REPUBLIC OF ESTONIA
MINISTRY OF CLIMATE

GREENHOUSE GAS EMISSIONS IN ESTONIA 1990-2023
NATIONAL INVENTORY DOCUMENT

SUBMISSION TO THE UNFCCC SECRETARIAT

Common Reporting Tables (CRT) 1990–2023

Estonia 2025

PREFACE

Estonia's National Inventory Document (NID) to the UNFCCC Secretariat contains following parts:

Description of the greenhouse gas emission inventory according to the UNFCCC reporting guidelines (18/CMA.1) containing description of the organization of the national greenhouse gas inventory, IPCC and other methods applied in calculation of the year 2023 emissions and exemptions to the previous inventories. A summarizing table of the emissions data for the years 1990–2023 is included as well as the description of current emission trends.

The Estonian Environmental Research Centre (Ms Sirly-Ann Meriküll, Ms Reelika Mägi, Ms Linda Britte Männisalu, Mr Stanislav Štõkov and Mr Martin Ruul) and the Estonian Environment Agency (Ms Helen Karu, Ms Eve Suursild and Mr Madis Raudsaar) have compiled the inventory calculations and/or provided the description of the methodologies, and other information included in the National Inventory Document.

The Climate Department of the Estonian Environmental Research Centre Ms Cris-Tiina Pärn and Ms Kadi Meltz coordinated the process of the inventory preparation.

The Ministry of Climate is the single national entity with the overall responsibility for the Estonian greenhouse gas inventory. The Estonian Environmental Research Centre has the responsibility for the preparation and finalization of inventory reports and their submission to the UNFCCC Secretariat and the European Commission on behalf of the Ministry of Climate.

Financial resources for inventory compilation are planned in the National Administrative Agreement and State Budget.

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Background information on climate change

According to WMO State of the Global Climate 2023[1] was the warmest year on record with the global average near-surface temperature at 1.45 (±0.12)°C above the pre-industrial baseline. The past nine years, 2015-2023, were the nine warmest years on record.

Europe is the fastest warming continent, with temperatures rising at around twice the global average rate. In Estonia, the second period of fast warming started in 1970s. January characterizes the highest increase in temperature. Statistically significant warming is also characteristic of April, July and August. According to the climate normal the average temperature for 1991-2020 is 1.5 degrees higher than the average of 1901-1930.

Precipitation constitutes the climate indicator with the biggest variability in time and space. Large fluctuations of precipitation can be observed between single days, weeks, months, seasons and even years. The difference in precipitation between locations situated close to one another may be significant, especially in summer. Although there has been a slight increase in precipitation normals, the most significant changes affect seasonal averages. In winter, the average precipitation for 1991-2020 has increased by 21% compared to 1961-1990. At the same time, autumn has become drier by 5%.

The duration of snow cover has generally decreased in Estonia in the last few decades, but due to its high variability this trend is not statistically significant. Beginning of permanent snow cover has not reliably changed throughout the period of 1951-2015. In some regions the end date of the permanent snow cover has receded four weeks. Duration of permanent snow cover has shortened in several places, the most 1.5 months.

It is extremely difficult to adequately assess long-term changes in wind speed as it largely depends on the obstacles to wind situated close to the measuring site. However, research has been conducted into changes in wind directions in the period from 1966–2008. This indicates that the proportion of westerly and south-westerly winds has significantly increased in winter while the proportion of south-easterly and easterly winds has decreased.

In 2015, the Estonian Environment Agency drew up an overview of the climatic changes in Estonia, which occurred in the last century, as well as of the projections and assessments of the future climate in Estonia until 2100. The above-mentioned report formed the basis for the assessment of the sectors influenced by the atmospheric condition in drawing up the national development plan for adaptation to the impacts of climate change. Climate projections for Estonia are updated as part of the LIFE-SIP AdaptEST project, which will be implemented in the period 2023-2032. Comprehensive reports on atmospheric climate projections and marine environment climate projections will be published by the beginning of 2027.

[1] WMO State of the Global Climate in 2023. [www] https://wmo.int/publication-series/state-of-global-climate-2023 (20.02.2025)

Background information on greenhouse gas inventories

Estonia signed the Framework Convention on Climate Change at the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992. In 1994 Estonia ratified the UNFCCC, in 2002 the Kyoto Protocol and in 2016 the Paris Agreement. Under these international agreements, Estonia is committed to provide annually information on its national anthropogenic greenhouse gas emissions by sources and removals by sinks for all greenhouse gases not controlled by the Montreal Protocol.

