OFFICE OF THE ENVIRONMENT
PRINCIPALITY OF LIECHTENSTEIN

Liechtenstein's Greenhouse Gas Inventory 1990–2024

National Inventory Document 2026

Submission of April 2026
under the United Nations Framework Convention on Climate Change
and under the Paris Agreement

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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_2eq)	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.

In 2025, Liechtenstein submitted its Second Nationally Determined Contribution (NDC) to the UNFCCC, which aims at a reduction of greenhouse gases by 55% by 2030 and 68% by 2035 compared to 1990 and to reach net zero by 2050 (Government 2025). 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).

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 2023–2025).

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 40'886 inhabitants (2024) 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 2024 amount to 151.0 kt CO_2 equivalent (CO_2eq) excluding LULUCF sources or sinks (including LULUCF: 140.6 kt CO_2eq). This refers to 3.7 t CO_2eq per capita.

Total emissions in 2024 (excl. LULUCF) have declined by 33.9% compared to 1990. Compared to 2023, they decreased by 10.2%. When including LULUCF categories, total emissions decreased by 39.5% between 1990–2024 and by 14.0% between 2023–2024.

Uncertainties

Uncertainty analyses with Approach 1 and Approach 2 are carried out and presented in chp. 1.6.3. The results of the Approach 2 analysis with Monte Carlo simulations shows the following uncertainties:

- The total uncertainty level of Liechtenstein's 2024 national total GHG emissions excluding LULUCF is 4.83% with a nearly symmetric 95% confidence interval between -4.84% to 4.83% (see Table 1-13).
- The trend in national total emissions excluding LULUCF between 1990 and 2024 is -33.91%. With a probability of 95% the trend lies within the range of -41.44% to -26.44%, which corresponds to a mean trend uncertainty of 7.50% (see Table 1-13).
- Incuding LULUCF, level uncertainty is 6.06% and trend uncertainty is 7.85%. Both uncertainties are higher than the analysis without LULUCF (see Table 1-13).

Recalculations

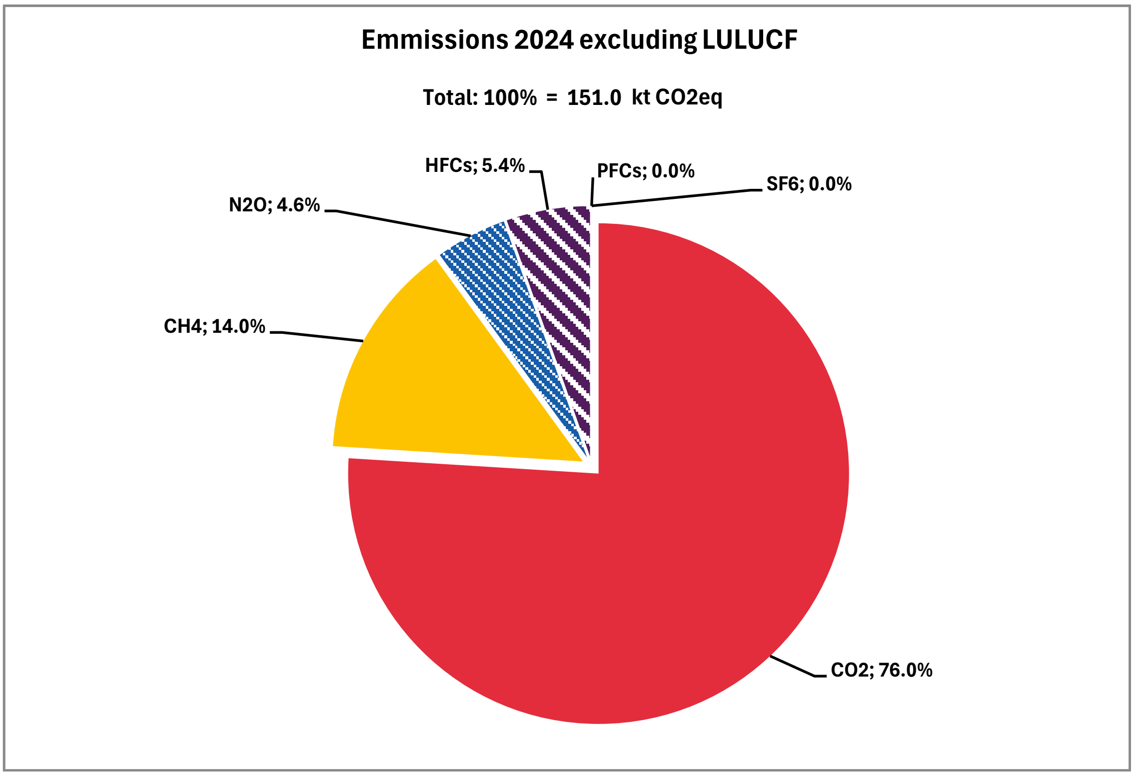
Some emissions have been recalculated due to updates in respective sectors. In this submission, only minor recalculations were implemented. The difference between the total emissions (in CO_2 equivalent) for the latest and the previous submission equals 2.2% when including LULUCF and 0.4% when excluding LULUCF (see Table 10-1).

There are minor recalculations in the LULUCF sector in the whole period 1990–2023 arising mainly from the new geo-referenced approach. The new approach leads to more fluctuating development of land-use changes and related carbon stock changes (see chp. 6.3.1.5). In source category 2F Product uses as ODS substitutes, recalculations regarding HFC and PFC lead to slightly increased emissions. In addition, small recalculations were carried out in the waste sector (activity data for backyard composting in source category 5B Biological treatment of waste).

The results are discussed in chp. 10. For the base year 1990, the recalculations carried out in submission 2026 lead to an increase of 0.01% in the national total emissions (excluding LULUCF categories).

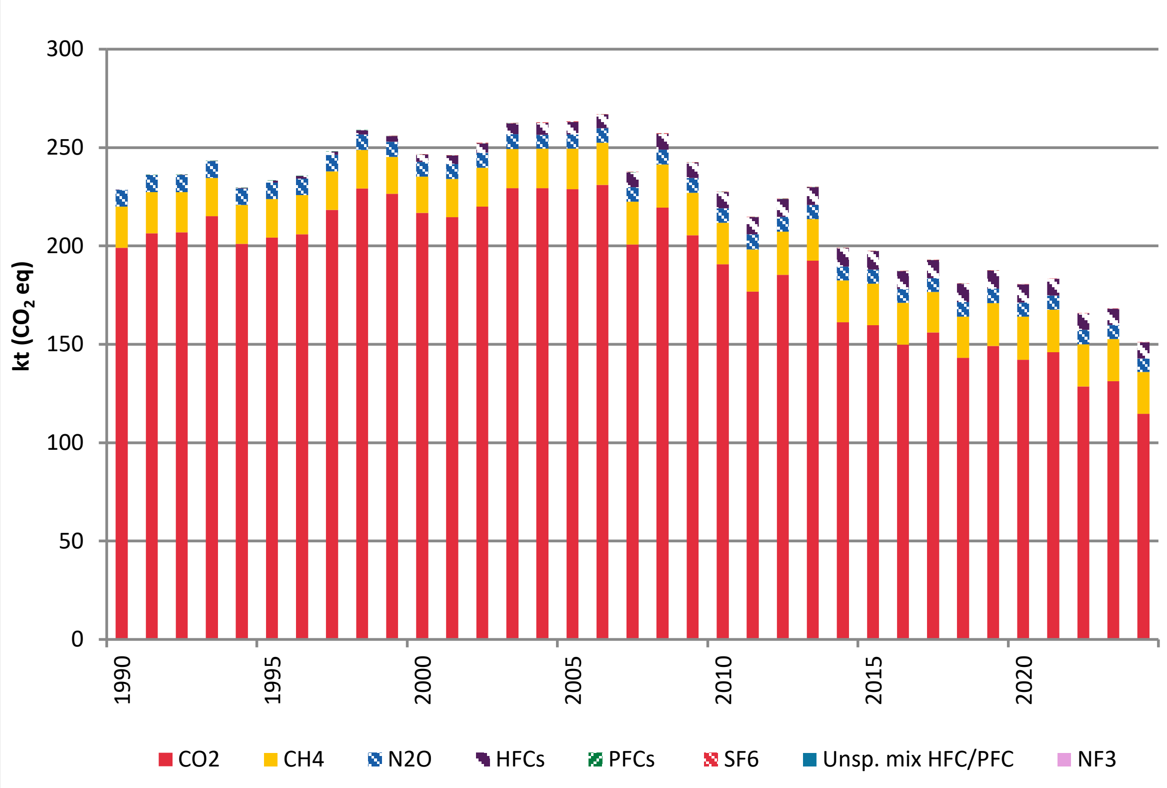
ES.3. Overview of source and sink category emission estimates and trends

ES Figure 1 shows the emissions in 2024 by GHG. The main GHG is CO_2 with a share of 76%. CH_4 and N_2O contribute with 14% and 4.6%, F-gases with about 5.4%, 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 2024, emissions have decreased compared to the previous reporting year 2023 (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 76.0% in 2024 (excl. LULUCF).
- The share of CH_4 increased from 9.2% in 1990 to 14% in 2024 (excl. LULUCF).
- The share of N_2O increased from 3.7% (1990) to 4.6% (2024).
- The share of the sum of all F-gases (within total emissions excl. LULUCF) increased from 0.00004% (1990) to 5.4% (2024).

ES Table 2 represents the GHG emissions and removals by categories. Sector 1 Energy is the largest source of national emissions, contributing to 77.5% of the emissions (excluding LULUCF) in 2024. Emissions caused within the energy sector decreased by 41.9% over the period 1990–2024. The emissions from sector 2 Industrial processes and product use increased by a factor of about 13.9 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 2024 are 4.5% below the level of 1990. Emissions and removals in the sector 4 LULUCF form a net sink in 2024. The emissions from sector 5 Waste have increased by 4.7% 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_2eq (kt) by gas. The last column shows the percentage change in emissions in 2024 as compared to the base year 1990. HFC emissions have increased by about a factor of 85'000 in 2024 compared to 1990.

Greenhouse Gas Emissions	**1990**	**1995**	**2000**	**2005**	**2010**
	CO_2 equivalent (kt)				
CO_2 emissions incl. net CO_2 from LULUCF	202.8	206.3	238.5	236.4	208.0
CO_2 emissions excl. net CO_2 from LULUCF	199.0	204.2	216.8	228.9	190.7
CH_4 emissions incl. CH_4 from LULUCF	21.0	19.6	18.3	20.6	21.1
CH_4 emissions excl. CH_4 from LULUCF	21.0	19.6	18.3	20.6	21.1
N_2O emissions incl. N_2O from LULUCF	8.7	8.6	8.0	7.6	7.7
N_2O emissions excl. N_2O from LULUCF	8.5	8.4	7.7	7.2	7.3
HFCs	0.0	1.1	3.5	6.3	8.3
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)	232.5	235.6	268.5	271.2	245.2
Total (excluding LULUCF)	228.5	233.3	246.4	263.3	227.5

Greenhouse Gas Emissions	**2015**	**2016**	**2017**	**2018**	**2019**
	CO_2 equivalent (kt)				
CO_2 emissions incl. net CO_2 from LULUCF	157.2	151.8	157.5	151.5	149.4
CO_2 emissions excl. net CO_2 from LULUCF	159.8	149.9	155.9	143.2	149.2
CH_4 emissions incl. CH_4 from LULUCF	21.0	21.1	20.6	20.9	21.8
CH_4 emissions excl. CH_4 from LULUCF	21.0	21.1	20.6	20.9	21.8
N_2O emissions incl. N_2O from LULUCF	7.6	7.6	7.5	7.7	7.8
N_2O emissions excl. N_2O from LULUCF	7.2	7.1	7.1	7.2	7.3
HFCs	9.4	9.1	9.3	9.4	9.2
PFCs	0.0	0.0	0.0	0.0	0.0
SF_6	0.0	0.0	0.0	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)	**195.3**	**189.5**	**194.9**	**189.6**	**188.2**
Total (excluding LULUCF)	**197.5**	**187.2**	**192.9**	**180.8**	**187.5**

Greenhouse Gas Emissions	**2020**	**2021**	**2022**	**2023**	**2024**	**1990-2024**
	CO_2 equivalent (kt)					**%**
CO_2 emissions incl. net CO_2 from LULUCF	134.8	135.0	119.1	126.4	104.0	-48.7%
CO_2 emissions excl. net CO_2 from LULUCF	142.1	145.9	128.6	131.3	114.7	-42.4%
CH_4 emissions incl. CH_4 from LULUCF	21.9	21.6	21.4	21.5	21.2	0.6%
CH_4 emissions excl. CH_4 from LULUCF	21.9	21.6	21.4	21.5	21.2	0.6%
N_2O emissions incl. N_2O from LULUCF	7.6	7.6	7.7	7.5	7.4	-15.7%
N_2O emissions excl. N_2O from LULUCF	7.2	7.2	7.3	7.1	7.0	-17.7%
HFCs	9.3	8.6	8.5	8.2	8.1	see caption
PFCs	0.0	0.0	0.0	0.0	0.0	-
SF_6	0.1	0.1	0.1	0.0	0.0	-
Unspecified mix of HFCs and PFCs	NA,NO	NA,NO	NA,NO	NA,NO	NO	-
NF_3	NA,NO	NA,NO	NA,NO	NA,NO	NO	-
Total (including LULUCF)	**173.6**	**172.9**	**156.8**	**163.6**	**140.6**	**-39.5%**
Total (excluding LULUCF)	**180.5**	**183.4**	**165.8**	**168.1**	**151.0**	**-33.9%**

ES Table 2 Summary of Liechtenstein's GHG emissions by source and sink categories in CO_2eq(kt). The last column indicates the percent change in emissions in 2024 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**	**229.6**
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***	***255.8***
4. LULUCF	**4.1**	**-12.9**	**-1.3**	**-3.8**	**15.7**	**2.3**	**-7.7**	**10.9**	**0.6**	**-0.8**
Total (including LULUCF)	***232.5***	***223.1***	***234.8***	***239.4***	***245.2***	***235.6***	***227.8***	***258.8***	***259.5***	***255.0***

Source and Sink Categories	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
1. Energy	**220.0**	**217.7**	**223.0**	**232.3**	**231.9**	**231.5**	**233.7**	**203.3**	**222.2**	**208.0**
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	27.6
1.A.3. Transport	91.5	88.0	84.0	83.8	82.2	81.7	79.1	83.3	87.7	81.8
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**	**6.1**	**6.8**	**7.1**	**7.4**	**8.2**	**8.7**	**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**	**1.8**	**1.7**
Total (excluding LULUCF)	***246.4***	***246.1***	***252.4***	***262.5***	***262.8***	***263.3***	***266.9***	***237.6***	***257.3***	***242.5***
4. LULUCF	**22.0**	**4.3**	**3.1**	**4.6**	**4.7**	**7.9**	**10.6**	**22.2**	**21.8**	**18.6**
Total (including LULUCF)	***268.5***	***250.3***	***255.5***	***267.1***	***267.5***	***271.2***	***277.5***	***259.9***	***279.1***	***261.1***

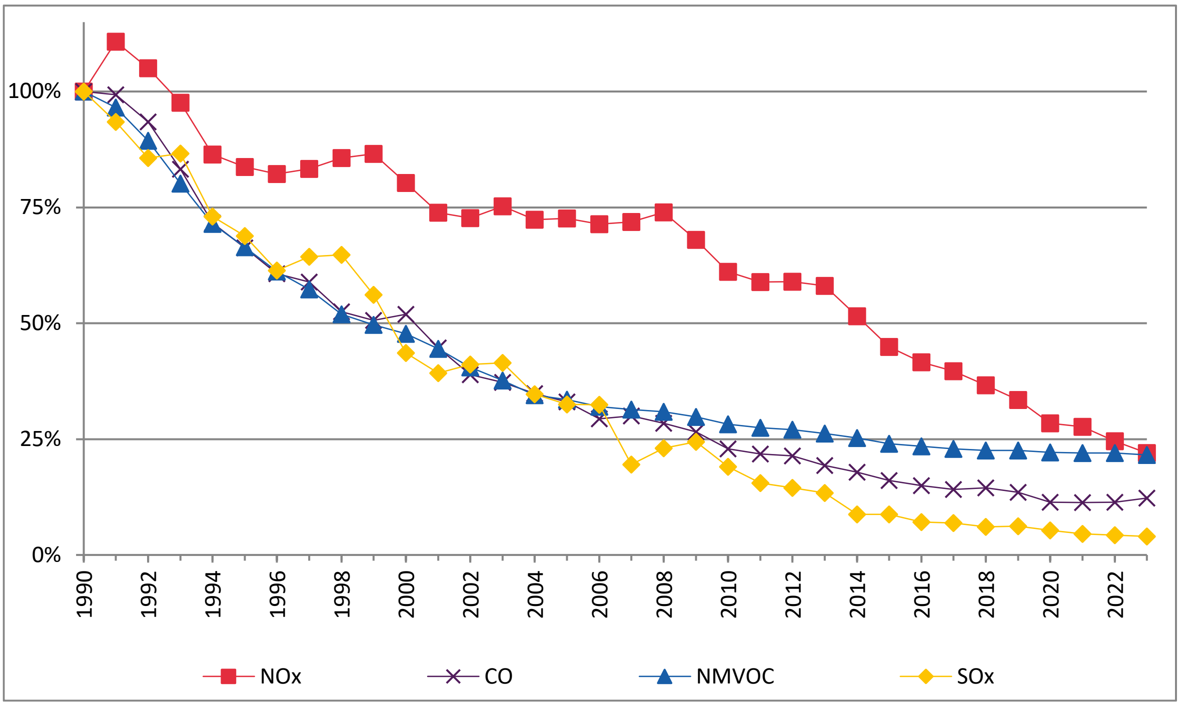
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	CO_2 equivalent (kt)									
1. Energy	**193.4**	**179.4**	**188.0**	**195.2**	**163.7**	**162.2**	**152.3**	**158.4**	**145.7**	**151.8**
1.A.1. Energy Industries	3.3	3.1	2.8	3.0	2.5	2.0	2.2	2.1	2.2	3.4
1.A.2. Manufacturing ind. & construction	26.1	23.6	25.7	26.4	27.3	27.6	26.0	27.8	24.7	24.2
1.A.3. Transport	77.6	76.8	79.8	79.6	73.7	61.8	60.4	60.8	58.8	57.3
1.A.4. Other Sectors	85.2	74.7	78.3	84.9	58.9	69.5	62.5	66.4	58.7	65.5
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	**8.7**	**9.1**	**9.4**	**9.6**	**9.7**	**9.8**	**9.3**	**9.6**	**9.7**	**9.4**
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**	**1.8**	**1.8**	**1.8**	**1.7**	**1.7**	**1.7**	**1.7**	**1.6**	**1.7**
Total (excluding LULUCF)	***227.5***	***214.7***	***223.9***	***230.1***	***199.0***	***197.5***	***187.2***	***192.9***	***180.8***	***187.5***
4. LULUCF	**17.7**	**10.5**	**8.0**	**0.6**	**2.1**	**-2.1**	**2.4**	**2.0**	**8.8**	**0.7**
Total (including LULUCF)	***245.2***	***225.2***	***231.9***	***230.7***	***201.2***	***195.3***	***189.5***	***194.9***	***189.6***	***188.2***

Source and Sink Categories	2020	2021	2022	2023	2024	1990-2024
	CO_2eq (kt)					%
1. Energy	**144.6**	**148.4**	**131.1**	**133.6**	**117.0**	**-41.9%**
1.A.1. Energy Industries	2.4	2.6	2.3	2.9	2.3	1229%
1.A.2. Manufacturing ind. & construction	23.0	23.3	21.3	19.9	18.5	-49.1%
1.A.3. Transport	52.7	56.0	50.2	54.0	43.0	-44.1%
1.A.4. Other Sectors	65.1	65.2	55.8	55.6	52.1	-40.5%
1.A.5. Other	NO	NO	NO	NO	NO	-
1.B. Fugitive emissions from fuels	1.3	1.4	1.4	1.3	1.3	211.6%
2. IPPU	**9.5**	**8.9**	**8.8**	**8.5**	**8.4**	**1293%**
3. Agriculture	**24.7**	**24.3**	**24.2**	**24.2**	**23.7**	**-4.5%**
5. Waste	**1.7**	**1.7**	**1.8**	**1.8**	**1.8**	**4.7%**
Total (excluding LULUCF)	***180.5***	***183.4***	***165.8***	***168.1***	***151.0***	***-33.9%***
4. LULUCF	**-6.9**	**-10.5**	**-9.1**	**-4.5**	**-10.3**	**-354.8%**
Total (including LULUCF)	***173.6***	***172.9***	***156.8***	***163.6***	***140.6***	***-39.5%***

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 2026 has not occurred yet, which is why **the overview and results provided below are from the submission to CLRTAP in 2025**. (Therefore, results for 2024 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 2026). 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 2025 (OE 2025f).

ES.5. Key Category Analysis

For 2024, among a total of 201 categories (excluding LULUCF categories), thirteen have been identified as Approach 1 key categories by the CRT Reporter Software (CRT Table7) with an aggregated contribution of 97.4% of the national total emissions. Within those thirteen key categories, seven stem from the energy sector, contributing 76.6% to total CO_2 equivalent emissions in 2024. The other key categories are from the sectors Agriculture (five categories, contribution 15.7%) and Industrial Processes and Product Use IPPU (one category, contribution 5.1%).

The three major sources, all from the energy sector, sum up to a contribution of 62.1% 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 category from the sector Agriculture is not key when performing the KCA for the full inventory (including LULUCF categories).

ES.6. Improvements introduced

In the current greenhouse gas inventory of Liechtenstein 1990–2024 (NID and CRT reporting tables), a major improvement was implemented in the LULUCF sector, as a geo-referenced approach was implemented for calculating LULUCF associated carbon stock changes based on the hectare raster of the AREA survey. The improvements in sector LULUCF 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 2026.

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 40'886 inhabitants (2024) 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 the last decade, 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. Recent publications, such as the new "Climate Scenarios for Switzerland" CH2025, provide a more detailed picture of the impact of global warming.

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 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).

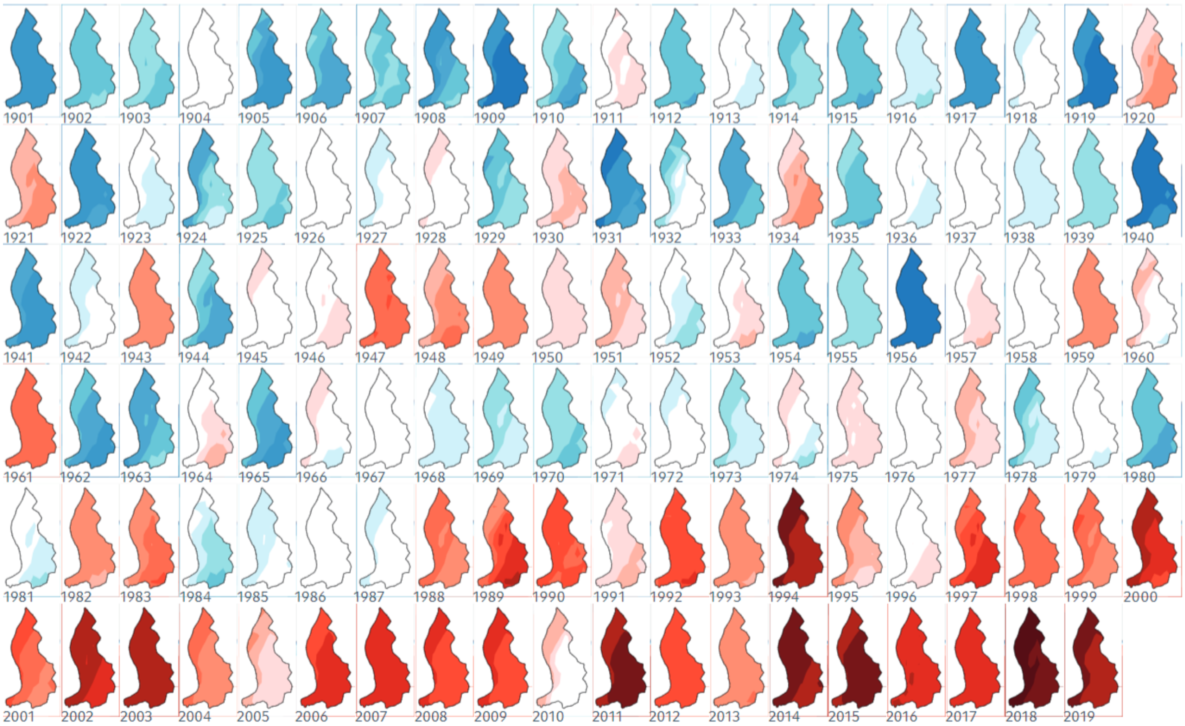


Figure 1-2 Deviation from mean annual temperature (mean of 1961–1990) in the principality of Liechtenstein between 1901 and 2019. Positive deviations are marked in red (max. +2.5°C), negative deviations in blue (min -2.5°C). Data: OE (2020h).

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.

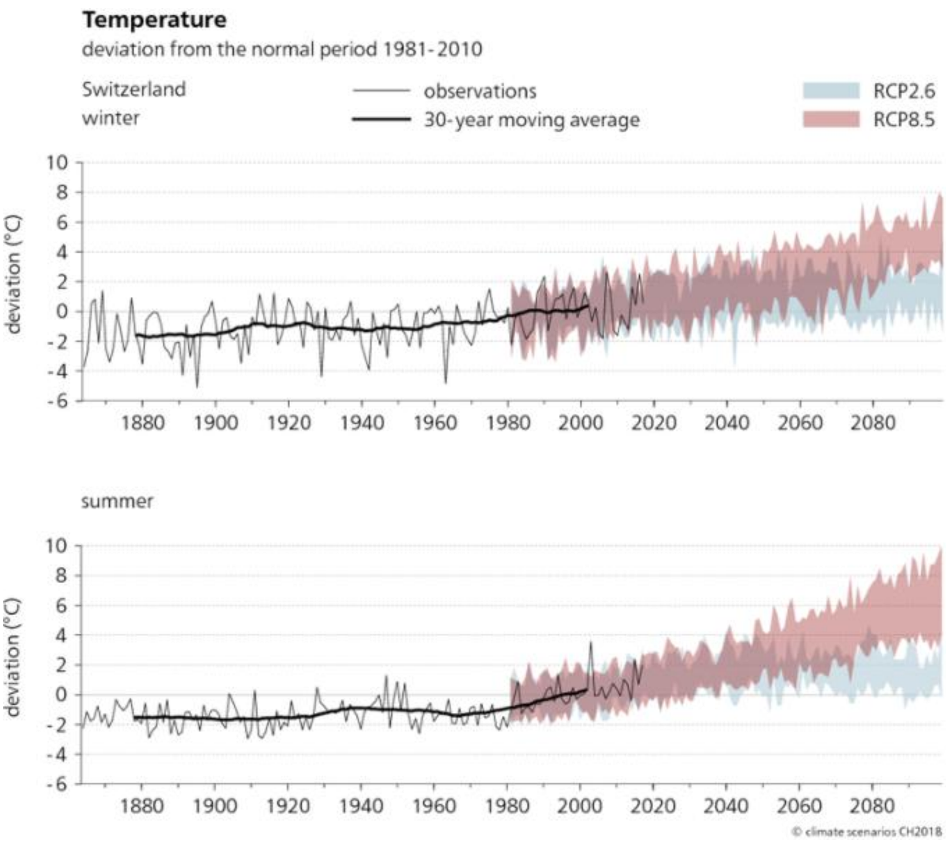


Figure 1-3 Past and expected future changes in seasonal temperature (°C) over north-eastern Switzerland for the scenario RCP2.6 (with mitigation measures) and RCP8.5 (without mitigation measures). The changes are depicted relative to the reference period 1981–2010 (from NCCS 2018).

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).

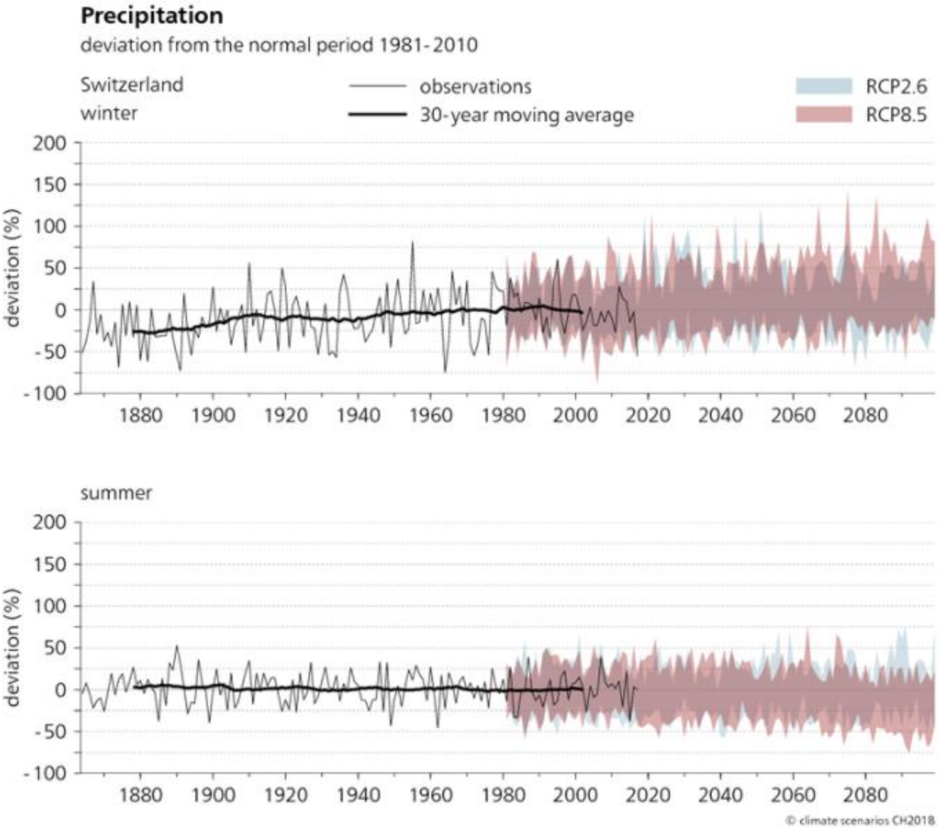


Figure 1-4 Past and expected future changes in seasonal precipitation (%) over north-eastern Switzerland for the scenario RCP2.6 (with mitigation measures) and RCP8.5 (without mitigation measures). The changes are depicted relative to the reference period 1981–2010 (from NCCS 2018).

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.

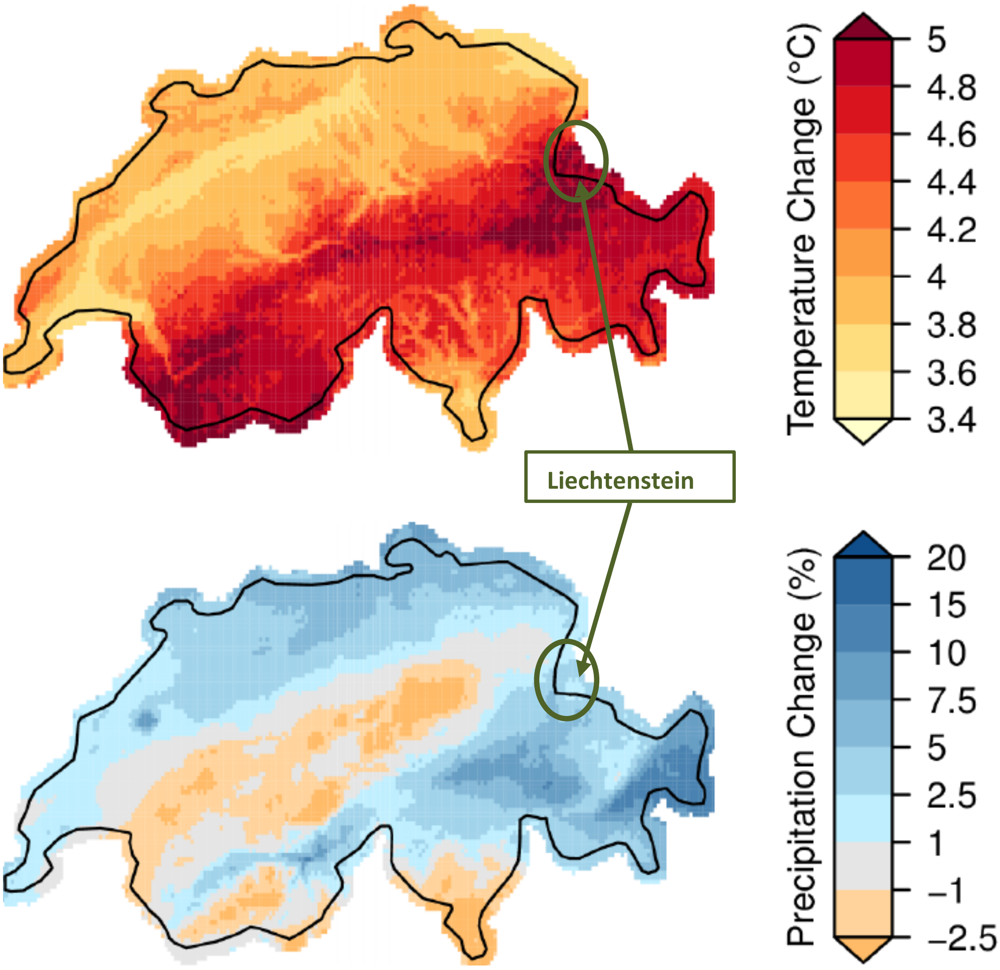


Figure 1-5 Ensemble median changes in annual mean temperature (upper map) and annual mean precipitation (lower map) for the "unabated emissions scenario" period 2085 in the high-resolution grid of 2 km for Switzerland and Liechtenstein (NCCS 2018).

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 revised 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, has last been revised in 2024 and has been adopted in January 2025. The revision of the CO_2Ordinance linked to the revised Act has been completed in spring 2025. The Action Plan on Biodiversity 2030+ was published in 2024 (Government 2024a).

Liechtenstein’s climate policy goal is to achieve its “Nationally Determined Contribution” (NDC) under the Paris Agreement. In 2025, Liechtenstein submitted its Second Nationally Determined Contribution (NDC) to the UNFCCC, which aims at a reduction of greenhouse gases by 55% by 2030 and 68% by 2035 compared to 1990 and to reach net zero by 2050 (Government 2025). 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 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.

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 to be published in 2026.

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. In addition, heat maps have been made available in 2025, aiming at supporting spatial planning in increasing shading and ventilation in densely populated areas.

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.

At the beginning of 2025, Liechtenstein submitted its first Biennial Transparency Report (BTR 1) (OE 2025g), which is going to be reviewed in spring 2026.

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, 2024 and 2025, Liechtenstein submitted the Greenhouse Gas Inventory and National Inventory Document under the UNFCCC (OE 2023–2025).

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.

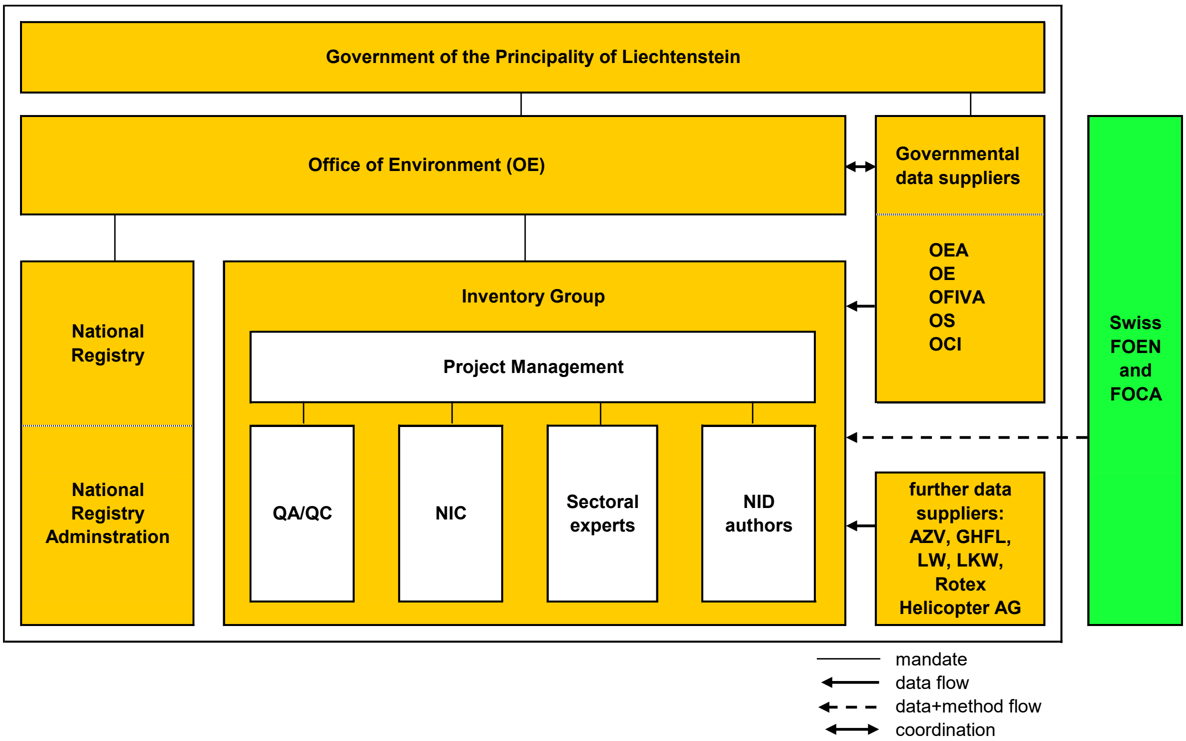


Figure 1-6 National Inventory System: Institutional setting and data suppliers. OE: Office of Environment; OEA: Office of Economic Affairs; OFIVA: Office of Food Inspections and Veterinary Affairs; OS: Office of Statistics: OCI: Office of Construction and Infrastructure; AZV: Liechtenstein's wastewater 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 (CRT) 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 2026 in spring 2026.

The NID 2026 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 2025) also includes the fossil fuel consumption of the Principality of Liechtenstein, except for gas consumption of Liechtenstein, which is excluded from SFOE (2025). 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.

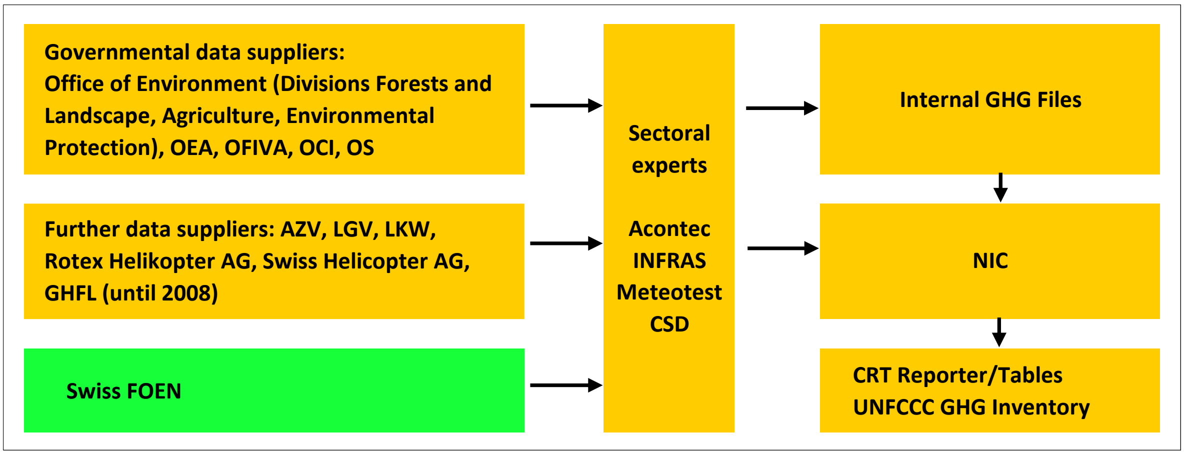


Figure 1-7 Data suppliers and data collection for setting up the UNFCCC GHG Inventory (see Glossary for abbreviations).

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 2026 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 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(II) and 4(III). 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 2025).

1.3.2 Specific assumptions for the year 2024

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 2024 were available as projections in the EMIS (Swiss Emission Information System) database of the Swiss Federal Office for the Environment dated from April 2025 corresponding to the emission data which Switzerland submitted in April 2025 in its NID to the UNFCCC (FOEN 2025). This data for the year 2024 is used, for example, in category 2F.

Table 1-2 Notation keys for applied methods and emission factors 2024 (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 (CO2, CH4, and N2O)	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 (summaries) do not always display the correct notation keys for the applied methods and emission factors, which is the reason why the information above has been adapted manually where necessary and may 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 2024 level and trend assessment without LULUCF categories
- Reporting year 2024 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 2024, among a total of 201 categories (excluding LULUCF categories), thirteen have been identified as Approach 1 key categories by the CRT Reporter Software (CRT Table7) with an aggregated contribution of 97.4% of the national total emissions (see Table 1-3).

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

Within those thirteen key categories, seven stem from the energy sector, contributing 76.6% to total CO_2 equivalent emissions in 2024. The other key categories are from the sectors Agriculture (five categories, contribution 15.7%) and Industrial Processes and Product Use IPPU (one category, contribution 5.1%).

The three major sources, all from the energy sector, sum up to a contribution of 62.1% 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 2023), the following change has occurred in the KCA for the reporting year 2024 of the current submission:

- 3B Manure Management N_2O is a new key category according to trend assessment
- 3D1 Direct N_2O Emissions From Managed Soils is still a key category according to level assessment and, newly, also according to trend assessment.
- 3D2 Indirect N_2O Emissions From Managed Soils is a new key category according to level assessment.

Table 1-3 List of Liechtenstein's Approach 1 key categories 2024 excluding LULUCF. Sorted by share of total emissions.

Key Category Analysis 2024 (excluding LULUCF) IPCC Source Categories (and fuels, if applicable)	GHG	Emissions 2024 [kt CO2eq]	Share of Total Emissions	Cumulative Total	Result of Assessment
1.A.3.b Road Transportation	CO2	42.47	28.1%	28.1%	KC Level, KC Trend
1.A.4 Other Sectors - Gaseous Fuels	CO2	28.19	18.7%	46.8%	KC Level, KC Trend
1.A.4 Other Sectors - Liquid Fuels	CO2	23.15	15.3%	62.1%	KC Level, KC Trend
3.A Enteric Fermentation	CH4	15.61	10.3%	72.5%	KC Level, KC Trend
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	9.96	6.6%	79.1%	KC Level, KC Trend
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	8.43	5.6%	84.7%	KC Level, KC Trend
2.F.1 Refrigeration and Air conditioning	F-gases	7.70	5.1%	89.8%	KC Level, KC Trend
3.B Manure Management	CH4	2.67	1.8%	91.5%	KC Level, KC Trend
3.D.1 Direct N2O Emissions From Managed Soils	N2O	2.64	1.7%	93.3%	KC Level, KC Trend
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO2	2.20	1.5%	94.7%	KC Level, KC Trend
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	1.40	0.9%	95.7%	KC Level
3.B Manure Management	N2O	1.38	0.9%	96.6%	KC Trend
1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	1.27	0.8%	97.4%	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.

