistency of CRT tables with data in the inventory report. | |
| Double check performed. | |
| **Reviewers comments performed** | |
| Date / Signum | 04.04.2025 / RI |

| **Taken note of review** | |
|---|---|
| Date / Signum | 08.04.2025 / BES |

**If necessary: Additional comments of reviewer (yellow) and author's answers (green)**

| |
|---|
| none |
| |
| |

| | |
|---|---|
| Datum / Signum | 11.04.2025 / RI |

# Annex 5 Any additional information

## A5.1 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 $CH_4$ and $N_2O$, the country-specific implied emission factors of the Swiss GHG inventory are applied. Here some information concerning the modelling approach is provided:

The emission computation in the road transportation model is based on the following parameters (INFRAS 2017):

- Emission factors: specific emissions in grams per activity data unit.
- Traffic activity data: vehicle kilometres travelled (hot emissions, evaporative losses during operation), number of starts/stops and vehicle stock (cold start, evaporative losses from gasoline passenger cars, light duty vehicles and motorcycles), fuel consumption per vehicle category.

Emission are calculated as follows:

- Hot emissions: $E_{hot} = VKT \cdot EF_{hot}$
- Cold start excess emissions: $E_{start} = N_{start} \cdot EF_{start}$
- Evaporation soak and diurnal VOC emissions: $E_{evap,i} = N_{evap,i} \cdot EF_{evap,i}$
- Evaporation running VOC losses: $E_{evap-RL} = VKT \cdot EF_{Evap-RL}$

with

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

  a) evaporation soak emissions, i.e. emissions after stopping when the engine is still hot; and

  b) evaporation diurnal emissions, i.e. emissions due to daily air temperature differences.

  For a) the corresponding activity is the number of stops, for b) it is the number of vehicles.
- Emission factors are differentiated for all fuel types: Gasoline (4-stroke), gasoline (2-stroke), diesel oil, LPG, bioethanol, biodiesel, gas (CNG), biogas.

Emission factors for gases other than $CO_2$ are derived from “emission functions” which are determined from a compilation of measurements from various European countries with

programmes using similar driving cycles (legislative as well as standardized real-world cycles, like “Common Artemis Driving Cycle” (CADC)), recently also complemented by measurements from RDE tests, as input. The method was developed in 1990–1995 and has been extended and updated in 2000, 2004, 2010, 2017, 2019 and latest in 2022. These emission factors are compiled in the “Handbook of Emission Factors for Road Transport” (HBEFA, see INFRAS 2022a). The latest version 4.2 – which was used for the update of the emissions in the current submission, resulting in a recalculation of the complete time series – is presented on the website (http://www.hbefa.net/) and documented in Notter et al. (2022), INFRAS (2019a) and Matzer et al. (2019).

The emission factors are differentiated by so-called “traffic situations”, which represent characteristic patterns of driving behaviour determined by road type, speed limit, area type (rural/urban), traffic density, and road gradient. They serve as a key to the disaggregation of the activity data. The underlying database contains dynamic fleet compositions simulating the release of new exhaust technologies and the fading out of old technologies.

The export function for model results in the format required for climate reporting accounts for temporally varying fuel properties like $CO_2$ emission factors or heating values.

# A5.2 Agriculture

Emissions of agricultural activities are estimated according to the model in the Swiss National Inventory (FOEN 2024). Detailed data for estimating emission factors are shown in the tables below.

## A.5.2.1 Additional data for estimating $CH_4$ emissions from 3A Enteric fermentation

Table A - 5 Data for estimating enteric fermentation emission factors for cattle (for 2023).

| Type | Age[a] | Weight[a] kg | Weight Gain[a] kg/day | Feeding Situation / Further Specification[a] | Milk[b] kg/day | Work hrs/day | Pregnant[a] % | Digestibility of feed %[d] | $CH_4$ Conversion[d] % | Em. Factor kg/head/year[e] |
|---|---|---|---|---|---|---|---|---|---|---|
| Mature Dairy Cattle | NA | 679 | 0 | | 18.9-24.5 c | 0 | 305 days of lactation | 72 | 6.9 | 140 |
| Other Mature Cattle | NA | 650 | 0 | | 8.2 | 0 | | 62 | 6.5 | 107 |
| 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 | 95 | 0.0 | 0 |
| Pre-Weaned Calves | 0-10 month | 60-325 | 1.0 | "Natura beef" production, milk from mother cow and additional feed. | 0 | 0 | 0 | 65 | 4.0 | 16 |
| Breeding Cattle 1st Year | 0-12 month | 50-300 | 0.8 | Calves: Feeding plan for a dismission with 14 to 15 weeks. Milk, feed concentrate (100kg in total), hay (80 kg in total).<br>Cattle: Premature race (Milk-race) | 0 | 0 | 0 | 68 | var | 30 |
| Breeding Cattle 2nd Year | 12-24 month | 300-NA | 0.8 | Premature race (Milk-race) | 0 | 0 | 0 | 65 | 6.3 | 59 |
| Breeding Cattle 3rd Year | 24-36 month | NA-600 | 0.8 | Premature race (Milk-race) | 0 | 0 | 0 | 65 | 6.3 | 59 |
| Fattening Cattle | 0-12 month | 70-550 | 1.15 | Calves: Diet based on milk or milk-powder and feed concentrate, hay and/or silage<br>Cattle: Feeding recommendations for fattening steers, concentrate based | 0 | 0 | 0 | 68 | var | 43 |