As a member of the European Union, Estonia has reporting obligations also under Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action (hereafter referred to as the EU Governance Regulation)[2]. The implementation of the EU Governance Regulation is further specified in the Commission Implementing Regulation (EU) No 2020/1208 and the Commission Delegated Regulation (EU) No 2020/1044.

Estonia has prepared greenhouse gas inventories since the year 1994. Inventory reports are submitted to the UNFCCC Secretariat and the European Commission annually.

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

In 2023, the total emissions of GHGs (with indirect CO_2 and with LULUCF), measured as CO_2 eq., were 12 993.25 kt, and without LULUCF 10 862.46 kt. From 1990 to 2023 emissions with LULUCF decreased by 63.2%. Table ES.1 shows the trend in GHG by gases and total emissions with and without LULUCF during the period 1990–2023. Figure ES.1 shows greenhouse gas emissions trends in 1990–2023 (with indirect CO_2), with LULUCF and without LULUCF in CO_2 eq.

In 2023, the most important GHG in Estonia was carbon dioxide (CO_2), contributing 80.5% to total national GHG emissions expressed in CO_2 eq. (with LULUCF, including indirect CO_2), followed by methane (CH_4), 10%, and nitrous oxide (N_2O), 7.7%. Fluorocarbons (so-called 'F-gases') account for about 1.8% of total emissions (see Table ES.2). The Energy sector accounted for 80.7% of total GHG emissions (without LULUCF), followed by Agriculture (14.1%), Waste (2.8%) and Industrial processes and product use (2.4%) (including indirect CO_2).

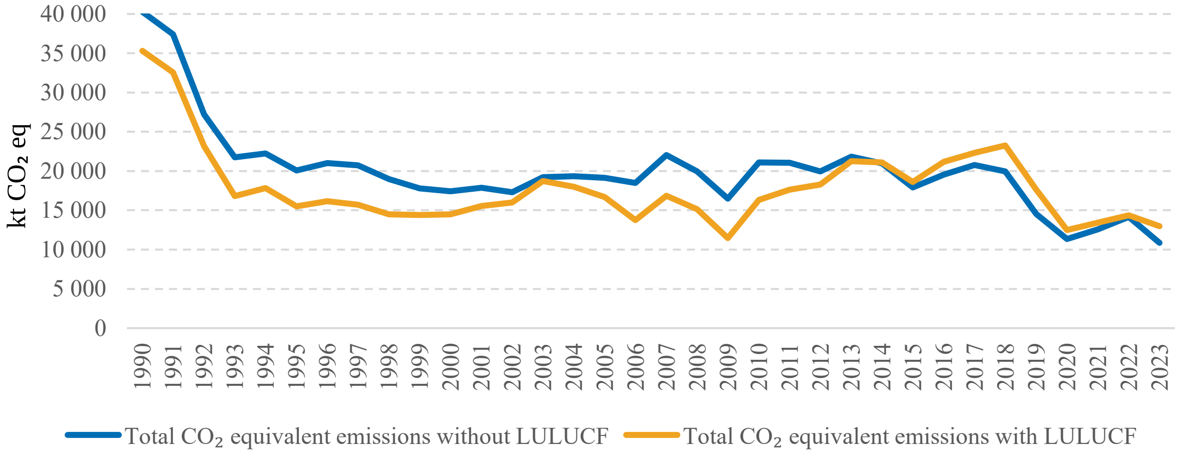


Figure ES.1. Estonia's greenhouse gas emissions in 1990–2023 (with indirect CO_2), with LULUCF and without LULUCF, kt CO_2 eq.

[2] Regulation (EU) 2018/1999 of the European Parliament and the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action. (EU Governance Regulation)

Table ES.1. Greenhouse gas emissions in Estonia. Emission trends, kt CO_2 eq.