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) IPCC Source Categories (and fuels, if applicable)	GHG	Emissions 1990 [kt CO_2eq]	Share of Total Emissions	Cumulative Total	Result of Assessment
1.A.4 Other Sectors - Liquid Fuels	CO2	76.71	33.6%	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 chps 3–7, the corresponding key categories excluding LULUCF are documented for each source.

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 2024 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 28.2% 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
- 4D1c Other Wetlands Remaining Other Wetlands
- 4E1 Settlements Remaining Settlements
- 4E2 Land Converted to Settlements
- 4G Harvested Wood Products

Furthermore, one category from the agriculture sector is not key when performing the KCA for the full inventory (including LULUCF categories):

- 3D2 Indirect N_2O Emissions From Managed Soils

Compared to newest inventory year of the previous submission (reporting year 2023), the following changes have occurred in the KCA for the reporting year 2024 of the current submission:

- 3D1 Direct N_2O Emissions From Managed Soils is still a key category according to level assessment and, newly, also according to trend assessment.
- 4B1 Cropland Remaining Cropland, CO_2 is still a key category according to level assessment but no longer according to trend assessment.
- 4C1 Grassland Remaining Grassland, CO_2 is still a key category according to level assessment and, newly, also according to trend assessment.
- 4E1 Settlements Remaining Settlements, CO_2 is still a key category according to level assessment and, newly, also according to level assessment.

In the KCA 1990 including LULUCF categories, five key categories contributing 6.7% 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
- 4C1 Grassland Remaining Grassland, CO_2
- 4D1c Other Wetlands Remaining Other Wetlands, CO_2
- 4G Harvested Wood Products, CO_2

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

- 3B Manure management, CH_4

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:

- 3D2 Indirect N_2O Emissions from Managed Soils is no longer a key category
- 4C1 Grassland Remaining Grassland, CO_2 is a key category

Table 1-5 List of Liechtenstein's Approach 1 key categories 2024 including LULUCF. Sorted by share of total emissions.

Key Category Analysis 2024 (including LULUCF) **IPCC Source Categories (and fuels, if applicable)**	GHG	Emissions 2024 abs. values [kt CO_2eq]	Share of Total Emissions	Cumulative Total	Result of Assessment
1.A.3.b Road Transportation	CO2	42.47	22.2%	22.2%	KC Level, KC Trend
1.A.4 Other Sectors - Gaseous Fuels	CO2	28.19	14.7%	36.9%	KC Level, KC Trend
1.A.4 Other Sectors - Liquid Fuels	CO2	23.15	12.1%	49.0%	KC Level, KC Trend
4.A.1 Forest Land Remaining Forest Land	CO2	15.74	8.2%	57.2%	KC Level, KC Trend
3.A Enteric Fermentation	CH4	15.61	8.1%	65.3%	KC Level, KC Trend
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	9.96	5.2%	70.5%	KC Level, KC Trend
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	8.43	4.4%	74.9%	KC Level, KC Trend
2.F.1 Refrigeration and Air conditioning	F-gases	7.70	4.0%	78.9%	KC Level, KC Trend
4.A.2 Land Converted to Forest Land	CO2	7.63	4.0%	82.9%	KC Level, KC Trend
4.B.1 Cropland Remaining Cropland	CO2	3.18	1.7%	84.6%	KC Level
3.B Manure Management	CH4	2.67	1.4%	86.0%	KC Level, KC Trend
4.C.2 Land Converted to Grassland	CO2	2.65	1.4%	87.4%	KC Level, KC Trend
3.D.1 Direct N2O Emissions From Managed Soils	N2O	2.64	1.4%	88.7%	KC Level, KC Trend
4.E.2 Land Converted to Settlements	CO2	2.32	1.2%	89.9%	KC Level, KC Trend
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO2	2.20	1.1%	91.1%	KC Level, KC Trend
4.E.1 Settlements Remaining Settlements	CO2	2.20	1.1%	92.2%	KC Level, KC Trend
4.G Harvested Wood Products	CO2	2.14	1.1%	93.4%	KC Level, KC Trend
4.D.1.c Other Wetlands Remaining Other Wetlands	CO2	1.96	1.0%	94.4%	KC Level, KC Trend
4.C.1 Grassland Remaining Grassland	CO2	1.91	1.0%	95.4%	KC Level, KC Trend
3.B Manure Management	N2O	1.38	0.7%	96.1%	KC Trend
1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	1.27	0.7%	96.8%	KC Trend

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

Key Category Analysis 1990 (including LULUCF) **IPCC Source Categories (and fuels, if applicable)**	GHG	Emissions 1990 abs. values [kt CO_2eq]	Share of Total Emissions	Cumulative Total	Result of Assessment
1.A.4 Other Sectors - Liquid Fuels	CO2	76.71	31.1%	31.1%	KC Level
1.A.3.b Road Transportation	CO2	75.29	30.5%	61.5%	KC Level
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	20.99	8.5%	70.0%	KC Level
3.A Enteric Fermentation	CH4	15.42	6.2%	76.3%	KC Level
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	15.20	6.2%	82.4%	KC Level
1.A.4 Other Sectors - Gaseous Fuels	CO2	10.21	4.1%	86.6%	KC Level
4.A.2 Land Converted to Forest Land	CO2	4.28	1.7%	88.3%	KC Level
4.B.1 Cropland Remaining Cropland	CO2	4.22	1.7%	90.0%	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%	92.5%	KC Level
4.G Harvested Wood Products	CO2	2.69	1.1%	93.6%	KC Level
4.C.1 Grassland Remaining Grassland	CO2	2.07	0.8%	94.5%	KC Level
4.D.1.c Other Wetlands Remaining Other Wetlands	CO2	1.98	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**
ARR 2022 ID#E.7	1.A.3.b Road transportation – biodiesel – CO_2 Estimate and report CO_2 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	Implemented in submission 2026	The emissions from the fossil part of the biofuels are accounted for in submission 2026 (in source category 1.A.3.b. Road transportation – liquid fuels – CO_2).	1 Energy

Reference	Identified Issues, e.g. recommendations or planned improvements	Status	Comment/Reason NID	Sector
	with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.			

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 2025). 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 2025c).

1.6 General uncertainty assessment

1.6.1 Approaches

This chapter presents the main results of the uncertainty evaluation Approach 1 and Approach 2 in accordance with the 2006 IPCC Guidelines (IPCC 2006/chp. 3 Uncertainties). Concerning key assumptions and requirements for both approaches we refer to the guidelines, here we only recap the clues of both approaches:

Approach 1: based on propagation of error, uncertainty in the emission level in 2024 and in the trend between the reporting year (2024) 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.

- Approach 2: is based on Monte Carlo analysis (IPCC 2006, UNFCCC 2014a). Uncertainty is evaluated with level (2024) and trend (1990–2024) analyses. This approach provides a detailed category-by-category assessment of uncertainty, particularly where uncertainties are large, distribution is non-normal, the algorithms are complex functions and/or there are correlations between some of the activity data, emission factors or both. The principle of Monte Carlo analysis is to select random values for emission factor and activity data from within their individual probability distributions, and to calculate the corresponding emission values. This procedure is repeated until an adequately stable result has been found. The results of all iterations yield the overall emission probability distribution.

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 A.2.1.1 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 2025) 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 medium high	2% 10% 40%
CH_4	low medium high	15% 30% 60%
N_2O	low medium high	40% 80% 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_2eq emissions **excluding LULUCF:**
The Approach 1 level uncertainty for the year 2024 is estimated to be 4.93%, trend uncertainty (1990–2024) is 5.70% (see Table 1-8). The level uncertainty for the year 1990 amounts 6.95% (see Table 1-9).

Uncertainty of national total CO_2eq emissions **including LULUCF**:
The Approach 1 level uncertainty for the year 2024 is estimated to be 7.37%, trend uncertainty (1990–2024) is 7.20% (see Table 1-10). The level uncertainty for the year 1990 amounts 7.01% (see Table 1-11).

Compared to the **previous submission in 2025 (reporting year 2023),** the results of the current Approach 1 analyses show slightly lower uncertainties for the assessment excluding and including LULUCF.

- Level uncertainty 2023 (previous submission): 5.19% (excluding LULUCF) and 6.69% (including LULUCF)

- Trend uncertainty 1990–2023 (previous submission): 6.12% (excluding LULUCF) and 7.03% (including LULUCF)

The results for the uncertainty analysis for the year 2024 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 2024 excluding LULUCF categories is 0.26 percentage points lower than in the previous submission for the level assessment and 0.42 percentage points lower for the trend assessment. This slight reduction in level uncertainty has two main reasons. First, two categories from the agriculture sector (3B N_2O, 3D2 N_2O) are new key categories compared to the previous submission, which means that for these categories individual uncertainty values were used and not the non-key rest uncertainties. The individual values are generally lower than the conservative estimates for the non-key rest categories, which leads to a reduction of overall uncertainty. Second, the energy statistics show a strong reduction of gasoline consumption between 2023 and 2024 (see chp. 2.2.2), which leads to a reduction of absolute uncertainties within category 1A3b Road transportation.
- Overall uncertainty for 2024 including LULUCF is 0.68 percentage points higher than in the previous submission for the level assessment and 0.18 percentage points higher for the trend assessment. This increase is mainly due to category 4A1 being a larger sink in 1990 compared to the previous submission and also a smaller sink in 2024 compared to the year 2023 of the previous submission, thereby contributing to a higher overall uncertainty. In the non-key rest category for N_2O, a slight increase in emission levels in the most recent year compared to 2023 in the previous submission lead to slightly higher absolute uncertainty (level and trend). In addition, there were minor changes in emission levels or uncertainty values, which influenced overall level or trend uncertainty of the inventory (e.g. decreased emission levels in source category 1A4 Other sectors liquid fuels or slightly increased combined uncertainty for F-Gases in source category 2F Product uses as substitutes for ODS).

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 (2024) and trend (1990–2024) 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 2024 emissions or removals**	**AD unc.**	**EF unc.**	**Comb. unc.**	**Contr. to variance by Category in 2024**	**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 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	2.2	5.0	0.5	5.0	0.005	0.01	0.01	0.005	0.103	0.011
1A2			2. Manufacturing industries & construction	Liquid F.	CO_2	21.0	8.4	20.0	0.1	20.0	1.248	0.02	0.06	0.002	1.580	2.497
				Gaseous F.	CO_2	15.2	10.0	5.0	0.5	5.0	0.110	0.00	0.07	0.000	0.466	0.218
1A3b			3. Transp.; b. Road Transp.		CO_2	75.3	42.5	9.2	0.1	9.2	6.646	0.03	0.28	0.002	3.646	13.290
1A4			4. Other Sectors	Liquid F.	CO_2	76.7	23.2	15.9	0.1	15.9	5.950	0.12	0.15	0.008	3.450	11.899
				Gaseous F.	CO_2	10.2	28.2	3.9	0.3	3.9	0.539	0.09	0.19	0.027	1.036	1.073
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	0.177	0.004	0.01	0.155	0.421	0.201
2F1	2. IPPU	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		F-gases	0.0	7.7	12.0	12.0	17.0	0.752	0.03	0.05	0.405	0.867	0.916
3A	3. Agriculture	A. Enteric Ferment.			CH_4	15.4	15.6	6.5	19.2	20.3	4.399	0.02	0.10	0.456	0.944	1.099
3B		B. Manure Management			CH_4	2.9	2.7	6.5	54.6	55.0	0.948	0.003	0.02	0.174	0.162	0.057
					N_2O	1.2	1.4	35.5	56.7	66.9	0.375	0.003	0.01	0.143	0.460	0.232
3D1		D. Agricul-tural Soils	1. Direct Soil Emissions		N_2O	3.3	2.6	13.9	80.4	81.6	2.036	0.002	0.02	0.166	0.344	0.146
			2. Indirect Soil Emissions		N_2O	1.9	1.4	26.9	60.3	66.1	0.375	0.001	0.01	0.033	0.353	0.126
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	0.101	0.00	0.01	0.01	0.32	0.101
					N_2O	2.0	1.5	56.6	56.6	80.0	0.668	0.00	0.01	0.05	0.82	0.671
					F-gases	-	0.5	14.1	14.1	20.0	0.004	0.00	0.00	0.03	0.06	0.005
Total						**228.5**	**151.0**				**24.33**					**32.54**
										Percentage uncertainty in total inventory:	**4.93**				*Trend uncertainty:*	**5.70**

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	1. Energy	A. Fuel combustion activities	2. Manufacturing industries & construction	Liquid F.	CO_2	21.0	20.0	0.1	20.0	3.377
1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries & construction	Gaseous F.	CO_2	15.2	5.0	0.5	5.0	0.112
1A3b	1. Energy	A. Fuel combustion activities	3. Transp.; b. Road Transp.		CO_2	75.3	9.2	0.1	9.2	9.122
1A4	1. Energy	A. Fuel combustion activities	4. Other Sectors	Liquid F.	CO_2	76.7	15.9	0.1	15.9	28.523
1A4	1. Energy	A. Fuel combustion activities	4. Other Sectors	Gaseous F.	CO_2	10.2	3.9	0.3	3.9	0.031
3A	3. Agriculture	A. Enteric Fermentation			CH_4	15.4	6.5	19.2	20.3	1.873
3D1	3. Agriculture	D. Agricul-tural Soils	1. Direct Soil Emissions		N_2O	3.3	13.9	80.4	81.6	1.374
non-key rest					CO_2	0.6	7.1	7.1	10.0	0.001
non-key rest					CH_4	5.6	21.2	21.2	30.0	0.545
non-key rest					N_2O	5.2	56.6	56.6	80.0	3.289
non-key rest					F-gases	0.0001	14.1	14.1	20.0	0.000
Total						**228.5**				**48.25**
							Percentage uncertainty in total inventory:			**6.95**

Table 1-10 Approach 1 level (2024) and trend (1990–2024) 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 2024 emissions or removals**	**AD unc.**	**EF unc.**	**Comb. unc.**	**Contr. to variance by Category in 2024**	**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 the trend in total national emissions**
(categories including LULUCF)						kt CO_2 eq	kt CO_2 eq	%	%	%	-	%	%	%	%	-
1A1	**1. Energy**	A. Fuel combustion activities	1. Energy industries	Gaseous F.	CO_2	0.1	2.2	5.0	0.5	5.0	0.006	0.01	0.02	0.005	0.11	0.012
1A2			2. Manufacturing ind. & constr.	Liquid F.	CO_2	21.0	8.4	20.0	0.1	20.0	1.439	0.02	0.06	0.001	1.70	2.877
				Gaseous F.	CO_2	15.2	10.0	5.0	0.5	5.0	0.127	0.003	0.07	0.002	0.50	0.251
1A3b			3. Transport; b. Road Transportation		CO_2	75.3	42.5	9.2	0.1	9.2	7.659	0.01	0.30	0.001	3.91	15.317
1A4			4. Other Sectors	Liquid F.	CO_2	76.7	23.2	15.9	0.1	15.9	6.857	0.10	0.16	0.01	3.70	13.713
				Gaseous F.	CO_2	10.2	28.2	3.9	0.3	3.9	0.621	0.09	0.20	0.03	1.11	1.237
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	0.204	0.00	0.01	0.16	0.45	0.229
2F1	**2. IPPU**	F. Prod. uses as subst. for ODS	1. Refriger. & air cond.		F-gases	0.0	7.7	12.0	12.0	17.0	0.866	0.033	0.05	0.40	0.93	1.025
3A	**3. Agriculture**	A. Enteric Ferment.			CH_4	15.4	15.6	6.5	19.2	20.3	5.069	0.03	0.11	0.52	1.01	1.297
3B		B. Manure Managem.			CH_4	2.9	2.7	6.5	54.6	55.0	1.092	0.00	0.02	0.21	0.17	0.074
					N_2O	1.2	1.4	35.5	56.7	66.9	0.432	0.00	0.01	0.16	0.49	0.268
3D1		D. Agricultural Soils	1. Dir. Soil Em.		N_2O	3.3	2.6	13.9	80.4	81.6	2.346	0.00	0.02	0.23	0.37	0.188
4A1	**4. LULUCF**	A. Forest Land	1. Forest land remaining forest		CO_2	-0.3	-15.7	2.7	34.9	35.0	15.352	0.07	0.11	2.33	0.43	5.626
4A2			2. Land converted to Forest Land		CO_2	-4.3	-7.6	17.2	34.9	38.9	4.460	0.02	0.05	0.76	1.32	2.316
4B1		B. Cropland	1. Cropland remaining cropland		CO_2	4.2	3.2	30.8	23.0	38.4	0.754	0.00	0.02	0.06	0.98	0.972
4C1		C. Grassland	1 Grassland Remaining Grassland		CO_2	2.1	1.9	6.0	41.0	41.4	0.315	0.00	0.01	0.12	0.12	0.026
4C2			2. Land converted to grassland		CO_2	0.1	2.6	13.6	28.0	31.1	0.343	0.011	0.02	0.31	0.36	0.228
4D1		D. Wetlands	1. Wetlands remaining wetlands		CO_2	2.0	2.0	10.5	50.0	51.1	0.508	0.003	0.01	0.16	0.21	0.070
4E1		E. Settle-ments	1 Settlements Remaining Settlements		CO_2	0.0	-2.2	6.4	42.3	42.8	0.447	0.01	0.02	0.40	0.14	0.184
4E2			2. Land converted to settlements		CO_2	1.7	2.3	19.4	31.8	37.3	0.376	0.006	0.02	0.18	0.45	0.236
4G		G. HWP			CO_2	-2.7	2.1	50.0	54.8	74.2	1.270	0.016	0.02	0.89	1.07	1.941
non-key rest					CO_2	1.4	1.0	7.1	7.1	10.0	0.005	0.00	0.01	0.00	0.07	0.005
					CH_4	2.3	1.6	21.2	21.2	30.0	0.116	0.00	0.01	0.02	0.34	0.117
					N_2O	4.2	3.3	56.6	56.6	80.0	3.607	0.00	0.02	0.19	1.90	3.643
					F-gases	-	0.5	14.1	14.1	20.0	0.004	0.00	0.00	0.03	0.07	0.005
Total						**232.5**	**140.6**				**54.28**					**51.86**
										Percentage uncertainty in total inventory:	**7.37**				*Trend uncertainty:*	**7.20**

Table 1-11 Approach 1 level (1990) uncertainty including 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 including 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	3.260
1A2		A. Fuel combustion activities	2. Manufacturing industries & construction	Gaseous F.	CO_2	15.2	5.0	0.5	5.0	0.108
1A3b		A. Fuel combustion activities	3. Transp.; b. Road Transp.		CO_2	75.3	9.2	0.1	9.2	8.806
1A4		A. Fuel combustion activities	4. Other Sectors	Liquid F.	CO_2	76.7	15.9	0.1	15.9	27.536
1A4		A. Fuel combustion activities	4. Other Sectors	Gaseous F.	CO_2	10.2	3.9	0.3	3.9	0.030
3A	3. Agriculture	A. Enteric Ferment.			CH_4	15.4	6.5	19.2	20.3	1.809
3B	3. Agriculture	B. Manure Management			CH_4	2.9	6.5	54.6	55.0	0.484
3D1	3. Agriculture	D. Agricul-tural Soils	1. Direct Soil Emissions		N_2O	3.3	13.9	80.4	81.6	1.326
4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO_2	-4.3	17.2	34.9	38.9	0.514
4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO_2	4.2	30.8	23.0	38.4	0.488
4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland		CO_2	2.1	6.0	41.0	41.4	0.136
	4. LULUCF	D. Wetlands	1. Wetlands remaining wetlands		CO_2	2.0	10.5	50.0	51.1	0.190
4D1	4. LULUCF	G. HWP			CO_2	-2.7	50.0	54.8	74.2	0.736
non-key rest					CO_2	3.0	7.1	7.1	10.0	0.017
non-key rest					CH_4	2.7	21.2	21.2	30.0	0.120
non-key rest					N_2O	5.5	56.6	56.6	80.0	3.518
non-key rest					F-gases	0.0001	14.1	14.1	20.0	0.000
Total						**232.5**				**49.08**
									Percentage uncertainty in total inventory:	**7.01**

The level uncertainties are also evaluated by gas according to the results of the Approach 1 uncertainty assessment excluding LULUCF for the year 2024.

Table 1-12 Level uncertainties by gas 2024 for the total national emissions excluding LULUCF.

Gas	Emissions 2024 (excluding LULUCF) kt CO2 eq	Mean absolute uncertainty kt CO2 eq	Mean relative uncertainty
CO2	114.7	5.7	5%
CH4	21.2	3.6	17%
N2O	7.0	2.8	40%
F-gases	8.2	1.3	16%
Total	**151.0**	**7.4**	**4.93%**

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

In the present analysis, Monte Carlo simulations were performed to estimate uncertainties both in emissions 2024 and in emission trends 1990–2024, at the source category level (individually accounting for the key categories, while the rest of the categories is aggregated by gas and treated as four “rest” categories CO_2, CH_4, N_2O and F-gases) as well as for the inventory as a whole (excluding and including LULUCF categories). The simulations were run with the commercial software package Crystal Ball (® Decisioneering, Release 11.1.2.4.400). This tool generates random numbers within user defined probability ranges and probability distributions. As a result, selected statistics are produced for the forecast variables.

Assumptions for the Monte Carlo simulations are given in Annex A2.2. In this chapter, only the main results of the simulations for level and trend analyses are presented.

Table 1-13 Approach 2 level (2024) and trend (1990–2024) uncertainty.

Approach 2 (Monte Carlo) Uncertainty Analysis						
Version	Level uncertainty 2024			Trend uncertainty 1990-2024		
	2.5 percentile	97.5 percentile	**mean**	2.5 percentile	97.5 percentile	**mean**
excl. LULUCF	-4.84%	4.83%	**4.83%**	-41.44%	-26.44%	**7.50%**
incl. LULUCF	-6.07%	6.04%	**6.06%**	-47.39%	-31.69%	**7.85%**

Results of the Approach 2 uncertainty analysis for the reporting year 2024:

The Approach 2 level uncertainty (2024) in the national total annual CO_2 equivalent emissions **excluding LULUCF** was 4.83% (with a nearly symmetric 95% confidence interval from -4.84% to 4.83%, see Table 1-13). The trend in national total emissions excluding LULUCF between 1990 and 2024 is -33.91%. With a probability of 95% the trend lies within the range of -41.44% and -26.44%, which corresponds to a mean trend uncertainty of 7.50%, see Table 1-13.

The Approach 2 level uncertainty (2024) in the national total annual CO_2 equivalent emissions **including LULUCF** was 6.06% (with a symmetric 95% confidence interval from -6.07% to 6.04%, see Table 1-13). The trend in national total emissions including LULUCF between 1990 and 2024 is -39.51%. With a probability of 95% the trend lies within the range of -47.39% and -31.69%, which corresponds to a mean trend uncertainty of 7.85%, see Table 1-13.

That means that level and trend uncertainty are higher if LULUCF categories are included in the uncertainty analysis, which is caused by large contributions, large uncertainties and strong trends of several LULUCF categories.

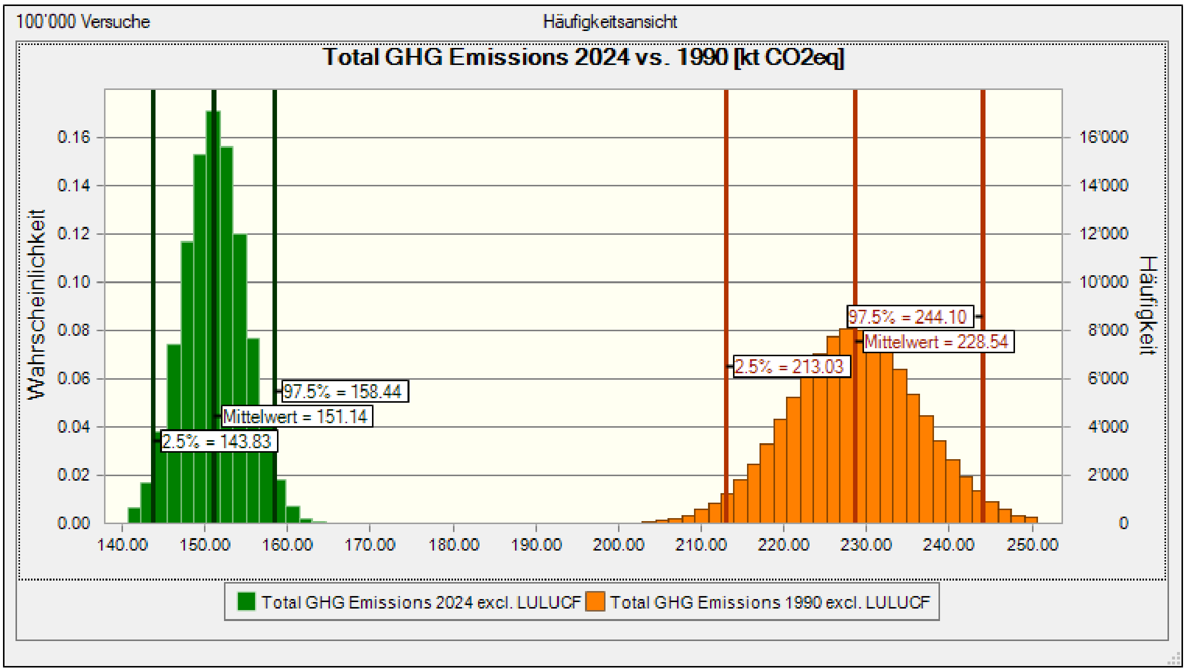


Figure 1-8 Probability distributions of the simulated total emissions excluding LULUCF for the base year 1990 (in orange) and year 2024 (in green). The vertical lines show simulated mean and percentile values (black for 2024, red for 1990). The number of Monte Carlo runs is 100'000 ("Versuche"). x-axis: total emissions [kt CO_2 eq]. Y-axis: Probability (left, "Wahrscheinlichkeit") and Frequency (right, "Häufigkeit"). The simulated values deviate slightly from the reported inventory values (see Table A - 6 for detailed deviations).

In the course of Monte Carlo simulation, the uncertainties are also evaluated by gas (see Table 1-14). As expected, CO_2 emissions have the highest precision or the lowest uncertainties among the Kyoto gases.

Table 1-14 Approach 2 level uncertainties by gas for the total national emissions 2024 excluding LULUCF. Total emissions 2024 are simulated and can deviate from reported inventory values (see Table A-8)

Gas	Simulated Emission 2024 (excl. LULUCF)	Lower bound 2.5 percentile	Upper bound 97.5 percentile	Mean absolute uncertainty	Mean relative uncertainty
	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	kt CO_2 eq	%
CO_2	114.7	108.9	120.5	5.8	5%
CH_4	21.2	17.6	24.7	3.6	17%
N_2O	7.1	4.7	9.6	2.4	34%
Aggregated F-Gases	8.2	6.9	9.5	1.3	16%
Total	**151.1**	**143.8**	**158.4**	**7.3**	**4.83%**

Detailed results per category of the Monte Carlo simulation are presented in Table A - 5, inputs on probability distributions and correlation coefficients in Table A - 3 and Table A - 4.

The following chart – called Tornado plot – shows the results of a sensitivity analysis, depicting the most important uncertainties. These can either be emission factors, activity data or emissions. The bars depict the amount of uncertainty introduced compared to total emissions (on x-axis). On the left-hand side, the variable is indicated containing the information of type (EM emission, EF emission factor, AD activity data), NFR number and gas (if gas is missing, it is replaced with “0”). The letter “t” refers to year 2024.

Categories 1A3b (CO_2), 1A4 Liquid fuels (CO_2) and 3A_CH4 Enteric Fermentation (CH_4), are the most important contributors to level uncertainty.

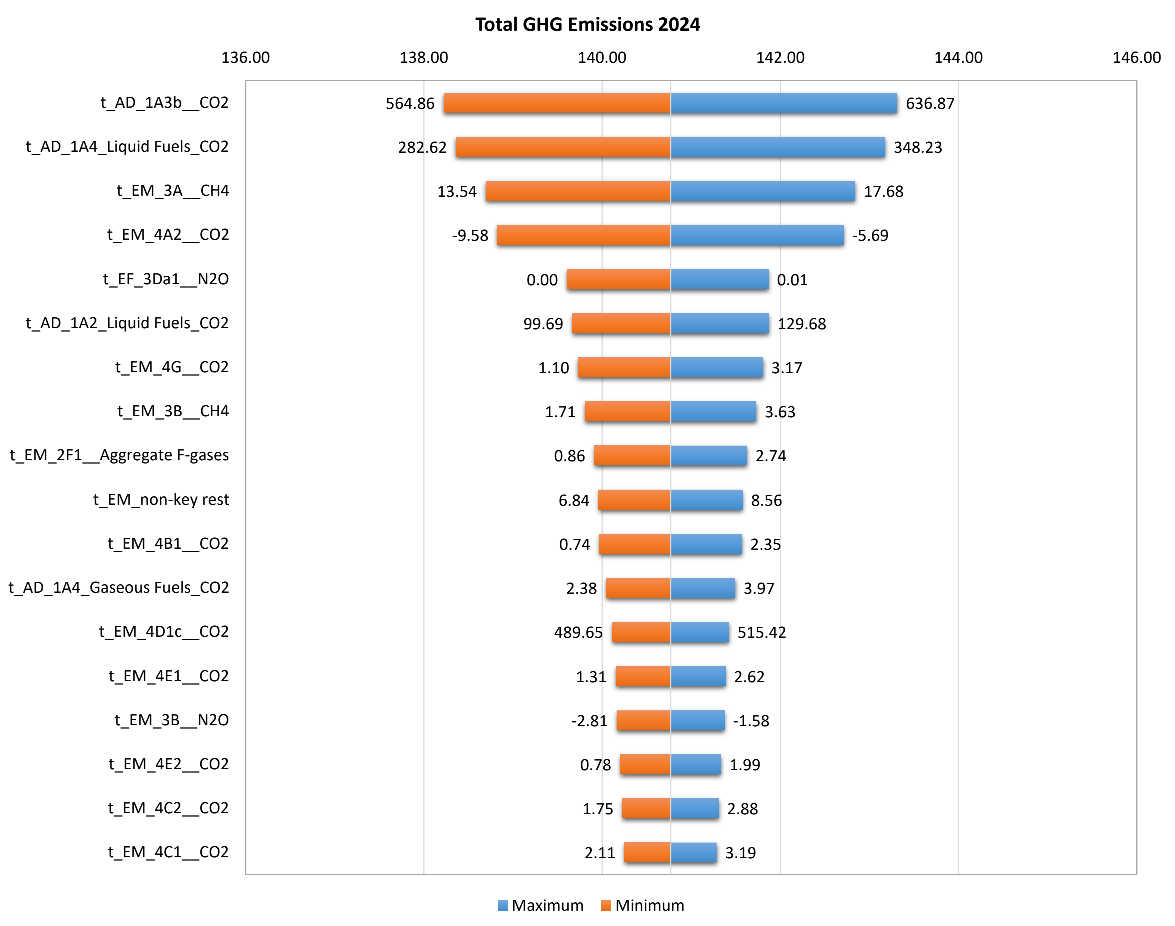


Figure 1-9 Tornado plot of the uncertainties by category. Abbrev.: “t” refers to the submission year 2024, “EF” emission factor, “AD” activity data, “EM” emissions. x-axis: Simulated national total of CO_2 eq emissions (in kt) including LULUCF in 2024 (the simulated values deviate slightly from the reported inventory values, see Table A - 6 for details). The width of the bar shows the combined uncertainty introduced by the corresponding uncertainty.

Further results of the Monte Carlo simulations are shown in Annex 2.2.

1.6.4.1 Comparison of Approach 1 and Approach 2

In the GHG inventory, the amount of the uncertainties can be high, their statistical distribution may clearly deviate from normal distributions and they can be correlated. Approach 1 is based on simple error propagation, which assumes only small, normally distributed and uncorrelated uncertainties. The application of the Approach 1 is therefore not the optimal method for determining the uncertainties of a GHG inventory. The more appropriate choice, which is recommended by the IPCC 2006 Guidelines (IPCC 2006), is the Monte Carlo simulation (Approach 2), which is designed for uncertainties of any extent, any statistical distribution and any correlated parameters. The results of the Monte Carlo simulation are therefore considered to provide a more realistic picture of the uncertainties than the results of Approach 1.

Level uncertainty

Approach 2 excl. LULUCF leads to an overall level uncertainty of 4.83%, which is slightly lower than the result of Approach 1 (4.93%). The correct treatment of large uncertainties, asymmetric distributions for agricultural sources and accounting for relevant correlations lead all together to a slight decrease in the level uncertainty.

For the level uncertainty incl. LULUCF, Approach 2 also leads to a lower overall level uncertainty (6.06%) than Approach 1 (7.37%).

Trend uncertainty

In terms of trend uncertainty, the results of Approach 2 show higher uncertainties than the results of Approach 1. If LULUCF categories are excluded, Approach 2 leads to an uncertainty of 7.50% and Approach 1 to 5.70%, whereas when LULUCF categories are included, the numbers are 7.85% and 7.20%, respectively. Positive correlations for activity data and emission factors between the base year and 2024 tend to increase trend uncertainty. This effect is slightly enforced for the analysis including LULUCF due to the strong trends and rather high uncertainty values in this sector.

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 2024 amount to 151.0 kt CO_2 eq. The significance threshold for aggregated emissions equals to 0.76 kt CO_2 eq.

The emissions from UAN application in category 3I are very likely <0.005 kt CO_2 in the year 2024 (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 1990–2024.

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

Liechtenstein's greenhouse gas emissions in the year 2024 amount to 151.0 kt CO_2 equivalent (CO_2eq) excluding LULUCF sources or sinks (including LULUCF: 140.6 kt CO_2eq). This refers to 3.7 t CO_2eq per capita.

Total emissions in 2024 (excl. LULUCF) have declined by 33.9% compared to 1990. Compared to 2023, they decreased by 10.2%. When including LULUCF categories, total emissions decreased by 39.5% between 1990–2024 and by 14.0% between 2023–2024.

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 2024. 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 2024	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
	CO_2 equivalent (kt)						
1 Energy	114.5	1.70	0.76	-	-	-	117.0
2 IPPU	0.10	NO	0.13	8.14	0.00	0.00	8.4
3 Agriculture	0.04	18.3	5.42	-	-	-	23.7
5 Waste	0.01	1.17	0.65	-	-	-	1.8
Total (excluding LULUCF)	**114.7**	**21.2**	**7.0**	**8.1**	**0.000**	**0.00**	**151.0**
4 LULUCF	-10.7	NO	0.40	-	-	-	-10.3
Total (including LULUCF)	**104.0**	**21.2**	**7.4**	**8.1**	**0.000**	**0.00**	**140.6**
International Bunkers	*1.59*	*0.00*	*0.01*	-	-	-	*1.60*

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 76% of the total emissions in 2024 (excluding emissions from LULUCF), CO_2 is the most dominant greenhouse gas emitted in Liechtenstein. CH_4 emissions represent 14.0% and N_2O emissions 4.6% of the total emissions.

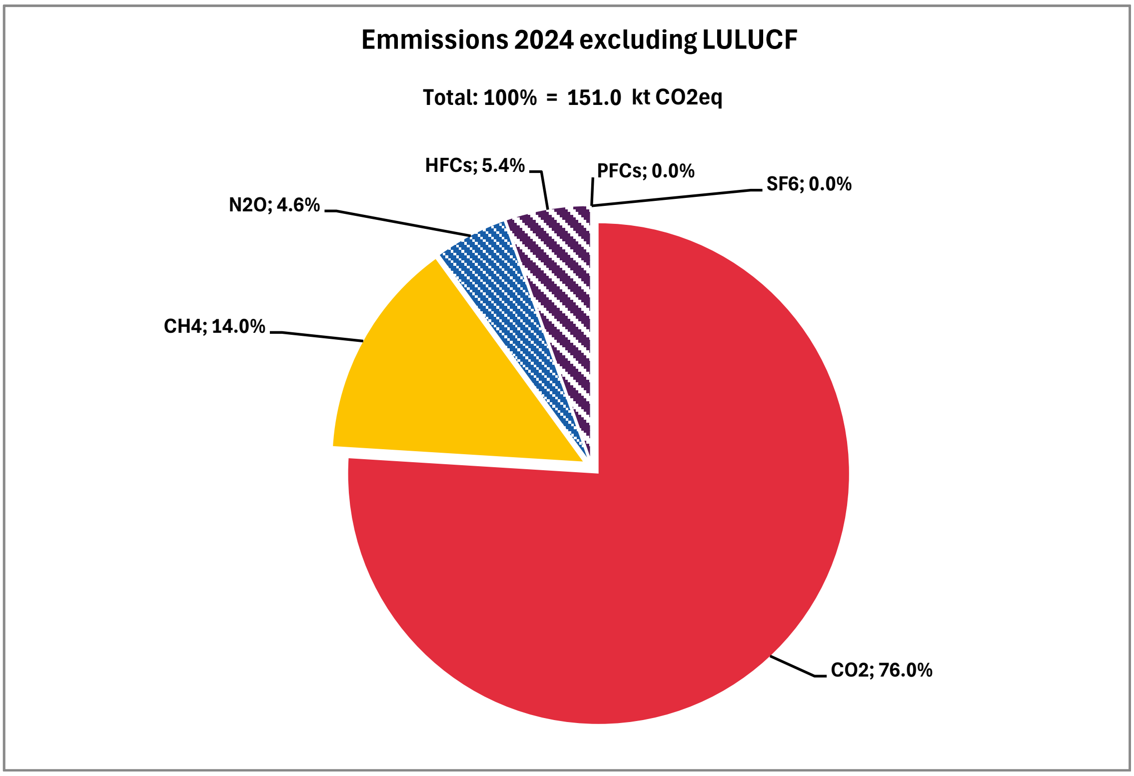


Figure 2-1 Liechtenstein's GHG emissions by gases excluding LULUCF emissions.

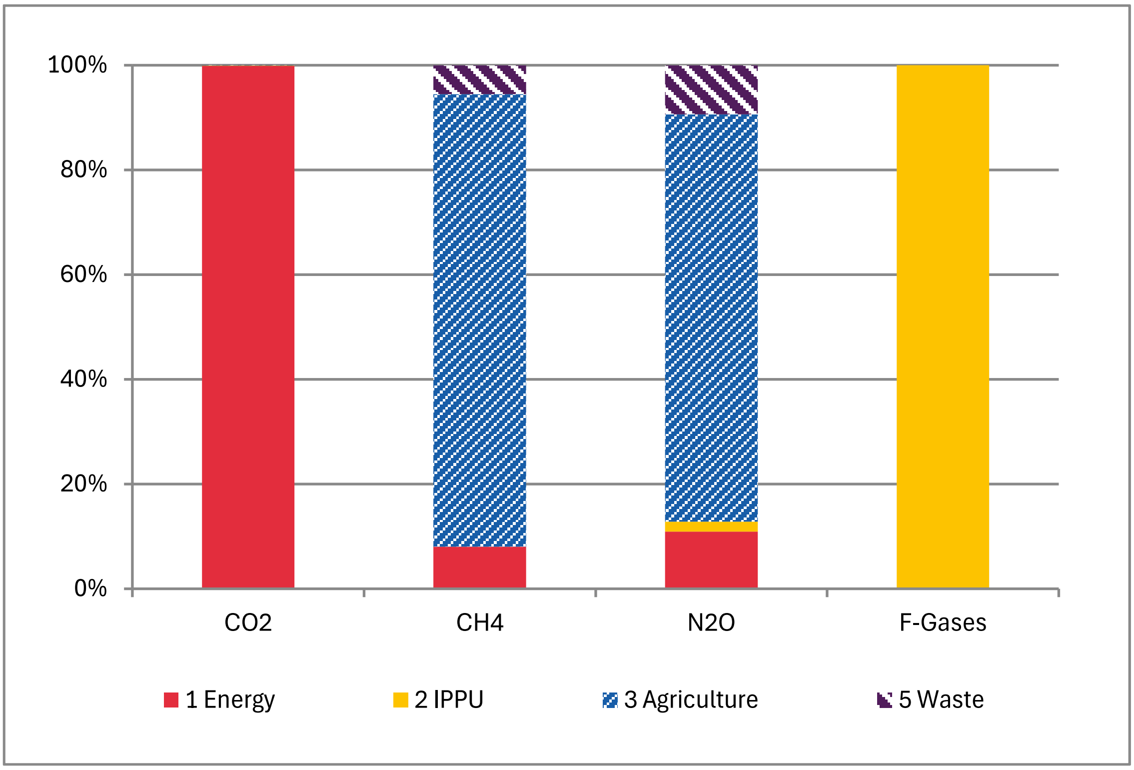


Figure 2-2 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions in 2024.

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

2.2.1 Emission trends by gas

Emission trends 1990–2024 by gas are summarised in Table 2-2 and in Figure 2-3.

Table 2-2 Summary of Liechtenstein's GHG emissions in CO_2eq (kt) by gas. The last column shows the percentage change in emissions in 2024 as compared to the base year 1990. HFC emissions have increased by about a factor of 85'000 in 2024 compared to 1990.