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 2019 and Zeltz 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.

## A.5.2.2 Additional data for estimating CH4 emissions from 3B Manure management

Table A - 6 Data for estimating manure management $CH_4$ emission factors (for 2023).

| Type | Weight kg [a] | Digestibility of Feed | 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 | 679 | 72 | 279 - 319 | 15.89 c | 8.98421479 | 3.86 - 4.42 | 0.24 |
| Other Mature Cattle | 650 | 62 | 250.6 | 10.96 c | 8 | 4.75 | 0.18 |
| Fattening Calves | 60-200 | 95 | 47.1 | 2.02 a | 8 | 0.12 | 0.18 |
| Pre-Weaned Calves | 60-325 | 65 | 60.1 | 2.98 a | 8 | 0.67 | 0.18 |
| Breeding Cattle 1st Year | 50-300 | 68 | 75.4 | 3.75 a | 8 | 1.19 | 0.18 |
| Breeding Cattle 2nd Year | 300-NA | 65 | 143.6 | 7.78 a | 8 | 2.51 | 0.18 |
| Breeding Cattle 3rd Year | NA-600 | 65 | 143.6 | 7.78 a | 8 | 2.51 | 0.18 |
| Fattening Cattle | 70-550 | 68 | 103.7 | 5.64 a | 8 | 1.67 | 0.18 |
| Sheep | NA | 65 | 22.5 | 0.90-1.47 c | 8 | 0.40 b | 0.19 |
| Goats | NA | 65 | 25.4 | 1.08-1.50 c | 8 | 0.30 b | 0.18 |
| Horses | NA | 70 | 108.7 | 7.78-7.93 c | 4 | 1.90 b | 0.33 |
| Mules and Asses | NA | 70 | 39.6 | NA | 4 | 0.94 b | 0.33 |
| Swine | NA | NA | NA | NA | 6 | 0.31 b | 0.45 |
| Poultry | NA | NA | 1.3 | NA | NA | 0.02 b | 0.39 |

a RAP 1999

b IPCC 2006 and IPCC 2019

c Richner and Sinaj 2017

d metabolizable energy (ME)

### A.5.2.3 Additional data for estimating $N_2O$ emissions from 3D Agricultural soils

Table A - 7 Data for estimating $N_2O$ emissions from crop residues.

| 2023 | | Total crop production kg DM | Nitrogen incorporated with crop residues $F_{(CR)}$ t N | $N_2O$ emissions from crop residues t $N_2O$ |
|---|---|---|---|---|
| **1. Cereals** | Wheat | 680'621 | 2.9 | 0.045 |
| | Barley | 142'545 | 0.7 | 0.011 |
| | Maize | 343'910 | 3.2 | 0.051 |
| | Oats | 6'685 | 0.04 | 0.00 |
| | Rye | 21'527 | 0.09085 | 0.0014277 |
| | Other: | | | |
| | Triticale | 52'530 | 0.26 | 0.0040 |
| | Spelt | 40'430 | 0.37 | 0.0058 |
| | Mix of Fodder Cereals | - | - | - |
| | Mix of Bread Cereals | - | - | - |
| | Millet | - | - | - |
| **2. Pulse** | Dry Beans | 28'594 | 1.1 | 0.018 |
| | Peas (Eiweisserbsen) | 11'764 | 0.3 | 0.005 |
| | Soybeans | - | - | - |
| | Leguminous Vegetables | 8'723 | 0.9 | 0.014 |
| | Lupines | - | - | - |
| **3. Tuber and Root** | Potatoes | 678'274 | 2.5 | 0.039 |
| | Other: | | | |
| | Fodder Beet | 15'750 | 0.11 | 0.002 |
| | Sugar Beet | 356'202 | 2.5 | 0.040 |
| **5. Other** | Fruit | 13'396 | 0.13 | 0.0020 |
| | Grass | 27'244'535 | 90 | 1.4 |
| | Green Corn | - | - | - |
| | Non-Leguminous Vegetables | 1'070'412 | 13 | 0.20 |
| | Rape | 48'983 | 0.84 | 0.013 |
| | Renewable Energy Crops | - | - | - |
| | Silage Corn | 6'047'465 | 3.6 | 0.056 |
| | Sunflowers | - | - | - |
| | Tobacco | - | - | - |
| | Vine | 23'800 | 0.42 | 0.0065 |
| | Oil Squash | - | - | - |
| | Oil Hemp | - | - | - |
| | Oil Flax | - | - | - |
| | Hops | - | - | - |
| | Medicinal Plants and Herbs | - | - | - |
| **Total Non-leguminous** | | 9'542'530 | 30.30 | 0.48 |
| **Total Leguminous** | | 49'081 | 2.39 | 0.04 |
| **Total excluding grass** | | 9'591'612 | 32.69 | 0.51 |
| **Total including grass** | | 36'836'146 | 122.81 | 1.93 |