GREENHOUSE GAS EMISSIONS	1990**	2005	2020	2021	2022	2023	Change from base to latest reported year
	kt CO_2 eq.						%
CO_2 emissions without net CO_2 from LULUCF	36 906.19	17 089.78	9 198.25	10 390.91	11 966.23	8 744.26	-76.31
Indirect CO_2 (from NMVOCs reported under IPPU 2.D.3 Solvent use and road paving with asphalt)*	18.52	21.88	22.55	29.29	27.98	23.89	29.00
CH_4 emissions without CH_4 from LULUCF	2 154.79	1 306.02	1 113.33	1 122.69	1 107.33	1 086.34	-49.58
N_2O emissions without N_2O from LULUCF	1 216.60	611.70	842.80	861.30	875.32	837.80	-31.14
HFCs	NO, NA	128.15	179.92	190.21	197.10	190.85	100.00
PFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	-
Unspecified mix of HFCs and PFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	-
SF_6	NO,NA	1.11	3.03	3.07	3.13	3.21	100.00
NF_3	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	-
Total (without LULUCF)	40 277.58	19 136.76	11 337.32	12 568.18	14 149.11	10 862.46	-73.03
Total (with LULUCF)	35 307.53	16 694.42	12 478.10	13 416.66	14 347.32	12 993.25	-63.20
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**1990****	**2005**	**2020**	**2021**	**2022**	**2023**	**Change from base to latest reported year**
			(%)				
1. Energy	36 182.03	16 629.14	9 192.01	10 388.63	11 978.01	8 762.44	-75.78
2. Industrial processes and product use	952.36	723.69	288.07	294.64	274.92	265.16	-72.16
3. Agriculture	2 734.62	1 221.38	1 544.83	1 568.26	1 583.00	1 534.73	-43.88
4. Land use, land-use change and forestry(5)	- 4 970.05	- 2 442.34	1 140.78	848.48	198.20	2 130.79	-142.87
5. Waste	408.57	562.55	312.40	316.65	313.18	300.13	-26.54

* Indirect CO2 emissions are calculated from NMVOCs reported under IPPU 2.D.3 Solvent use and road paving with asphalt. These emissions are reported under paragraph 4.5.3.2 Solvent use in NID and in CRT sectoral table 2(I). A-Hs2.

** 1990 is a base year

Table ES.2. Greenhouse gas emissions in Estonia – annual contributions of the various greenhouse gases

GHG EMISSIONS kt CO_2 eq.		**CO_2 emissions excluding net CO_2 from LULUCF**	**CH_4 emissions excluding CH_4 from LULUCF**	**N_2O emissions excluding N_2O from LULUCF**	**HFCs**	**SF_6**	**Total (excluding LULUCF)**
1990	kt	36 906.19	2 154.79	1 216.60	NO	NO	40 277.58
	%	91.63%	5.35%	3.02%			100.00%
2005	kt	17 089.78	1 306.02	611.70	128.15	1.11	19 136.76
	%	89.30%	6.82%	3.20%	0.67%	0.01%	100.00%
2020	Kt	9 198.25	1 113.33	842.80	179.92	3.03	11 337.32
	%	81.13%	9.82%	7.43%	1.59%	0.03%	100.00%
2021	kt	10 390.91	1 122.69	861.30	190.21	3.07	12 568.18
	%	82.68%	8.93%	6.85%	1.51%	0.02%	100.00%
2022	kt	11 966.23	1 107.33	875.32	197.10	3.13	14 149.11
	%	84.57%	7.83%	6.19%	1.39%	0.02%	100.00%
2023	kt	8 744.26	1 086.34	837.80	190.85	3.21	10 862.46
	%	80.50%	10.00%	7.71%	1.76%	0.03%	100.00%

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

The greenhouse gas emissions and removals are divided into the following sectors according to Decision 18/CMA.1 of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement and to the 2006 IPCC Guidelines: Energy, Industrial processes and product use, Agriculture, Land use, land-use change and forestry (LULUCF) and Waste.

Figure ES.2 shows the contributions of sectors to total greenhouse gas emissions.