Greenhouse Gas Emissions	1990	1995	2000	2005	2010
	CO_2 equivalent (kt)				
CO_2 emissions incl. net CO_2 from LULUCF	202.8	206.3	238.5	236.4	208.0
CO_2 emissions excl. net CO_2 from LULUCF	199.0	204.2	216.8	228.9	190.7
CH_4 emissions incl. CH_4 from LULUCF	21.0	19.6	18.3	20.6	21.1
CH_4 emissions excl. CH_4 from LULUCF	21.0	19.6	18.3	20.6	21.1
N_2O emissions incl. N_2O from LULUCF	8.7	8.6	8.0	7.6	7.7
N_2O emissions excl. N_2O from LULUCF	8.5	8.4	7.7	7.2	7.3
HFCs	0.0	1.1	3.5	6.3	8.3
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)	232.5	235.6	268.5	271.2	245.2
Total (excluding LULUCF)	228.5	233.3	246.4	263.3	227.5

Greenhouse Gas Emissions	2015	2016	2017	2018	2019
	CO_2 equivalent (kt)				
CO_2 emissions incl. net CO_2 from LULUCF	157.2	151.8	157.5	151.5	149.4
CO_2 emissions excl. net CO_2 from LULUCF	159.8	149.9	155.9	143.2	149.2
CH_4 emissions incl. CH_4 from LULUCF	21.0	21.1	20.6	20.9	21.8
CH_4 emissions excl. CH_4 from LULUCF	21.0	21.1	20.6	20.9	21.8
N_2O emissions incl. N_2O from LULUCF	7.6	7.6	7.5	7.7	7.8
N_2O emissions excl. N_2O from LULUCF	7.2	7.1	7.1	7.2	7.3
HFCs	9.4	9.1	9.3	9.4	9.2
PFCs	0.0	0.0	0.0	0.0	0.0
SF_6	0.0	0.0	0.0	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)	**195.3**	**189.5**	**194.9**	**189.6**	**188.2**
Total (excluding LULUCF)	**197.5**	**187.2**	**192.9**	**180.8**	**187.5**

Greenhouse Gas Emissions	2020	2021	2022	2023	2024	1990-2024
	CO_2 equivalent (kt)					%
CO_2 emissions incl. net CO_2 from LULUCF	134.8	135.0	119.1	126.4	104.0	-48.7%
CO_2 emissions excl. net CO_2 from LULUCF	142.1	145.9	128.6	131.3	114.7	-42.4%
CH_4 emissions incl. CH_4 from LULUCF	21.9	21.6	21.4	21.5	21.2	0.6%
CH_4 emissions excl. CH_4 from LULUCF	21.9	21.6	21.4	21.5	21.2	0.6%
N_2O emissions incl. N_2O from LULUCF	7.6	7.6	7.7	7.5	7.4	-15.7%
N_2O emissions excl. N_2O from LULUCF	7.2	7.2	7.3	7.1	7.0	-17.7%
HFCs	9.3	8.6	8.5	8.2	8.1	see caption
PFCs	0.0	0.0	0.0	0.0	0.0	-
SF_6	0.1	0.1	0.1	0.0	0.0	-
Unspecified mix of HFCs and PFCs	NA,NO	NA,NO	NA,NO	NA,NO	NO	-
NF_3	NA,NO	NA,NO	NA,NO	NA,NO	NO	-
Total (including LULUCF)	**173.6**	**172.9**	**156.8**	**163.6**	**140.6**	**-39.5%**
Total (excluding LULUCF)	**180.5**	**183.4**	**165.8**	**168.1**	**151.0**	**-33.9%**

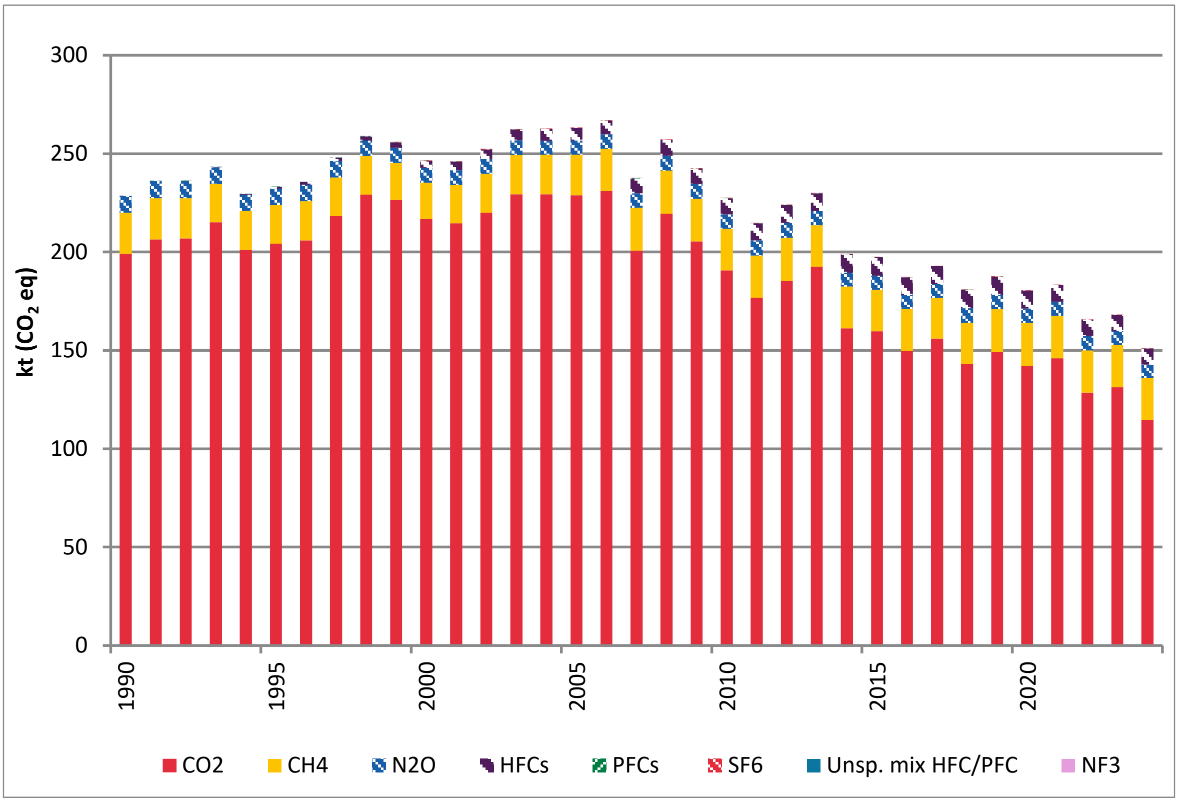


Figure 2-3 Trend of Liechtenstein's greenhouse gas emissions by gases. CO_2, CH_4 and N_2O correspond to the respective total emissions excluding LULUCF. Note that NF_3 emissions are not occurring.

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_2eq) excluding LULUCF sources or sinks decreased by 33.9% from 1990 to 2024.
- Total emissions (in CO_2eq) including LULUCF show a decrease of 39.5% in 2024 compared to 1990 levels.
- CO_2 emissions (excluding net CO_2 from LULUCF) have declined by 42.4% between 1990 and 2024. In comparison to the previous reporting year 2023, CO_2 emissions (excluding net CO_2 from LULUCF) decreased by 12.6% in 2024. In general, the most important drivers over the past decades 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 76.0% in 2024 (excl. LULUCF).
- CH_4 emissions (excluding CH_4 from LULUCF) have increased by 0.6% since 1990. Compared to 2023, CH_4 emissions (excluding LULUCF) show a decrease of 1.4% in 2024. 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 14% in 2024 (excl. LULUCF).

- N_2O emissions (excluding N_2O from LULUCF) have declined by 17.7% in 2024 compared to 1990. Compared to 2023, N_2O emissions (without LULUCF) in 2024 decreased by 2.4%. 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 4.6% (2024).
- 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 5.4% (2024).

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_2eq (kt). The last column shows the percent change in emissions in 2024 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**	**229.6**
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***	***255.8***
4. LULUCF	**4.1**	**-12.9**	**-1.3**	**-3.8**	**15.7**	**2.3**	**-7.7**	**10.9**	**0.6**	**-0.8**
Total (including LULUCF)	***232.5***	***223.1***	***234.8***	***239.4***	***245.2***	***235.6***	***227.8***	***258.8***	***259.5***	***255.0***

Source and Sink Categories	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO_2 equivalent (kt)									
1. Energy	**220.0**	**217.7**	**223.0**	**232.3**	**231.9**	**231.5**	**233.7**	**203.3**	**222.2**	**208.0**
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	27.6
1.A.3. Transport	91.5	88.0	84.0	83.8	82.2	81.7	79.1	83.3	87.7	81.8
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**	**6.1**	**6.8**	**7.1**	**7.4**	**8.2**	**8.7**	**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**	**1.8**	**1.7**
Total (excluding LULUCF)	***246.4***	***246.1***	***252.4***	***262.5***	***262.8***	***263.3***	***266.9***	***237.6***	***257.3***	***242.5***
4. LULUCF	**22.0**	**4.3**	**3.1**	**4.6**	**4.7**	**7.9**	**10.6**	**22.2**	**21.8**	**18.6**
Total (including LULUCF)	***268.5***	***250.3***	***255.5***	***267.1***	***267.5***	***271.2***	***277.5***	***259.9***	***279.1***	***261.1***

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	CO_2 equivalent (kt)									
1. Energy	**193.4**	**179.4**	**188.0**	**195.2**	**163.7**	**162.2**	**152.3**	**158.4**	**145.7**	**151.8**
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	26.0	27.8	24.7	24.2
1.A.3. Transport	77.6	76.8	79.8	79.6	73.7	61.8	60.4	60.8	58.8	57.3
1.A.4. Other Sectors	85.2	74.7	78.3	84.9	58.9	69.5	62.5	66.4	58.7	65.5
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	**8.7**	**9.1**	**9.4**	**9.6**	**9.7**	**9.8**	**9.3**	**9.6**	**9.7**	**9.4**
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**	**1.8**	**1.8**	**1.8**	**1.7**	**1.7**	**1.7**	**1.7**	**1.6**	**1.7**
Total (excluding LULUCF)	***227.5***	***214.7***	***223.9***	***230.1***	***199.0***	***197.5***	***187.2***	***192.9***	***180.8***	***187.5***
4. LULUCF	**17.7**	**10.5**	**8.0**	**0.6**	**2.1**	**-2.1**	**2.4**	**2.0**	**8.8**	**0.7**
Total (including LULUCF)	***245.2***	***225.2***	***231.9***	***230.7***	***201.2***	***195.3***	***189.5***	***194.9***	***189.6***	***188.2***

Source and Sink Categories	2020	2021	2022	2023	2024	1990-2024
	CO_2eq (kt)					%
1. Energy	**144.6**	**148.4**	**131.1**	**133.6**	**117.0**	**-41.9%**
1.A.1. Energy Industries	2.4	2.6	2.3	2.9	2.3	1229%
1.A.2. Manufacturing ind. & construction	23.0	23.3	21.3	19.9	18.5	-49.1%
1.A.3. Transport	52.7	56.0	50.2	54.0	43.0	-44.1%
1.A.4. Other Sectors	65.1	65.2	55.8	55.6	52.1	-40.5%
1.A.5. Other	NO	NO	NO	NO	NO	-
1.B. Fugitive emissions from fuels	1.3	1.4	1.4	1.3	1.3	211.6%
2. IPPU	**9.5**	**8.9**	**8.8**	**8.5**	**8.4**	**1293%**
3. Agriculture	**24.7**	**24.3**	**24.2**	**24.2**	**23.7**	**-4.5%**
5. Waste	**1.7**	**1.7**	**1.8**	**1.8**	**1.8**	**4.7%**
Total (excluding LULUCF)	***180.5***	***183.4***	***165.8***	***168.1***	***151.0***	***-33.9%***
4. LULUCF	**-6.9**	**-10.5**	**-9.1**	**-4.5**	**-10.3**	**-354.8%**
Total (including LULUCF)	***173.6***	***172.9***	***156.8***	***163.6***	***140.6***	***-39.5%***

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.

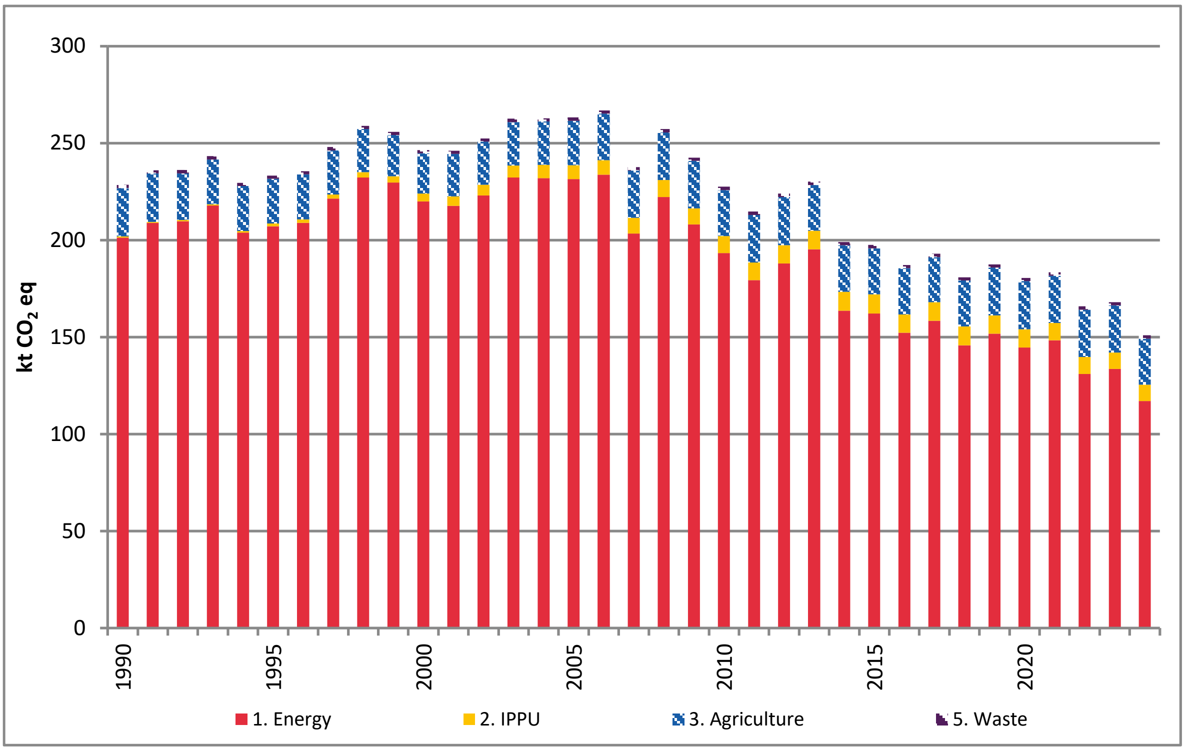


Figure 2-4 Trend of Liechtenstein's greenhouse gas emissions by main source categories in CO_2eq (kt) (excl. net CO_2 from LULUCF).

The following emission trends are observed in the sectors:

Sector 1 Energy

In 2024, 77.5% of Liechtenstein's GHG emissions (excluding LULUCF) originate from sector 1 Energy, which is 2.0 percentage points less than in 2023. The share of sector 1 Energy in the total emissions declined by 10.6 percentage points since 1990. Also, the total emissions of the sector 1 Energy have clearly decreased in comparison to 1990 levels (by 41.9%). The source categories within sector 1 Energy show the following trends between 1990 and 2024:

- 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 13 since 1990.
- 1A2 Manufacturing industries and construction: Total emissions from this source category have declined by 49.1% since 1990. Gaseous fuels are the more important energy carrier in 1A2 in Liechtenstein in 2024, followed by liquid fuels. In 2024, emissions from gaseous fuels decreased by 34.5% compared to 1990 and decreased by 2.5% compared to 2023. Liquid fuel emissions decreased by 59.7% compared to 1990.
- 1A3 Transport: Up to 2006, fuel consumption in road transportation was mostly in line with the general development of road-vehicle kilometres of all vehicle categories.

Total emissions started decreasing since 2013. The overall trend in sector 1A3b shows a decrease of 44.9% (1990–2024). This overall decrease may be related an increasing share of electric vehicles and – depending on fuel prices in Liechtenstein and surrounding countries – to fuel tourism (see chp. 3.2.7.2; SFOE 2018). Note that there was an unexplained increase in gasoline consumption in the year 2023 (see energy statistics; OS 2025a). In 2024, gasoline consumption is on a similar level as in 2022 again. Accordingly, there is a strong decrease of emissions between 2023 and 2024 (-20.4%), which is a result of the gasoline consumption as documented in the energy statistics.

- 1A4 Other sectors: GHG emissions in source category 1A4 have decreased by 6.3% compared to the previous reporting year 2023. 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 lower than in 2023 (see Figure 2-5). Additionally, increased energy efficiency and the progressive substitution of fossil fuels with renewables result in a decoupling of heating degree days and CO_{2eq} emissions.
  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 Since 2020 the fuel levy is increased every year and by 2030 50 percent of emissions have to be compensated. 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.

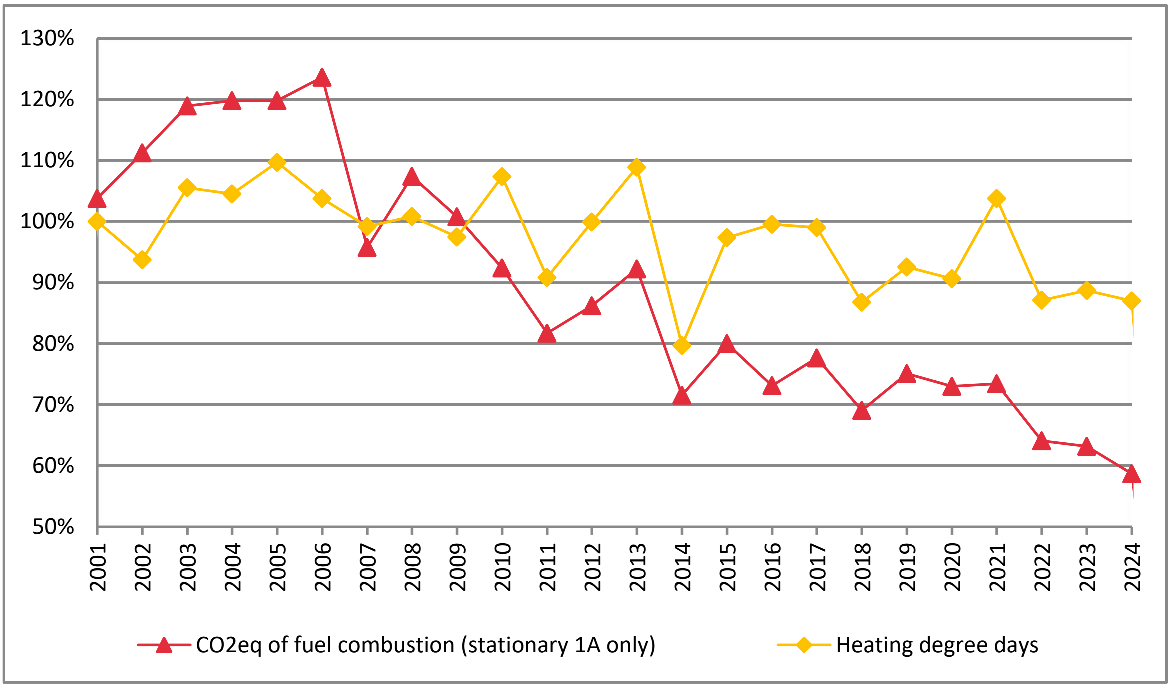


Figure 2-5 Relative trend for CO_2 emissions from 1A Fuel Combustion compared with the number of heating degree days. The drop of emissions in 2007 is driven by high oil and gas prices.

- 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 1990–2024 (211.6%).

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 5.6% of the total GHG-emissions (excluding LULUCF) in 2024. Nevertheless, the use of F-gases has increased substantially over the period 1990–2024, leading to a relative increase in emissions in sector 2 of about a factor of 13.9. 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 (40.8% increase in 2024 compared to 1990), the increasing number of households in Liechtenstein (+75.5%), the increasing number of employees in the industrial and service sectors (+120.7%) and the increasing number of registered cars (+85.5%).

Sector 3 Agriculture

In 2024, sector Agriculture contributes to 15.7% of total GHG-emissions (excluding LULUCF) in Liechtenstein. Agricultural emissions in 2024 are 4.5% 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.

In comparison with the previous submission, the general trends of emissions and removals persist, however, there is more fluctuation in the values of single years. This is due to the new geo-referenced approach for modelling land-use changes, see chp. 6.3.1.5 and Figure 10-1.

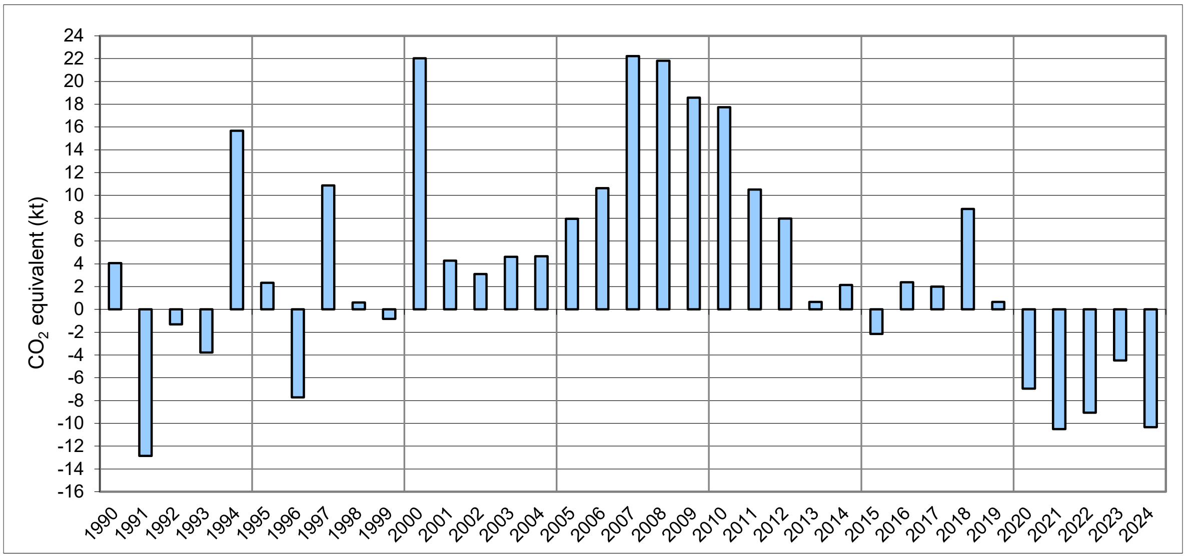


Figure 2-6 Liechtenstein's CO_2 emissions/removals of source category 4 LULUCF in kt CO_2 equivalent.

Sector 5 Waste

In Liechtenstein, only little emissions occur from the sector Waste contributing to 1.2% of total GHG emissions excl. LULUCF in 2024, since all municipal solid waste is exported to a Swiss incineration plant. The waste sector shows a slight increase between 1990 and 2024 (4.7%). 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 2026 has not occurred yet, which is why **the overview and results provided below are from the submission to CLRTAP in 2025**. (Therefore, results for 2024 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 2026). 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 2025 (OE 2025f).

Precursor gases and SO_2	1990	1995	2000	2005	2010
	t				
NO_x	655	548	526	475	400
CO	3’209	2’127	1’666	1’061	734
NMVOC	1’510	1’004	721	506	426
SO_x	106	73	46	35	20

Precursor gases and SO_2	2014	2015	2016	2017	2018
	t				
NO_x	338	294	273	260	240
CO	573	517	481	454	465
NMVOC	381	363	354	346	341
SO_x	9.4	9.3	7.5	7.4	6.5

Precursor gases and SO_2	2019	2020	2021	2022	2023	1990-2023
	t					%
NO_x	219	186	181	161	144	-78%
CO	434	365	364	366	393	-88%
NMVOC	340	334	333	332	327	-78%
SO_x	6.6	5.6	4.9	4.5	4.2	-96%

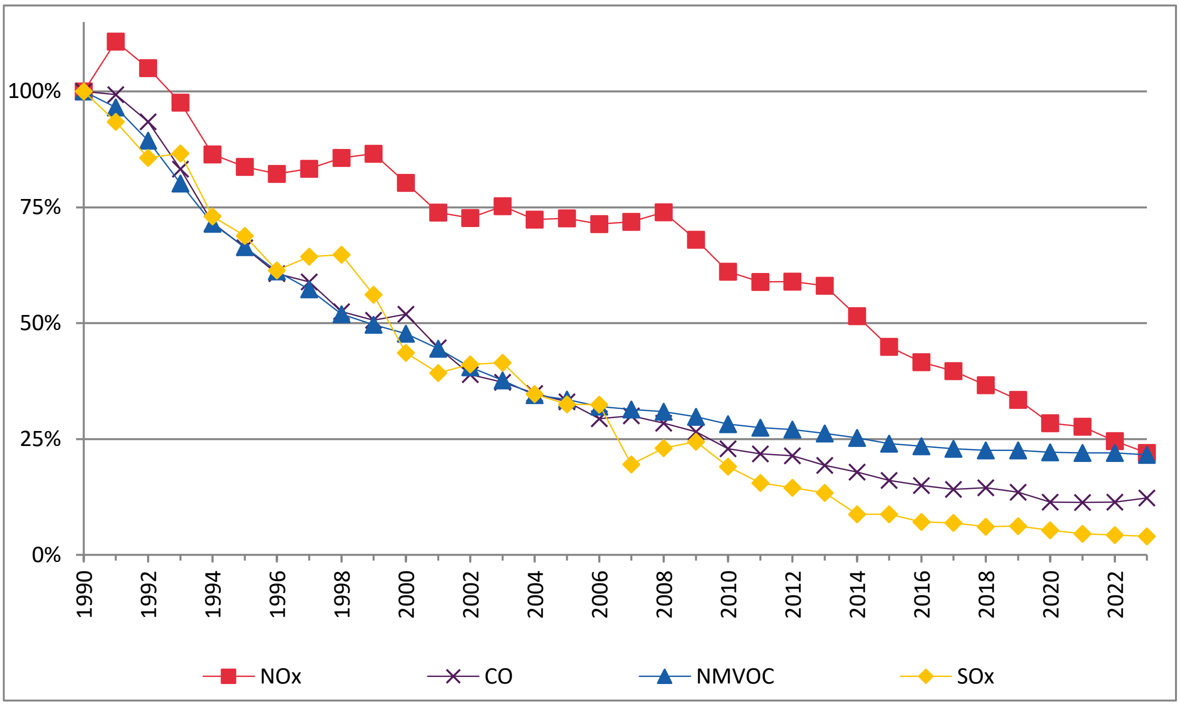


Figure 2-7 Trend of NO_x, CO, NMVOC and SO_x emissions as of CLRTAP submission 2025 (OE 2025f).

The complete CLRTAP Inventory data can be found on the internet (see OE 2025f): https://www.ceip.at/status-of-reporting-and-review-results/2025-submission

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. 117.0 kt CO_2 equivalents were emitted within this sector in 2024, which corresponds to 77.5% of total emissions (151.0 kt CO_2 equivalent, excluding LULUCF). The emissions of the time period 1990–2024 are shown in Figure 3-1.

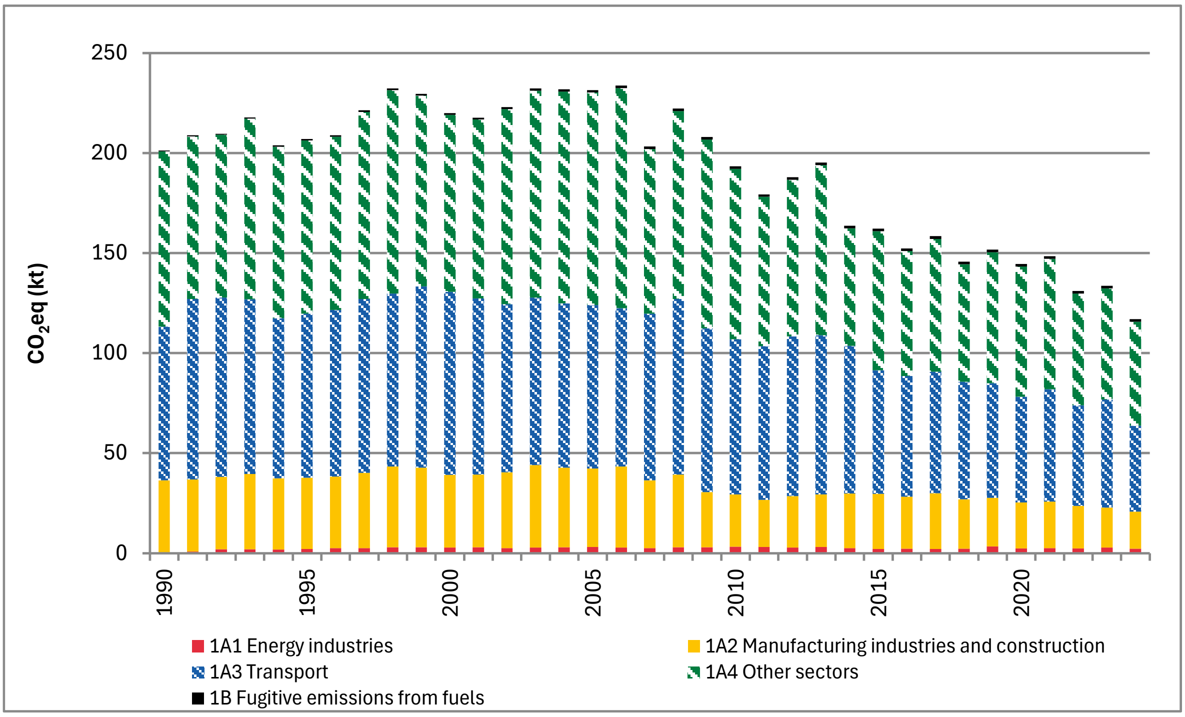


Figure 3-1 Liechtenstein's GHG emissions of the sector 1 Energy by sub-sectors. Note that there are no emissions in source category 1A5.

Table 3-1 summarises the emissions from sector 1 Energy by individual gases 1990–2024. 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	228.6	190.5
CH_4	1.4	1.5	1.7	2.0	2.0
N_2O	1.1	1.6	1.7	0.9	0.9
Sum	**201.3**	**207.0**	**220.0**	**231.5**	**193.4**

Gas	2015	2016	2017	2018	2019
	CO_2 equivalent (kt)				
CO_2	159.6	149.7	155.7	143.0	149.0
CH_4	1.8	1.8	1.8	1.8	1.8
N_2O	0.8	0.8	0.9	0.9	0.9
Sum	**162.2**	**152.3**	**158.4**	**145.7**	**151.8**

Gas	2020	2021	2022	2023	2024	1990-2024
	CO_2 equivalent (kt)					%
CO_2	142.0	145.8	128.4	131.1	114.5	-42.3%
CH_4	1.8	1.8	1.8	1.7	1.7	19.2%
N_2O	0.8	0.9	0.8	0.8	0.8	-33.9%
Sum	**144.6**	**148.4**	**131.1**	**133.6**	**117.0**	**-41.9%**

Table 3-2 shows more details of the emissions of sector 1 Energy in 2024. 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 2024	**CO_2**	**CH_4**	**N_2O**	**Total**	
Sources	**CO_2 equivalent (kt)**				**%**
1. Energy	**114.5**	**1.7**	**0.8**	**117.0**	***100.0%***
1.A. Fuel combustion activitity	**114.5**	**0.4**	**0.8**	**115.7**	***98.9%***
1.A.1. Energy Industries	2.2	0.0	0.0	2.3	***1.9%***
1.A.2. Manufacturing industries and construction	18.4	0.0	0.1	18.5	***15.8%***
1.A.3. Transport	42.6	0.1	0.3	43.0	***36.7%***
1.A.4. Other Sectors	51.4	0.3	0.3	52.1	***44.5%***
1.A.5. Other	NO	NO	NO	NO	**-**
1.B. Fugitive emissions from fuels	**0.0**	**1.3**	**NO**	**1.3**	***1.1%***
1.D.1. International bunkers	**1.6**	**0.0**	**0.0**	**1.6**	-
1.D.3. CO_2 emissions from biomass	**26.3**	**-**	**-**	**26.3**	-

Emissions from sector 1 Energy may be characterised as follows:

- Concerning the total emissions (CO_2eq) from sector 1 Energy, a trend of -41.9% can be observed between 1990 and 2024. From 2023 to 2024 emissions decreased by 12.4%. This decrease is mainly caused by an decrease in emissions in sector 1A3 Transport and 1A4 Other Sectors. Note that there was an unexplained increase in gasoline consumption in the year 2023 (see energy statistics; OS 2025a). In 2024, gasoline consumption is on a similar level as in 2022 again. Accordingly, there is a strong decrease of emissions between 2023 and 2024 (-20.4%), which is a result of the gasoline consumption as documented in the energy statistics.
- The three source categories 1A2, 1A3 and 1A4 dominate the emissions of sector 1 Energy and cover altogether 97.0% (113.5 kt CO_2eq) of total emissions of sector 1.
  - 1A3 Transport accounts for 36.7% of the emissions in 2024.
  - 1A4 Other sectors (commercial/institutional, residential) contributes to 44.5% of the total energy-related emissions.
  - 1A2 Manufacturing industries and construction contributes to 15.8% of the emissions.
  - 1A1 Energy industries and 1B Fugitive emissions only play a minor role. In 2024, they cover1.9% and 1.1%, 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 1.6 kt CO_2 eq.
- CO_2 emissions from biomass add up to 26.3 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 97.9% of the category in 2024 and 98.7% in 1990.
- In 2024, CH_4 emissions accounted for 1.5% of total emissions in the sector 1 Energy. The increasing trend since 1990 (+19.2%) is a result of the increase in consumption of natural gas and the subsequent increase of fugitive emissions of methane (increase by 211.6%). 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 89.2%, 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 2024 and for 0.6% in 1990.

The Liechtenstein greenhouse gas inventory identifies 7 key categories within the energy sector (key category analysis excluding LULUCF categories, see chp. 1.4). The emissions in 1990 and 2024 of these categories are depicted in Figure 3-2. In 2024, CO_2 emissions from 1A3b Road Transportation are most dominant.

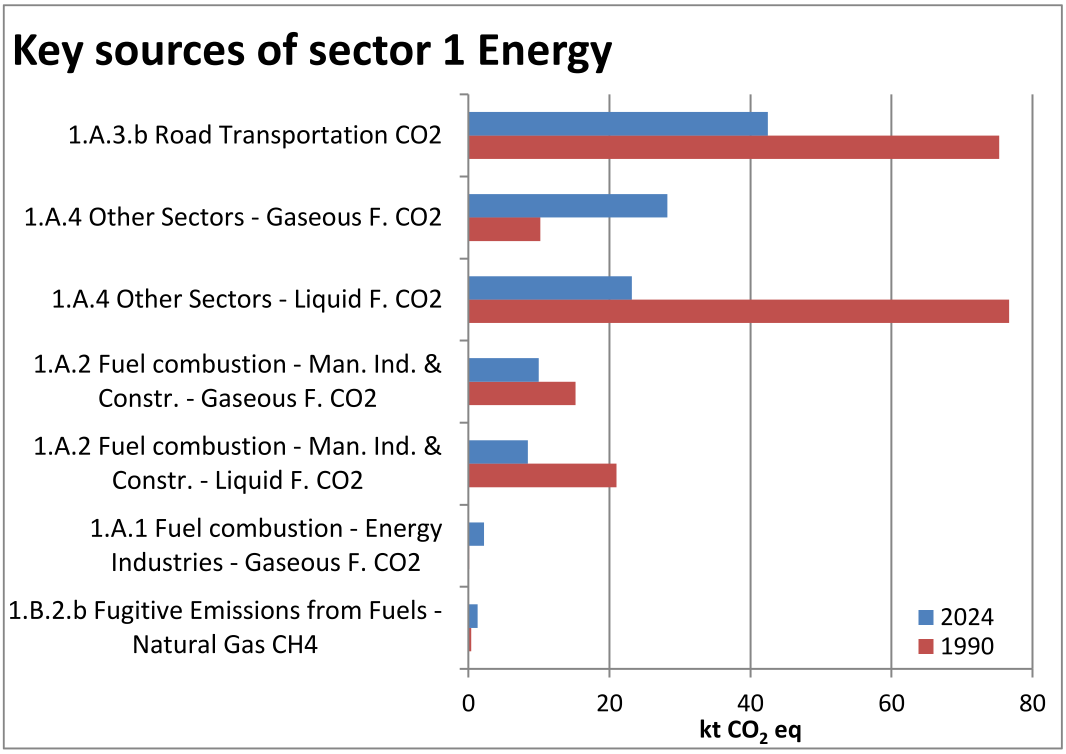


Figure 3-2 Key sources in the energy sector (KCA excl. LULUCF). Emissions in CO_2 equivalents (kt) per key source category in 2024 and in the base year 1990.

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 chp. 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 1990–2024. Energy consumption differs by 1.87% in 2024, whereas CO_2 emissions show a difference of 2.0% in 2024.

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.

Small differences in CO_2 emissions and energy consumption 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 CO_2 emissions and energy consumption. In addition, the sectoral approach accounts for the share of biofuels in gasoline and diesel, which leads to an additional reduction in the fossil CO_2 emissions and fossil energy consumption. Consequently, the fossil CO_2 emissions and fossil energy consumption 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	0.09	0.14	0.19
CO_2 emissions	0.01	0.02	0.07	0.13	0.17
	2015	2016	2017	2018	2019
	percent (%)				
Energy consumption	0.51	0.79	1.07	1.45	1.44
CO_2 emissions	0.52	0.83	1.15	1.57	1.55
	2020	2021	2022	2023	2024
	percent (%)				
Energy consumption	1.43	1.43	1.60	1.83	1.87
CO_2 emissions	1.54	1.55	1.73	1.97	2.03

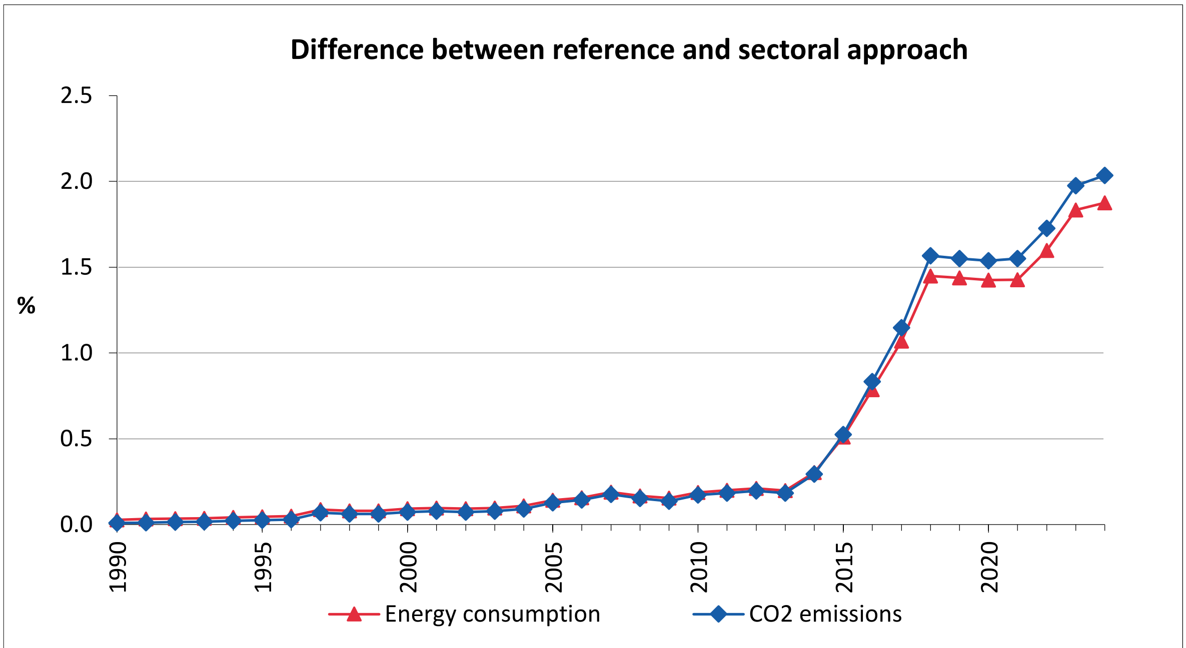


Figure 3-3 Time series for the differences between reference and sectoral approach. Numbers are taken from the table above.

Recalculation in the Reference Approach

- The share of fossil carbon in bioethanol and biodiesel has been introduced, effectively reducing the share of sustainable fuels in gasoline and diesel. The recalculation affects the years 1990 to 2023. The data is taken from Switzerland's road transportation model (INFRAS 2025)

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 2024, 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, …, 2025). 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 2012-2025).

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

In 2024, there are four 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 2024, kerosene consumption increases slightly compared to 2023 due to higher flight activities and the addition of a new helicopter.

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 2006–2025).

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
2024	23.22	1.39		21.83

3.2.3 Feedstocks and non-energy use of fuels

Energy data are taken from Liechtenstein's energy statistics (OS 2025a). 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 2025b). 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 2025b). 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 2024 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 2024. 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 2024		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 1990–2024. 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**	**2015**	**2016**	**2017**	**2018**	**2019**
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**	**2020**	**2021**	**2022**	**2023**	**2024**
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 2025a). 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 2025
- 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 2025a, OS 2025b, OS 2025g). 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:

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 (2025a, OS 2025b), OEP (2006c), OEP (2008) and Rotex Helicopter AG (2006–2025).

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	0.8	1.7	2.1
Sum biomass	**58.5**	**53.2**	**110.4**	**112.6**	**207.3**

Fuel	**2015**	**2016**	**2017**	**2018**	**2019**
			TJ		
Gasoline	410	384	376	369	363
Diesel	498	518	546	531	514
Gas Oil	569	452	487	395	491
Natural Gas	914	908	953	884	896
LPG	3.7	3.6	3.5	3.8	3.6
Hard Coal	0.00	0.00	0.00	0.00	0.00
Kerosene (domestic)	0.81	0.56	0.35	0.40	1.14
Sum	**2’395**	**2’266**	**2’366**	**2’183**	**2’268**
1990=100%	85%	81%	84%	78%	81%
Kerosene (bunker)	16.36	12.59	11.75	14.98	15.34
Biomass					
Wood	209.4	202.5	189.1	225.4	206.9
Sewage gas	0.5	1.8	2.5	1.8	1.4
Biofuel	7.7	11.9	17.5	22.0	22.9
Sum biomass	**217.5**	**216.2**	**209.0**	**249.2**	**231.3**

Fuel	**2020**	**2021**	**2022**	**2023**	**2024**	**1990-2024**
			TJ			%
Gasoline	326	341	303	419	292	-64%
Diesel	493	523	485	413	380	52%
Gas Oil	477	408	365	402	355	-72%
Natural Gas	863	963	809	749	721	58%
LPG	3.7	3.4	3.0	9.0	10.2	-24%
Hard Coal	0.00	0.00	0.00	0.00	0.00	-100%
Kerosene (domestic)	0.81	0.84	0.85	1.05	1.39	35%
Sum	**2’163**	**2’240**	**1’966**	**1’994**	**1’759**	**-37%**
1990=100%	77%	80%	70%	71%	63%	
Kerosene (bunker)	12.83	13.18	13.99	17.03	21.83	274%
Biomass						
Wood	163.9	158.9	193.0	184.1	210.4	390%
Sewage gas	0.5	0.9	1.8	0.5	4.6	-70%
Biofuel	21.9	23.4	23.2	26.6	24.1	-
Sum biomass	**186.2**	**183.2**	**218.1**	**211.2**	**239.2**	**309%**

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
2024	8’276	0	8’276	0.840	9’852	0.845	8’325	357

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 2025a), 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 2025a) 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 1990–2024 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 2025e). 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 2025e).
- 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 2001–2024 (see Rotex Helicopter AG 2006–2025) 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 chps. 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 2024: The Energy Statistics of Liechtenstein (e.g. OS 2025a) 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 2024. 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 2024.