Table A - 8 Data for estimating $N_2O$ emissions from crop residues (fractions).

| 2023 | | Residue/ Crop ratio kg/kg | Dry matter fraction of residue kg/kg | Nitrogen content of residues kg/kg |
|---|---|---|---|---|
| **1. Cereals** | Wheat | 1.1 | 0.85 | 0.0037 |
| | Barley | 1.0 | 0.85 | 0.0051 |
| | Maize | 1.1 | 0.85 | 0.0086 |
| | Oats | 1.3 | 0.85 | 0.0049 |
| | Rye | 1.2 | 0.85 | 0.0036 |
| | Other : | | | |
| | Triticale | 1.3 | 0.85 | 0.0039 |
| | Spelt | 1.6 | 0.85 | 0.0059 |
| | Mix of Fodder Cereals | 1.0 | 0.85 | 0.0051 |
| | Mix of Bread Cereals | 1.1 | 0.85 | 0.0037 |
| | Millet | 1.3 | 0.85 | 0.020 |
| **2. Pulse** | Dry Beans | 1.1 | 0.85 | 0.035 |
| | Peas (Eiweisserbsen) | 1.3 | 0.85 | 0.024 |
| | Soybeans | 1.0 | 0.85 | 0.041 |
| | Leguminous Vegetables | 3.9 | 0.16 | 0.033 |
| | Lupines | 1.0 | 0.85 | 0.041 |
| **3. Tuber and Root** | Potatoes | 0.47 | 0.13 | 0.013 |
| | Other : | | | |
| | Fodder Beet | 0.37 | 0.15 | 0.023 |
| | Sugar Beet | 0.53 | 0.15 | 0.022 |
| **5. Other** | Fruit | NA | 0.17 | 0.0040 |
| | Grass | 0.31 | NA | 0.020 |
| | Green Corn | 0.053 | 0.32 | 0.019 |
| | Non-Leguminous Vegetables | 0.46 | 0.13 | 0.023 |
| | Rape | 2.6 | 0.85 | 0.0071 |
| | Renewable Energy Crops | 2.6 | 0.85 | 0.0071 |
| | Silage Corn | 0.053 | 0.32 | 0.012 |
| | Sunflowers | 2.0 | 0.60 | 0.015 |
| | Tobacco | 1.2 | NA | 0.022 |
| | Vine | NA | 0.20 | 0.0060 |
| | Tobacco | 0.46 | 0.13 | 0.023 |
| | Rape | 4.6 | 0.85 | 0.011 |
| | Oil Squash | 1.3 | 0.85 | 0.0071 |
| | Oil Hemp | NA | 1.0 | NA |
| | Oil Flax | 2.5 | NA | 0.033 |

## A5.3 2F Product uses as ODS substitutes and 2G $N_2O$ from Product use

Emissions of F-gases from source category 2F and $N_2O$ emissions from source category 2G are calculated based on specific emission factors derived from emissions reported in Switzerland's GHG inventory 2024 (FOEN 2024) 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 4-9 and Table 4-10). 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 2005–2007), 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 2024).

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 2024).