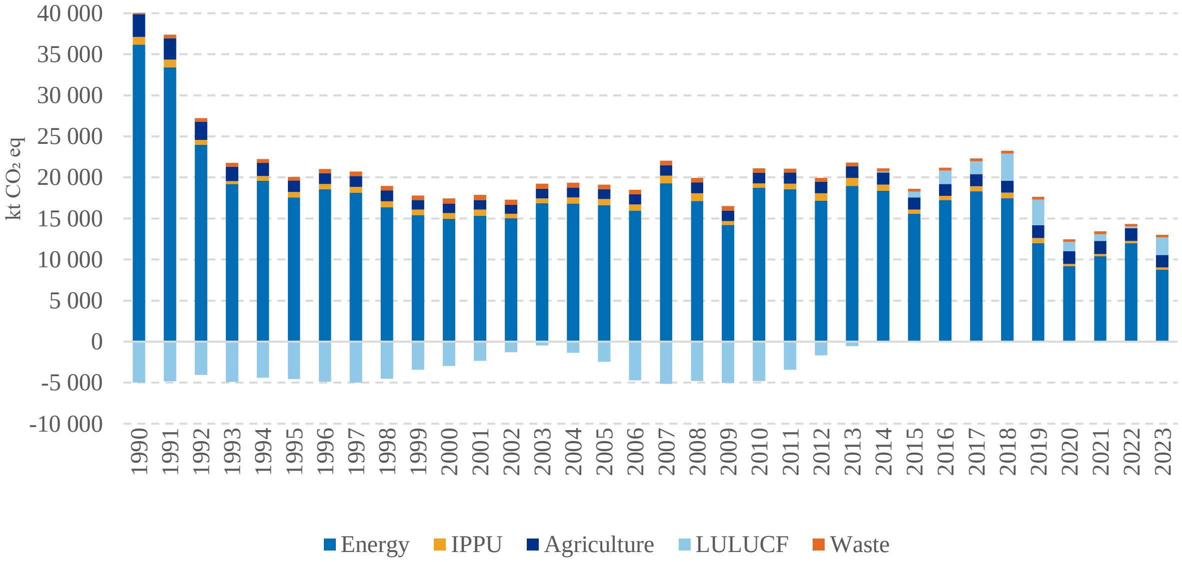


Figure ES.2. Greenhouse gas emissions trends by sector, kt CO_2 eq.

The Energy sector is the most significant source of greenhouse gas emissions in Estonia with 80.7% share of the total emissions (without LULUCF) in 2023. Since the base year, total GHG emissions from Energy sector in Estonia have decreased by 76%. The key driver for the fall in emissions is the transition from a planned economy to a market economy. The GHG emission decrease in 2023 compared to the previous two years was mainly in the Energy industries, because fuel prices and electricity prices were lower compared to 2022 and EU ETS allowance prices elevated, which significantly reduced competitiveness of electricity generation from oil shale in the electricity market. This resulted in a significant drop in oil shale consumption in the Public electricity and power production sector and decreased emissions by 47.56 % from 7071.52 kt CO_2 eq. in 2022 to 3708.52 kt CO_2 eq. in 2023.

Agriculture is the second most significant source of greenhouse gas emissions in Estonia. In 2023 the agriculture sector contributed 14.1% of the total emissions (without LULUCF). Since the base year emissions have decreased by 43.9%, mostly due to the decreasing livestock population and quantities of synthetic fertilizers and manure applied to agricultural fields.

The Waste sector contributed 2.8% of the total greenhouse gas emissions (without LULUCF) in 2023. The total emissions in CO_2 eq. from the Waste sector decreased by 26.5% compared to the base year.

In 2023 Industrial processes and product use greenhouse gas emissions contributed 2.4% of the total greenhouse gas emissions (without LULUCF) in Estonia. Emissions have decreased by 72.2% between 1990 and 2023 because of the closing of some relevant industries and reduced output of the remaining industries. In recent years the decrease is occurring additionally in the decreased usage and therefore emissions of HFCs. Industrial CO_2 emissions have fluctuated strongly since 1990, reaching the lowest level in 1993. The decrease in the emissions during the early 1990s was caused by the transition from a planned economy to a market economy after 1991 when Estonia regained its independence.

In 2023, the LULUCF sector acted as a CO_2 source, totaling with emissions 2130.79 kt CO_2 eq. Since 1990, net removals have decreased by 142.9%.