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 2025) and published in the national energy statistics (OS 2025a).

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 1990–2024 (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 2025). 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 2025a) 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 2025b). 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 2025b) 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 2025a).

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.

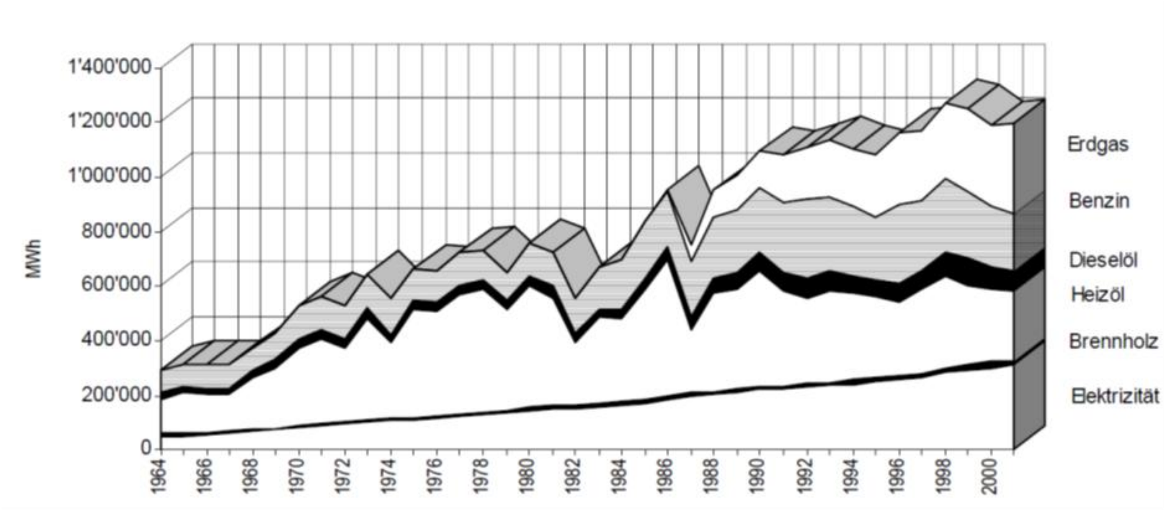


Figure 3-4 Liechtenstein's energy consumption and fuel shares 1964–2001 (OS 2001) in MWh. From top to bottom, the following fuels are shown: natural gas (Erdgas), gasoline (Benzin), diesel (Dieselöl), gas oil (Heizöl), wood (Brennholz), electricity (Elektrizität).

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 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 2024, 35% of Liechtenstein's electricity consumption was produced domestically and 65% was imported (see Table 3-15). In absolute values, the electricity consumption 2024 amounts to around 410 GWh. This corresponds to an increase of 2.1% compared to 2023. Domestic electricity generation increased by 13.4% mainly due to increases in solar power generation. The electricity imports decreased by 3.0% compared to 2023.

Table 3-15 Electricity consumption, generation and imports in Liechtenstein (OS 2025b).

Electricity consumption, generation and imports in Liechtenstein 2024	MWh	Share
Total electricity consumption in Liechtenstein	409'996	100%
Electricity generation in Liechtenstein 2024	142'309	35%
Hydro power	81'998	20%
Natural gas co-generation	1'093	0.3%
Biogas co-generation	291	0.1%
Biomass co-generation	826	0.2%
Photovoltaic	58'101	14.2%
Electricity imports in Liechtenstein 2024	267'687	65%

Liechtenstein's domestic electricity generation is dominated by hydroelectric power plants and photovoltaic plants (see Figure 3-5). Other electricity sources are fossil natural gas and biogas or wood biomass fuelled combined heat and power generation plants.

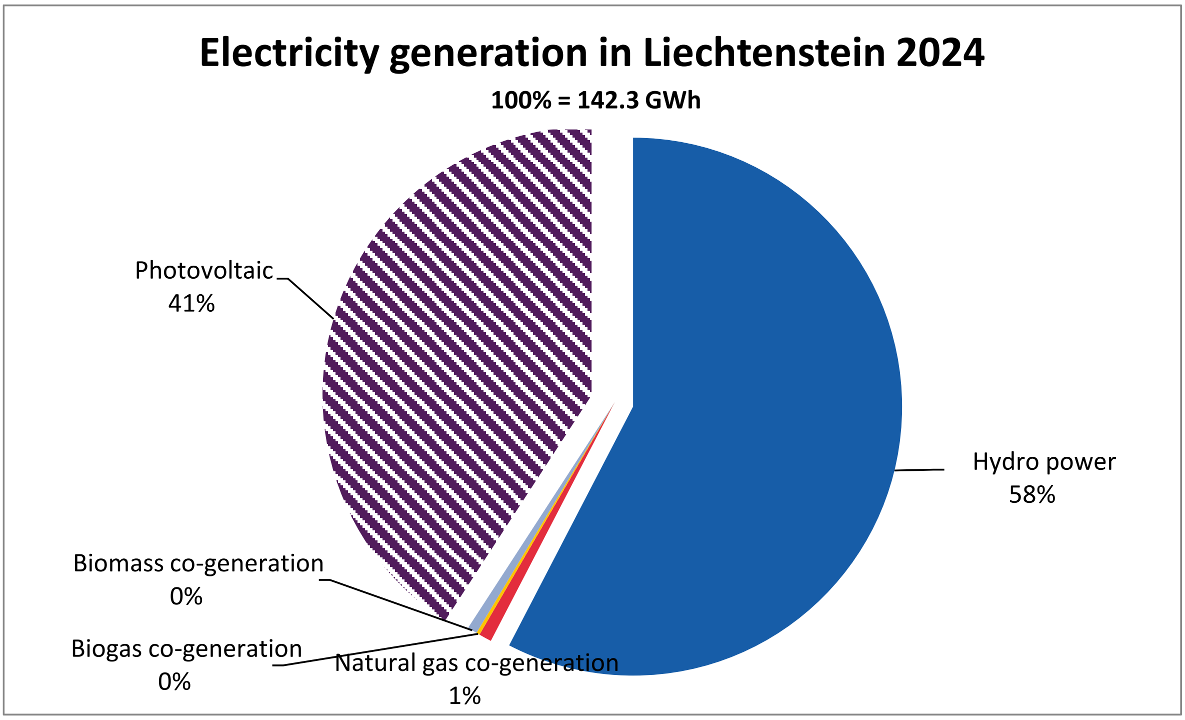


Figure 3-5 Structure of electricity generation in Liechtenstein 2024. Data source: Energy Statistics 2024 (OS 2025b).

Renewable sources account for 99.2% of domestic electricity generation in Liechtenstein. Compared to 2023, the electricity produced by photovoltaic plants has increased by 26.4%. Photovoltaic is thus representing 41% of the total domestic electricity production in 2024.

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 2025a) 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).

Biomass

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

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 2024 (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 2025a). 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 2025b) (for more information see section 3.2.4.2).

In 2024, natural gas accounts for 73% 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 18 from 1990 to 2024. 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 and the amount of biogas and sewage gas consumption in the combined heat and power plant of the wastewater treatment facility increased. Therefore, total biomass consumption increased substantially from 2020 to 2024.

While in 1990, biomass contributed with 88% to electricity production and heat fuel consumption, it only represents about 27% in 2024.

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	**2015**	**2016**	**2017**	**2018**	**2019**	
1A1a Public electricity and heat production	TJ					
Natural gas	36.02	38.16	37.26	38.32	60.17	
Biomass	1.39	2.63	3.38	2.85	3.06	
Source/fuel	**2020**	**2021**	**2022**	**2023**	**2024**	**1990-2024**
1A1a Public electricity and heat production	TJ					%
Natural gas	42.90	45.30	40.52	50.12	39.24	1717%
Biomass	1.76	7.09	9.53	7.94	14.32	-8%

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 chp. 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 chp. 3.2.11.

3.2.5.5 Category-specific recalculations

No category-specific recalculations have been carried out in the 1A1 Energy Industries sector for submission 2026.

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 2025a) 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 chp. 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 2024

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 2025a). 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 2025). Data are taken from OS (2025a).

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 2025).

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	40.3	48.1	47.7
Biodiesel	NO	NO	NO	NO	0.05

Source/fuel	2015	2016	2017	2018	2019
1A2e Food processing, beverages and tobacco	TJ				
Gas oil	113.8	90.4	97.5	78.9	98.2
Natural gas	258.6	260.2	277.9	256.5	227.2
Biomass (Biogas from WWTP)	6.3	5.8	6.6	6.9	6.3
1A2g Other off-road vehicles and machinery					
Diesel	62.9	63.5	67.2	60.7	57.0
Biodiesel	0.53	0.72	0.95	1.02	1.10

Source/fuel	2020	2021	2022	2023	2024	1990-2024
1A2e Food processing, beverages and tobacco	TJ					%
Gas oil	95.3	81.6	73.1	80.4	71.0	-72%
Natural gas	206.9	230.6	205.3	182.0	177.5	-34%
Biomass (Biogas from WWTP)	6.0	6.0	5.2	4.9	4.5	-
1A2g Other off-road vehicles and machinery						
Diesel	57.9	57.7	59.5	50.0	43.7	36%
Biodiesel	1.27	1.61	1.95	1.76	1.70	-

Table 3-20 documents the decrease of gas oil consumption from 1990 to 2024. 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 chp. 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 2024 the consumption of gaseous fuels decreased by 34% 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 2024 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 1990-2024. 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 chp. 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 chp. 3.2.11.

3.2.6.5 Category-specific recalculations

For the 2026 submission, the following recalculations lead to minor changes (<0.1 kt CO_2eq) in CO_2, CH_4 and N_2O emissions in 2023.

- 1A2g: The activity data for biodiesel and bioethanol 1997–2023 were updated, to include the fossil share, which are taken from the newest road transportation model of Switzerland (INFRAS 2025).

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 2025). For CH_4 and N_2O, country-specific emission factors from Switzerland's road transportation model (INFRAS 2025) 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 chp. 3.2.4.2.

Since the energy statistic of Liechtenstein (OS 2025a) 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 (2024: 43’441 registered employees, and about 24’935 commuters, whereof 39.8% are non-Swiss citizens, see OS 2025f) 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 1990–2024.

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 2025) (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 1990–2024 (INFRAS 2025). 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 2025).
- 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	29.91	17.68	13.77	11.23	8.97
N_2O	kg/TJ	3.52	5.08	4.84	1.66	0.97
		Diesel				
CO_2	t/TJ	73.6	73.6	73.6	73.5	73.4
CH_4	kg/TJ	2.63	2.11	1.40	0.87	0.60
N_2O	kg/TJ	0.57	0.65	0.87	1.25	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	29.91	17.68	13.77	11.23	8.97
N_2O	kg/TJ	3.52	5.08	4.84	1.66	0.97
Gas	**unit**	**2015**	**2016**	**2017**	**2018**	**2019**
		Gasoline				
CO_2	t/TJ	73.8	73.8	73.8	73.8	73.8
CH_4	kg/TJ	6.76	6.45	6.19	5.84	5.42
N_2O	kg/TJ	0.60	0.56	0.52	0.51	0.50
		Diesel				
CO_2	t/TJ	73.3	73.3	73.3	73.3	73.3
CH_4	kg/TJ	1.12	1.44	1.79	2.03	2.20
N_2O	kg/TJ	2.81	2.94	3.09	3.20	3.27
		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	6.76	6.45	6.19	5.84	5.42
N_2O	kg/TJ	0.60	0.56	0.52	0.51	0.50
Gas	**unit**	**2020**	**2021**	**2022**	**2023**	**2024**
		Gasoline				
CO_2	t/TJ	73.8	73.8	73.8	73.8	73.8
CH_4	kg/TJ	5.28	4.95	4.68	4.48	4.26
N_2O	kg/TJ	0.66	0.61	0.52	0.50	0.49
		Diesel				
CO_2	t/TJ	73.3	73.3	73.3	73.3	73.3
CH_4	kg/TJ	2.17	2.29	2.40	2.47	2.53
N_2O	kg/TJ	3.35	3.38	3.39	3.43	3.47
		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	5.28	4.95	4.68	4.48	4.26
N_2O	kg/TJ	0.66	0.61	0.52	0.50	0.49

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	2015	2016	2017	2018	2019
		Bioethanol				
CO_2	t/TJ	73.8	73.8	73.8	73.8	73.8
CH_4	kg/TJ	6.66	6.70	6.75	6.53	6.19
N_2O	kg/TJ	0.65	0.62	0.58	0.57	0.57
		Biodiesel				
CO_2	t/TJ	73.3	73.3	73.3	73.3	73.3
CH_4	kg/TJ	1.11	1.45	1.83	2.13	2.32
N_2O	kg/TJ	2.76	2.90	3.09	3.25	3.37
		Biogas (since 2013)				
CO_2	t/TJ	56.1	56.1	56.1	56.1	56.1
CH_4	kg/TJ	27.36	25.71	23.80	22.72	21.56
N_2O	kg/TJ	3.16	3.11	3.26	3.15	3.14

Gas	unit	2020	2021	2022	2023	2024
		Bioethanol				
CO_2	t/TJ	73.8	73.8	73.8	73.8	73.8
CH_4	kg/TJ	6.06	6.06	6.16	6.16	6.16
N_2O	kg/TJ	0.70	0.66	0.56	0.56	0.56
		Biodiesel				
CO_2	t/TJ	73.3	73.3	73.3	73.3	73.3
CH_4	kg/TJ	2.37	2.51	2.62	2.62	2.62
N_2O	kg/TJ	3.50	3.58	3.62	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	19.72	18.45	15.69	15.69	15.69
N_2O	kg/TJ	4.26	3.59	3.12	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, 2001–2024 as well as domestic fuel consumption for 2012–2024 (Rotex Helicopter AG 2006–2025). The fleet consists of four 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 1990–2024 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	**2015**	**2016**	**2017**	**2018**	**2019**	
1A3a Domestic aviation (helicopters only)	TJ					
Kerosene (domestic)	0.81	0.56	0.35	0.40	1.14	
Source/fuel	**2020**	**2021**	**2022**	**2023**	**2024**	**1990-2024**
1A3a Domestic aviation (helicopters only)	TJ					%
Kerosene (domestic)	0.81	0.84	0.85	1.05	1.39	35%

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 2025).

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	976	770	591	
Diesel	200	184	239	302	408	
Natural Gas	NO	NO	NO	32.4	59.4	
Lubricants (1A3biv)	0.1047	0.0499	0.0775	0.0626	0.0406	
Biogas	NO	NO	NO	NO	NO	
Bioethanol	NO	NO	0.78	1.73	1.61	
Biodiesel	NO	NO	NO	NO	0.4	
Sum	**1’020**	**1’086**	**1’216**	**1’106**	**1’061**	
1990=100%	100%	107%	119%	109%	104%	
Fuel	**2015**	**2016**	**2017**	**2018**	**2019**	
	TJ					
Gasoline	404	374	360	349	343	
Diesel	415	433	455	438	424	
Natural Gas	17.4	9.5	5.6	7.0	5.4	
Lubricants (1A3biv)	0.0183	0.0160	0.0149	0.0137	0.0120	
Biogas	0.43	0.21	0.13	0.19	0.15	
Bioethanol	3.82	6.57	10.41	13.95	13.95	
Biodiesel	3.18	4.44	5.85	6.68	7.43	
Sum	**844**	**827**	**837**	**815**	**794**	
1990=100%	83%	81%	82%	80%	78%	
Fuel	**2020**	**2021**	**2022**	**2023**	**2024**	**1990-2024**
	TJ					%
Gasoline	308	326	290	399	275	-66%
Diesel	400	427	385	326	301	50%
Natural Gas	2.8	2.5	2.1	1.6	1.4	-
Lubricants (1A3biv)	0.0108	0.0094	0.0069	0.0082	0.0050	-95%
Biogas	0.08	0.06	0.05	0.04	0.03	-
Bioethanol	12.14	10.31	9.04	13.62	11.02	-
Biodiesel	7.91	10.75	11.39	10.38	10.60	-
Sum	**731**	**776**	**697**	**751**	**599**	**-41%**
1990=100%	72%	76%	68%	74%	59%	

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 chp. 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 chp. 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 0.05 kt CO_2eq in 2023:

- 1A3b: The activity data for biodiesel and bioethanol 1990–2023 were updated, to include the fossil part of the carbon content, which are taken from the newest road transportation model of Switzerland (INFRAS 2025).
- 1A3b: The emission data for vehicles has been updated according to the latest road model of Switzerland for the years 1990–2023 (INFRAS 2025). This has changed the consumption of gasoline, diesel and lubricants.

3.2.7.6 Category-specific planned improvements

In submission 2026, the planned improvement of disaggregating road transport data by vehicle type could not yet be implemented due to a lack of data. This improvement is scheduled for submission 2027.

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 2025a) 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 2025 (FOEN 2025).

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 2025 (FOEN 2025). 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 2024.

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 2024.

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 2025a). 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 2025e). 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	2015	2016	2017	2018	2019
	TJ				
1A4a Commercial/institutional	**645.60**	**561.29**	**588.32**	**538.53**	**567.10**
Gas oil	341.39	271.17	292.35	236.73	294.70
LPG	3.68	3.63	3.50	3.82	3.59
Natural gas	170.73	161.40	174.91	158.49	140.78
Coal	NO	NO	NO	NO	NO
Biomass	129.81	125.09	117.56	139.49	128.04
1A4b Residential	**639.13**	**620.03**	**640.90**	**604.66**	**656.06**
Gas oil	113.80	90.39	97.45	78.91	98.23
Alkylate gasoline	0.12	0.20	0.20	0.12	0.12
Natural gas	430.90	438.68	456.84	424.07	462.20
Coal	NO	NO	NO	NO	NO
Biomass	94.32	90.75	86.41	101.56	95.51

Source/fuel	2020	2021	2022	2023	2024	1990-2024
	TJ					%
1A4a Commercial/institutional	**539.98**	**516.01**	**476.05**	**483.93**	**478.10**	**-49%**
Gas oil	285.92	244.81	219.15	241.34	213.02	-72%
LPG	3.68	3.36	3.04	9.02	10.17	-24%
Natural gas	147.81	171.06	138.54	123.38	130.58	-7%
Coal	NO	NO	NO	NO	NO	-
Biomass	102.57	96.78	115.32	110.20	124.33	383%
1A4b Residential	**637.21**	**670.37**	**580.63**	**554.18**	**533.21**	**71%**
Gas oil	95.31	81.60	73.05	80.45	71.01	-72%
Alkylate gasoline	0.15	0.12	0.10	0.12	0.14	-
Natural gas	462.88	513.75	422.23	391.74	371.95	802%
Coal	NO	NO	NO	NO	NO	-
Biomass	78.87	74.90	85.24	81.87	90.12	425%

Since 1990, gas oil consumption decreased 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 1st 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 2023 to 2024.

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 2025b) 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 2025e).

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	17.51	18.24	18.50
Biodiesel	NO	NO	NO	NO	0.02

Source/fuel	2015	2016	2017	2018	2019
1A4c Other Sectors - Agriculture/forestry	TJ				
Alkylate gasoline	0.47	0.80	0.82	0.49	0.48
Diesel	15.62	14.60	15.53	22.65	22.03
Biodiesel	0.14	0.17	0.23	0.39	0.44

Source/fuel	2020	2021	2022	2023	2024	1990-2024
1A4c Other Sectors - Agriculture/forestry	TJ					%
Alkylate gasoline	0.60	0.50	0.42	0.50	0.55	-
Diesel	23.83	24.17	25.25	22.48	20.54	15%
Biodiesel	0.53	0.69	0.84	0.81	0.82	-

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 chp. 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 chp. 3.2.11.

3.2.8.5 Category-specific recalculations

No category-specific recalculations have been carried out in 1A4 Other sectors for submission 2026.

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 2025):

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 2025). 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) = 0.29%
- Liquid fuels (1A2, 1A4): U(EF CO_2) = 0.06%
- 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) = 9.17%, U(EF) = 0.07%.

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) = 3.9%, U(EF) = 0.29%

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 chp. 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 1990–2024. The entire time series are therefore consistent.

Completeness

The emissions for the entire time series 1990–2024 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 2025a).

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 2024 (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	-	-
		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		1990-2024
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		1990-2024
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 2025, edition 2024 includes data up to 2024, 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		2015	2016	2017	2018	2019
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	341.2	347.0	352.0	355.6	360.7
Connections	number	4’486	4’491	4’571	4’651	4’715

Source/fuel		2020	2021	2022	2023	2024	1990-2024
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	51.6	51.6	51.4	52.0	82%
HDPE (Polyethylene) < 100 mbar	km	363.5	366.8	370.0	374.6	371.7	455%
Connections	number	4’758	4’768	5’330	4’523	4’523	844%

Table 3-36 documents the continuous increase of Liechtenstein’s gas supply network since 1990. By 2024, the number of connections installed have increased by about a factor of 8.4 compared to 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	2015	2016	2017	2018	2019
1B2b Fugitive emissions from natural gas						
Natural gas volume industry	Mio. m^3	7.1	7.2	7.7	7.1	6.3
Natural gas volume other	Mio. m^3	18.1	17.9	18.6	17.3	18.5
Sum natural gas volume	Mio. m^3	**25.2**	**25.1**	**26.3**	**24.4**	**24.7**

Source/fuel	Unit	2020	2021	2022	2023	2024	1990-2024
1B2b Fugitive emissions from natural gas							%
Natural gas volume industry	Mio. m^3	5.7	6.4	5.7	5.0	4.9	-34%
Natural gas volume other	Mio. m^3	18.1	20.2	16.7	15.7	15.0	195%
Sum natural gas volume	Mio. m^3	**23.9**	**26.6**	**22.4**	**20.7**	**19.9**	**59%**

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 2023 and for the changing rates 2023/2024).

3.3.2.5 Category-specific recalculations

No category-specific recalculations have been carried out in 1B2 Fugitive emissions from oil and natural gas and other emissions from energy production for submission 2026.

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).

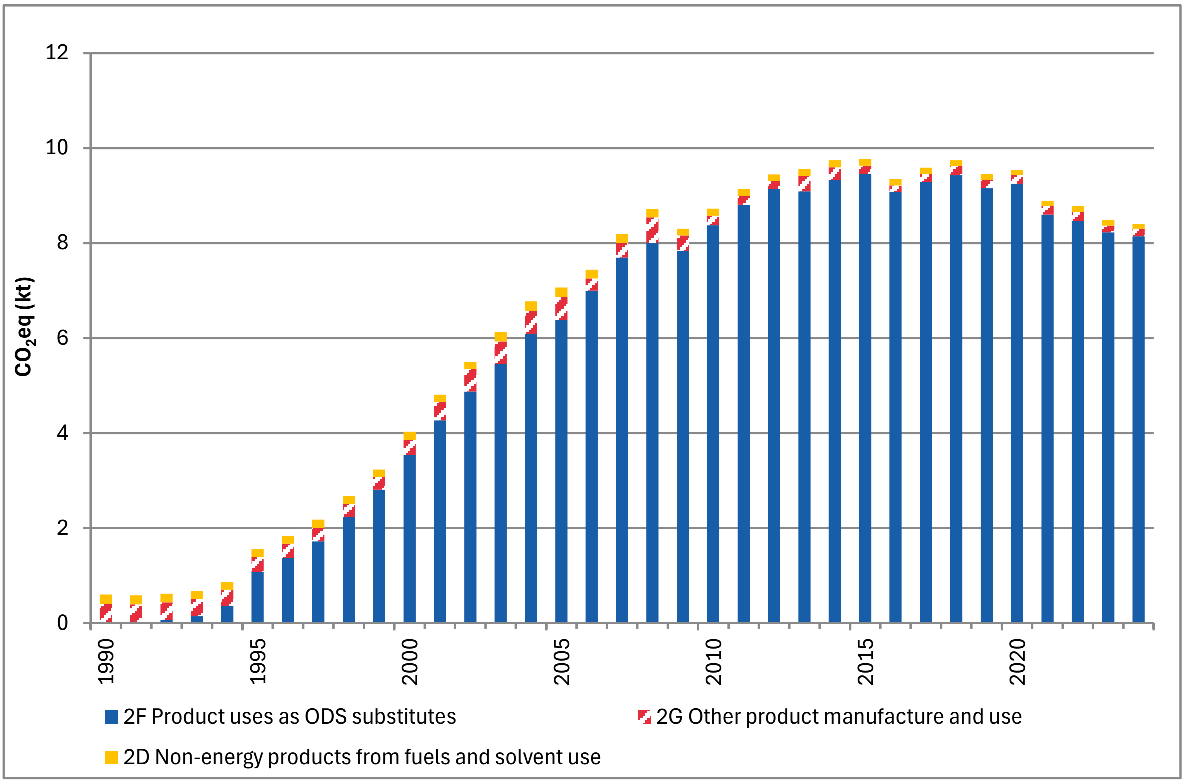


Figure 4-1 Liechtenstein's GHG emissions of sector 2 Industrial processes and product use. Note that there are no emissions in sectors 2A, 2B, 2C, 2E and 2H.

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 8.5 kt CO_2 equivalent in 2024. Emissions of the IPPU sector play therefore a minor role in Liechtenstein's inventory and contribute to 5.6% to the total emissions excluding LULUCF. 8.1 kt CO_2 equivalent were emitted in sector 2F Product uses as ODS substitutes and another 0.2 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 13.9 since 1990. This trend is in particular dominated by the increase in HFC emissions. CO_2 emissions decreased by 50% and N_2O emissions decreased by 67% between 1990 and 2024.

From 2023 to 2024, the total F-gas emissions decreased by 0.8%, HFC emissions decreased by 1.0%, PFC emissions decreased by 1.6% and SF_6 emissions increased by 70.0%.

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	6.65	8.40
Sum	**0.60**	**1.55**	**4.03**	**7.07**	**8.73**

Gas	2015	2016	2017	2018	2019
	CO2 equivalent (kt)				
CO_2	0.14	0.14	0.13	0.12	0.12
N_2O	0.14	0.13	0.12	0.12	0.13
F-Gases	9.49	9.08	9.33	9.50	9.21
Sum	**9.77**	**9.35**	**9.59**	**9.75**	**9.45**

Gas	2020	2021	2022	2023	2024	1990-2024
	CO2 equivalent (kt)					%
CO_2	0.11	0.11	0.12	0.11	0.10	-50%
N_2O	0.13	0.13	0.13	0.13	0.13	-67%
F-Gases	9.31	8.65	8.53	8.24	8.17	8506600%
Sum	**9.54**	**8.89**	**8.78**	**8.48**	**8.41**	**1293%**

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		2015	2016	2017	2018	2019	
Inhabitants Switzerland	number	8’282’000	8’373’000	8’452’000	8’514’000	8’575’000	
Emissions 2D1 Switzerland	kt	30.5	30.2	29.5	27.0	26.1	
2D1 EF CO_2 from Lubricant use - CO_2	kg/inhabitant	3.68	3.60	3.49	3.17	3.05	
Emission factors 2D Non-energy products from fuels and solvents		2020	2021	2022	2023	2024	1990-2024 %
Inhabitants Switzerland	number	8’638’000	8’705’000	8’777’000	8’889’000	9’007’000	34%
Emissions 2D1 Switzerland	kt	23.5	25.0	25.5	24.7	22.6	-52%
2D1 EF CO_2 from Lubricant use - CO_2	kg/inhabitant	2.73	2.87	2.91	2.77	2.51	-64%

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 2025b). 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	2015	2016	2017	2018	2019	
	Number of inhabitants					
Liechtenstein	37’623	37’810	38’114	38’380	38’749	
Number of inhabitants for AD calculations	2020	2021	2022	2023	2024	1990-2024 %
	Number of inhabitants					
Liechtenstein	39’055	39’315	39’677	40’015	40’886	41%

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

Switzerland's GHG inventory 2026 was not yet available for Liechtenstein's submission 2026. For Switzerland, the following recalculations have been carried out in submission 2025, which also influence Liechtenstein's emission time series reported in Submission 2026:

- The activity data of lubricant use in 2-stroke engines and thus also of unspecified lubricant use have changed for the entire time series due to recalculated gasoline and bioethanol consumption in 1A3biv 2-stroke motorcycles.

In addition, the following recalculations lead to changes in CO_2 emissions:

- 2D1: Since the number of inhabitants in Switzerland was updated based on newest available statistics (SFSO 2025d) the activity data (number of inhabitants) has changed in 2022.
- 2D: The emission factors for the use of lubricants for the year 2022 were not correct in the last submission. The mistake has been corrected.

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 2025a) 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 2025 (FOEN 2025).

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 2025 (FOEN 2025), 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 2025a):

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 of FOEN 2025)*
- *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. 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 2025). Parameters for commercial and industrial applications are given in Table 4-46. 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 HFC-125 HFC-134a HFC-143a C_3F_8	Total emissions reported for Switzerland	Number of persons employed in industrial and service sector
Transport Refrigeration	HFC-125 HFC-134a HFC-143a	Total emissions reported for Switzerland	Number of inhabitants
Industrial Refrigeration	Included in commercial refrigeration		
Stationary Air Conditioning	HFC-32 HFC-125 HFC-134a HFC-143a	Total emissions reported for Switzerland	Number of persons employed in industrial and service sector
Mobile Air Conditioning	HFC-134a	Total emissions reported for Switzerland (cars, trucks, railway)	Number of registered cars

Foam blowing agents (2F2)

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

More details of the underlying data models are documented in Switzerland's National Inventory Report 2025 (FOEN 2025), 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 of FOEN 2025) 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 2025).*

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 2025 (FOEN 2025), 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 of metered dose inhalers and further technical applications). The consumption of metered dose inhalers was extrapolated for the time period 2021 to 2023 considering the development of HFC use of former years and the reported consumption of inhalers containing HFC in Switzerland (Carbotech, 2025). For imports of HFC-365mfc considered for use in solvent sprays a Tier 2a approach is applied for the whole time period.

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 2025a). The following explanations are taken from Switzerland's National Inventory Document 2025 (FOEN 2025):

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 2025, 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 2023 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 2023 (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 2025).

	Product life time	HFC/PFC Stock 2023	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	1'536	R404a, R407C, R449a, R410a, R507, R422d, R448a	NR	0.5	1995: 12.5 2023: 7.8	24	80-90	NE
Industrial refrigeration	15	447	HFC134a, R410a, R407c, R404a, R422d, R507, R513a	NR	0.5	1995: 10 2023: 5	15	75-90	NE
Transport refrigeration: trucks/vans	10	57	R404a, R134a, R449a	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	2'430	R410a, HFC134a, R407c, R404a, HFC32, R417a, R449a, R513a, R452a	NR	1995: 3 2023: 1	1995:10 2023:4	28	74-89	NE
Stationary air conditioning: indirect cooling systems	15			NR	1.0	1995: 6 2023: 4	19	85-89	NE
Stationary air conditioning: heat pumps	15			1995: 4.7-7.5 2023: 2.8-4.5	1995: 3 2023: 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	2'386	HFC134a	1995: 0.84 2023: 0.55	NO	8.5	50	58.0	1995: 31-72 2023: 59
Mobile air conditioning: truck/van cabins	12			1.1	NO	1995: 10 2023: 8.5	50	69-73	90 trucks / 50 vans
Mobile air conditioning: buses	12			7.5	NO	1995: 20 2023:15	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 2025a). The following explanations are taken from Switzerland's National Inventory Document 2025 (FOEN 2025):

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 2025).

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				NR / 0.7**	
XPS foam HFC-152a	50	6.5	NR	100 / 0**	
PU spray all HFC	50	13.6 / 0 *	<1%	95 / 2.5 **	
Unknown use:					
HFC 134a, HFC 227ea, HFC 365 mfc			10	10 / 4.5 **	
HFC 152a	20	NR	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 2025a). The following explanations are taken from Switzerland's National Inventory Document 2025 (FOEN 2025):

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		2024	
Number of households				
Liechtenstein	10’556	Source: National census 1990 (OEA 2010)	18’529	Source: National census 2010 with trend extrapolation (OEA 2010)
Switzerland	2’841’850	Source: National census 1990 (SFSO 2005)	4’063’044	Source: Population and Households Statistics (SFSO 2025e)
Conversion Factor CH→LIE	0.371%		0.456%	
Number of employees in industrial and service sector				
Liechtenstein	19’554	Source: Employment statistics Liechtenstein (OS 2025e)	43’164	Source: Employment statistics Liechtenstein (OS 2025e)
Switzerland	3’658’406	Source: Employment statistics Switzerland (SFSO 2025b)	5’215’261	Source: Employment statistics Switzerland (SFSO 2025b)
Conversion Factor CH→LIE	0.534%		0.828%	
Number of registered passenger cars				
Liechtenstein	16’891	Source: Statistical Yearbook Liechtenstein (OS 2025c)	31’333	Source: Statistical Yearbook Liechtenstein (OS 2025c)
Switzerland	2’985’397	Source: National motorcar statistics for Switzerland (SFSO 2025c)	4’796’090	Source: National motorcar statistics for Switzerland (SFSO 2025c)
Conversion factor CH→LIE	0.566%		0.653%	

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 2024		
Liechtenstein	40’886	Source: OS 2025d
Switzerland	9’007’000	Source: SFSO 2025d
Conversion Factor CHE→LIE	0.454%	

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 2025 (FOEN 2025) for HFC, which were derived from a Monte Carlo simulation. It amounts to 12%. 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 2023 and for the changing rates 2023/2024).

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 2026 was not yet available for Liechtenstein’s submission 2026. For Switzerland, the following recalculations have been carried out in submission 2025, which also influence Liechtenstein’s emission time series reported in Submission 2026:

- 2F1: There are changes in activity data 2020–2022 for the disposal of HFC and PFC from commercial and industrial equipment: The modelling of the remaining refrigerant amount for use in stationary refrigeration was reduced.
- 2F1: There are changes in activity data 2022 of HFC and PFC use for mobile and air-conditioning and stationary refrigeration related to changes in the vehicle and equipment statistics.
- 2F1: There are changes in the activity data 2020–2022: The portion of HFC in air-conditioning of vans was revised.
- 2F2: There are changes in activity data 2020–2022 related to the portion of PU-Spray containing HFC-134a.

In addition, the following recalculations lead to changes in HFC and PFC emissions:
- 2F1, 2F2, 2F4: Since the number of inhabitants in Switzerland was updated based on newest available statistics (SFSO 2025d) the activity data (number of inhabitants) has changed in 2022.
- 2F1: Since the number of vehicles in Liechtenstein was updated based on newest available statistics (OS 2025c) the activity data (number of inhabitants) has changed in 2021–2023.

In 2023, the above mentioned recalculations lead to an increase in HFC/PFC emissions of around 0.73 kt CO_2eq.

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 2025a). 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 2025a, SFSO 2025d) 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 1990–2024.

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	2015	2016	2017	2018	2019
2G1 Electrical equipment - SF6 product life factor (% per annum)	0.041	0.016	0.049	0.074	0.050
2G3 N_2O from product uses - N_2O (g/inhabitant)	14.0	12.8	12.3	12.3	12.2

Emission factors 2G Other product manufacture and use	2020	2021	2022	2023	2024	1990-2024 %
2G1 Electrical equipment - SF6 product life factor (% per annum)	0.057	0.054	0.071	0.016	0.028	-
2G3 N_2O from product uses - N_2O (g/inhabitant)	12.2	12.1	12.2	12.2	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

Activity data 2G Other product manufacture and use	2015	2016	2017	2018	2019
2G1 Electrical equipment - SF_6 amount in operating systems (average annual stocks) in kt	0.0040	0.0040	0.0040	0.0041	0.0041
2G3 N_2O from product uses - number of inhabitants	37'623	37'810	38'114	38'380	38'749

Activity data 2G Other product manufacture and use	2020	2021	2022	2023	2024	1990-2024 %
2G1 Electrical equipment - SF_6 amount in operating systems (average annual stocks) in kt	0.0041	0.0042	0.0042	0.0043	0.0043	-
2G3 N_2O from product uses - number of inhabitants	39'055	39'315	39'677	40'015	40'886	41%

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 2025d. Data on the Swiss inhabitants (see Table 4-9) are taken from SFSO 2025d.

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 2023 and for the changing rates 2023/2024).

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

- 2G3: Since the number of inhabitants in Switzerland was updated based on newest available statistics (SFSO 2025d) the activity data (number of inhabitants) has changed in 2022.

In 2023, the above mentioned recalculations lead to an increase in N_2O emissions of <0.001 kt CO_2eq.

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 submission 2025. Note that the nitrogen flow model AGRAMMON has not been changed during this update. 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 23.7 kt CO_2 equivalents in 2024, which is a contribution of 15.7% to the total of Liechtenstein's greenhouse gas emissions (excluding LULUCF). Main agricultural sources of greenhouse gases in 2024 were enteric fermentation (3A) emitting 15.6 kt CO_2eq, followed by manure management (3B) with 4.1 kt CO_2eq and agricultural soils (3D) with 4.0 kt CO_2eq. Urea application (3H) only contributes to a minor share of emissions (<0.1 kt CO_2eq). Overall emissions from agriculture decreased by 4.5% between 1990 and 2024 (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 (2023), emissions have slightly decreased (by 2%).

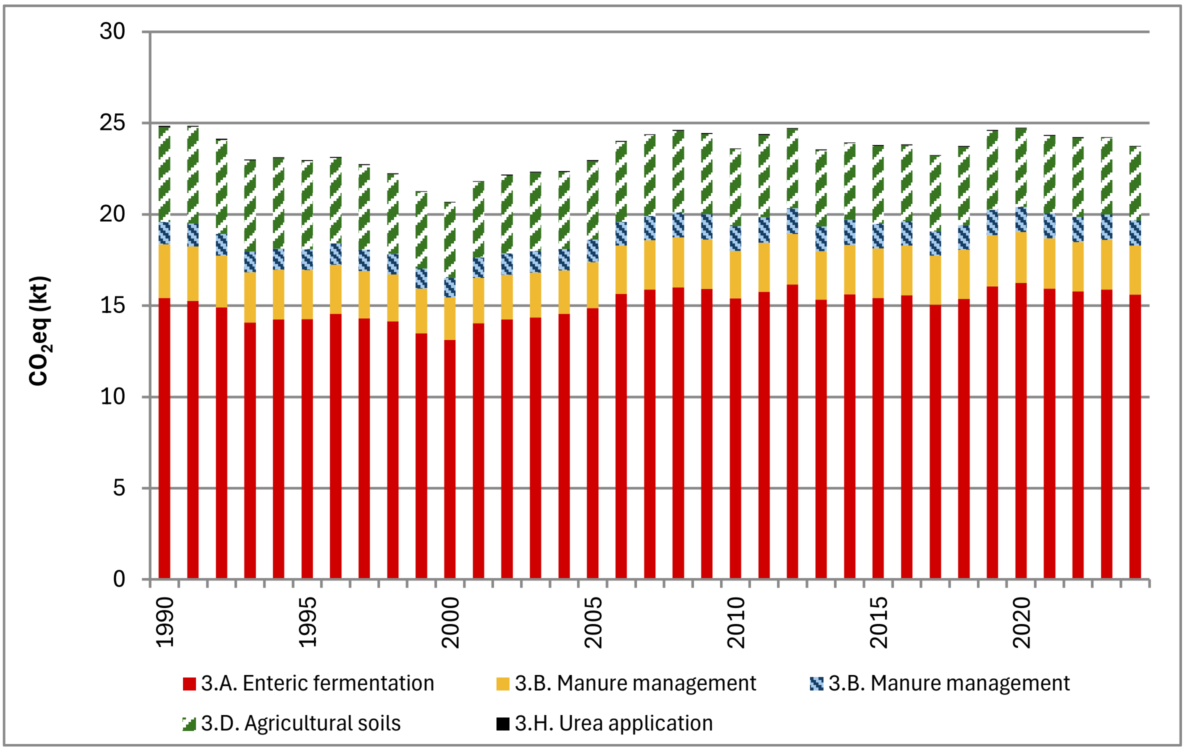


Figure 5-1 Liechtenstein's GHG emissions of the sector 3 Agriculture by sub-sectors. Note that emissions in sub-sectors 3C, 3E, 3F, 3G, 3I are not occurring.

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 39.5% in 2024 compared to 1990. The development of urea application is similar as in Switzerland (see Swiss inventory, FOEN 2025, chp. 5.1). CH_4 emissions are slightly below 1990 levels (-0.4%). N_2O emissions decreased by 15.7% between 1990 and 2024. 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	2015	2016	2017	2018	2019
	CO_2 equivalent (kt)				
CO_2	0.05	0.04	0.04	0.05	0.05
CH_4	18.13	18.28	17.74	18.07	18.86
N_2O	5.62	5.51	5.47	5.62	5.71
Sum	**23.80**	**23.83**	**23.25**	**23.74**	**24.62**

Gas	2020	2021	2022	2023	2024	1990-2024
	CO_2 equivalent (kt)					%
CO_2	0.04	0.04	0.05	0.04	0.04	-39.5%
CH_4	19.03	18.68	18.48	18.60	18.29	-0.4%
N_2O	5.67	5.62	5.70	5.60	5.42	-15.7%
Sum	**24.75**	**24.34**	**24.22**	**24.24**	**23.74**	**-4.5%**

There are five 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 2024.