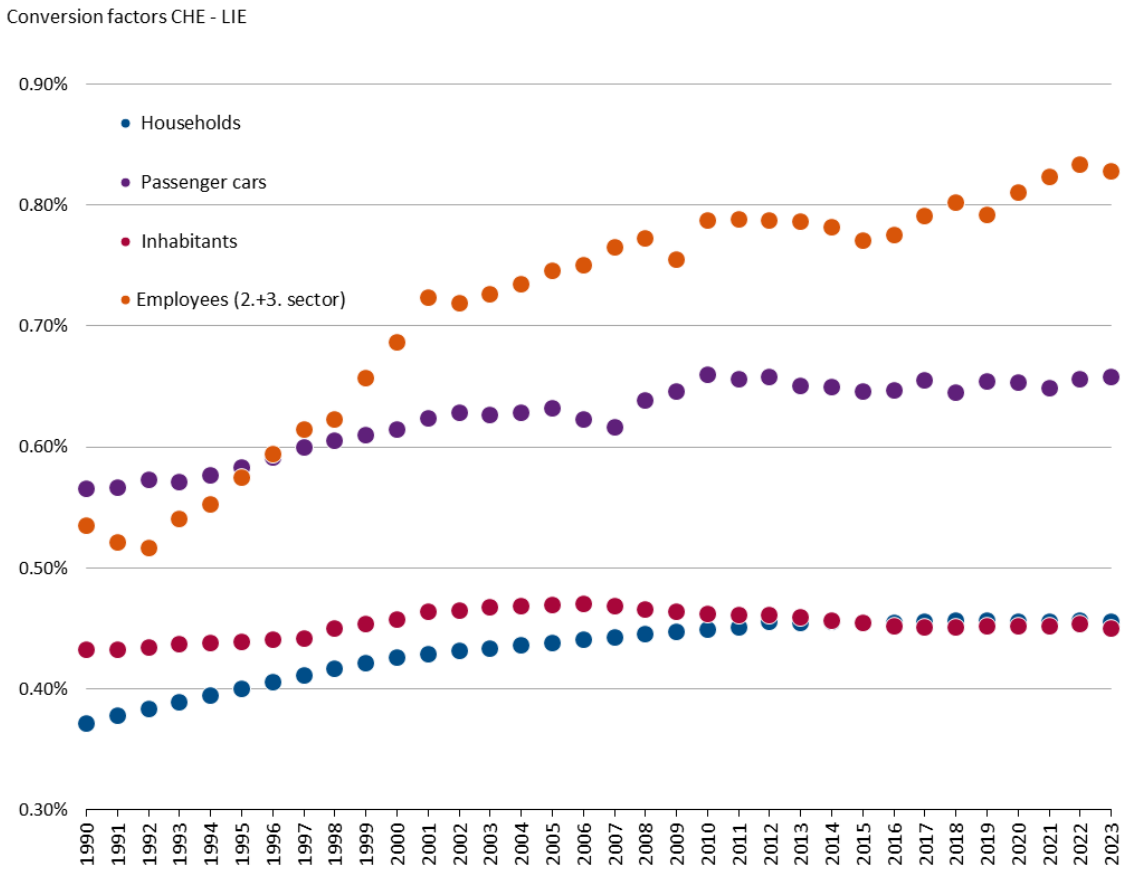



Figure A - 1 Conversion factors used to derive emissions in Liechtenstein from emissions reported in Switzerland's national GHG inventory 2024.

## A5.4 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:

814.201

Liechtensteinisches Landesgesetzblatt

Jahrgang 1997 Nr. 42 ausgegeben am 5. Februar 1997

# Verordnung
vom 17. Dezember 1996
# zum Gewässerschutzgesetz (GSchV)

Aufgrund von Art. 8 Abs. 1 und 2, Art. 16, 24 Abs. 3 und Art. 67 des Gewässerschutzgesetzes (GSchG) vom 15. Mai 2003, LGBl. 2003 Nr. 159[2], verordnet die Regierung:[3]

## V. Klärschlamm[47]

Art. 35a[48]

*Düngeverbot*

Klärschlamm darf nicht als Dünger verwendet werden.

Art. 36

*Klärschlamm-Entsorgungsplan*

1) Die Inhaber von Abwasserreinigungsanlagen erstellen einen Klärschlamm-Entsorgungsplan und passen ihn in den fachlich gebotenen Zeitabständen den neuen Erfordernissen an.[49]

2) Der Klärschlamm-Entsorgungsplan legt mindestens fest:

a) wie der Klärschlamm der Abwasserreinigungsanlagen entsorgt werden soll;

b) welche Massnahmen, einschliesslich der Erstellung und Änderung von Anlagen, die der Entsorgung des Klärschlamms dienen, erforderlich sind und bis zu welchem Zeitpunkt diese umgesetzt werden.[50]

3) Der Klärschlamm-Entsorgungsplan ist dem Amt für Umwelt zur Genehmigung zu übermitteln.[51]

# Annex 6 Common reporting tables

This NID describes reporting tables in CRT format produced by the ETF Reporting Tools ("CRT Reporter") provided by the UNFCCC (version March 2025) for the years 1990–2023.

The CRT reporter still seems to generate errors in the numerical output of some reporting tables or does not allow placing output at the expected locations. A non-exhaustive list of issues and errors identified so far is provided here.

- Table4(II): Due to technical problems with the CRT Reporter, the $N_2O$ emission of 4(II)D wetlands is included in the number of 4(II)A forest land.
- Table4(III): Text of the Documentation box is multiplied.
- Table4.Gs2: Export and Import of sawnwood are exchanged.

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