ES.4. Other information (e.g. indirect GHGs, precursor gases)

Estonia has chosen to report indirect CO_2 emissions calculated from NMVOC emissions from the CRT subcategory 2.D.3. This subcategory consists of

1. Solvent use (Chapter 4.5.1.);
2. Road paving with asphalt (Chapter 4.5.1.).

ES.5. Key category analysis

The results of the key category analysis are presented in Table 1.2. In this report Tier 1 and Tier 2 method has been used.

ES.6. Improvements introduced

Estonia is consistently working on enhancing the quality of the inventory including finding ways to ensure that the best available activity data is used in emission calculations as well as working on developing country-specific parameters and emission factors subject to available resources. Information on improvements introduced since previous submission can be found under sectoral chapters.

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

1.1. Background information on GHG inventories and climate change (e.g. as it pertains to the national context, to provide information to the general public)

1.1.1. Background information on climate change

According to WMO State of the Global Climate 2023[3] was the warmest year on record with the global average near-surface temperature at 1.45 (±0.12)°C above the pre-industrial baseline. The past nine years, 2015-2023, were the nine warmest years on record.

Air temperature has increased at a more rapid rate in Estonia in the second half of the 20th century than the global average. Climate warming was especially intense from 1966–2010. January characterizes the highest increase in temperature. The annual average temperature has increased by 1.8 degrees. Statistically significant warming is also characteristic of April, July and August.

The monthly mean maximum and minimum temperatures have increased in parallel with average warming. It is interesting to note that the increase in the maximum temperature is higher from April to October (except June) while the same applies to the minimum temperature from December to February. The daily temperature range therefore indicates an increasing trend in the warm half-year, especially in April and May, while a decreasing trend can be noted in winter.

Precipitation constitutes the climate indicator with the biggest variability in time and space. Large fluctuations of precipitation can be observed between single days, weeks, months, seasons and even years. The difference in precipitation between locations situated close to one another may be significant, especially in summer. As the measuring methodology of precipitation has changed over time, it is quite difficult to ascertain trends in precipitation. However, the opinion that the amount of precipitation in winter will increase in Northern Europe as the climate becomes warmer is generally recognized.

In the period 1966–2010, it is apparent that the increase in annual precipitation is statistically significant in some Estonian meteorological stations and insignificant in others. A positive trend has above all been noted in January and June, and to a lesser extent in February, March and August. However, a decreasing trend in precipitation has been observed in April, May and September. In summary, it may be stated that precipitation has somewhat increased in winter and summer and decreased in spring and autumn.

It is understandable that changes in snow cover are closely related to changes in air temperature and precipitation. As the air temperature increases, the number of days with snow cover should decrease and the snow cover itself should become more erratic. However, an increase in winter precipitation may result in thicker snow cover.

The duration of snow cover has generally decreased in Estonia in the last few decades, but due to its high variability this trend is not statistically significant. While a number of mild winters with little snow were recorded in the late 1980s and early 1990s, such winters have become scarcer in the last few years and snowy winters have become more frequent.

[3] WMO State of the Global Climate in 2023. [www] https://wmo.int/publication-series/state-of-global-climate-2023 (27.12.2024)

It is extremely difficult to adequately assess long-term changes in wind speed as it largely depends on the obstacles to wind situated close to the measuring site. However, research has been conducted into changes in wind directions in the period from 1966–2008. This indicates that the proportion of westerly and south-westerly winds has significantly increased in winter while the proportion of south-easterly and easterly winds has decreased.

Extreme climate phenomena occur in Estonia from time to time. In summer, hot weather and unstable air stratification along with thunderstorms result in whirlwinds (tornadoes/ waterspouts) of destructive force. In winter, the most hazardous climate phenomena have been powerful snowstorms accompanying cyclones, resulting in the obstruction and even closure of road traffic.

1.1.2. Background information on greenhouse gas inventories

Estonia signed the Framework Convention on Climate Change at the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992. In 1994 Estonia ratified the UNFCCC and in 2002, the Kyoto Protocol and in 2016 the Paris Agreement[4]. Estonia has prepared the present National Inventory Document (NID) following the requirements of the UNFCCC and the Paris Agreement.

Single national entity with overall responsibility for the Estonian greenhouse gas inventory is the Estonian Ministry of Climate (MoC) (formerly Ministry of the Environment). Financial resources for inventory compilation are planned in the National Administrative Agreement and in State Budget.