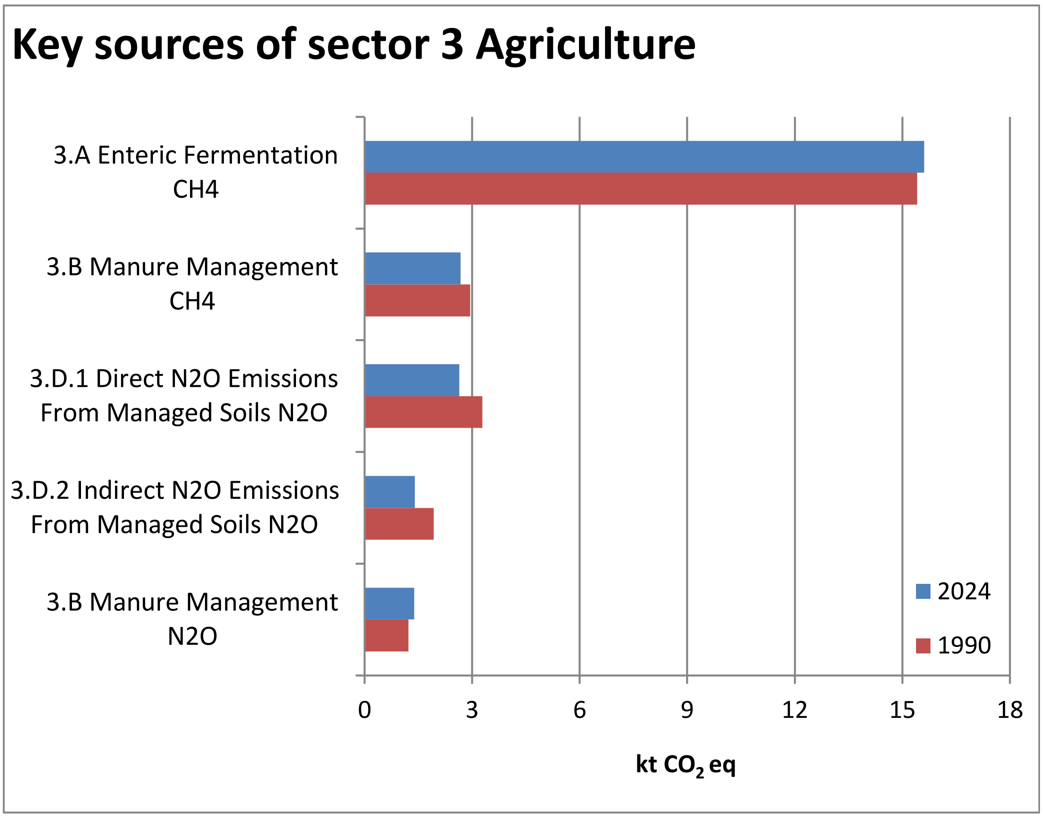


Figure 5-2 Key categories from agriculture (KCA excl. LULUCF). Emissions in CO_2 equivalents (kt) per key source category in 2024 and in the base year 1990.

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 Other mature cattle 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 Milksheep
3A3	Swine	Swine
3A4a	Goats	Goats
3A4b	Horses	Horses < 3 years Horses > 3 years
3A4c	Mules and Asses	Mules and Asses
3A4d	Poultry	Poultry

5.2.2 Methodological issues: Enteric fermentation (3A)

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.

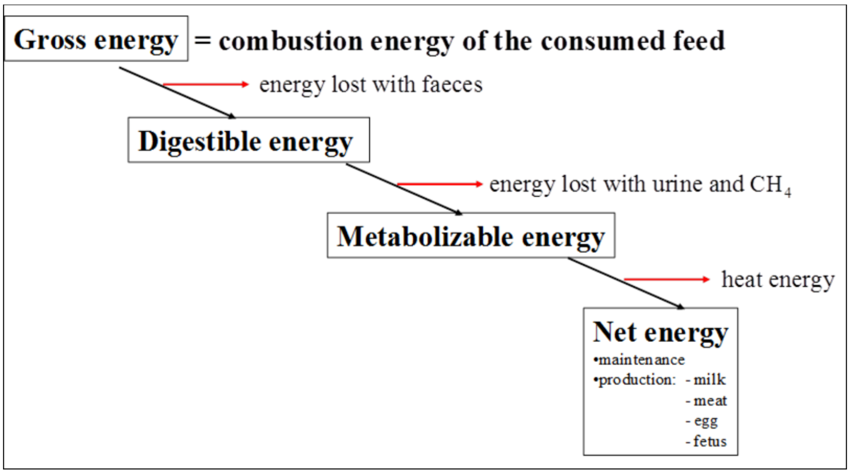


Figure 5-3 Levels of feed energy conversion (Soliva 2006a).

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)

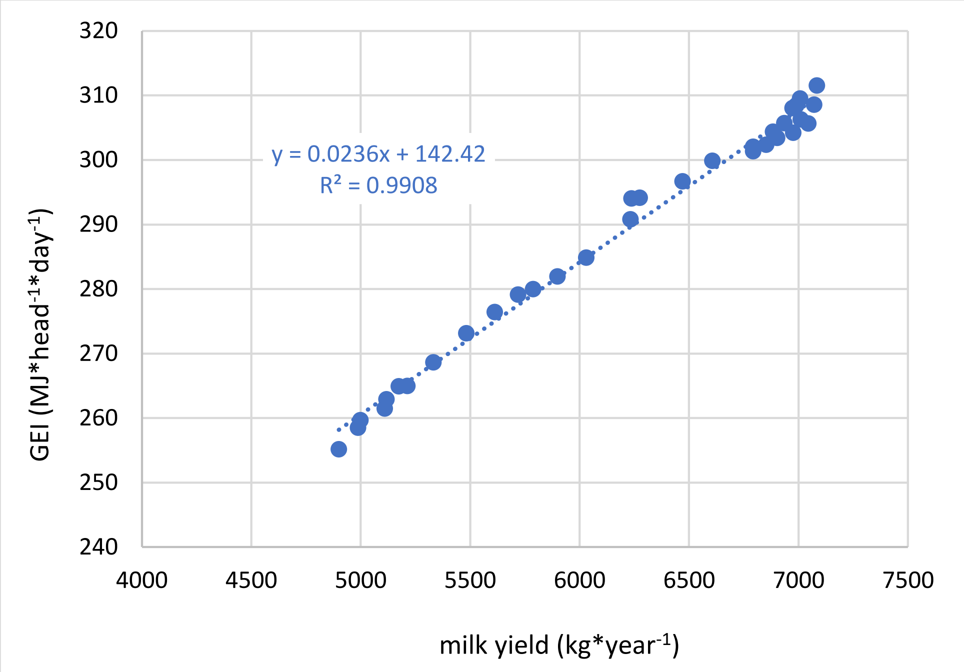


Figure 5-4 Linear regressions relating gross energy intake (GE) to milk yield for mature dairy cattle for Switzerland (based on FOEN 2024).

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 2024 (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		**2015**	**2016**	**2017**	**2018**	**2019**
Population Size Mature Dairy Cattle	head	2'299	2'232	2'246	2'271	2'332
Lactation Period	day	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	22.73	23.09	23.15	23.55	24.53
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	8.20	8.20	8.20

Milk Production Cattle		**2020**	**2021**	**2022**	**2023**	**2024**
Population Size Mature Dairy Cattle	head	2'311	2'231	2'194	2'187	2'199
Lactation Period	day	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	24.09	23.74	23.36	23.26	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	2015	2016	2017
	MJ/head/day							
Cattle	640.8	639.5	650.1	659.6	657.5	663.0	667.3	666.0
Mature Dairy Cattle	279.1	280.5	291.6	302.5	299.8	306.0	308.6	309.0
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	106.4	108.1	106.4
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	108.2	108.5	108.6
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	2018	2019	2020	2021	2022	2023	2024
	MJ/head/day						
Cattle	668.9	675.7	673.5	670.8	668.6	667.5	667.3
Mature Dairy Cattle	312.0	319.0	315.8	313.3	310.5	309.9	309.9
Other Mature Cattle	250.6	250.6	250.6	250.6	250.6	250.6	250.6
Growing Cattle (weighted average)	106.3	106.1	107.1	106.9	107.5	107.0	106.8
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	108.5	108.5	108.6	108.8	108.7	102.5
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 2024. 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 (2006)
Growing Cattle	6.1%	Weighted average
Fattening Calves	*0.0%*	*Based on Tables 10.12 and 10A.2 in IPCC (2006) (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 (2006)*
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	2015	2016	2017
	1000 head							
Cattle	6.33	5.86	4.95	5.57	5.99	6.03	6.23	5.79
Mature Dairy Cattle	2.85	2.64	2.44	2.49	2.43	2.30	2.23	2.25
Other Mature Cattle	0.02	0.05	0.07	0.36	0.38	0.47	0.41	0.43
Growing Cattle (weighted average)	3.46	3.17	2.43	2.72	3.19	3.27	3.59	3.11
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*	*0.34*	*0.30*	*0.32*
Breeding Cattle 1st Year	*1.14*	*1.06*	*0.65*	*0.60*	*0.81*	*0.83*	*0.98*	*0.79*
Breeding Cattle 2nd Year	*0.90*	*0.70*	*0.54*	*0.68*	*0.81*	*0.82*	*0.97*	*0.78*
Breeding Cattle 3rd Year	*0.63*	*0.58*	*0.34*	*0.35*	*0.46*	*0.47*	*0.55*	*0.44*
Fattening Cattle	*0.72*	*0.73*	*0.77*	*0.74*	*0.74*	*0.73*	*0.70*	*0.71*
Sheep	2.78	2.63	2.98	3.06	3.66	3.89	4.05	4.12
Swine	3.25	2.43	1.99	1.70	1.69	1.75	1.79	1.88
Goats	0.17	0.15	0.16	0.32	0.43	0.29	0.33	0.36
Horses (weighted average)	0.17	0.16	0.16	0.27	0.34	0.30	0.27	0.26
Horses <3 years	*0.03*	*0.03*	*0.02*	*0.03*	*0.03*	*0.03*	*0.02*	*0.01*
Horses >3 years	*0.13*	*0.14*	*0.14*	*0.24*	*0.30*	*0.27*	*0.25*	*0.24*
Mules and Asses	0.07	0.13	0.22	0.14	0.15	0.16	0.17	0.16
Poultry	4.44	6.25	8.06	10.45	12.92	12.50	12.83	12.46

Population size	2018	2019	2020	2021	2022	2023	2024	1990-2024
	1000 head							%
Cattle	5.89	6.12	6.39	6.27	6.27	6.35	6.24	-1.4%
Mature Dairy Cattle	2.27	2.33	2.31	2.23	2.19	2.19	2.20	-23%
Other Mature Cattle	0.45	0.49	0.48	0.50	0.47	0.52	0.47	2245%
Growing Cattle (weighted average)	3.17	3.30	3.60	3.55	3.61	3.64	3.57	3%
Fattening Calves	*0.08*	*0.08*	*0.08*	*0.08*	*0.07*	*0.07*	*0.08*	50%
Pre-Weaned Calves	*0.33*	*0.36*	*0.36*	*0.36*	*0.35*	*0.38*	*0.38*	2407%
Breeding Cattle 1st Year	*0.80*	*0.83*	*0.95*	*0.94*	*0.97*	*0.97*	*0.95*	-16%
Breeding Cattle 2nd Year	*0.79*	*0.82*	*0.94*	*0.93*	*0.96*	*0.96*	*0.93*	3%
Breeding Cattle 3rd Year	*0.45*	*0.47*	*0.53*	*0.53*	*0.55*	*0.55*	*0.54*	-15%
Fattening Cattle	*0.72*	*0.75*	*0.74*	*0.72*	*0.71*	*0.72*	*0.70*	-3%
Sheep	3.99	3.88	3.83	4.23	4.44	4.46	4.19	51%
Swine	1.77	1.72	1.47	1.63	1.56	1.49	1.49	-54%
Goats	0.43	0.43	0.51	0.54	0.50	0.50	0.41	142%
Horses (weighted average)	0.24	0.25	0.24	0.23	0.24	0.24	0.28	66%
Horses <3 years	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.24*	612%
Horses >3 years	*0.23*	*0.24*	*0.22*	*0.21*	*0.23*	*0.23*	*0.04*	-70%
Mules and Asses	0.23	0.22	0.23	0.23	0.22	0.21	0.19	158%
Poultry	12.92	15.01	15.44	20.64	20.70	20.66	20.74	368%

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.

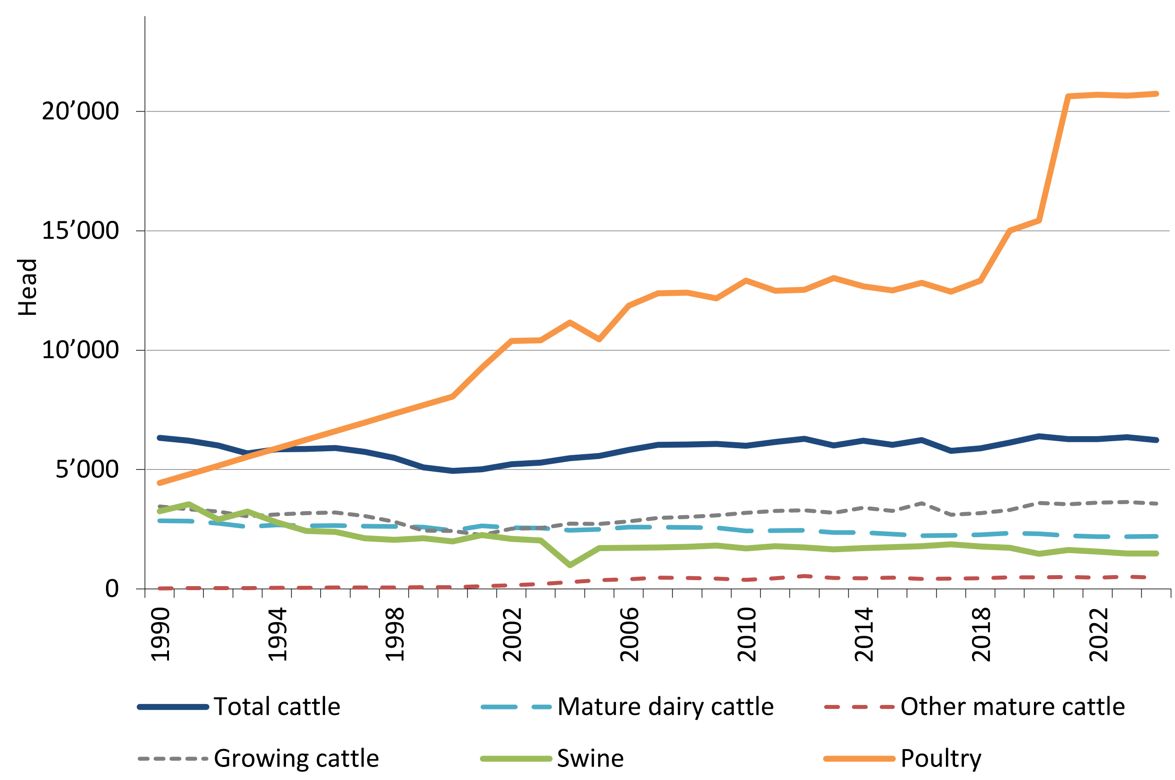


Figure 5-5 Development of population size of main animal categories (Division of Agriculture).

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 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. Uncertainty values used in Approach 2 (some of which are asymmetric) are depicted in Table A - 5.

The time series 1990–2024 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 2023 as well as an analysis of the increase or decrease of emissions between 2023 and 2024 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 NID (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

No category-specific recalculations have been carried out in 3A Enteric fermentation for submission 2026.

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).
N_2O emissions from 2B Manure Management are a key category by 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 2024 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 63% 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 Other mature cattle Growing cattle (fattening calves, Pre-weaned calves, breeding cattle 1st year, breeding cattle 2nd year, breeding cattle 3rd year, fattening cattle)
3B2	Sheep	Fattening sheep Milk sheep
3B3	Swine	Piglets Fattening pig over 25 kg Dry sows Nursing sows Boars
3B4	Other livestock	Goats Horses (Horses < 3 years, Horses > 3 years) Poultry Mules and Asses

Table 5-9 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 Pre-Weaned Calves Breeding Cattle 1st year Breeding Cattle 2nd year Breeding Cattle 3rd year Fattening Cattle	Growing Cattle	Fattening Calves Pre-Weaned Calves Breeding Cattle 1st year Breeding Cattle 2nd year Breeding Cattle 3rd year Fattening Cattle
Sheep	Sheep		Fattening Sheep Milk Sheep	
Swine	Swine		Piglets Fattening Pig over 25 kg Dry Sows Nursing Sows Boars	
Goats	Goats		Goat places	
Horses	Horses < 3 years Horses > 3 years		Horses < 3 years Horses > 3 years	
Mules and Asses	Mules an Asses		Mules an Asses	
Poultry	Poultry		Growers Layers Broilers Turkey Other Poultry (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 2024. 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 2024. 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 (2024).

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**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**1990 - 2024 (%)**
Fattening Calves	50	81	112	83	81	77	75	75	76	78	77	75	74	73	75	50%
Pre-Weaned Calves	15	35	11	266	281	342	304	318	331	359	356	364	346	380	376	2407%
Breeding Cattle 1st Year	1’136	1’057	649	601	814	828	982	785	801	828	948	935	971	969	950	-16%
Breeding Cattle 2nd Year	903	699	544	676	808	822	974	778	794	822	940	927	964	961	931	3%
Breeding Cattle 3rd Year	631	575	343	348	459	466	553	442	451	467	534	526	547	545	537	-15%
Fattening Cattle	723	725	774	743	743	732	700	709	720	747	740	721	705	716	703	-3%
Growing Cattle	3’458	3’172	2’433	2’717	3’186	3’267	3’588	3’107	3’173	3’301	3’595	3’548	3’607	3’644	3’572	3%
Mature Dairy Cattle	2’850	2’643	2’440	2’489	2’425	2’299	2’232	2’246	2’271	2’332	2’311	2’231	2’194	2’187	2’199	-23%
Other Mature Cattle	20	47	74	362	382	465	413	432	450	489	484	495	471	517	469	2245%
Total Cattle	**6’328**	**5’862**	**4’947**	**5’568**	**5’993**	**6’031**	**6’233**	**5’785**	**5’894**	**6’122**	**6’390**	**6’274**	**6’272**	**6’348**	**6’240**	**-1%**
Fattening Sheep	1’636	1’079	1’522	2’005	2’061	2’094	2’087	2’168	2’165	2’225	1’992	2’176	2’245	2’243	2’160	32%
Milksheep	0	0	0	41	0	1	0	0	0	0	0	0	0	22	19	-
Total Sheep	**2’781**	**2’632**	**2’983**	**3’063**	**3’656**	**3’892**	**4’050**	**4’123**	**3’989**	**3’884**	**3’829**	**4’228**	**4’436**	**4’457**	**4’189**	**51%**
Goat Places	111	100	96	171	253	182	217	242	293	267	297	350	385	386	392	253%
Total Goats	**171**	**145**	**164**	**324**	**434**	**285**	**330**	**361**	**431**	**431**	**511**	**544**	**498**	**495**	**413**	**142%**
Horses <3 years Agr.	33	27	20	28	31	29	17	12	11	16	14	12	5	10	235	612%
Horses >3 years Agr.	133	135	136	237	304	272	249	243	233	236	221	214	234	232	40	-70%
Total Horses Agr.	**166**	**162**	**156**	**265**	**335**	**301**	**266**	**255**	**244**	**252**	**235**	**226**	**239**	**242**	**275**	**66%**
Total Mules and Asses Agr.	**73**	**133**	**223**	**144**	**154**	**163**	**172**	**157**	**230**	**218**	**230**	**227**	**215**	**214**	**188**	**158%**
Piglets	506	452	398	222	301	285	226	197	183	172	291	214	105	189	189	-63%
Fattening Pig over 25 kg	1’006	1’091	1’229	1’162	1’058	1’206	1’153	1’309	1’149	1’131	901	1’106	1’047	1’021	1’195	19%
Dry Sows	207	191	91	96	101	87	77	70	68	73	80	80	85	88	86	-58%
Nursing Sows	66	62	22	21	18	12	25	25	27	25	13	16	23	13	13	-80%
Boars	5	5	4	3	3	10	2	2	2	2	3	2	2	2	2	-60%
Total Swine	**3’251**	**2’429**	**1’992**	**1’703**	**1’690**	**1’747**	**1’789**	**1’875**	**1’772**	**1’724**	**1’465**	**1’632**	**1’557**	**1’487**	**1’485**	**-54%**
Growers	105	53	0	0	61	246	141	131	95	100	104	162	164	153	173	65%
Layers	4’145	5’506	6’866	10’112	12’175	12’056	12’438	12’141	12’371	14’322	15’143	20’337	20’242	20’222	20’368	391%
Broilers	0	500	1’000	250	390	0	100	0	300	400	60	51	71	61	61	-
Turkey	22	55	87	52	103	43	44	46	13	37	0	0	0	0	0	-
Other Poultry	163	134	106	39	191	153	104	137	137	151	129	90	223	226	140	-14%
Total Poultry	**4’435**	**6’248**	**8’059**	**10’453**	**12’920**	**12’498**	**12’827**	**12’455**	**12’916**	**15’010**	**15’436**	**20’640**	**20’700**	**20’662**	**20’742**	**368%**

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.

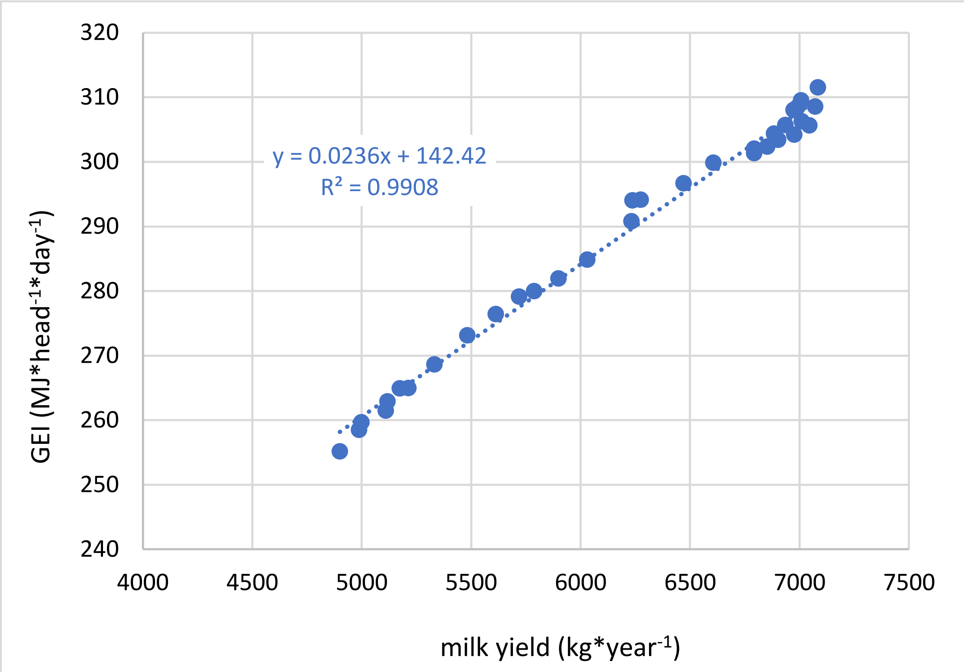


Figure 5-6 Linear regression relating nitrogen excretion (NexDC) of mature dairy cattle to milk yield (based on FOEN 2024).

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

Nitrogen Excretion	1990	1995	2000	2005	2010	2015	2016	2017
	kg N/head/year							
Cattle (weighted average)	66.9	66.9	71.8	71.8	68.7	68.2	66.3	68.9
Mature Dairy Cattle	104.4	104.7	108.6	110.7	110.1	111.3	111.8	111.9
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	35.8	35.5
Fattening Calves	*13.0*	*13.0*	*13.0*	*14.2*	*16.0*	*18.0*	*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*	*38.0*	*38.0*	*38.0*
Sheep (weighted average)	8.8	6.1	7.7	10.1	8.5	8.1	7.7	7.9
Swine (weighted average)	8.8	11.9	11.5	11.0	10.3	10.2	9.6	10.0
Goats	11.0	11.7	10.0	9.0	9.9	10.9	11.2	11.4
Horses (weighted average)	43.6	43.7	43.7	43.8	43.8	43.8	43.9	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	2018	2019	2020	2021	2022	2023	2024
	kg N/head/year						
Cattle (weighted average)	68.9	69.2	67.4	66.9	66.1	65.9	66.2
Mature Dairy Cattle	112.4	113.8	113.2	112.7	112.2	112.0	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	35.4	35.6	35.6	35.7	35.5	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)	8.1	8.6	7.8	7.7	7.6	7.6	7.8
Swine (weighted average)	9.5	9.6	9.6	10.0	10.0	10.3	11.6
Goats	11.6	10.5	9.9	10.9	13.1	13.3	16.1
Horses (weighted average)	43.9	43.9	43.9	43.9	44.0	43.9	42.3
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).

Uncertainty values used in Approach 2 (some of which a are asymmetric) are depicted in Table A - 5.

Table 5-16 Uncertainties for source category 3B Manure management 2024. 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 1990–2024 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 2023 as well as an analysis of the increase or decrease of emissions between 2023 and 2024 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 NID (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

No category-specific recalculations have been carried out in 3B Manure management for submission 2026.

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 and trend (KCA excluding LULUCF categories).

Indirect N_2O emissions from agricultural soils (3D2) are a key category by trend (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 2024 were animal manure applied to soils (32%), nitrogen input from atmospheric deposition (21%), inorganic nitrogen fertilisers (15%), nitrogen leaching and run-off (14%) and nitrogen in crop residues returned to soils (12%).

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

Direct and indirect N_2O emissions have decreased by 20% and 28% in 2024 compared to 1990 levels, respectively. The lowest N_2O emission level is reached in the latest reporting year 2024. Total N_2O emissions from managed soils have been decreasing between 1990 and 2000 and have remaining on constant levels with slight fluctuation since (generally reflecting the development 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.

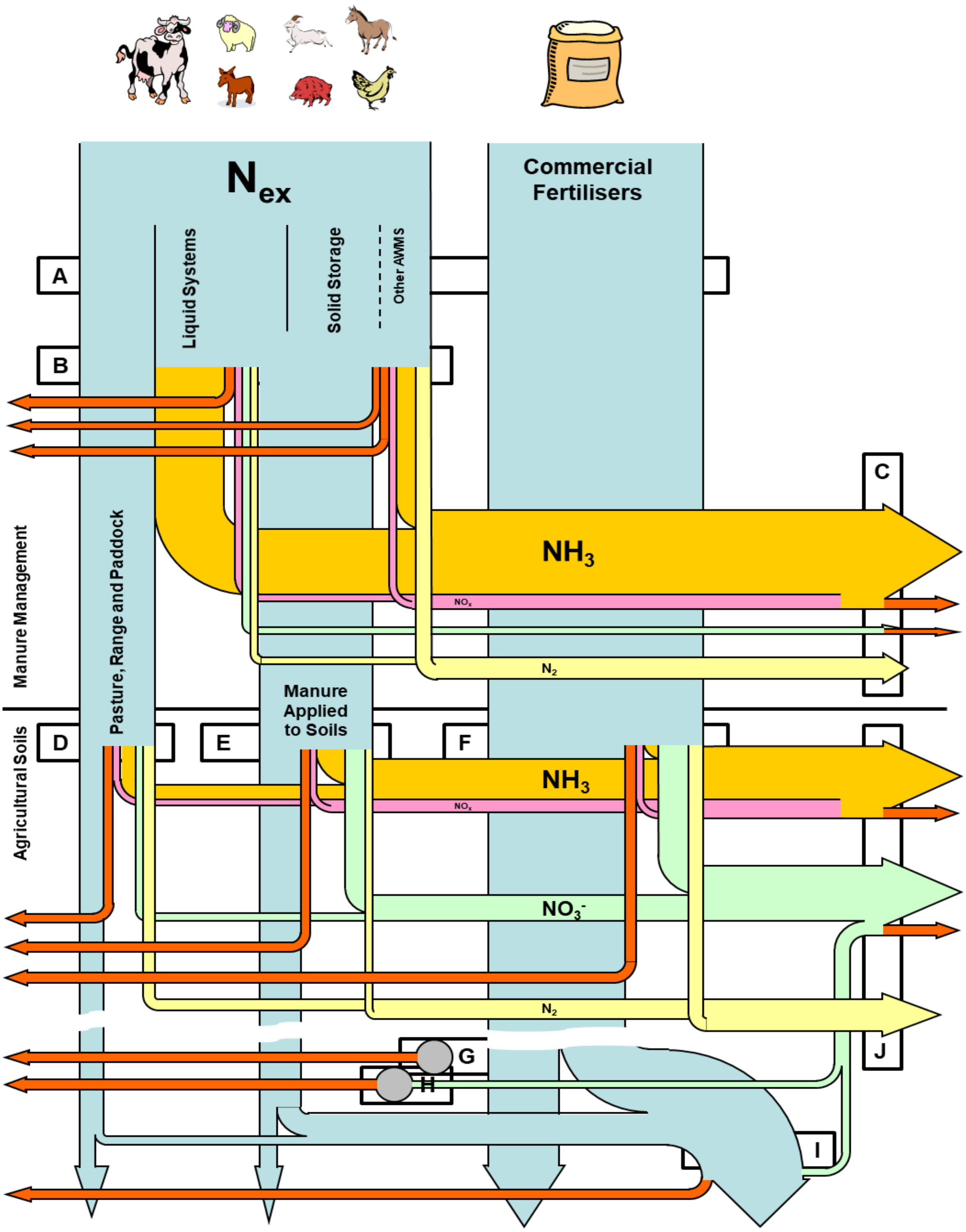


Figure 5-7 Diagram depicting the methodology of the approach to calculate the N_2O emissions in agriculture (red arrows). Black frames and the respective letters refer to the nitrogen flows in Table 5-18. Note that the figure shows explicitly the methodology of the approach and not necessarily the physical 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	**2024**		
		tN		*equals*	
A	1 Pasture, range and paddock	53.58	99.59		3.Da3
	2 Liquid/slurry systems	281.62	282.20	= B	3.B(b)
	3 Solid storage	131.11	75.27		3.B(b)
	4 Other AWMS	23.60	43.82		3.B(b)
	5 Commercial fertiliser	278.07	150.16	= F	3.Da1,2,7
B	1 Pasture, range and paddock	53.58	99.59		3.Da3
	2 NH_3 volatilisation housing	28.57	50.42		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	5.64		
	7 Manure applied to soils	364.49	312.15	= A1-A4	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	0.68		3.B(b)5
	11 NH3 volatilisation storage	30.41	26.90		3.B(b)5
	12 N2 volatilization solid storage and deep litter	4.38	3.69		
C	1 NH_3 deposition manure management	58.98	77.33	= B2+B10	
	2 NO_x deposition manure management	1.43	1.24	= B4+B9	3.B(b)5
	3 Leaching manure management	0.00	0.00	= B5	
D	1 Available N PR&P	39.44	75.68		
	2 N_2O emission PR&P	0.30	0.55		3.Da3
	3 NO_x volatilisation PR&P	0.29	0.55	= B1	
	4 NH_3 volatilisation PR&P	2.51	5.05		
	5 Leaching and run-off PR&P	11.04	17.77		
E	1 Available N animal manure	193.89	189.44		
	2 N_2O emission application animal manure	3.64	3.12		3.Da2
	3 NO_x volatilisation application animal manure	2.00	1.72	= B6	
	4 NH_3 volatilisation application animal manure	89.83	62.19		
	5 Leaching and run-off application animal manure	75.11	55.69		
F	1 Available N com. fertiliser	199.77	114.50		
	2 N_2O emission application com. fertiliser	2.78	1.50		3.Da1,2,7
	3 NO_x volatilisation application com. fertiliser	1.53	0.83	= A5	
	4 NH_3 volatilisation application com. fertiliser	16.68	6.54		
	5 Leaching and run-off application com. fertiliser	57.31	26.79		
G	1 Cultivation of organic soils (ha)	1.77	0.00		3.Da6
H	1 Mineralisation/immobilisation soil organic matter	0.00	0.00		3.Da5
I	1 N in crop residues pasture, range and paddock	79.59	84.69		3.Da4
	2 N in crop residues arable crops	34.11	30.73		
J	1 NH_3 deposition fertiliser appl. and PR&P	109.02	73.78	= D4+E4+F4	3.Db1
	2 NO_x deposition fertiliser appl. and PR&P	3.83	3.09	= D3+E3+F3	
	3 Leaching and run-off fertiliser appl. and PR&P	143.46	100.24	= 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	20.59		

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:

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

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 chp. 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 2025). 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 2025).

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	2015	2016	2017
		t N/yr							
1. Inorganic N fertilisers	Urea	37	31	29	29	27	30	27	28
	Other mineral fertilisers	200	169	155	158	147	162	145	152
2. Organic N fertilisers	a. Animal manure	364	333	279	297	308	307	307	300
	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	0.4	0.5	0.5
3. Urine and dung deposited by grazing animals		54	51	71	98	97	95	96	92
4. Crop residues	Arable crops	34	44	32	30	27	30	30	32
	Residues PR&P	80	84	86	93	86	85	85	86
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)		1.8	1.7	1.7	1.6	1.5	1.4	1.4	1.4
7. Other (domestic inorganic fertilisers)		9.9	8.4	7.6	7.8	7.3	8.0	7.2	7.5

Activity Data		2018	2019	2020	2021	2022	2023	2024	1990 -2024
		t N/yr							%
1. Inorganic N fertilisers	Urea	31	29	26	26	29	25	22	-39%
	Other mineral fertilisers	166	155	138	142	156	137	121	-39%
2. Organic N fertilisers	a. Animal manure	305	317	317	316	313	315	312	-14%
	b. Sewage sludge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
	c. Other organic fertilisers	0.4	0.5	0.5	0.5	0.5	0.4	0.5	57%
3. Urine and dung deposited by grazing animals		94	98	99	99	99	100	100	86%
4. Crop residues	Arable crops	32	33	35	31	33	33	31	-10%
	Residues PR&P	86	86	98	89	90	90	85	6%
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)		1.4	1.4	1.4	1.3	1.3	1.3	1.3	-26%
7. Other (domestic inorganic fertilisers)		8.2	7.7	6.8	7.0	7.7	6.8	6.0	-39%

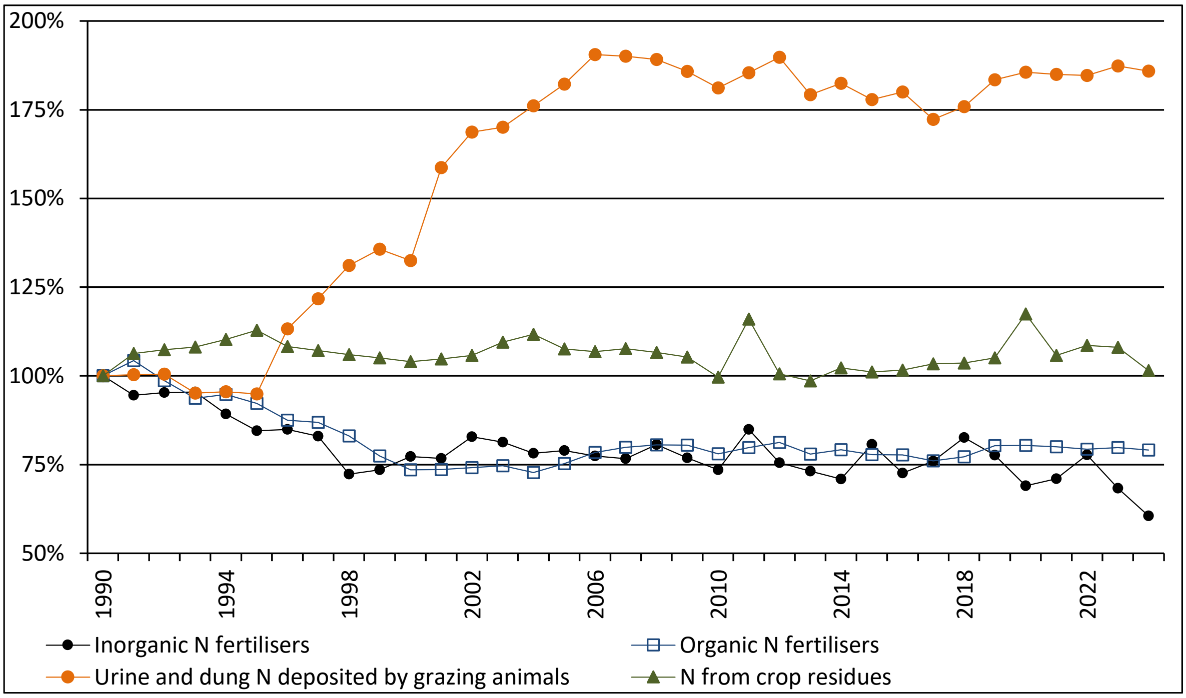


Figure 5-8 Relative development of the most important activity data for source category 3Da direct N_2O emissions from managed soils

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 43% in 2024 (OS 2014h, OS 2025h). 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 4.4% in 2024 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 2024.

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	2015	2016	2017
	%							
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)	6.00	6.84	5.27	4.31	4.57	4.83	4.36	4.36
Urea	13.42	11.04	8.73	3.21	15.73	12.60	8.56	11.28
Other Mineral Fertilisers	3.06	2.58	2.36	2.41	2.25	2.47	2.22	2.32
Recycling Fertilisers (weighted average)	14.45	12.52	11.37	11.51	10.72	11.77	10.59	11.08
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	20.10	20.11	20.05
Mature Dairy Cattle	26.69	26.78	25.38	25.30	23.76	22.19	22.19	22.19
Other Mature Cattle	24.16	23.68	21.76	22.65	22.45	21.61	21.61	21.61
Growing Cattle (weighted average)	24.84	24.75	22.72	22.86	21.99	21.07	21.12	21.07
Sheep (weighted average)	3.72	4.38	4.14	5.23	5.50	4.92	4.92	4.92
Swine (weighted average)	21.52	21.02	19.79	20.02	18.82	18.05	18.04	18.05
Other Livestock (weighted average)	5.73	7.32	7.32	7.70	8.26	8.59	8.74	8.73
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)	4.68	4.68	4.78	4.86	4.88	4.91	4.91	4.92
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	4.57	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	10.58	11.10	11.17
NH_3 from Agricultural Soils (kg/ha/year)	0.24	0.25	0.35	0.45	0.35	0.36	0.38	0.38
NO_x from applied fertilisers ($Frac_{NOXA}$)	4.96	4.08	3.23	1.19	5.81	4.66	3.17	4.17
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	2018	2019	2020	2021	2022	2023	2024	1990 -2024
	%							%
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)	4.36	4.36	4.36	4.36	4.36	4.36	4.36	-27%
Urea	11.28	12.44	10.62	7.41	18.36	18.61	11.53	-14%
Other Mineral Fertilisers	2.52	2.37	2.11	2.17	2.37	2.09	1.85	-39%
Recycling Fertilisers (weighted average)	12.05	11.32	10.06	10.35	11.33	9.97	8.83	-39%
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 ($Frac_{GASMT}$)	20.04	20.07	20.16	19.97	19.90	19.90	19.92	-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	21.10	21.10	21.11	21.11	21.11	-15%
Sheep (weighted average)	4.92	4.92	4.92	4.92	4.92	4.90	4.90	32%
Swine (weighted average)	18.03	18.03	18.05	18.04	18.01	18.03	18.05	-16%
Other Livestock (weighted average)	8.60	8.94	9.04	9.64	9.53	9.52	9.48	65%
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)	4.92	4.95	4.95	5.07	5.07	5.06	5.07	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)	10.88	11.65	12.03	13.85	13.64	13.55	11.64	133%
NH_3 from Agricultural Soils (kg/ha/year)	0.31	0.40	0.44	0.45	0.37	0.36	0.38	57%
NO_x from applied fertilisers ($Frac_{NOXA}$)	4.17	4.60	3.93	2.74	6.79	6.88	4.26	-14%
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	2015	2016	2017
		t N/yr							
	Animals manure N applied to soils	364	333.0	279.2	296.8	307.8	307.1	306.6	300.0
	Commercial fertiliser	278.1	240.7	202.4	195.7	182.3	200.0	180.0	188.4
Deposition	Sum volatised N (NH_3 and NO_x)	112.8	104.7	81.2	83.5	81.7	79.4	77.4	76.1
	NH_3 emissions from commercial fertilisers	16.7	16.5	10.7	8.4	8.3	9.7	7.8	8.2
	NH_3 emissions from applied animal manure	89.8	82.4	64.1	67.1	65.4	61.7	61.7	60.1
	NH_3 emissions from pasture, range and paddock	2.51	2.38	3.39	4.75	4.73	4.68	4.73	4.54
	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	1.10	0.99	1.04
	NO_x emissions from applied animal manure	2.00	1.83	1.54	1.63	1.69	1.69	1.69	1.65
	NO_x emissions from PR&P	0.29	0.28	0.39	0.54	0.53	0.52	0.53	0.51
Leaching and run-off	Sum leaching and run-off	166.9	155.1	132.0	133.7	124.9	128.0	124.6	124.6
	Leaching and run-off from commercial fertilisers	57.3	49.6	39.8	36.7	32.5	35.7	32.1	33.6
	Leaching and run-off from applied animal manure	75.1	68.6	55.0	55.7	54.9	54.8	54.7	53.5
	Leaching and run-off from pasture, range and paddock	11.0	10.5	14.0	18.3	17.3	17.0	17.2	16.5
	Leaching and run-off from crop residues	23.4	26.4	23.3	22.9	20.2	20.5	20.6	21.0
	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		2018	2019	2020	2021	2022	2023	2024	1990 -2024
		t N/yr							%
	Animals manure N applied to soils	305	317	317.0	315.6	313.0	314.7	312.2	-14%
	Commercial fertiliser	204.7	192.4	171.2	176.1	192.7	169.5	150.2	-46%
Deposition	Sum volatised N (NH_3 and NO_x)	77.9	80.2	79.5	79.0	79.0	78.3	76.9	-32%
	NH_3 emissions from commercial fertilisers	8.9	8.4	7.5	7.7	8.4	7.4	6.5	-61%
	NH_3 emissions from applied animal manure	61.0	63.6	63.9	63.0	62.3	62.6	62.2	-31%
	NH_3 emissions from pasture, range and paddock	4.63	4.86	4.93	5.02	5.01	5.08	5.05	101%
	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	1.13	1.06	0.94	0.97	1.06	0.93	0.83	-46%
	NO_x emissions from applied animal manure	1.68	1.74	1.74	1.74	1.72	1.73	1.72	-14%
	NO_x emissions from PR&P	0.52	0.54	0.55	0.55	0.54	0.55	0.55	86%
Leaching and run-off	Sum leaching and run-off	128.7	129.7	128.7	126.8	129.9	126.2	120.8	-28%
	Leaching and run-off from commercial fertilisers	36.5	34.3	30.5	31.4	34.4	30.2	26.8	-53%
	Leaching and run-off from applied animal manure	54.3	56.5	56.6	56.3	55.8	56.1	55.7	-26%
	Leaching and run-off from pasture, range and paddock	16.8	17.5	17.7	17.7	17.6	17.9	17.8	61%
	Leaching and run-off from crop residues	21.0	21.3	23.8	21.4	22.0	21.9	20.6	-12%
	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 chp. 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.

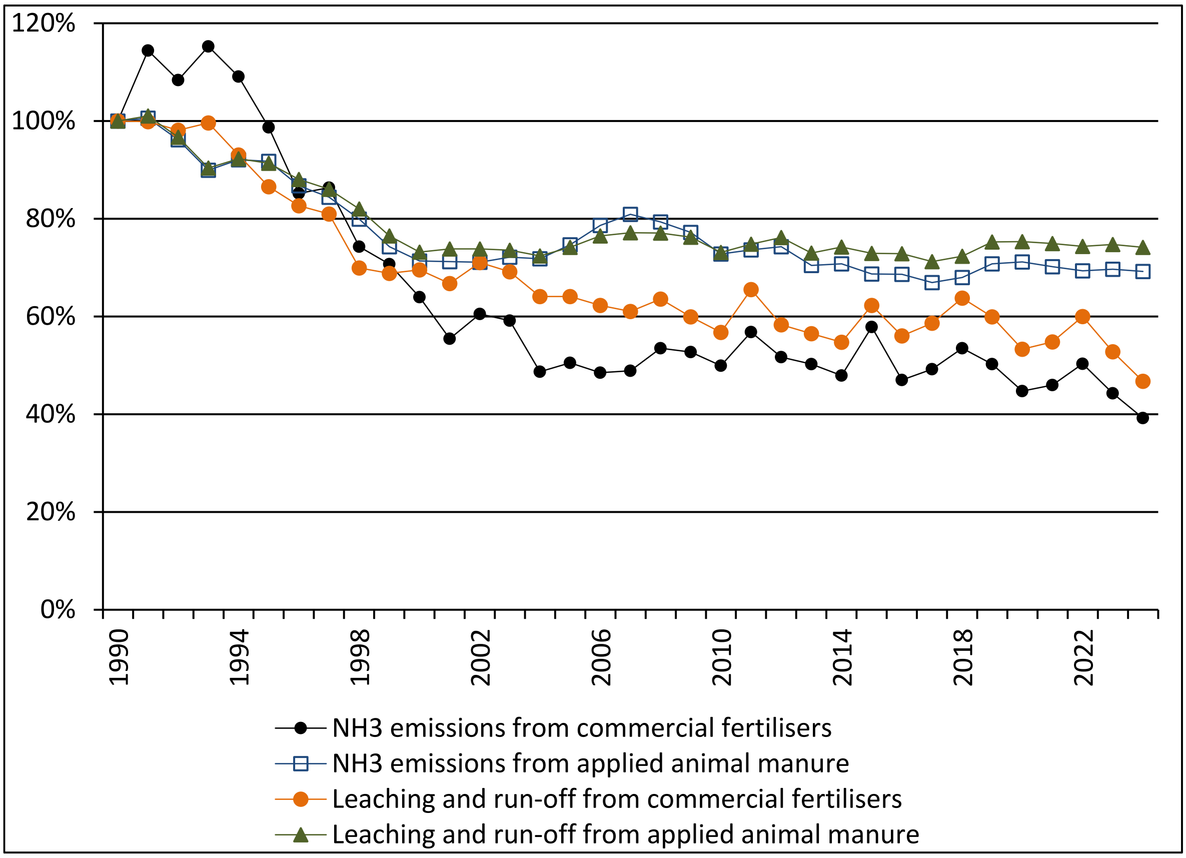


Figure 5-9 Relative development of the most important activity data for source category 3Db indirect N_2O emissions from managed soils.

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):

$$N_2O_{(L)} - N = \left(F_{CN} + F_{AM} + F_{PRP} + F_{CR} + F_{SOM}\right) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

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.

Uncertainty values used in Approach 2 (some of which are asymmetric) are depicted in Table A - 5.

Table 5-23 Approach 1 uncertainties for 3D Agricultural soils in 2024. 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	80.4	81.6
3D2 Indirect soil emissions	Atmospheric deposition	42.0	80.0	90.4
	Leaching and run-off	22.3	90.9	93.6
	3D2 aggregate	26.9	60.3	66.1

For further uncertainty results also consult chp. 1.6.

The time series 1990–2024 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 2023 as well as an analysis of the increase or decrease of emissions between 2023 and 2024 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 NID (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

No category-specific recalculations have been carried out in 3D Agricultural soils for submission 2026.

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 2024, 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 (IPCC 2006).

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 have been carried out in 3H Urea application for submission 2026.

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 2024 (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.

The land areas in the period 1990–2024 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 mainland-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.

In the latest submission, a geo-referenced approach was implemented for calculating LULUCF associated carbon stock changes based on the hectare raster of the AREA survey. This improvement also makes it possible to map GHG emissions and removals. Figure 6-3 shows an example of a comparison between the base year 1990 and the latest reporting year.

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 1990–2024. 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 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.

LULUCF	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt CO2 eq									
Gain of living biomass in forest	-49.44	-49.54	-49.66	-49.74	-49.86	-49.86	-49.92	-49.85	-49.79	-49.83
Loss of living biomass in forest	50.56	34.25	45.40	41.92	61.71	47.69	39.02	50.13	41.58	39.92
Land-use change, soil and HWP	2.94	2.42	2.94	4.03	3.83	4.51	3.19	10.58	8.82	9.08
Sector 4 LULUCF (total)	**4.06**	**-12.86**	**-1.32**	**-3.79**	**15.68**	**2.34**	**-7.71**	**10.87**	**0.62**	**-0.84**

LULUCF	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt CO2 eq									
Gain of living biomass in forest	-49.85	-49.72	-49.69	-49.65	-49.67	-49.65	-49.62	-49.65	-49.67	-49.79
Loss of living biomass in forest	65.74	41.42	41.87	45.67	47.65	47.41	52.02	61.08	63.01	60.01
Land-use change, soil and HWP	6.15	12.56	10.91	8.59	6.67	10.19	8.24	10.78	8.46	8.36
Sector 4 LULUCF (total)	**22.04**	**4.27**	**3.09**	**4.61**	**4.65**	**7.94**	**10.65**	**22.22**	**21.80**	**18.58**

LULUCF	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	kt CO2 eq									
Gain of living biomass in forest	-49.91	-40.59	-40.66	-40.72	-40.75	-40.84	-40.75	-40.72	-40.74	-40.71
Loss of living biomass in forest	58.57	40.56	40.80	35.82	35.78	32.30	31.01	32.08	39.48	32.86
Land-use change, soil and HWP	9.09	10.54	7.84	5.55	7.12	6.40	12.11	10.62	10.07	8.50
Sector 4 LULUCF (total)	**17.75**	**10.51**	**7.98**	**0.64**	**2.15**	**-2.14**	**2.38**	**1.99**	**8.82**	**0.66**

LULUCF	2020	2021	2022	2023	2024	Mean				
	kt CO2 eq									
Gain of living biomass in forest	-40.84	-40.88	-40.93	-41.00	-41.06	-46.16				
Loss of living biomass in forest	28.23	25.43	26.96	27.32	26.52	42.62				
Land-use change, soil and HWP	5.67	4.95	4.90	9.20	4.20	7.43				
Sector 4 LULUCF (total)	**-6.95**	**-10.50**	**-9.06**	**-4.48**	**-10.34**	**3.89**				

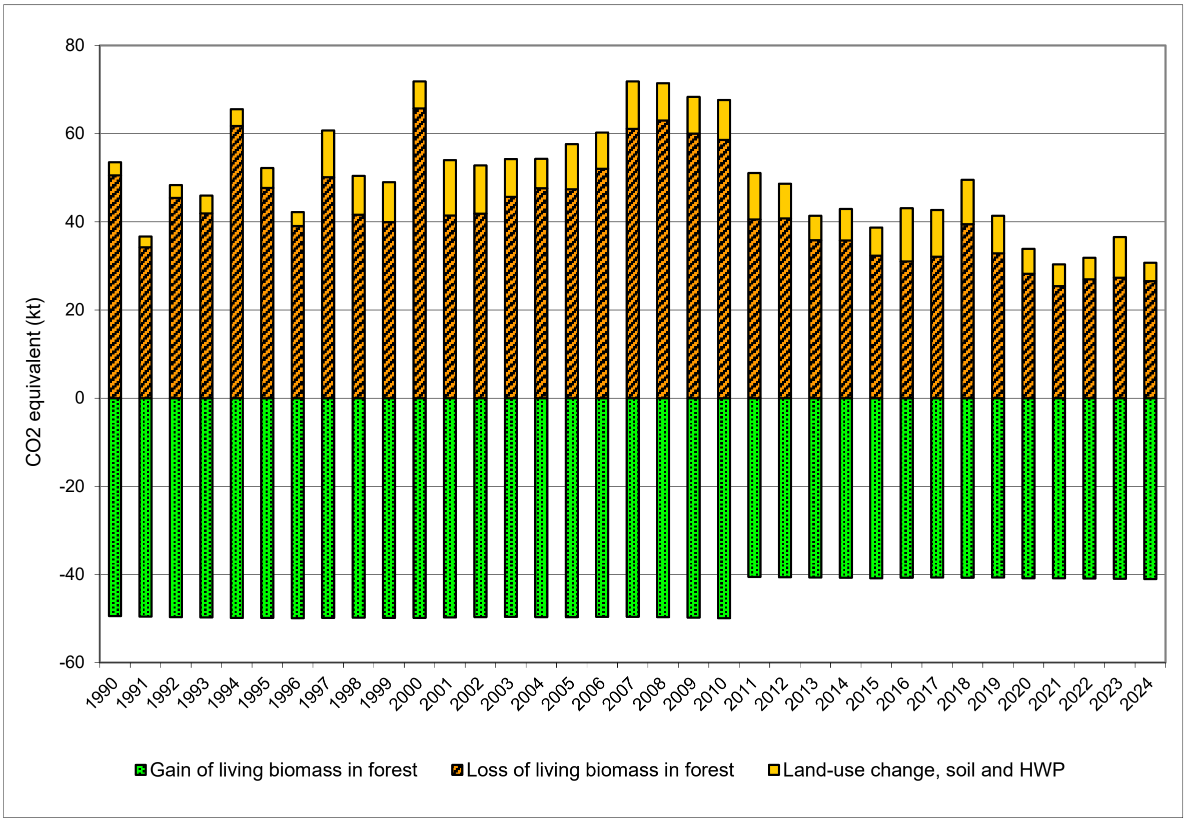


Figure 6-1 Liechtenstein's CO_2 removals due to the increase (growth) of living biomass on forest land, the CO_2 emissions due to the decrease (harvest and mortality) of living biomass on forest land and the net CO_2 equivalent emissions due to land-use changes and from use of soils.

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.

Excluding the category 4G Harvested wood products, the LULUCF total was 6.5 kt CO_2 in the base year 1990 and -12.9 kt CO_2 in the latest reporting year (Table 6-2). Figure 6-3 shows the associated net emissions and removals for both years on maps. For displaying, the hectare raster was aggregated to a 1x1 km^2 raster.

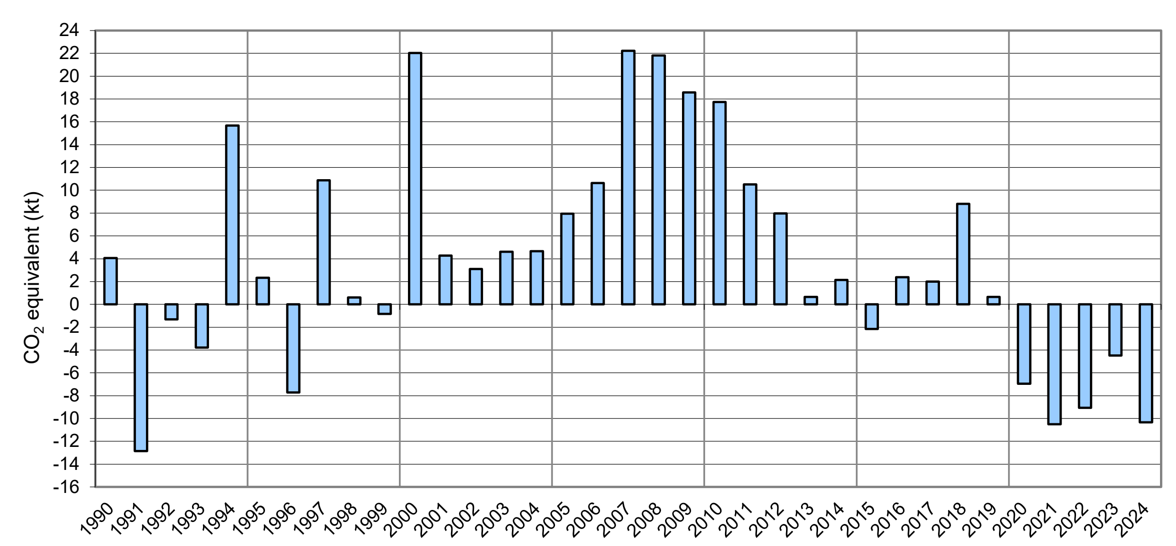


Figure 6-2 Liechtenstein's CO2 emissions/removals of sector 4 LULUCF.

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	**3.79**	**-13.09**	**-1.57**	**-4.07**	**15.41**	**2.09**	**-7.98**	**10.46**	**0.23**	**-1.18**
A. Forest Land	**-4.61**	**-20.99**	**-10.08**	**-13.73**	**5.84**	**-8.18**	**-16.94**	**-5.69**	**-14.12**	**-15.94**
1. Forest Land remaining Forest Land	-0.33	-16.18	-5.53	-8.97	9.99	-3.50	-11.91	-1.14	-9.32	-10.95
2. Land converted to Forest Land	-4.28	-4.81	-4.55	-4.76	-4.14	-4.67	-5.03	-4.55	-4.80	-4.99
B. Cropland	**4.39**	**4.38**	**4.47**	**4.41**	**4.39**	**4.30**	**4.39**	**4.36**	**4.45**	**4.36**
1. Cropland remaining Cropland	4.22	4.22	4.22	4.19	4.19	4.12	4.12	4.12	4.08	4.08
2. Land converted to Cropland	0.16	0.16	0.25	0.22	0.20	0.18	0.27	0.24	0.37	0.27
C. Grassland	**2.17**	**1.76**	**2.44**	**1.74**	**2.01**	**2.79**	**2.03**	**5.92**	**5.48**	**5.35**
1. Grassland remaining Grassland	2.07	1.89	1.71	1.79	2.01	1.47	1.93	2.26	1.94	1.35
2. Land converted to Grassland	0.10	-0.13	0.74	-0.05	0.00	1.31	0.10	3.66	3.54	4.00
D. Wetlands	**2.65**	**2.66**	**2.17**	**2.19**	**2.21**	**2.71**	**2.19**	**3.22**	**2.52**	**2.29**
1. Wetlands remaining Wetlands	1.98	1.96	1.96	1.96	2.00	2.00	2.00	2.00	2.06	2.06
2. Land converted to Wetlands	0.67	0.69	0.21	0.22	0.21	0.71	0.19	1.21	0.46	0.23
E. Settlements	**1.71**	**1.38**	**1.52**	**2.51**	**2.61**	**1.92**	**1.10**	**3.06**	**1.58**	**2.27**
1. Settlements remaining Settlements	0.04	-0.36	0.21	0.41	0.24	0.24	-0.13	0.40	-0.74	0.10
2. Land converted to Settlements	1.67	1.75	1.31	2.10	2.37	1.68	1.23	2.66	2.33	2.17
F. Land converted to Other Land	**0.17**	**0.19**	**0.17**	**0.87**	**0.22**	**0.24**	**0.74**	**0.88**	**1.43**	**1.42**
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	**21.68**	**3.85**	**2.62**	**4.09**	**4.17**	**7.47**	**10.24**	**21.73**	**21.31**	**18.17**
A. Forest Land	**9.97**	**-14.20**	**-13.58**	**-9.66**	**-7.54**	**-7.66**	**-3.03**	**5.93**	**7.90**	**4.55**
1. Forest Land remaining Forest Land	13.91	-9.39	-8.94	-5.24	-3.36	-3.58	0.92	9.65	11.50	8.44
2. Land converted to Forest Land	-3.93	-4.81	-4.64	-4.42	-4.18	-4.09	-3.95	-3.72	-3.61	-3.89
B. Cropland	**4.30**	**4.33**	**4.40**	**4.81**	**4.39**	**4.25**	**4.26**	**4.25**	**4.22**	**4.18**
1. Cropland remaining Cropland	4.05	4.08	4.05	4.08	4.12	4.08	4.08	4.05	4.05	4.05
2. Land converted to Cropland	0.26	0.25	0.35	0.73	0.28	0.17	0.18	0.20	0.17	0.13
C. Grassland	**3.75**	**6.41**	**6.61**	**5.01**	**2.93**	**5.32**	**4.92**	**4.97**	**4.22**	**2.96**
1. Grassland remaining Grassland	1.38	1.57	2.20	1.62	1.34	1.85	1.57	1.62	1.41	1.70
2. Land converted to Grassland	2.37	4.84	4.41	3.39	1.59	3.48	3.35	3.35	2.80	1.26
D. Wetlands	**2.36**	**2.77**	**2.28**	**3.26**	**2.29**	**2.31**	**2.31**	**2.83**	**2.30**	**2.83**
1. Wetlands remaining Wetlands	2.06	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.10
2. Land converted to Wetlands	0.30	0.69	0.20	1.18	0.21	0.23	0.23	0.75	0.22	0.73
E. Settlements	**1.10**	**3.72**	**2.57**	**0.60**	**1.19**	**2.62**	**1.46**	**2.76**	**1.70**	**2.00**
1. Settlements remaining Settlements	0.08	0.11	0.83	-0.62	-0.30	0.36	-0.03	0.59	0.00	0.49
2. Land converted to Settlements	1.03	3.61	1.74	1.22	1.49	2.26	1.50	2.17	1.70	1.51
F. Land converted to Other Land	**0.94**	**1.48**	**0.89**	**0.51**	**1.26**	**0.88**	**0.47**	**1.05**	**0.94**	**1.52**
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	**17.27**	**10.04**	**7.53**	**0.23**	**1.75**	**-2.58**	**1.88**	**1.54**	**8.28**	**0.14**
A. Forest Land	**2.84**	**-5.90**	**-5.78**	**-10.83**	**-10.90**	**-15.02**	**-16.36**	**-15.59**	**-8.61**	**-15.42**
1. Forest Land remaining Forest Land	6.91	-1.50	-1.39	-6.30	-6.39	-9.85	-11.00	-9.93	-2.78	-9.15
2. Land converted to Forest Land	-4.07	-4.40	-4.40	-4.53	-4.51	-5.17	-5.36	-5.66	-5.83	-6.26
B. Cropland	**4.21**	**4.18**	**4.17**	**4.15**	**4.20**	**4.02**	**4.00**	**4.00**	**3.93**	**3.75**
1. Cropland remaining Cropland	4.01	4.01	4.05	4.08	4.05	3.91	3.98	3.98	3.87	3.74
2. Land converted to Cropland	0.20	0.16	0.12	0.07	0.15	0.11	0.02	0.02	0.05	0.01
C. Grassland	**4.66**	**4.38**	**4.96**	**3.13**	**4.56**	**5.35**	**6.74**	**6.26**	**6.48**	**5.12**
1. Grassland remaining Grassland	1.76	2.47	2.42	1.53	1.55	1.39	0.66	0.93	2.34	1.30
2. Land converted to Grassland	2.91	1.91	2.54	1.59	3.01	3.95	6.08	5.33	4.14	3.83
D. Wetlands	**2.32**	**3.23**	**2.31**	**2.43**	**2.74**	**2.28**	**2.32**	**2.75**	**2.00**	**2.55**
1. Wetlands remaining Wetlands	2.12	2.12	2.12	2.14	2.14	2.14	2.08	2.08	1.83	2.29
2. Land converted to Wetlands	0.20	1.11	0.19	0.29	0.60	0.14	0.24	0.67	0.17	0.25
E. Settlements	**2.56**	**3.36**	**1.26**	**0.75**	**0.60**	**-0.36**	**3.96**	**3.14**	**0.65**	**1.40**
1. Settlements remaining Settlements	0.23	0.24	-0.02	-0.02	-0.20	-2.35	-0.75	-1.32	-1.15	-2.16
2. Land converted to Settlements	2.33	3.12	1.28	0.77	0.80	1.99	4.71	4.46	1.79	3.56
F. Land converted to Other Land	**0.46**	**0.59**	**0.40**	**0.40**	**0.35**	**0.96**	**1.03**	**0.81**	**1.44**	**0.38**
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	2024
Total Land-Use Categories	**-7.36**	**-10.90**	**-9.50**	**-4.89**	**-10.74**
A. Forest Land	**-20.45**	**-23.46**	**-22.25**	**-22.21**	**-23.38**
1. Forest Land remaining Forest Land	-13.81	-16.57	-15.15	-14.92	-15.74
2. Land converted to Forest Land	-6.64	-6.89	-7.10	-7.29	-7.63
B. Cropland	**3.62**	**3.58**	**3.52**	**3.44**	**3.21**
1. Cropland remaining Cropland	3.60	3.56	3.49	3.42	3.18
2. Land converted to Cropland	0.03	0.02	0.03	0.02	0.03
C. Grassland	**3.86**	**3.24**	**3.30**	**5.97**	**4.55**
1. Grassland remaining Grassland	1.99	1.47	1.83	2.00	1.91
2. Land converted to Grassland	1.88	1.77	1.47	3.97	2.65
D. Wetlands	**2.22**	**2.17**	**2.14**	**2.10**	**2.08**
1. Wetlands remaining Wetlands	2.06	2.02	2.01	1.98	1.96
2. Land converted to Wetlands	0.16	0.15	0.14	0.12	0.11
E. Settlements	**0.73**	**1.00**	**0.66**	**1.40**	**0.12**
1. Settlements remaining Settlements	-1.00	-2.18	-1.90	-0.78	-2.20
2. Land converted to Settlements	1.73	3.19	2.56	2.17	2.32
F. Land converted to Other Land	**0.34**	**0.30**	**0.91**	**2.24**	**0.54**
G. Harvested wood products	**2.31**	**2.27**	**2.22**	**2.18**	**2.14**

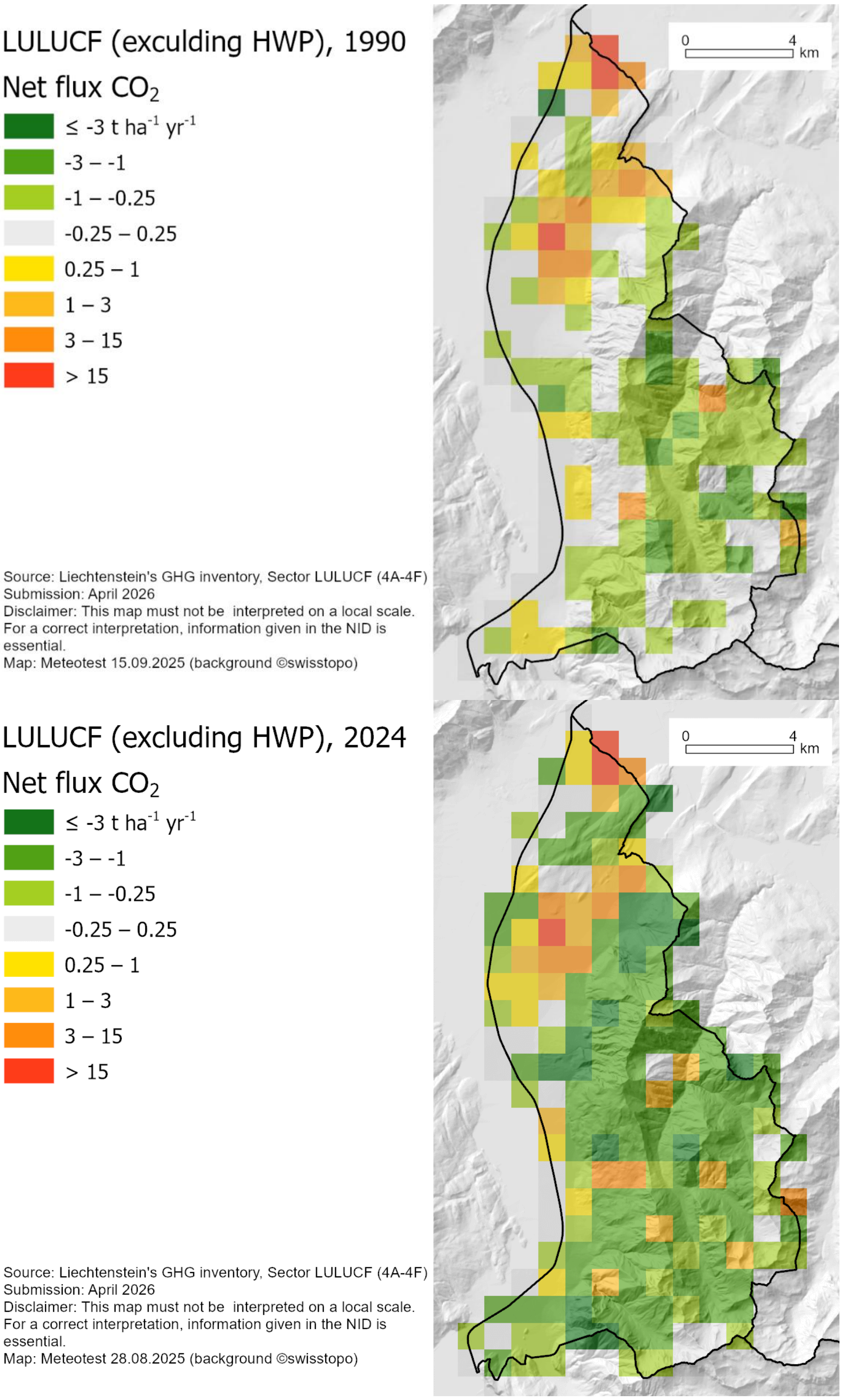


Figure 6-3 Maps of net CO_2 emissions and removals in the LULUCF sector (excluding category 4G HWP) in Liechtenstein in 1990 (top panel) and in 2024 (bottom panel), aggregated to a 1x1 km raster. Positive values refer to net emissions, negative values to net removals.

6.1.3 Approach for calculating carbon emissions and removals

6.1.3.1 Work steps

The procedure for calculating carbon emissions and removals in the LULUCF sector in a geo-referenced way is very similar to the approaches used in Switzerland (FOEN 2025). 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 (see Table 6-3) were introduced as combination categories (CC), defined on the basis of the AREA land-use and land-cover categories. Liechtenstein's land-use statistics uses the same nomenclature as the Swiss land-use statistics (AREA survey, SFSO 2006a).
- Criteria for the spatial stratification of land use (altitude and soil type) were adopted from Switzerland (chp. 6.2.2). The strata are used for structuring input data as well as for aggregating results.
- Determine the development of land use (in terms of combination categories CC) for each sampling point (i.e. each cell) of the hectare raster over the inventory period. This is done by interpolation between the AREA surveys and extrapolation into the time before the first recorded and after the last available aerial photographs (chp. 6.3.1.2). Backward extrapolation to 1971 produces land-use changes prior to 1990 (which are necessary when using a conversion time of 20 years).
- Annual carbon emissions and removals are calculated for each AREA sampling point. The required input data can either be gathered as average values for the CC per strata (see chp. 6.1.4) or they can be extracted from GIS-data. The latter possibility has not been applied so far.
- 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.
- Calculate net carbon stock changes in the pools living biomass (deltaC_l), dead wood (deltaC_d), litter (deltaC_h), and soil (deltaC_s) for all cells of the hectare raster (i.e. total land area) for each year in the period 1990–2024. The temporal development of a carbon pool in a cell is based on the stock in the previous year.
- 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).

In Liechtenstein, all land besides Other land is considered to be managed. Other land (see Table 6-3) is unmanaged. It is defined as the residual country’s land area without relevant human activity

The procedure of calculating emissions and removals in LULUCF and the different institutions involved are displayed schematically in Figure 6-4.

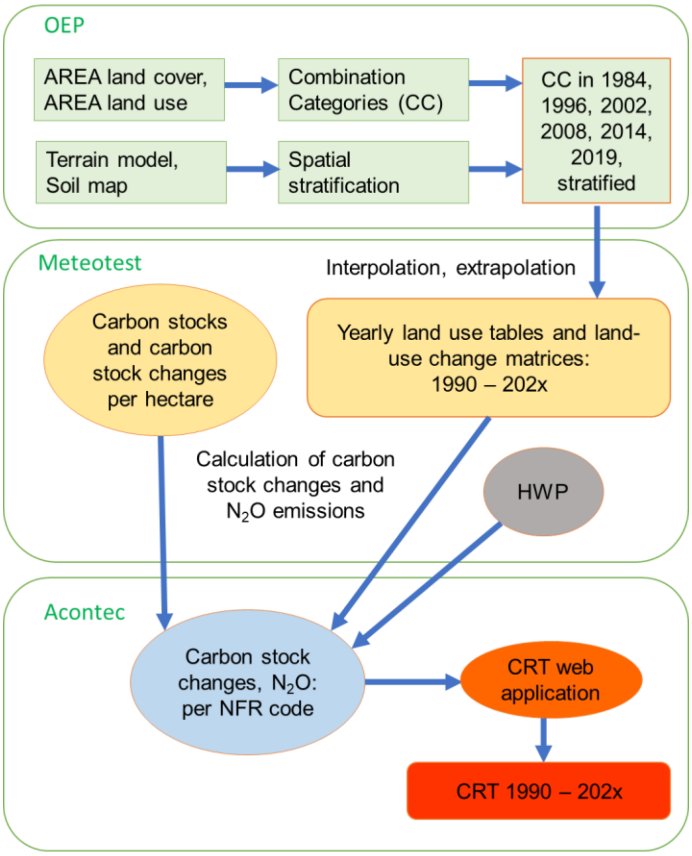


Figure 6-4 Procedure of calculating emissions and removals from LULUCF and producing Common Reporting Tables (CRT) in Liechtenstein.

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	CC code
A. Forest land	productive forest	dense and open forest meeting the criteria of forest land	12
	unproductive forest	brush forest and inaccessible forest meeting the criteria of forest land	13
B. Cropland	cropland	arable and tillage land (annual crops and leys in arable rotations)	21
C. Grassland	permanent grassland	meadows, pastures (low-land and alpine)	31
	shrub vegetation	agricultural and unproductive areas predominantly covered by shrubs	32
	vineyard, low-stem orchard, tree nursery	perennial agricultural plants with woody biomass and grass understorey	33
	copse	agricultural and unproductive areas covered by perennial woody biomass including trees	34
	stony grassland	grass, herbs and shrubs on stony surfaces	36
	unproductive grassland	unmanaged grass vegetation	37
D. Wetlands	surface water	lakes and rivers	41
	unproductive wetland	reed, unmanaged wetland	42
E. Settlements	buildings and constructions	areas without vegetation such as houses, roads, construction sites, dumps	51
	herbaceous biomass in settlements	areas with low vegetation, e.g. lawns	52
	shrubs in settlements	areas with perennial woody biomass (no trees)	53
	trees in settlements	areas with perennial woody biomass including trees	54
F. Other land	other land	areas without soil and vegetation: rocks, sand, scree, glaciers	61

6.1.3.2 Calculating carbon stock changes

The method is based largely on the Swiss procedure according to FOEN (2025).

For calculating carbon stock changes, the following input data (mean values per hectare) are required for each year of the inventory period. In the geo-referenced approach, they are quantified at the level of individual raster cells (by stratified averages or by GIS-data). Thus, the index i in the following definitions refers to a raster cell (corresponding to one sampling point of the AREA surveys), and the index CC refers to the land-use category in the processed year:

$stockC_{l,i,CC}$: 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

The input data were spatially assigned to the raster cells. Based on this dataset and by adding the activity data, annual changes in carbon stocks (t C ha^{-1} yr^{-1}) in living biomass ($deltaC_l$), dead wood ($deltaC_d$), litter ($deltaC_h$), and soils ($deltaC_s$) were calculated for each cell of the nationwide hectare raster, starting with the year 1990. To do this, it was first determined whether or not a land-use change had occurred on a raster cell in the current year or in the preceding 1–20 years (depending on the conversion time applied to the carbon pool under consideration). The applicable calculation approach was then selected from Table 6-4. In this way, a consistent time series since 1990 is created for each carbon pool in each raster cell across Liechtenstein.

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:

$deltaC_{l,i,ba} = (gainC_{l,i,a} - lossC_{l,i,b}) * A_i$ (6.1)

$deltaC_{d,i,ba} = changeC_{d,i,a} * A_i$ (6.2)

$deltaC_{s,i,ba} = changeC_{s,i,a} * A_i$ (6.3)

The stock-difference approach for calculating carbon stock changes is defined as:

$deltaC_{l,i,ba} = [(stockC_{l,i,a} - stockC_{l,i,b}) / CT] * A_i$ (6.4)

$deltaC_{d,i,ba} = [(stockC_{d,i,a} - stockC_{d,i,b}) / CT] * A_i$ (6.5)

$deltaC_{s,i,ba} = [(stockC_{s,i,a} - stockC_{s,i,b}) / CT] * A_i$ (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: index referring to a raster cell

A_i: area of a raster cell (equals to one hectare)

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 1972. 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 1990–2024 except for the gain and 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 1990–2024, except the cells highlighted in green and orange (see main text). Values in purple-coloured cells were recalculated in Submission 2026.

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	14.62	61.82	NO	0	0	0	0	0	NO
	2	47.53	0	14.62	80.81	NO	0	0	0	0	0	NO
	3	42.36	0	13.55	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:		NO: land-use type does not occur on organic soil
1	< 600 m	
2	601 - 1200 m	
3	> 1200 m	

On organic soils, a value of 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	44.2	51.7	
4C1	Grassland remaining Grassland	CO_2	6.0	41.0	41.4	yes
4C2	Land converted to Grassland	CO_2	13.6	28.0	31.1	yes
4D1	Wetlands remaining Wetlands	CO_2	10.5	50.0	51.1	yes
4D2	Land converted to Wetlands	CO_2	40.9	50.0	64.6	
4E1	Settlements remaining Settlements	CO_2	6.4	42.3	42.8	yes
4E2	Land converted to Settlements	CO_2	19.4	31.8	37.2	yes
4F1	Other Land remaining Other Land	CO_2	NA	NA	NA	
4F2	Land converted to Other Land	CO_2	40.9	41.4	58.2	
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).

Land Use (NOLU04) acc. to AREA

16 Combination Categories (CC)	Settlement and urban areas: Building areas								Transport surfaces					Special urban areas							Recreational areas and cemeteries						Agricultural areas: Orchards, vineyards, horticulture			Arable and grassland			Alpine grazing areas			Forest areas: Forest (not used for agriculture)				Unproductive areas: Lakes and rivers			Unproductive land			
Land Cover (NOLC04) acc. to AREA	101 Industrial and commercial areas > 1 ha	102 Industrial and commercial areas < 1 ha	103 Residential areas (one and two-family house	104 Residential areas (terraced houses)	105 Residential areas (blocks of flats)	106 Public buildings and surroundings	107 Agricultural buildings and surroundings	108 Unspecified buildings and surroundings	121 Motorways	122 Roads	123 Parking areas	124 Railway surface	125 Airports and airfields	141 Energy supply plants	142 Waste treatment plants	143 Other supply or waste treatment plants	144 Dumps	145 Quarries, mines	146 Construction sites	147 Unexploited urban areas	161 Public parks	162 Sport facilities	163 Golf courses	164 Camping areas	165 Garden allotments	166 Cemeteries	201 Orchards	202 Vineyards	203 Horticulture	221 Arable land, in general	222 Semi-natural grassland, in general	223 Farm pastures, in general	241 Alpine meadows, in general	242 Alpine pastures, in general	243 Alpine sheep grazing pastures, in general	301 Forest	302 Afforestation	303 Lumbering areas	304 Damaged forest	401 Lakes	402 Streams, rivers	403 Flood protection structures	421 Unused	422 Avalanche and rockfall protection structures	423 Alpine sports facilities	424 Landscape intervention
10 Artificial areas																																														
11 Sealed surfaces	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51		51	51											51	51	51		51	51	51
12 Buildings	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51																				
13 Greenhouses	52	52	52	52	52	52	52	52			52	52	52						52	52	52	52	52	52	52	52			21																	
14 Gardens with border and patch structures	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52		21	21	21	21		21			12										
15 Lawns	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52		31	31																	
16 Trees in artificial areas	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54			54	54	54	54	54	54	54	54																				
17 Mix of small structures	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52		21	21																	
20 Grass and herb vegetation																																														
21 Grass and herb vegetation	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	31	31	31	21	31	31	31	31	31		12	12	12	37	37	37	37	37	37	31
30 Brush vegetation																																														
31 Shrub	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53		32	32								12	12	12	32	32	32	32	32	32	32
32 Brush meadows	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53		32	32		32	32	32	32			12	12	12	32	32	32	32	32	32	32
33 Short-stem fruit trees	53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53	33		33																	
34 Vines	53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53		33	33																	
35 Permanent garden plants and brush crops	52	52	52	52	52	52	52	52	52	52	52	52								52	52				52	52			33							12										
40 Tree vegetation																																														
41 Closed forest	54	54	54	54	54	54	54	54	54		54									54	54	54		54	54	54	34									12	12					12		12		
42 Forest edges	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54	54	54	54	54	34									12	12	12	12			12		12		
43 Forest strips	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54	34									12	12					12		12		
44 Open forest	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54	34				12	12	12	12	13	12	12	12	12			12		12	12	12
45 Brush forest																					53			53												13						13		13		
46 Linear woods	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	34	34	34	34	34	34	34	34	34		12	12	12	34	34	34	34	34	34	34
47 Clusters of trees	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	34	34	34	34	34	34	34	13	34		12	12	12	34	34	34	34	34	34	34
50 Bare land																																														
51 Solid rock	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51												13	13	61	61	61	61	61	61	61
52 Granular soil	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51		61	61									12	12	61	61	61	61	61	61	61
53 Rocky areas	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52		36	36			36	36	36			12	13	13	36	36	36	36	36	36	36
60 Watery areas																																														
61 Water	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41														41	41	41				41
62 Glacier, perpetual snow																																											61			
63 Wetlands	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42					42	42	42	42	42			12	13	42	42	42	42	42	42	42
64 Reedy marshes	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42				21	42	42	42	42	42					42	42	42	42			

Combination Categories (CC):

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

6.2.2 Spatial stratification

In order to quantify carbon stocks and increases/decreases, a further spatial stratification of the territory turned out to be useful. For forests and grassland three different altitudinal belts were differentiated. The whole territory of Liechtenstein is considered to be part of the pre-alpine region, 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 6-5). 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 6-5. 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.

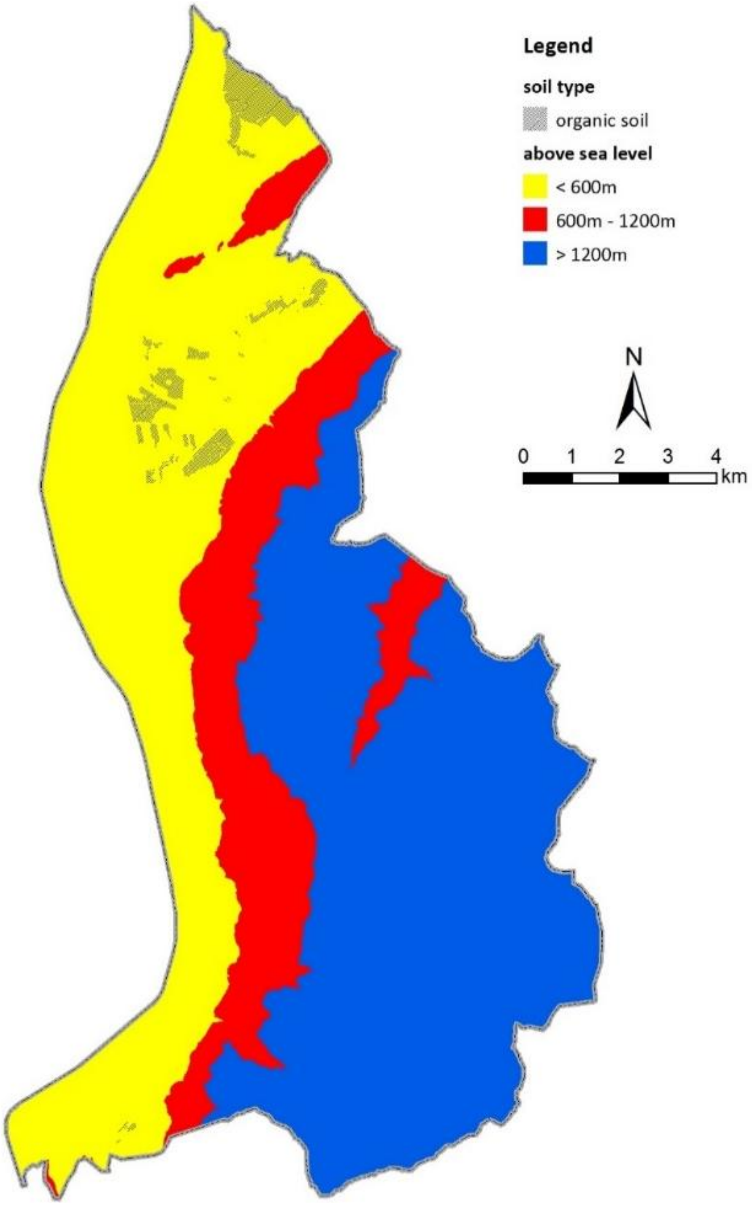


Figure 6-5 Map of Liechtenstein showing the altitude classes and soil types. Reference: OEP 2006d.

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 2024, while the area of cropland (CC21) decreases by 24% since 1990. The most significant land-use changes in absolute terms since 1990 can be observed in the categories cropland CC21 (decrease by 464 ha), grassland CC31–CC37 (decrease by 280 ha) and settlements CC51–CC54 (increase by 535 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 1990–2024 (in ha) and changes (in hectares and in %, see bottom lines) between 1990 and 2024.