The Institute of Ecology at Tallinn University was responsible for the inventories under contract to the Ministry of the Environment (MoE) in Estonia until summer 2006. The 2008–2013 inventories were produced in collaboration between the MoE, Estonian Environment Information Centre (EEIC), Tallinn University of Technology (TUT) and Estonian Environmental Research Centre (EERC). The 2014–2025 inventory were produced in collaboration between the MoC (until 2023 MoE), Estonian Environment Agency (EstEA) and EERC, responsibilities between different institutions are shown in Figure 1.1.

This document presents the national inventory of greenhouse gas emissions and removals from 1990 to 2023. The GHGs covered are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). Estimates on the precursor gases nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2) were also included in inventory data.

The document and associated Common Reporting Tables (CRT) (prepared with ETF GHG INVENTORY Reporting Tool (December 2024 release)) were prepared in accordance with the UNFCCC reporting guidelines on annual inventories. The methodology used in calculations of emissions is harmonized with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines). According to decision 18/CMA.1 paragraph 38 Estonia's 2025 national inventory report consists of a national inventory document and the common reporting tables.

The structure of this NID follows the UNFCCC reporting guidelines from Decision 18/CMA.1. Chapter 1 introduces the background of greenhouse gas inventories and the arrangement for inventory preparation. Chapter 2 presents the overall emission trend in Estonia from the year 1990 to the year 2023. Chapters 3–8 give information of GHG emission trends from the base year 1990 to year 2023 for the following sectors: Energy, Industrial processes and product use,

[4] Pariisi kokkuleppe ratifitseerimise seadus. [www] https://www.riigiteataja.ee/akt/201112016002 (07.03.2025)

Agriculture, Land use, land-use change and forestry, and Waste. Chapter 9 gives an overview of indirect CO_2 and nitrous oxide emissions. In Chapter 10 improvements and recalculations since the previous submission are summarized.

1.2. A description of national circumstances and institutional arrangements

1.2.1. National entity or national focal point

Single national entity with overall responsibility for the Estonian greenhouse gas inventory is Ministry of Climate (MoC) (until 30.06.2023 Ministry of Environment). In 2018 a change in the national inventory system was made when MoE appointed the Estonian Environmental Research Centre (EERC) to be the institution to have the overall responsibility of maintaining the national system, coordinating the inventory preparation process as a whole, being responsible for the final quality control and quality assurance and submitting the final inventory to the European Commission (EC) and to the UNFCCC Secretariat on behalf of MoC. The inventory will continue to be produced in collaboration between MoC, EERC and EstEA as until now.

The MoC is responsible for:

- maintaining the national inventory system;
- contributing to the renewal of the QA/QC plan;
- planning financial resources for inventory preparation and inventory methodological developments;
- entering into formal agreements with the inventory coordinator (EERC); and
- making the greenhouse gas inventory available to the public.

EERC is responsible for:

- maintaining the national inventory system;
- coordinating the inventory preparation process as a whole;
- compiling the National Inventory Report according to the parts submitted by the inventory compilers;
- coordinating the renewal and implementation of the QA/QC plan and final QA/QC of the inventory;
- sending the final inventory to the MoC and approving the inventory before the official submissions;
- reporting the greenhouse gas inventory to the EC and to the UNFCCC, including the National Inventory Document and Common Reporting Tables on behalf of MoC;
- coordinating cooperation between the inventory compilers, the EC and UNFCCC Secretariat;
- coordinating the UNFCCC inventory reviews and communication with the expert review team, including responses to the review findings.
- informing the inventory compilers of the requirements of the national system and ensuring that existing information in national institutions is considered and used in the inventory where appropriate;
- informing the inventory compilers of new or revised guidelines; and
- the overall archiving system.

The EERC is responsible for preparing the estimates for the Energy, Industrial processes and product use, Agriculture and Waste sectors. The Forest Department of the Estonian Environment Agency is responsible for LULUCF estimates. Sectoral experts collect activity data, estimate emissions and/or removals, implement QC procedures and record the results, fill in sectoral data to the ETF Reporting Tool and prepare the sectoral parts of the NID. These experts are also responsible for archiving activity data, estimates and all other relevant information according to the archiving system.