	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	5'154	876	1'946	3'208	599	31	717	345	397	208	161	924	308	11	148	1'013	16'046
1991	5'167	885	1'942	3'195	584	32	711	343	396	202	160	939	309	12	150	1'019	16'046
1992	5'171	891	1'934	3'181	582	33	712	342	393	197	160	948	311	12	157	1'022	16'046
1993	5'179	898	1'936	3'165	575	32	707	342	392	193	159	963	311	10	158	1'026	16'046
1994	5'188	898	1'936	3'159	566	33	707	341	390	192	158	963	314	10	160	1'031	16'046
1995	5'194	905	1'925	3'153	562	33	708	338	387	188	159	975	314	10	163	1'032	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	5'190	912	1'918	3'142	556	31	706	338	380	188	162	996	321	12	157	1'037	16'046
1998	5'188	911	1'902	3'143	555	34	691	335	380	191	163	1'014	327	17	156	1'039	16'046
1999	5'181	920	1'887	3'143	549	35	683	339	380	196	162	1'023	331	18	157	1'042	16'046
2000	5'182	926	1'880	3'136	550	34	673	342	379	204	161	1'043	330	16	155	1'035	16'046
2001	5'176	933	1'882	3'126	554	34	662	345	376	210	162	1'058	330	18	157	1'023	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	938	1'871	3'139	542	33	644	346	378	218	160	1'082	334	20	155	1'013	16'046
2004	5'173	942	1'849	3'149	548	33	634	340	373	218	161	1'103	342	17	151	1'013	16'046
2005	5'168	947	1'832	3'154	549	35	629	340	373	215	160	1'117	348	18	148	1'013	16'046
2006	5'166	950	1'819	3'154	548	35	631	340	371	214	161	1'131	354	17	145	1'010	16'046
2007	5'172	947	1'791	3'155	551	35	631	336	369	212	162	1'146	363	17	143	1'016	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	5'190	939	1'758	3'166	544	33	615	336	371	204	163	1'175	374	19	138	1'021	16'046
2010	5'197	945	1'747	3'164	536	33	612	336	372	202	163	1'193	364	20	142	1'020	16'046
2011	5'213	945	1'734	3'164	530	32	607	335	376	199	163	1'204	371	19	137	1'017	16'046
2012	5'229	955	1'732	3'154	514	35	597	330	376	199	165	1'211	373	19	140	1'017	16'046
2013	5'236	955	1'716	3'165	503	36	596	331	374	197	165	1'224	377	18	139	1'014	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	5'249	964	1'678	3'184	495	37	592	321	376	197	161	1'239	393	16	140	1'004	16'046
2016	5'252	973	1'667	3'193	494	37	597	324	372	196	160	1'240	398	16	134	993	16'046
2017	5'253	991	1'636	3'217	477	35	597	321	375	193	159	1'252	400	18	135	987	16'046
2018	5'256	1'005	1'621	3'230	462	35	597	325	380	187	156	1'255	404	19	133	981	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	5'276	1'022	1'587	3'230	441	38	591	340	385	175	154	1'271	430	17	130	959	16'046
2021	5'288	1'028	1'569	3'239	430	38	584	339	385	174	152	1'277	444	15	128	956	16'046
2022	5'291	1'035	1'534	3'255	417	38	584	337	388	173	152	1'281	458	15	134	954	16'046
2023	5'303	1'030	1'508	3'263	416	37	575	340	387	175	149	1'300	458	15	138	952	16'046
2024	5'313	1'034	1'482	3'286	401	36	563	345	386	165	149	1'304	469	17	136	960	16'046
Change ha	159	158	-464	78	-198	5	-154	-	-11	-43	-12	380	161	6	-12	-53	-
Change %	3	18	-24	2	-33	16	-21	0	-3	-21	-7	41	52	55	-8	-5	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	970	1	1'946	1'177	22	31	389	15	88	168	137	769	272	7	132	45	6'169
Z2: 601-1200 m	1'977	8		360	8		77	11	6	15		87	28	2	13	71	2'663
Z3: >1200 m	2'207	867		1'671	569		251	319	303	25	24	68	8	2	3	897	7'214
	5'154	876	1'946	3'208	599	31	717	345	397	208	161	924	308	11	148	1'013	16'046
Soil																	
mineral	5'149	876	1'821	3'143	599	31	713	345	395	206	49	920	308	11	148	1'013	15'727
organic	5		125	65			4		2	2	112	4					319
	5'154	876	1'946	3'208	599	31	717	345	397	208	161	924	308	11	148	1'013	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 1990–2024.

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	-	1	-	-	1	-	-	-	-	1	-	-	-	1	5
		13	3		-	-	-	-	-	-	1	-	-	-	-	-	-	-	4
	Cropland	21	-	-		18	-	-	1	-	-	-	-	2	1	-	-	-	22
	Grassland	31	1	2	11		2	-	3	2	-	-	-	9	2	-	-	1	33
		32	4	6	-	1		-	-	2	-	-	-	1	-	-	-	-	14
		33	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
		34	4	-	-	3	-	-		-	-	-	-	2	-	-	-	-	9
		36	-	1	-	3	2	-	1		-	-	-	-	-	-	-	-	7
		37	-	-	-	-	2	-	-	-		-	-	-	-	-	-	-	2
	Wetlands	41	-	-	-	-	-	-	-	-	-		-	-	-	-	-	2	2
		42	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
	Settlement	51	-	-	-	3	-	-	-	-	1	-	-		1	-	1	-	6
		52	-	-	-	1	-	-	-	-	-	-	-	7		3	7	-	18
		53	-	-	-	-	-	-	-	-	-	-	-	2	-		-	-	2
		54	-	-	-	-	-	-	-	-	-	-	-	-	4	-		-	4
	Other Land	61	-	-	-	1	-	-	-	3	1	-	-	-	-	-	-		5
		Increase	12	10	11	31	6	-	6	7	3	-	-	24	8	3	8	4	133

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 1990–2024 six data sets are used:

- AREA1: Land-Use Statistics 1984
- AREA2: Land-Use Statistics 1996
- AREA3: Land-Use Statistics 2002
- AREA4: Land-Use Statistics 2008
- AREA5: Land-Use Statistics 2014
- AREA6: 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. For interpolating land-use changes between two AREA surveys (see Figure 6-6), it is assumed that the probability of a land-use change is uniformly distributed over the interim period between two surveys. Therefore, the year of the land-use change for a specific hectare is chosen randomly within the interim period.

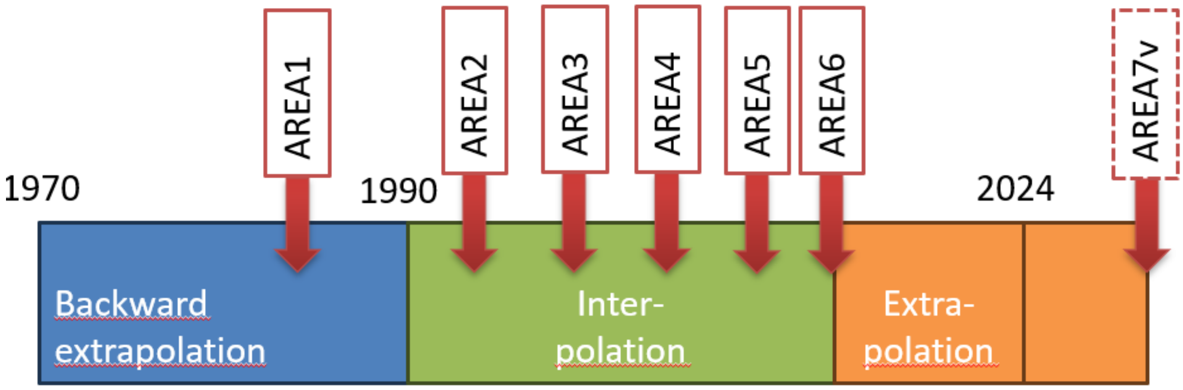


Figure 6-6 Procedures for determining the land-use categories 1990-2024 on a hectare cell: Interpolation between the AREA surveys 1 to 6, extrapolation after AREA6 using a virtual 7th survey (AREA7v) and backward extrapolation to account for land-use changes that occurred before 1990.

Extrapolation after 2019 is done by taking the average trend of the time period 2008 to 2019.

In other words, the land-use categories after the flight year of AREA6 were interpolated between AREA6 and a "virtual" 7th survey (AREA7v; see Figure 6-6). AREA7v was modelled for each sample point using a Markov-chain approach, where transition probabilities between AREA6 and AREA7v were assessed based on the transition distribution between AREA4 and AREA6 within the same elevation zone (see Figure 6-6).

For assessing land-use changes before 1990, it was assumed that between 1971 and 1989 the annual rates of all types of land-use change (per elevation zone) were the same as the corresponding rates between the AREA1 and AREA2 surveys (see also chp. 6.1.3.3). Based on this assumption, it was possible to model the land-use changes before 1990 by backward extrapolation (Figure 6-6). Knowledge of the earlier land-use pattern is required to calculate the carbon stock changes induced by land-use changes that occurred between 1971 and 1989, given a conversion time of up to 20 years.

In the extrapolation modelling, land-use changes were randomly assigned within the respective spatial strata (elevation zone), taking into account so-called "exclusion zones". These zones, in which no land-use changes are allowed, were defined as continuous areas of uniform land use, based on the assumption that land-use changes occur primarily in the border areas.

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 chps. (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

Activity data 1990–2023 were recalculated as follows:

- 4A–F: In the latest submission a geo-referenced approach was implemented for calculating carbon stock changes based on the hectare grid of the AREA survey. In contrast to the previous statistical approach, the following implications can be observed:
  Multiple land-use changes on the same hectare point can now be modelled unambiguously on the time axis. Such hectares no longer appear twice or even multiple times in the cumulative areas under categories 4X2 Land converted to X. This leads to somewhat larger areas in the CRT categories 4X1 at the cost of categories 4X2 in all inventory years. For example, the area of 4C2 is reduced by 0.07 kha (average

1990–2023).
As the smallest spatial unit is one hectare there are no fractions of hectares in the activity data anymore. This leads to a somewhat more fluctuating development of the land-use changes as the year of change for each hectare cell is chosen randomly between the AREA surveys.

- 4C, 4D: All areas are now considered as managed. In previous submissions, the categories CC36, CC37, CC41 and CC42 were reported as unmanaged in CRT Table4.1. However, this classification was not plausible: For example, there are hunting, fishing and touristic activities on those areas and CC42 are mainly drained areas. The calculation of carbon stock changes is not affected by this reclassification.

6.3.1.6 Planned improvements for activity data

There are no planned improvements.

6.3.2 Information on approaches used for natural disturbances

The approach to addressing emissions and subsequent removals from natural disturbances on managed lands is not applicable as the LULUCF categories are excluded from the target according to Lichtenstein's Second Nationally Determined Contribution (Government 2025).

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 3% between 1990 and 2024. The annual net CO_2 emissions/removals are in the range -13.17

kt CO_2 (2021) to 22.44 kt CO_2 (2000). The source category 4A 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 chps. 2.2.2 and 6.1.2). From 2011 onwards, it was always a net sink.

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/en (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)		Region 3 (Pre-Alps)		
	Units	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		New values (NFI4 2009/2017)		Previous values 2008	
Living biomass	Units	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 1986–2024 and the annual harvesting relative to the reference period of the two NFI (1999–2010, 2011-2022). Source: OE 2025b.

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	1.322
2012	26'813	1.329
2013	22'316	1.106
2014	22'259	1.103
2015	19'089	0.946
2016	18'012	0.893
2017	18'986	0.941
2018	25'573	1.267
2019	19'689	0.976
2020	15'468	0.767
2021	12'958	0.642
2022	14'293	0.708
2023	14'566	0.722
2024	13'820	0.685
Mean 1999-2010	20'714	1.000
Mean 2011-2022	20'177	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 1990–2024 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 LWI 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 LWI 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	-2.18
zone 2	-3.25	-2.31	-2.32	-2.04	-2.03	-1.83	-1.76	-1.82	-2.24	-1.87
zone 3	-2.67	-1.71	-1.72	-1.51	-1.50	-1.36	-1.30	-1.35	-1.66	-1.38

Altitude	2020	2021	2022	2023	2024
zone 1	-1.87	-1.68	-1.78	-1.80	-1.74
zone 2	-1.60	-1.44	-1.53	-1.54	-1.50
zone 3	-1.18	-1.07	-1.13	-1.14	-1.11

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 2025, chp. 6.4.2.3), 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 (2025) 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 2025).

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) and for unproductive forest (CC13).

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 6-7 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 6-7), 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)

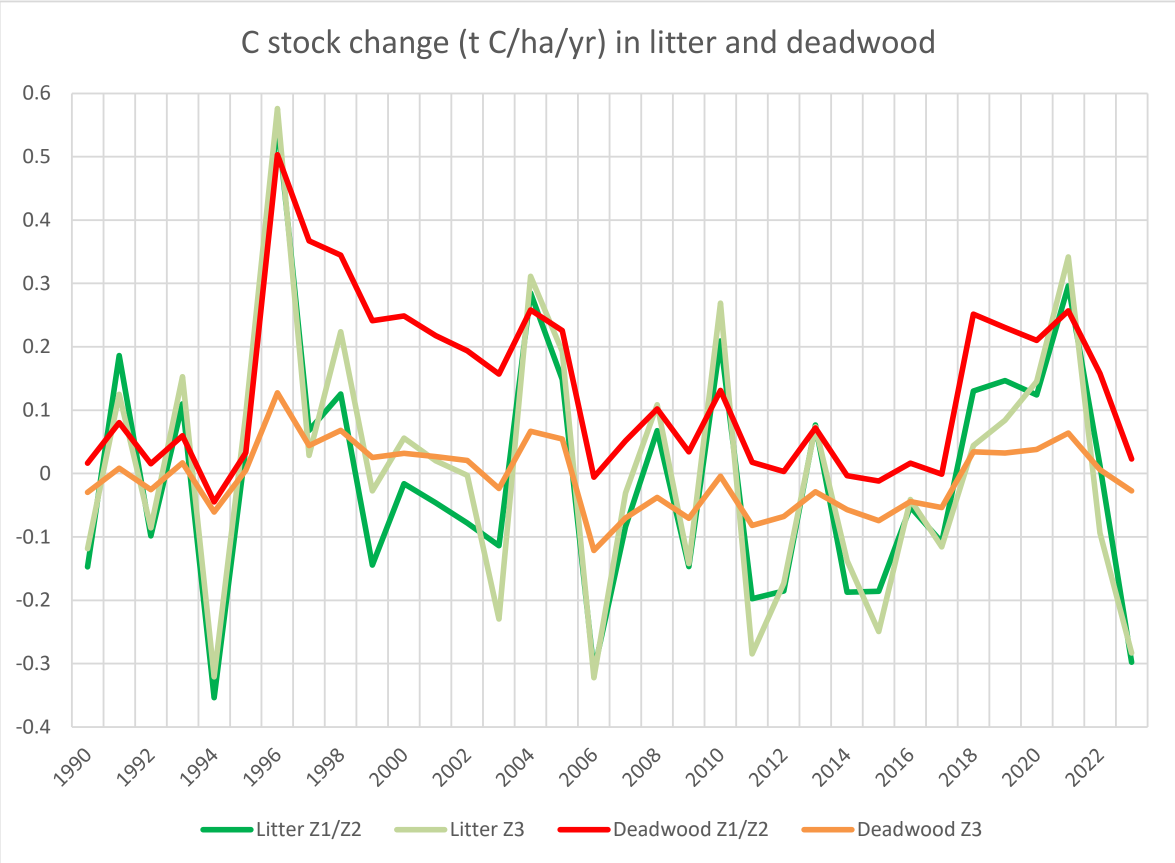


Figure 6-7 Carbon stock changes in deadwood and litter modelled with Yasso20 for different elevation zones (Z1/Z2: ≤1'200m, Z3: >1'200 m) in the NFI-region 3. Data source: FOEN 2025.

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 2024 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). It was assumed that 100% of organic soil on Forest land is subject to drainage as organic soils occur solely in the Rhine Valley plain (Ruggeller Ried).

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 2026: 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 Oertig (2025). 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 2023 and for the changing rates 2023/2024).

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 2023, the following recalculations lead to a increase of CO_2 emissions by 0.22 kt CO_2eq.

- 4A, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.
- 4A: Carbon stocks in litter for unproductive forest (CC13): New values from FOEN 2025 were adopted.
- 4A: It is assumed that all forest areas on organic soils are drained and thus emit CO_2. In former submissions, it was assumed that only a share of 3% was drained. This assumption was adopted from Switzerland, however it is not plausible for the situation in Liechtenstein, where organic soils occur solely in the Rhine Valley plain (Ruggeller Ried).
- 4A, loss of living biomass 2019 and 2022: There were small updates in the statistics on wood harvesting.

6.4.6 Category-specific planned improvements

There are no planned improvements.

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. 4B2 Land Converted to Cropland is not a key source.

9% 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 2024 by 24%.

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 chp. 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, chp. 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 chp. 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 A.2.1.2 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 A.2.1.2, 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 44.2% for the sum of the pools in organic and mineral soils (Annex A.2.1.2).

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 2023 and for the changing rates 2023/2024).

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 2023, the following recalculations lead to a decrease of CO_2 emissions by 0.15 kt CO_2eq and to minor changes (<0.05 kt CO_2eq) regarding the emissions of N_2O.

- 4B, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

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 is a key source concerning level and trend. 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. Conversion to grassland occurs mainly from cropland, forest land and other land. These changes are however less important than the reverse conversions, for example from grassland to forest (mainly by the raising timber line) and from grassland to settlements. The total area of grassland decreased by 5% in 2024 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).

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 A.2.1.2 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 A.2.1.2, 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 41.0% for the sum of the pools in organic and mineral soils of category 4C1 (Annex A.2.1.2).

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 0.178 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 2024, the absolute uncertainty for 4C2 is 0.008 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 2024 is 0.160 t C ha^{-1} yr^{-1} (related to the total area of 4C2) as shown in Annex A.2.1.2.

The root sum squares of those three absolute uncertainties are 0.239 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 2024, the mean net carbon stock changes were -0.86 t C ha^{-1} for 4C2 (calculated from CRT Table4.C). The resulting relative EF-uncertainty is 28.0% 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, chp. 6.4.3)
- Biomass expansion functions, sampling uncertainty: 21.2% (see FOEN 2025, chp. 6.4.3)
- Biomass expansion functions, model uncertainty: 22.2% (FOEN 2025, chp. 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 2023 and for the changing rates 2023/2024).

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 2023, the following recalculations lead to an increase of CO_2 emissions by 1.80 kt CO_2eq and to minor changes (-0.08 kt CO_2eq) regarding the emissions of N_2O.

- 4C, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

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. 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). 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 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 2026: 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 A.2.1.2). The resulting relative EF uncertainty for 4D2 is 50.0% (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 2023 and for the changing rates 2023/2024).

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 2023, the following recalculations lead to an decrease of CO_2 emissions by 0.22 kt CO_2eq and to minor changes (<0.05 kt CO_2eq) regarding the emissions of N_2O.

- 4D, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

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 level and 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 2024, 535 net hectares were converted to settlements, which is an increase of 38%. 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 chp. 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 chp. 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

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	index referring to a raster cell
A_i	area of a raster cell (equals to one hectare)
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 A.2.1.2).

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 42.3% and 31.8%, respectively (see Table 6-6 and Annex A.2.1.2).

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 2023 and for the changing rates 2023/2024).

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 2023, the following recalculations lead to a decrease of CO_2 emissions by 0.34 kt CO_2eq and to minor changes (<0.05 kt CO_2eq) regarding the emissions of N_2O.

- 4E, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

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 2024 the area of "Other Land" has declined by 5%. 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 41.4% (see Annex A.2.1.2).

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 33/2024Category-specific recalculations

In 2023, the following recalculations lead to a increase of CO_2 emissions by 1.59 kt CO_2eq and to minor changes (<0.05 kt CO_2eq) regarding the emissions of N_2O.

- 4F, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

6.9.5 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, productive 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):

$$Emission(N_2O) = -deltaCs * 1 / (C:N) * EF1 * 44 / 28, \text{ if } deltaCs < 0 \qquad [kt\ N_2O]$$

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 (chp. 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 chp. 1.5.

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

6.10.5 Category-specific recalculations

In 2023, the following recalculations lead to an decrease (<0.2 kt CO_2eq) regarding the emissions of N_2O.

- 4(III), activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

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:

$$V_{1961} = V_{swiss,1961} * Population_{1961} / Population_{swiss,1961} = 3'671 \text{ m}^3$$

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 m³ in 1990 (see Figure 6-8).

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 m³ 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 m³).

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 m³ (30% of 3'500 m³).

With this information the time-series of sawnwood production in Liechtenstein was constructed as follows: 1990–2000 decline from 6'247 m³ to 4'500 m³, 2001–2010 decline from 4'500 m³ to 3'500 m³, 2011–2017 a constant value of 3'500 m³, after 2017 a constant value of 1'050 m³.

Production, gains and losses from sawnwood are listed in Table 6-18 and Figure 6-8 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 2024, 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 m³	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 m³	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	2024					
Sawnwood production, 1000 m³	1.05	1.05	1.05	1.05	1.05					
Gains sawnwood, kt C	0.26	0.26	0.26	0.26	0.26					
Losses sawnwood, kt C	-0.89	-0.88	-0.87	-0.86	-0.85					
Net emissions/removals, kt CO_2	**2.31**	**2.27**	**2.22**	**2.18**	**2.14**					

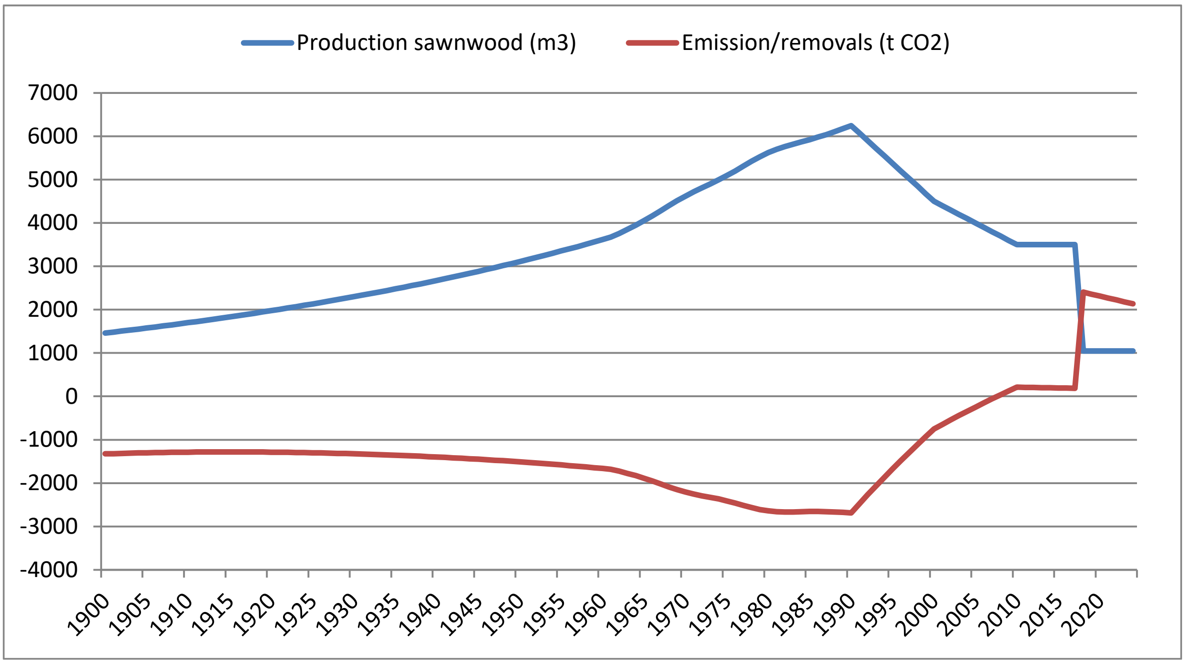


Figure 6-8 Liechtenstein's sawnwood production (m^3) and net emissions (positive sign) and removals (negative sign) of CO_2 (tons) from Harvested Wood Products between 1900 and 2024.

Import and export of sawnwood from 1990 to 2024 are reported in CRT Table4.Gs2. They were estimated on the basis of Swiss import and export data published in the Swiss NID (FOEN 2025) 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 2023 and for the changing rates 2023/2024).

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

6.11.5 Category-specific recalculations

No category-specific recalculations have been carried out in 4G Harvested Wood Products for submission 2026.

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 2024 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 1990–2024.

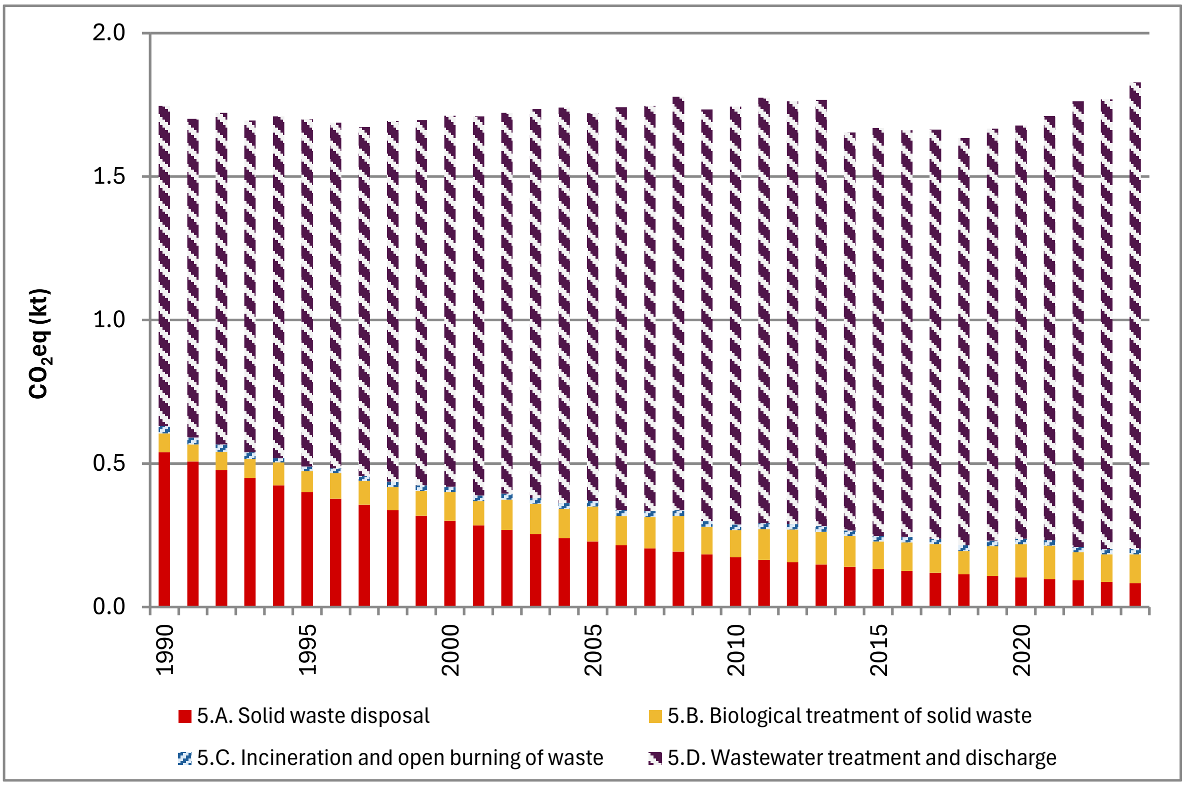


Figure 7-1 Liechtenstein's GHG emissions of sector 5 Waste. Note that there are no emissions in category 5E Other.

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	1.25	1.19	1.18	1.19	1.15
N_2O	0.48	0.50	0.52	0.52	0.59
Sum	**1.75**	**1.70**	**1.71**	**1.72**	**1.74**

Gas	2015	2016	2017	2018	2019
	CO2 equivalent (kt)				
CO_2	0.01	0.01	0.01	0.01	0.01
CH_4	1.05	1.06	1.06	1.04	1.06
N_2O	0.61	0.60	0.59	0.58	0.60
Sum	**1.67**	**1.66**	**1.66**	**1.63**	**1.67**

Gas	2020	2021	2022	2023	2024	1990-2024
	CO2 equivalent (kt)					%
CO_2	0.01	0.01	0.01	0.01	0.01	-19%
CH_4	1.07	1.08	1.12	1.12	1.17	-7%
N_2O	0.60	0.62	0.63	0.64	0.65	35%
Sum	**1.68**	**1.71**	**1.76**	**1.77**	**1.83**	**5%**

In sector 5 Waste a total of 1.83 kt CO_2 equivalents of greenhouse gases were emitted in 2024. 4.6% of the total emissions origin from 5A Solid waste disposal, 5.5% from 5B Biological treatment of solid waste, 1.1% from 5C Incineration and open burning of waste and 88.9% 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 2024 by 4.7%. 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 chp. 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] = ∑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 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 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 2023 and for the changing rates 2023/2024).

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

No category-specific recalculations have been carried out in 5A Solid Waste Disposal for submission 2026.

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 - centralized composting plants - backyard composting

7.3.2 Methodological issues: Biological Treatment of Solid Waste (5B)

Methodology

Emissions are calculated by a Tier 2 method based on chp. 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 2025/5B1 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 2021/5B1 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 2025c).

Activity data for backyard composting are derived from the Swiss NID (FOEN 2025). It is assumed that the amount of backyard composting per inhabitant in Switzerland is equivalent to that in Liechtenstein. 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 probably directly linked to the introduction of the polluter-pays-principle for mixed municipal solid waste management.

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	1.43	1.49	2.08	2.65	2.06

Waste composting		2015	2016	2017	2018	2019
Composted centrally	kt dm/a	2.13	2.22	2.22	1.80	2.34

Waste composting		2020	2021	2022	2023	2024
Composted centrally	kt dm/a	2.61	2.63	2.20	2.12	2.24

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 dm/inhabitant	6.6	8.8	10.0	9.1	6.1
Population	inhabitants	29'032	30'923	32'863	34'905	36'149
Composted backyard	kt dm/a	0.190	0.272	0.329	0.319	0.222

Waste composting		2015	2016	2017	2018	2019
organic waste	kg dm/inhabitant	4.8	4.8	4.7	4.7	4.7
Population	inhabitants	37'623	37'810	38'114	38'380	38'749
Composted backyard	kt dm/a	0.182	0.181	0.180	0.180	0.181

Waste composting		2020	2021	2022	2023	2024
organic waste	kg dm/inhabitant	4.6	4.6	4.6	4.5	4.4
Population	inhabitants	39'055	39'315	39'677	40'015	40'886
Composted backyard	kt dm/a	0.181	0.181	0.181	0.180	0.182

7.3.3 Uncertainties and Time-Series Consistency: Biological treatment of solid waste (5B)

For the current submission a simplified uncertainty analysis has been carried out as described in chp. 1.6. 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 2023 and for the changing rates 2023/2024).

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 0.02 kt CO_2eq in 2023:

- The activity data for the quantity of backyard composting has been reassessed for the years 1990–2023 based on an update of the underlying statistics of Switzerland's NID (FOEN 2025).

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. 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 NID (FOEN 2025).

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 NID (FOEN 2025, EMIS 2025/5C1 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 2025).

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 2025).

5C Open burning of waste	unit	**1990**	**1995**	**2000**	**2005**	**2010**
EF CO_2 fossil	kg/t waste	525.79	552.85	578.30	560.11	522.71

5C Open burning of waste	unit	**2015**	**2016**	**2017**	**2018**	**2019**
EF CO_2 fossil	kg/t waste	523.27	531.10	535.71	538.79	542.45

5C Open burning of waste	unit	**2020**	**2021**	**2022**	**2023**	**2024**
EF CO_2 fossil	kg/t waste	544.94	544.05	548.24	542.73	538.26

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 2025c).

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 2025).

Table 7-12 Activity data for category 5C Incineration and open burning of waste (OS 2025c, OE 2018d, FOEN 2025).

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%	50.5%	51.3%	50.5%	48.6%
fossil waste incinerated illegaly	kt	0.026	0.017	0.020	0.020	0.021

5C Open burning of waste	unit	2015	2016	2017	2018	2019
MSW generated	kt	8.50	8.27	8.32	8.26	7.98
Fraction incinerated illegally		0.5%	0.5%	0.5%	0.5%	0.5%
Waste incinerated illegally	kt	0.043	0.041	0.042	0.041	0.040
Fossil share of MSW		48.5%	48.8%	49.0%	49.3%	49.5%
fossil waste incinerated illegaly	kt	0.02	0.02	0.02	0.02	0.02

5C Open burning of waste	unit	2020	2021	2022	2023	2024
MSW generated	kt	8.20	8.11	7.87	8.03	8.33
Fraction incinerated illegally		0.5%	0.5%	0.5%	0.5%	0.5%
Waste incinerated illegally	kt	0.041	0.041	0.039	0.040	0.042
Fossil share of MSW		49.8%	50.0%	50.3%	50.3%	50.3%
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 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. 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 2023 and for the changing rates 2023/2024).

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

The following recalculations lead to changes in CO_2 emissions, resulting in an increase of <0.01 kt CO_2eq in 2024:

- The time series for the proportion of fossil carbon concerning waste incineration has been updated for the years 1991–2023 (except the years 2007 and 2012) based on Switzerland's NID (FOEN 2025).

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 2025).

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.

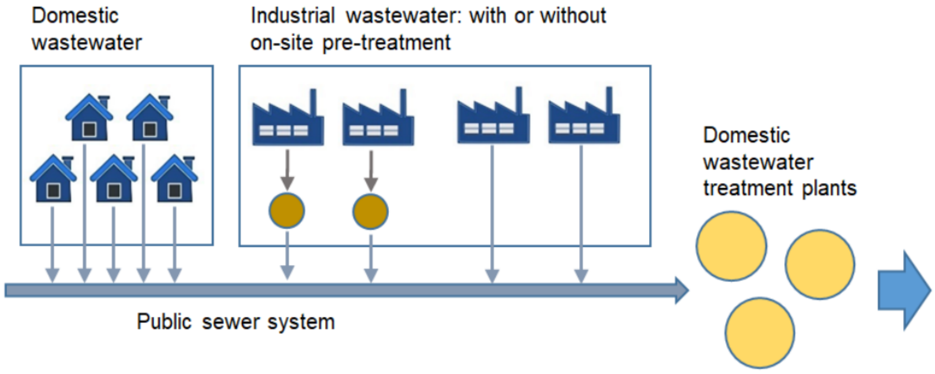


Figure 7-2 Graphical representation of domestic and industrial wastewater streams and treatment.

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 chp. 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 2025/5D1 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 0.65%-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 2025). 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 2025, SFOE 2002, SVGW 2016).

Sewage gas treatment		1990	1995	2000	2005	2010
Sewage gas for boilers	TJ	5.816	6.340	8.102	0.588	9.792
Sewage gas for CHP generation	TJ	6.266	7.719	10.999	18.852	10.969
Sewage gas flared	TJ	2.457	1.791	1.155	0.019	0.043
Sewage gas losses	t CH4	1.807	2.103	2.857	2.905	3.106
Sewage gas for upgrading	t CH4	0.000	0.000	0.000	0.000	0.000

Sewage gas treatment		2015	2016	2017	2018	2019
Sewage gas for boilers	TJ	0.062	0.526	0.739	0.317	0.524
Sewage gas for CHP generation	TJ	0.386	1.110	1.561	1.354	0.777
Sewage gas flared	TJ	0.023	0.026	0.034	0.022	0.013
Sewage gas losses	t CH4	0.067	0.245	0.344	0.250	0.194
Sewage gas for upgrading	t CH4	457.191	417.957	462.014	482.059	507.836

Sewage gas treatment		2020	2021	2022	2023	2024
Sewage gas for boilers	TJ	0.102	0.188	0.254	0.028	0.006
Sewage gas for CHP generation	TJ	0.381	0.636	1.446	0.468	4.270
Sewage gas flared	TJ	0.006	0.009	0.002	0.004	0.032
Sewage gas losses	t CH4	0.072	0.123	0.256	0.075	0.644
Sewage gas for upgrading	t CH4	547.939	532.642	438.287	444.646	389.426

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. The values are taken from "Nahrungsmittelbilanz der Schweiz" (AGRISTAT 2023). The value for year 2024 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 2025d, 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	37	37	36	38

5D Wastewater treatment and discharge		2015	2016	2017	2018	2019
Population	inhabitants	37'623	37'810	38'114	38'380	38'749
Degree of Utilization	%	97.0	97.0	97.0	97.0	97.0
Protein Consumption	kg/capita/yr	37.2	36.1	36.1	35.4	35.4

5D Wastewater treatment and discharge		2020	2021	2022	2023	2024
Population	inhabitants	39'055	39'315	39'677	40'015	40'886
Degree of Utilization	%	97.0	97.0	97.0	97.0	97.0
Protein Consumption	kg/capita/yr	35.8	36.5	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 chp. 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 2023 and for the changing rates 2023/2024).

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

No category-specific recalculations have been carried out in 5D Wastewater treatment and discharge for submission 2026.

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 Table 8.s1, 8s2)

1 Energy

Recalculation in 1A1

No category-specific recalculations have been carried out in 1A1 Energy Industries for submission 2026.

Recalculation in 1A2

For the 2026 submission, the following recalculations lead to minor changes (<0.1 kt CO_2eq) in CO_2, CH_4 and N_2O emissions in 2023.

- 1A2g: The activity data for biodiesel and bioethanol 1997–2023 were updated, to include the fossil share, which are taken from the newest road transportation model of Switzerland (INFRAS 2025).

Recalculation in 1A3

The following recalculations lead to changes in CO_2, CH_4 and N_2O emissions resulting in a decrease of 0.05 kt CO_2eq in 2023:

- 1A3b: The activity data for biodiesel and bioethanol 1990–2023 were updated, to include the fossil part of the carbon content, which are taken from the newest road transportation model of Switzerland (INFRAS 2025).
- 1A3b: The emission data for vehicles has been updated according to the latest road model of Switzerland for the years 1990–2023 (INFRAS 2025). This has changed the consumption of gasoline, diesel and lubricants.

Recalculation in 1A4

No category-specific recalculations have been carried out in 1A4 Other sectors for submission 2026.

Recalculation in 1B2

No category-specific recalculations have been carried out in 1B2 Fugitive emissions from oil and natural gas and other emissions from energy production for submission 2026.

2 IPPU

Recalculation in 2D

Switzerland's GHG inventory 2026 was not yet available for Liechtenstein's submission 2026. For Switzerland, the following recalculations have been carried out in submission 2025, which also influence Liechtenstein's emission time series reported in Submission 2026:

- The activity data of lubricant use in 2-stroke engines and thus also of unspecified lubricant use have changed for the entire time series due to recalculated gasoline and bioethanol consumption in 1A3biv 2-stroke motorcycles.

In addition, the following recalculations lead to changes in CO_2 emissions:

- 2D1: Since the number of inhabitants in Switzerland was updated based on newest available statistics (SFSO 2025d) the activity data (number of inhabitants) has changed in 2022.
- 2D: The emission factors for the use of lubricants for the year 2022 were not correct in the last submission. The mistake has been corrected.

Recalculation in 2F

Switzerland's GHG inventory 2026 was not yet available for Liechtenstein's submission 2026. For Switzerland, the following recalculations have been carried out in submission 2025, which also influence Liechtenstein's emission time series reported in Submission 2026:

- 2F1: There are changes in activity data 2020–2022 for the disposal of HFC and PFC from commercial and industrial equipment: The modelling of the remaining refrigerant amount for use in stationary refrigeration was reduced.
- 2F1: There are changes in activity data 2022 of HFC and PFC use for mobile and air-conditioning and stationary refrigeration related to changes in the vehicle and equipment statistics.
- 2F1: There are changes in the activity data 2020–2022: The portion of HFC in air-conditioning of vans was revised.
- 2F2: There are changes in activity data 2020–2022 related to the portion of PU-Spray containing HFC-134a.

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

- 2F1, 2F2, 2F4: Since the number of inhabitants in Switzerland was updated based on newest available statistics (SFSO 2025d) the activity data (number of inhabitants) has changed in 2022.
- 2F1: Since the number of vehicles in Liechtenstein was updated based on newest available statistics (OS 2025c) the activity data (number of inhabitants) has changed in 2021–2023.

In 2023, the above mentioned recalculations lead to an increase in HFC/PFC emissions of around 0.73 kt CO_2eq.

Recalculation in 2G

- 2G3: Since the number of inhabitants in Switzerland was updated based on newest available statistics (SFSO 2025d) the activity data (number of inhabitants) has changed in 2022.

In 2023, the above mentioned recalculations lead to an increase in N_2O emissions of <0.001 kt CO_2eq.

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

No category-specific recalculations have been carried out in 3A Enteric fermentation for submission 2026.

Recalculation in 3B

No category-specific recalculations have been carried out in 3B Manure management for submission 2026.

Recalculation in 3D

No category-specific recalculations have been carried out in 3D Agricultural soils for submission 2026. Recalculation in 3H

No category-specific recalculations have been carried out in 3H Urea application for submission 2026.

4 LULUCF

Recalculation in 4A

In 2023, the following recalculations lead to a increase of CO_2 emissions by 0.22 kt CO_2eq.

- 4A, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.
- 4A: Carbon stocks in litter for unproductive forest (CC13): New values from FOEN 2025 were adopted.
- 4A: It is assumed that all forest areas on organic soils are drained and thus emit CO_2. In former submissions, it was assumed that only a share of 3% was drained. This assumption was adopted from Switzerland, however it is not plausible for the situation in Liechtenstein, where organic soils occur solely in the Rhine Valley plain (Ruggeller Ried).

- 4A, loss of living biomass 2019 and 2022: There were small updates in the statistics on wood harvesting.

Recalculation in 4B

In 2023, the following recalculations lead to a decrease of CO_2 emissions by 0.15 kt CO_2eq and to minor changes (<0.05 kt CO_2eq) regarding the emissions of N_2O.

- 4B, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

Recalculation in 4C

In 2023, the following recalculations lead to an increase of CO_2 emissions by 1.80 kt CO_2eq and to minor changes (-0.08 kt CO_2eq) regarding the emissions of N_2O.

- 4C, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

Recalculation in 4D

In 2023, the following recalculations lead to an decrease of CO_2 emissions by 0.22 kt CO_2eq and to minor changes (<0.05 kt CO_2eq) regarding the emissions of N_2O.

- 4D, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

Recalculation in 4E

In 2023, the following recalculations lead to a decrease of CO_2 emissions by 0.34 kt CO_2eq and to minor changes (<0.05 kt CO_2eq) regarding the emissions of N_2O.

- 4E, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

Recalculation in 4F

In 2023, the following recalculations lead to a increase of CO_2 emissions by 1.59 kt CO_2eq and to minor changes (<0.05 kt CO_2eq) regarding the emissions of N_2O.

- 4F, activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

Recalculation in 4(III)

In 2023, the following recalculations lead to an decrease (<0.2 kt CO_2eq) regarding the emissions of N_2O.

- 4(III), activity data (areas) 1990–2023 (see chp. 6.3.1.5): The new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations.

Recalculation in 4G

No category-specific recalculations have been carried out in 4G Harvested Wood Products for submission 2026.

5 Waste

Recalculation in 5A

No category-specific recalculations have been carried out in 5A Solid Waste Disposal for submission 2026.

Recalculation in 5B

The following recalculations lead to changes in CH_4 and N_2O emissions, resulting in an increase of 0.02 kt CO_2eq in 2023:

- The activity data for the quantity of backyard composting has been reassessed for the years 1990 2023 based on an update of the underlying statistics of Switzerland's NID (FOEN 2025).

Recalculation in 5C

The following recalculations lead to changes in CO_2 emissions, resulting in an increase of <0.01 kt CO_2eq in 2024:

- The time series for the proportion of fossil carbon concerning waste incineration has been updated for the years 1991–2023 (except the years 2007 and 2012) based on Switzerland's NID (FOEN 2025).

Recalculation in 5D

No category-specific recalculations have been carried out in 5D Wastewater treatment and discharge for submission 2026.

10.2 Implications for emission and removal levels 1990 and 2023

Table 10-1 shows the recalculation results for the base year 2023. The recalculations have the following effect on the emissions in 2023 in comparison with the submitted emissions of the previous year:

- The difference in national total emissions 2023 amounts to a total increase of 0.73 kt CO_2eq (0.44%) without emissions/removals from LULUCF.
- Including LULUCF, the difference in national total emissions 2023 amounts to a total increase of 3.56 kt CO_2eq (+2.22%).

The following recalculations contributed substantially to the differences in emissions in 2023 between the current submission and the previous submission:

- There are minor recalculations in the LULUCF sector in the whole period 1990–2023 arising mainly from the new geo-referenced approach (see Figure 10-1). The new approach leads to more fluctuating development of land-use changes and related carbon stock changes (see chp. 6.3.1.5).

- Recalculations regarding HFC and PFC emissions (source category 2F) lead to changes especially in the years 2020–2023 (see chp. 4.7.5).
- Additional small recalculations have been carried out in the waste sector:
    - 5B Biological treatment of waste: The activity data for the quantity of backyard composting has been reassessed for the years 1990–2023 based on an update of the underlying statistics of Switzerland's NID (FOEN 2025).

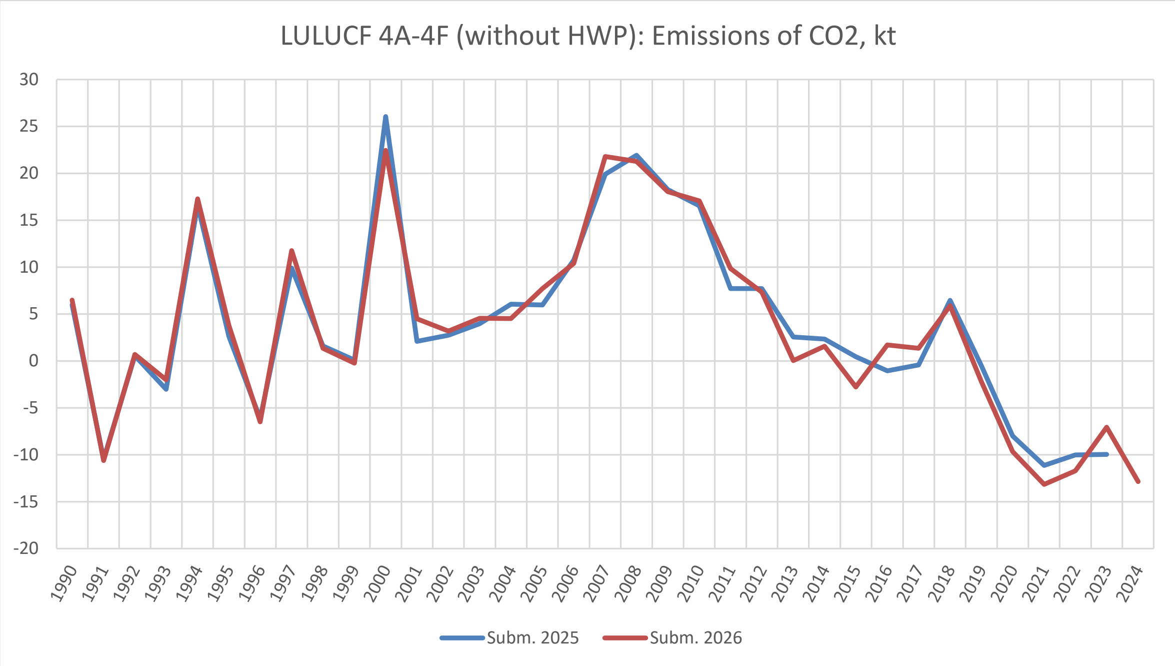


Figure 10-1 CO2 emissions in sector 4 LULUCF in the previous and latest submission (without HWP). The development of the emissions is very similar but there is more scatter in the latest submission due to the new geo-referenced approach.

Table 10-1 Overview of implications of recalculations on 2023 data. Emissions are shown before the recalculation according to the previous submission in 2025 "Prev." (OE 2025) and after the recalculation according to the present submission 2026 "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 2023	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	131.1	131.1	*0.03*	1.8	1.7	*-0.02*	0.8	0.8	*-0.03*	133.6	133.6	*-0.01*
2 IPPU (without F-gases)	0.1	0.1	-	NO	NO	*NO*	0.1	0.1	*0.00*	0.24	0.24	*0.00*
3 Agriculture	0.0	0.0	*-0.00*	18.6	18.6	-	5.6	5.6	*-0.00*	24.24	24.2	*-0.00*
4 LULUCF	-7.8	-4.9	*2.90*	NO	NO	*NO*	0.5	0.4	*-0.08*	-7.30	-4.5	*2.82*
5 Waste	0.0	0.0	*0.00*	1.1	1.1	*0.02*	0.6	0.6	*0.01*	1.75	1.77	*0.02*
Sum (without F-gases)	123.4	126.4	*2.94*	21.5	21.5	*-0.01*	7.6	7.5	*-0.10*	152.5	155.4	*2.83*

Recalculation	**HFC**			**PFC**			**SF_6**			**Sum (F-gases)**		
Emissions for 2023	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)	7.5	8.2	*0.73*	0	0	*0.00*	0.0	0.0	*0.00*	7.5	8.2	*0.73*

Recalculation	**Sum (all gases)**		
Emissions for 2023	Prev.	Latest	Differ.
Source and sink categories	CO_2 equivalent (kt)		
Total CO_2 eq Em. with LULUCF	**160.04**	**163.6**	***3.56***
	100.0%	102.2%	*2.22%*
Total CO_2 eq Em. without LULUCF	**167.34**	**168.1**	***0.73***
	100.0%	100.4%	*0.44%*

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 increase of 0.02 kt CO_2eq (0.01%) without emissions/removals from LULUCF.
- Including LULUCF, the difference in national total emissions 1990 amounts to a total increase of 0.52 kt CO_2eq (0.22%).

The main reason for differences in emissions in 1990 between the current submission and the previous submission are recalculations in sector LULUCF and in sector Agriculture.

- There are small recalculations in the LULUCF sector, as a new geo-referenced approach for interpolating and extrapolating yearly land-use data was implemented. Relevant changes occurred in the following source categories:
    - 4A Forest land (recalculations see chp. 6.4.5)
    - 4B Cropland (recalculations see chp. 6.5.5)
    - 4C Grassland (recalculations see chp. 6.6.5)
    - 4D Wetlands (recalculations see chp. 6.7.5)

- 4E Settlements (recalculations see chp. 6.8.5)

Additional small recalculations have been carried out in the Waste sector:

- 5B Biological treatment of waste: The activity data for the quantity of backyard composting has been reassessed for the years 1990–2023 based on an update of the underlying statistics of Switzerland's NID (FOEN 2025).

Table 10-2 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submission in 2025 "Prev." (OE 2025) and after the recalculation according to the present submission 2026 "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	*0.00*	1.4	1.4	*-0.00*	1.1	1.1	*0.00*	201.3	201.3	*0.00*
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	-	18.4	18.4	-	6.4	6.4	-	24.8	24.8	-
4 LULUCF	3.3	3.8	*0.51*	NO	NO	*NO*	0.3	0.3	*-0.01*	3.6	4.1	*0.50*
5 Waste	0.0	0.0	*-0.00*	1.2	1.3	*0.01*	0.5	0.5	*0.01*	1.7	1.7	*0.02*
Sum (without F-gases)	202.2	202.8	*0.51*	21.0	21.0	*0.01*	8.7	8.7	*-0.00*	232.0	232.5	*0.52*

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	**232.0**	**232.5**	***0.52***
	100.0%	100.2%	*0.22%*
Total CO_2 eq Em. without LULUCF	**228.5**	**228.5**	***0.02***
	100.0%	100.0%	*0.01%*

10.3 Implications for emission and removal trends, including time series consistency

Due to recalculations, the emission trend 1990–2023 reported in submission 2025 has changed. The emission trend showed a decrease by 26.75% before the recalculations (previous submission, national total without emissions/removals from LULUCF). After the recalculations in the latest submission 2026, the decreasing trend is slightly lower (-26.43%).

Table 10-3 Change of the emission trend 1990–2023 due to recalculations carried out in the latest submission 2025. “Previous” refers to the values from submission 2025 (OE 2025).

Recalculation	1990		2023		change 1990/2023	
Submission	previous	latest	previous	latest	previous	latest
	CO_2 eq (kt)				%	
Total excl. LULUCF	228.45	228.47	167.34	168.08	-26.75%	-26.43%

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
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 implem entation	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 implem entation	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.	Ongoing implem entation	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
	The ERT recommends that the Party fill any blank cells in the CRF tables with values or appropriate notation keys.			
ARR 2013 / 21	Implement additional QC procedures to avoid mistakes or discrepancies between the CRF tables and the NID.	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". 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 2027	A more detailed explanation was added in the NID 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 2027. Information on the use of the notation key "IE" is provided in NID chp. 1.7.	1 Energy
ARR 2022 ID#E.7	1.A.3.b Road transportation – biodiesel – CO2 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	Implemented in submission 2026	The emissions from the fossil part of the biofuels are accounted for in submission 2026 (in source category 1.A.3.b. Road transportation – liquid fuels – CO2).	1 Energy

Reference	Identified Issues, e.g. recommendations or planned improvements	Status	Comment/Reason NID	Sector
	accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.			
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 organic soils on cropland and grassland.	Planned improvement for 2027	The party will improve table 4(II) as recommended.	4 LULUCF
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 2027	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 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. 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	Ongoing implementation	This planned improvement will be implemented during the next update of the FOD-model of Liechtenstein.	5 Waste

Reference	Identified Issues, e.g. recommendations or planned improvements	Status	Comment/Reason NID	Sector
	waste disposal sites from 1950–1979 have been recalculated according to BUS 1978. Lichtenstein is planning to align its activity data at the time when the FOD model is going to be updated.			

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 Approach 1

A.2.1.1 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:

$$U_{\%,EF} = \sqrt{\sum_i (Em_{\%,i} * U_{\%,EF,i})^2} \quad (1)$$ error propagation for emission factors

$$U_{\%,AD} = \sqrt{\sum_i (Em_{\%,i} * U_{\%,AD,i})^2} \quad (2)$$ error propagation for activity data

Where:

$U_{\%,EF}$	aggregated relative uncertainty in emission factors
$U_{\%,AD}$	aggregated total relative uncertainty in activity data
$Em_{\%,i}$	disaggregated relative emissions of source i compared to total emissions
$U_{\%,EF,i}$	disaggregated relative uncertainty in emission factor of source i
$U_{\%,AD,i}$	disaggregated relative uncertainty in activity data of source i.

The results of the aggregation process are displayed in Table A - 1.

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%	**9.2%**
$U_{\%}$ Activity Data	10.0%	15.0%	**9.2%**
$U_{\%}$ Emission Factor	0.13%	0.07%	**0.07%**
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	0.08%	0.08%	**0.06%**
1A4 Gaseous fuels CO_2	(Sub)Categories		**Aggr. Uncertainties**
	1A4a	*1A4b*	*total/implied*
$U_{\%}$ Emissions	5.0%	5.0%	**3.9%**
$U_{\%}$ Activity Data	5.0%	5.0%	**3.9%**
$U_{\%}$ Emission Factor	0.4%	0.4%	**0.3%**

A.2.1.2 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 (2024).

Cate-gory	Process, pool	CSC	Process share	AD_Unc AREA survey	AD_Unc organic soil	AD_Unc combined	EF_Unc	EF_absUnc
		t C/ha (1)		%	%	%	%	t C/ha
4A1	total	0.73	1.00	2.7			34.9	
4A2	total	4.45	1.00	17.2			34.9	
4B1	organic soil	-0.64	1.00	6.9	30.0	30.8	23.0	
	total	-0.64	1.00	6.9			23.0	
4B2	organic soil	-0.09	0.85	26.9	30.0	40.3	23.0	0.043
	mineral soil	0.00	0.04	26.9			50.0	0.002
	total	-0.10	0.89	26.9			44.2	0.043
4C1	organic soil	-0.13	0.93	6.0	30.0	30.6	23.0	0.050
	mineral soil	0.01	0.06	6.0			50.0	0.004
	total	-0.12	0.99	6.0			41.0	0.050
4C2	organic soil	-0.40	0.47	13.6	30.0	32.9	23.0	0.160
	mineral soil	-0.02	0.02	13.6			50.0	0.008
	living biom.	-0.44	0.52	13.6			40.3	0.178
	total	-0.86	0.53	13.6			28.0	0.239
4D1	total	0.00	1.00	10.5			50.0	
4D2	mineral soil	-0.52	1.00	40.9			50.0	0.259
	living biom.	0.00	0.00	40.9			40.3	0.000
	total	-0.52	1.00	40.9			50.0	0.259
4E1	mineral soil	0.32	0.84	6.4			50.0	0.158
	living biom.	0.06	0.16	6.4			40.3	0.025
	total	0.38	1.00	6.4			42.3	0.160
4E2	mineral soil	-0.43	0.31	19.4			50.0	0.216
	living biom.	-0.95	0.69	19.4			40.3	0.383
	total	-1.38	1.00	19.4			31.8	0.440
4F2	mineral soil	-0.96	1.00	40.9			50.0	0.480
	living biom.	-0.22	0.00	40.9			40.3	0.088
	total	-1.18	1.00	40.9			41.4	0.488
4G	total	-0.05	1.00	50.0			57.0	

(1) related to total area (sum of organic and mineral soils) in 2022.

A2.2 Approach 2

A.2.2.1 Work steps

As a first step, the probability distributions need to be selected and their parameters need to be defined for the activity data and emission factors, based on measured data, literature or expert judgement as well as the Swiss Inventory. The mean values of the probability distributions are set equal to the values of the GHG inventory. In most cases, normal distributions are assumed. For some agricultural categories, triangular distributions are applied (see below).

In a second step, correlation coefficients for activity data, CO_2 emission factors and emission levels are chosen. Correlations may have a significant effect on the overall inventory uncertainty. Depending on whether correlations are negative or positive, they can lead to a decrease or increase in level uncertainty, respectively. Regrading trend uncertainty, positive correlations lead to a decrease and negative correlations to an increase in the trend uncertainty. Correlations were defined only for categories with relevant contributions to total uncertainty. If a large set of parameters is correlated between each other, the resulting correlation matrix might be mathematically inconsistent. In this case, the software Crystal Ball adjusts correlation coefficients iteratively such that the resulting correlation matrix is mathematically consistent. The modification of the correlation coefficients amounts in average to 0.10.

In the third step, Monte Carlo simulations are carried out to produce uncertainty results (see below). Several runs were performed to study the sensitivity to the choice of correlation strengths.

A.2.2.2 Assumptions for the probability distributions

For almost all source and sink categories, normal distributions are chosen. The important exceptions are agricultural source categories as indicated in Table A - 3, where triangular distributions are applied.

Table A - 3 Probability distribution assigned to activity data and emission factors (1990 and 2024) of categories that are not considered normally distributed. For all other categories, normal probability distributions have been assigned.

IPCC Source Category				Gas	Probability distribution	
					AD	EF
3Da1	3. Agriculture	3D Agricultural soils		N2O	normal	triangular
3Da6	3. Agriculture	3D Agricultural soils		N2O	normal	triangular
3Da3	3. Agriculture	3D Agricultural soils		N2O	triangular	triangular
3Db1	3. Agriculture	3D Agricultural soils		N2O	triangular	triangular
3Db2	3. Agriculture	3D Agricultural soils		N2O	triangular	triangular

A.2.2.3 Assumptions for the correlation coefficients

Since there are no quantitative correlation coefficients available, only the following values have been used (if any are assumed):

- "strong" positive correlations are set to r = 1.0 (like perfect correlations),
- "medium" correlations are set to r = ±0. 5.
- "weak" correlations are set to r = ±0.25.

The following correlations are assumed and taken into account in the analyses:

- Activity data of liquid and gaseous fuels from the categories 1A2 and 1A4 are negatively correlated (r = -0.5), since the total amount is well known but the partitioning into the different categories is less precisely known. By choosing negative correlations, overestimations in a category during the simulations are compensated by underestimations in one or more of the other categories. In addition, it is assumed that a lower consumption of liquid and gaseous fuels in the base year (b) will also lead to an lower consumption in 2024 (t) and vice versa. Therefore, a positive correlation is assumed for consumption of liquid fuels in 1A2 and 1A4 between the base year and the year 2024 (r=0.5). The same correlation is assumed for consumption of gaseaous fuels in 1A2 and 1A4.
- Activity data/emissions of 3A (Enteric Fermentation) and 3B (Manure Management) are positively correlated (r = 0.5) since they are both based on the same livestock numbers.
- The emission factors of agricultural categories are correlated between 1990 and 2024. A strong positive correlation is assumed.

Table A - 4 Correlation coefficients used for correlated activity data (AD), emission factors (EF) and emissions (EM).

	b_AD_1A2_Gaseous Fuels_CO2	b_AD_1A4_Gaseous Fuels_CO2	t_AD_1A2_Gaseous Fuels_CO2	t_AD_1A4_Gaseous Fuels_CO2
b_AD_1A2_Gaseous Fuels_CO2	1			
b_AD_1A4_Gaseous Fuels_CO2	-0.5	1		
t_AD_1A2_Gaseous Fuels_CO2	0.5	-0.5	1	
t_AD_1A4_Gaseous Fuels_CO2		0.5	-0.5	1

	b_AD_1A2_Liquid Fuels_CO2	b_AD_1A4_Liquid Fuels_CO2	t_AD_1A2_Liquid Fuels_CO2	t_AD_1A4_Liquid Fuels_CO2
b_AD_1A2_Liquid Fuels_CO2	1			
b_AD_1A4_Liquid Fuels_CO2	-0.5	1		
t_AD_1A2_Liquid Fuels_CO2	0.5	-0.5	1	
t_AD_1A4_Liquid Fuels_CO2		0.5	-0.5	1

	b_EM_3A_0_CH4	b_EM_3B_0_CH4	t_EM_3A_0_CH4	t_EM_3B_0_CH4
b_EM_3A_0_CH4	1			
b_EM_3B_0_CH4	0.5	1		
t_EM_3A_0_CH4	0.5		1	
t_EM_3B_0_CH4		0.5	0.5	1

	b_EF_3Da1/2/4/5/7_fertilizer_N2O	t_EF_3Da1/2/4/5/7_0_N2O
b_EF_3Da1/2/4/5/7_fertilizer_N2O	1	
t_EF_3Da1/2/4/5/7_0_N2O	1	1

	b_EF_3Da3_0_N2O	t_EF_3Da3_0_N2O
b_EF_3Da3_0_N2O	1	
t_EF_3Da3_0_N2O	1	1

	b_EF_3Da6_organic soils_N2O	t_EF_3Da6_0_N2O
b_EF_3Da6_organic soils_N2O	1	
t_EF_3Da6_0_N2O	1	1

	b_EF_3Db1_deposition_N2O	t_EF_3Db1_0_N2O
b_EF_3Db1_deposition_N2O	1	
t_EF_3Db1_0_N2O	1	1

	b_EF_3Db2_leaching and runoff_N2O	t_EF_3Db2_0_N2O
b_EF_3Db2_leaching and runoff_N2O	1	
t_EF_3Db2_0_N2O	1	1

The influence of correlations on Approach 2 results for level and trend uncertainty are negligible.

A.2.2.4 Detailed results of Monte Carlo simulations

Table A - 5 Results of Approach 2 uncertainty analysis, Monte Carlo simulation (Table 3.3 of the 2006 IPCC Guidelines, see also explanations therein on pp. 3.42–3.43 for each column). Simplified approach: only key categories are taken into account individually; further categories are summed up in “non-key rest” categories for the different gases (separately for LULUCF and non-LULUCF categories).

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2024 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2026	Inventory trend in national emissions 1990-2024	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO2 eq	kt CO2 eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
1A1 Gaseous Fuels CO2	0.12	2.20	-5.0	5.0	-0.5	0.5	-5.0	5.0	0.0002	1’717	-91	91
1A2 Liquid Fuels CO2	20.99	8.43	-20.0	20.0	-0.1	0.1	-20.1	20.0	0.0392	-60	-22	22
1A2 Gaseous Fuels CO2	15.20	9.96	-5.0	5.0	-0.5	0.5	-5.0	5.0	0.0034	-34	-6	6
1A3b CO2	75.29	42.47	-9.2	9.2	-0.1	0.1	-9.2	9.2	0.2093	-44	-11	11
1A4 Liquid Fuels CO2	76.71	23.15	-15.9	15.9	-0.1	0.1	-15.9	15.9	0.1857	-70	-17	17
1A4 Gaseous Fuels CO2	10.21	28.19	-3.9	3.9	-0.3	0.3	-3.9	3.9	0.0167	176	-11	12
1B2b CH4	0.41	1.27	-35.4	35.4	-35.4	35.4	-50.0	50.2	0.0055	212	-164	163
2F1 Aggregate F-gases	0.00	7.70	-12.0	12.0	-12.0	12.0	-17.1	17.0	0.0236	8’020’667	-1’370’679	1’367’076
3A CH4	15.42	15.61	-6.5	6.5	-19.2	19.2	-20.3	20.3	0.1376	1	-29	29
3B CH4	2.94	2.67	-6.5	6.5	-54.6	54.6	-54.8	54.6	0.0295	-9	-74	74
3B N2O	1.22	1.38	-35.5	35.5	-56.7	56.7	-66.5	66.4	0.0116	14	-102	101
3Da1/2/4/5/7 N2O	3.15	2.41	-15.3	12.3	-90.0	80.0	-69.6	71.0	0.0386	-26	-103	100
3Da6 N2O	0.01	0.01	-17.6	49.1	-75.0	200.0	-68.9	101.3	0.0000	7	-173	171
3Da3 N2O	0.12	0.23	-52.3	81.3	-100.0	333.3	-83.4	140.3	0.0037	229	-387	508
3Db1 N2O	1.17	0.85	-35.2	48.9	-80.0	80.0	-64.6	78.2	0.0056	-28	-107	99
3Db2 N2O	0.76	0.55	-22.5	22.2	-100.0	81.8	-77.7	78.6	0.0024	-32	-110	106
4A1 CO2	-0.33	-15.74	-2.7	2.7	-2.7	2.7	3.8	-3.8	0.0050	4’693	182	-184
4A2 CO2	-4.28	-7.63	-17.2	17.2	-34.9	34.9	38.9	-38.8	0.1214	78	80	-80
4B1 CO2	4.22	3.18	-30.8	30.8	-23.0	23.0	-38.5	38.4	0.0205	-25	-48	48
4C1 CO2	2.07	1.91	-6.0	6.0	-41.0	41.0	-41.4	41.6	0.0086	-8	-56	56
4C2 CO2	0.10	2.65	-13.6	13.6	-28.0	28.0	-31.1	31.1	0.0093	2’494	-806	807
4D1c CO2	1.98	1.96	-10.5	10.5	-50.0	50.0	-51.0	51.0	0.0138	-1	-72	72
4E1 CO2	0.04	-2.20	-6.4	6.4	-42.3	42.3	42.6	-42.7	0.0120	-5’172	-2’165	2’168
4E2 CO2	1.67	2.32	-19.4	19.4	-31.8	31.8	-36.9	37.2	0.0101	39	-63	64
4G CO2	-2.69	2.14	-50.0	50.0	-54.8	54.8	-74.2	74.0	0.0344	-180	95	-94
non-key rest (LULUCF only) CO2	-0.93	-0.71	-7.1	7.1	-7.1	7.1	10.0	-10.0	0.0001	-24	13	-13
non-key rest (LULUCF only) CH4	-	-	-21.2	21.2	-21.2	21.2	NO	NO	-	-	-	-
non-key rest (LULUCF only) N2O	2.20	1.80	-56.6	56.6	-56.6	56.6	-80.2	79.7	0.0284	-18	-103	103
non-key rest (LULUCF only) Aggregate F-gases	-	-	-14.1	14.1	-14.1	14.1	NO	NO	-	-	-	-
non-key rest (excl. LULUCF) CO2	0.45	0.29	-7.1	7.1	-7.1	7.1	-10.0	10.0	0.0000	-35	-12	12
non-key rest (excl. LULUCF) CH4	2.27	1.60	-21.2	21.2	-21.2	21.2	-29.9	30.0	0.0032	-30	-37	37
non-key rest (excl. LULUCF) N2O	2.03	1.54	-56.6	56.6	-56.6	56.6	-79.7	80.1	0.0208	-24	-100	100
non-key rest (excl. LULUCF) Aggregate F-gases	-	0.47	-14.1	14.1	-14.1	14.1	NO	NO	-	-	-	-
incl. LULUCF	**233**	**141**					**-6.07**	**6.04**		**-39.47**	**-7.87**	**7.83**
excl. LULUCF	**228**	**151**					**-4.84**	**4.83**		**-33.87**	**-7.52**	**7.48**

A.2.2.5 Relation between simulated and inventory values

The Monte Carlo method simulates a probability distribution of the Liechtenstein’s greenhouse gas emissions from which all relevant statistical parameters can be derived (mean, standard deviation and percentiles). The simulated mean value may slightly differ from the reported value.

The discrepancy between simulated and reported values becomes apparent when mean numbers in Figure 1-8 are compared to reported numbers in the summary tables. It is not a relevant issue for the uncertainty analysis but can be confusing for readers and reviewers who carefully study the numbers. For transparency reasons, the numbers are explained in Table A - 6.

The absolute percentiles generated by the simulation are firstly expressed as relative numbers (the simulated mean is set to 100%). Then the relative numbers are transferred to the numbers reported in the summary tables, then they are applied to derive the absolute uncertainties.

Table A - 6 Mean values, 2.5 and 97.5 percentiles of the Monte Carlo simulation and corresponding values of the reported emissions (as listed in summary tables).

Year	Parmeters	Unit	Emission (excl. LULUCF)	Lower bound 2.5 percentile	Upper bound 97.5 percentile	Lower uncertainty	Upper uncertainty
2024	**simulated values**						
	absolute	kt CO_2 eq	151	144	158	-7	7
	relative	%	100.00%	95.16%	104.83%	-4.84%	4.83%
	reported values						
	absolute	kt CO_2 eq	151	144	158	-7	7
	relative	%	100.00%	95.16%	104.83%	-4.84%	4.83%
1990	**simulated values**						
	absolute	kt CO_2 eq	229	213	244	-16	16
	relative	%	100.00%	93.21%	106.81%	-6.79%	6.81%
	reported values						
	absolute	kt CO_2 eq	228	213	244	-16	16
	relative	%	100.00%	93.21%	106.81%	-6.79%	6.81%

Annex 3 Detailed description of reference approach

No supplementary information to the statements given in chp. 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, CRT tables and NID 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 2017–2025). 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 2024 were compared with those of the year 2023 within the current Reporting Table Summary2.
    - The emissions of the year 2023 were compared between the current Reporting Table Summary2 of submission 2026 and the Reporting Table Summary2 of submission 2025.
    - The emissions of the base year 1990 were compared between the current Reporting Table Summary2 of submission 2026 and the Reporting Table Summary2 of the submission 2025.
- 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 - 7 Checklist for QC activities[3] 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: BES Bettina Schäppi, BRI Beat Rihm, DAG David Giger FEW Felix Weber, HE Hanspeter Eberle, JB Jürgen Beckbissinger, KJ Karin Jehle, LIB Lina Bernert, RI Regula Imhof.

Quality Control System for Climate Reporting Liechtenstein Submission 2026		**Respon-sible**	**Date**	**Visa**
Checklist for sectoral experts and NID authors				
Contact person:	Bettina Schäppi, INFRAS			
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	06.11.2025	JB, KJ
	INFRAS-internal checks, comparison with methods chosen	NA	07.11.2025	BES
2. Check for transcription errors in data input and reference	plausibility check of the basic input data for Solvent and Ind calculation	SE	13.11.2025	JB
	plausibility check of the basic input data from the LWA	SE	20.11.2025	JB
	check input Data for SF6 Emission calculation	SE	27.11.2025	JB
	check stationary Energy	NA	04.12.2025	BES
	check IPPU	NA	11.12.2025	BES
	check Waste	NA	11.12.2025	BES
	Agriculture: Plausibility check of data in background tables Acontec. Issues identified and discussed with Acontec	SE	12.12.2025	FEW, JB
3. Check that emissions are calculated correctly	Ongoing checks of the calculated emissions in all sectors	SE	26.11.2025	JB
	Clarification of data/figures	PM	18.12.2025	BES

[3] 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 2026		Respon-sible	Date	Visa
	INFRAS-internal control: Plausibility checks, "Delta-Analysis" combined with KCA, INFRAS-internal control of time series	NA	29.01.2026	BES, FEW
	INFRAS-internal checks during generation of tables/figure in chp. 2 Trends (independent control by second person BES)	SE	29.01.2026	BES
4. Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used	check energy-activity-data (reference approach)	SE	06.11.2025	JB
	check energy-activity-data (reference approach)	NA	11.12.2025	BES
	check Energy	SE	06.11.2025	JB
	check Energy	NA	14.12.2025	DAG
	check IPPU	SE	06.11.2025	JB
	check IPPU	NA	12.12.2025	BES
	check Agriculture	SE	06.11.2025	JB
	check Agriculture	NA	14.12.2025	FEW
	check LULUCF	SE	07.11.2025	JB
	check LULUCF	NA	07.01.2026	BRI
	check Waste	SE	07.11.2025	JB
	check Waste	NA	05.12.2025	LIB
5. Check the integrity of database files	integrity checked	SE	20.11.2025	JB
6. Check for consistency in data between source categories	check general data consistency	SE	20.11.2025	JB
	check Energy (stationary)	NA	11.12.2025	DAG
	check Energy (mobile)	NA	11.12.2025	DAG
	check IPPU	NA	12.12.2025	DAG
	check Agriculture	NA	11.01.2026	FEW
	check LULUCF	NA	06.01.2026	BRI
	check Waste	NA	16.01.2026	LIB
7. Check that the movement of inventory data among processing steps is correct	Processing checked	NIC	12.12.2025	KJ
	Data transfer from the land-use statistics to the LULUCF tables and clarification of comprehensive questions with JB	SE	07.11.2025	KJ
	check Agriculture	SE	13.11.2025	JB
	plausibility check / control of overall emissions from agriculture in CO2 equivalents, in total and for the source categories for all years	SE	13.11.2025	JB
	check LULUCF	SE	16.01.2026	KJ
8. Check that uncertainties in emissions and removals are estimated or calculated correctly	check Energy	NA	29.01.2026	FEW
	check IPPU	NA	29.01.2026	FEW
	check Agriculture	NA	29.01.2026	FEW
	check Waste	NA	29.01.2026	LIB, BES
9. Check time series consistency	check for temporal consistency in time series input data for each category.	NIC	29.01.2026	KJ
	check in the algorithm/method used for calculations throughout the time series.	NIC	29.01.2026	KJ
	check methodological and data changes resulting in recalculations.	NA	12.12.2025	BES
	check that the effects of mitigation activities have been appropriately reflected in time series calculations.	NIC	29.01.2026	KJ
10. Check completeness	Completeness check for all sectors	SE	27.11.2025	JB
	Completeness check for all sectors	NA	26.01.2026	BES

Quality Control System for Climate Reporting Liechtenstein Submission 2026		**Respon-sible**	**Date**	**Visa**
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	18.12.2025	KJ, JB, FEW, BES, LIB, BRI, DAG
	Check value of implied emission factors across time series.	NIC	22.01.2026	KJ
	Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series.	NIC/SE	8.12.2025	KJ, JB, FEW, BES, LIB, BRI, DAG
12. Review of internal documentation	Internal OE check of documentation; Clarification of open questions with SE	PM	13.12.2025	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	29.01.2026	LIB
14. Compare CRT tables with previous year	check Energy	NA	04.12.2025	DAG
	check IPPU	NA	05.12.2025	BES
	check Agriculture	NA	15.12.2025	FEW
	check Waste	NA	18.12.2025	LIB
	check LULUCF	NA	17.12.2025	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	7.11.2025	KJ
	check: Energy (stationary)	NA	05.12.2025	DAG
	check: Solvents	NA	05.12.2025	BES
	Clarification of comprehensive questions in different sectors with SE	PM/NA	11.12.2025	KJ
	Two independent checks of Energy (mobile)	SE	05.12.2025	DAG
	check waste	NA	16.01.2026	BES
	check Agriculture	SE	15.12.2025	FEW
	check LULUCF	SE	11.06.2025	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	11.12.2025	FEW
17. Check correctness of KCA, comparison with previous results	Plausibility checks of KCA	PM	05.02.2026	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	29.01.2026	LIB
18. Check correctness of uncertainty analysis, comparison with previous results	internal plausibility checks for all sectors	NA	29.01.2026	FEW
	INFRAS internal plausibility checks	NA	29.01.2026	BES
	check waste	NA	30.01.2026	BES

Quality Control System for Climate Reporting Liechtenstein Submission 2026		Respon-sible	Date	Visa
Check of transcription errors CRT → NID (numbers, tables, figures)	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	29.01.2026	BES, FEW
20. Check AD in NID and CRT and compare data with reference data sources	check waste	NA	12.02.2026	LIB
21. Check for complete and correct references in NID	INFRAS-internal checks	NA	26.02.2026	BES
22. Check for correctness, completeness, transparency and quality of NID	Proofread of complete draft NID	NA	26.02.2026	BES
	final proofread Executive Summary, feedback to KJ	NFP	01.04.2026	KJ
	final proofread inventory/NID, feedback and discussion with KJ	QM	03.04.2026	KJ
	final proofread inventory/NID, discussion with BES and JB	PM	02.04.2026	BES, KJ
	final proofread inventory/NID, feedback to KJ	SE	04.04.2026	HE
	Internal OE discussions on the inventory/NID draft with RI HE and KJ	PM	07.04.2026	KJ
	Feedback from OE internal discussions	PM	07.04.2026	KJ
	Final proofreading inventory/NID	PM	08.04.2026	KJ
23. Check for completeness of submission documents	Final check and Submission	PM/NIC NFP	11.04.2026	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	15.04.2026	BES, BRI
	Internal Review of documents submitted in April; all relevant documents archived	NIC	15.04.2026	KJ

A4.3 Checklists for QA activities (internal review)

Table A - 8 Checklists for QA activity internal review.

Liechtenstein's National Inventory Document
Review form for internal review of NID submission 2025

Reviewer	**Karin Jehle (KJ)**
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Chapter(s) reviewed	All

NID authors	Bettina Schaeppi (BES)
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Reviewer's comments (yellow) and answers of authors (green)	
Consistency checks were made. Checks between CRT data and NID were made. Questions sent as comments.	
Comments in the text were addressed.	
Reviewers comments performed	
Date / Signum	02.04.2026 / KJ

Taken note of review	
Date / Signum	08.04.2026 / BES

If necessary: Additional comments of reviewer (yellow) and author's answers (green)

None

Datum / Signum	10.04.2026 / KJ

Liechtenstein's National Inventory Document
Review form for internal review of NID submission 2025

Reviewer	**Regula Imhof (RI)**
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Chapter(s) reviewed	ES, chp. 1

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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	04.04.2026 / RI

Taken note of review	
Date / Signum	08.04.2026 / BES

If necessary: Additional comments of reviewer (yellow) and author's answers (green)

none

Datum / Signum	10.04.2026 / RI

Annex 5 Any additional information

A5.1 Road Transportation

Chp. 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}, $EF_{evap,i}$, $EF_{evap\text{-}RL}$: 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 - 9 Data for estimating enteric fermentation emission factors for cattle (for 2024).

Type	Age[a]	Weight[a]	Weight Gain[a]	Feeding Situation / Further Specification[a]	Milk[b]	Work	Pregnant[a]	Digestibility of feed	CH_4 Conversion[d]	Em. Factor
		kg	kg/day		kg/day	hrs/day	%	%[d]	%	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). 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 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 Zeitz et al. 2012.
e For better comparability emission factors of young cattle were converted to kg/head/year although the time span of most of the individual categories is less than 365 days.

A.5.2.2 Additional data for estimating CH4 emissions from 3B Manure management

Table A - 10 Data for estimating manure management CH_4 emission factors (for 2024).

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	102.5	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 - 11 Data for estimating N_2O emissions from crop residues.

2024		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	752’969	3.2	0.050
	Barley	121’482	0.6	0.010
	Maize	455’345	4.3	0.067
	Oats	3’834	0.02	0.00
	Rye	-	-	-
	Other:			
	Triticale	52’683	0.26	0.0041
	Spelt	22’070	0.20	0.0032
	Mix of Fodder Cereals	-	-	-
	Mix of Bread Cereals	6’704	0.03	0.00
	Millet	-	-	-
2. Pulse	Dry Beans	5’984	0.2	0.004
	Peas (Eiweisserbsen)	7’921	0.2	0.004
	Soybeans	1’737	0.1	0.001
	Leguminous Vegetables	597	0.1	0.001
	Lupines	-	-	-
3. Tuber and Root	Potatoes	660’850	2.4	0.038
	Other:			
	Fodder Beet	-	-	-
	Sugar Beet	377’804	2.7	0.042
5. Other	Fruit	11’854	0.11	0.0017
	Grass	25’596’386	85	1.3
	Green Corn	-	-	-
	Non-Leguminous Vegetables	978’294	12	0.18
	Rape	58’937	1.01	0.016
	Renewable Energy Crops	-	-	-
	Silage Corn	5’912’415	3.5	0.055
	Sunflowers	1’071	0.023	0.00036
	Tobacco	-	-	-
	Vine	14’440	0.25	0.0040
	Oil Squash	-	-	-
	Oil Hemp	-	-	-
	Oil Flax	-	-	-
	Hops	-	-	-
	Medicinal Plants and Herbs	-	-	-
Total Non-leguminous		9’430’751	30.12	0.47
Total Leguminous		16’239	0.60	0.01
Total excluding grass		9’446’990	30.73	0.48
Total including grass		35’043’376	115.42	1.81

Table A - 12 Data for estimating N_2O emissions from crop residues (fractions).

2024		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	0.32	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 2025 (FOEN 2025) 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 2025).

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 2025).

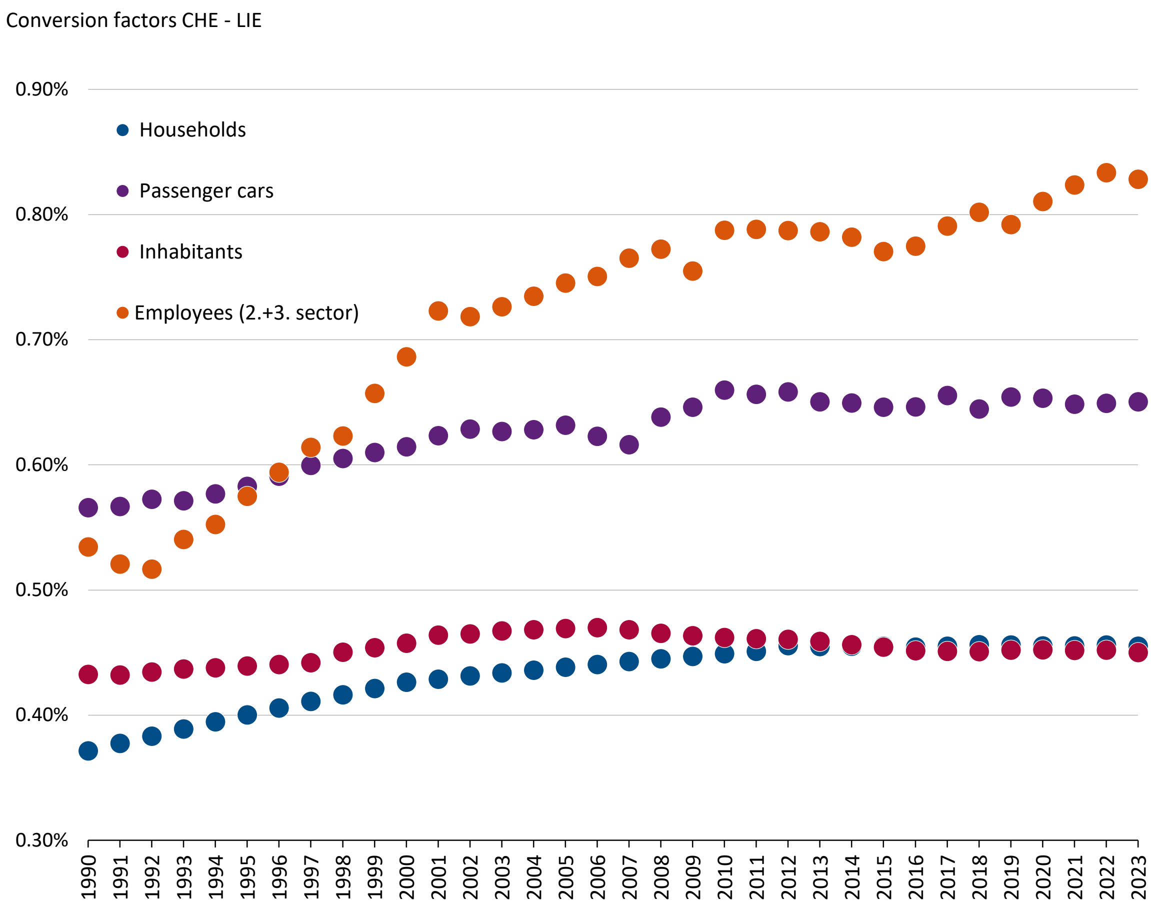

Figure A - 1 Conversion factors used to derive emissions in Liechtenstein from emissions reported in Switzerland's national GHG inventory 2025.

A5.4 Additional information on sewage sludge prohibition

As described in chp. 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]

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