In addition, the GHG inventory team cooperates with the team in charge of the preparation of the atmospheric pollutant emission inventory to the UNECE's Convention on Long-range Transboundary Air Pollution (CLRTAP) by having annual meetings between the two teams to find possibilities to make the information coherent between the two reports. Sectoral experts meet bilaterally from time to time with the aim of reducing differences in the estimates between the two inventories.

Financial resources for inventory compilation are planned in the National Administrative Agreement and in State Budget as MoC has appointed Estonian Environmental Research Centre (EERC) to be the institution to have the overall responsibility of maintaining the national system, coordinating the inventory preparation process as a whole, being responsible for the final quality control and quality assurance and submitting the final inventory to the European Commission (EC) and to the UNFCCC Secretariat on behalf of MoC.

Legal arrangements

In accordance with §143 of the Atmospheric Air Protection Act (RT I, 11.06.2024, 2), activities for the reduction of climate change are organised by the Ministry of Climate on the basis of the requirements for the restriction of the limit values of emissions of greenhouse gases provided by the UNFCCC, the Kyoto Protocol, the Paris Agreement and the European Union legislation.

In accordance with §6 of the Statutes of the Ministry of the Climate (RT I 29.12.2024, 49), the MoC is responsible for climate change related tasks and according to §22 section 2 point 7, the Climate Department task is to organize, develop and implement climate change mitigation and adaptation policies. In accordance with the Statutes of the Climate Department of the MoC, the department is responsible for organizing and coordinating GHG emission reporting activities under the UNFCCC, the Kyoto Protocol, the Paris Agreement and the European Union legislation. In the beginning of 2018 with an aim to improve/optimize the inventory compiling process in Estonia, MoE (since 2023 MoC) decided to appoint the Estonian Environmental Research Centre to be the overall coordinator of the GHG inventories.

The Estonian Environmental Research Centre (EERC) is a state-owned company established for general interest, all of the shares in which are held by the Republic of Estonia. EERC is subordinate to the Ministry of Climate. Any changes to and the approval of the statutes of the EERC are the responsibility of the Ministry of Climate.

As of 2018 according to §1.8 of the Statues of the Estonian Environmental Research Centre, EERC as a state-owned company guarantees the organisation and the timely submissions of the GHG inventories to the EC and to the UNFCCC. Statues of the EERC was amended in the beginning of 2018 according to decision made by the Minister of the Environment as it is the competence of the Minister of the Environment to amend the Statutes of the EERC. Also, EERC management supervision is carried out by the body 100% appointed by the Minister of the Environment (since 2023 Minister of Climate).

EERC compiles the GHG inventory on the basis of contract agreements with the MoC.

The Estonian Environment Agency (EstEA), institution that is responsible for the LULUCF estimates, is a state authority administered by MoC, which was formed as a result of the merger of the Estonian Meteorological and Hydrological Institute (EMHI) and the Estonian Environment Information Centre (EEIC) in 2013. In accordance with §9 section 9 of the Statute of the EstEA, the tasks of the Forest Department include planning, organizing and carrying out statistical forest inventories, monitoring land use, land-use changes and carbon cycle and fulfilling national and international reporting obligations.

The Statistics Estonia collects and coordinates the production of official statistics on the basis of the Official Statistics Act § 9 (RT I, 11.03.2022, 2).

1.2.2. Inventory preparation process

The three core institutions: MoC, EERC and EstEA work together to fulfill the requirements for the national system. The overview of the allocation of responsibilities is shown in Figure 1.1.

All three institutions are in close contact with one another. Several cooperation meetings are held annually to discuss and agree on methodological issues, problems that have arisen and improvements that need to be implemented. As Estonia is a small country and only two institutions are preparing the inventory estimates there is close contact between inventory experts (EERC and EstEA) and inventory coordinator (EERC) and as a result different problems and misunderstandings are also solved on a daily basis.

During the cooperation meetings the following subjects are addressed:

- preparation of the annual review;
- discussion on the comments received from the expert review and agreeing on possible changes that have to be made;
- discussion on the different problems that came up during the last inventory preparation and find solutions to improve the overall system;
- planning of methodological developments and possible changes in the future submissions;
- discussion on QA/QC plan, available resources and possible improvements;
- discussion on data availability and collection;
- agreement on recalculations;
- archiving system, updating and possible improvements;
- exchange of relevant information; and
- reporting the conclusions from the meetings.

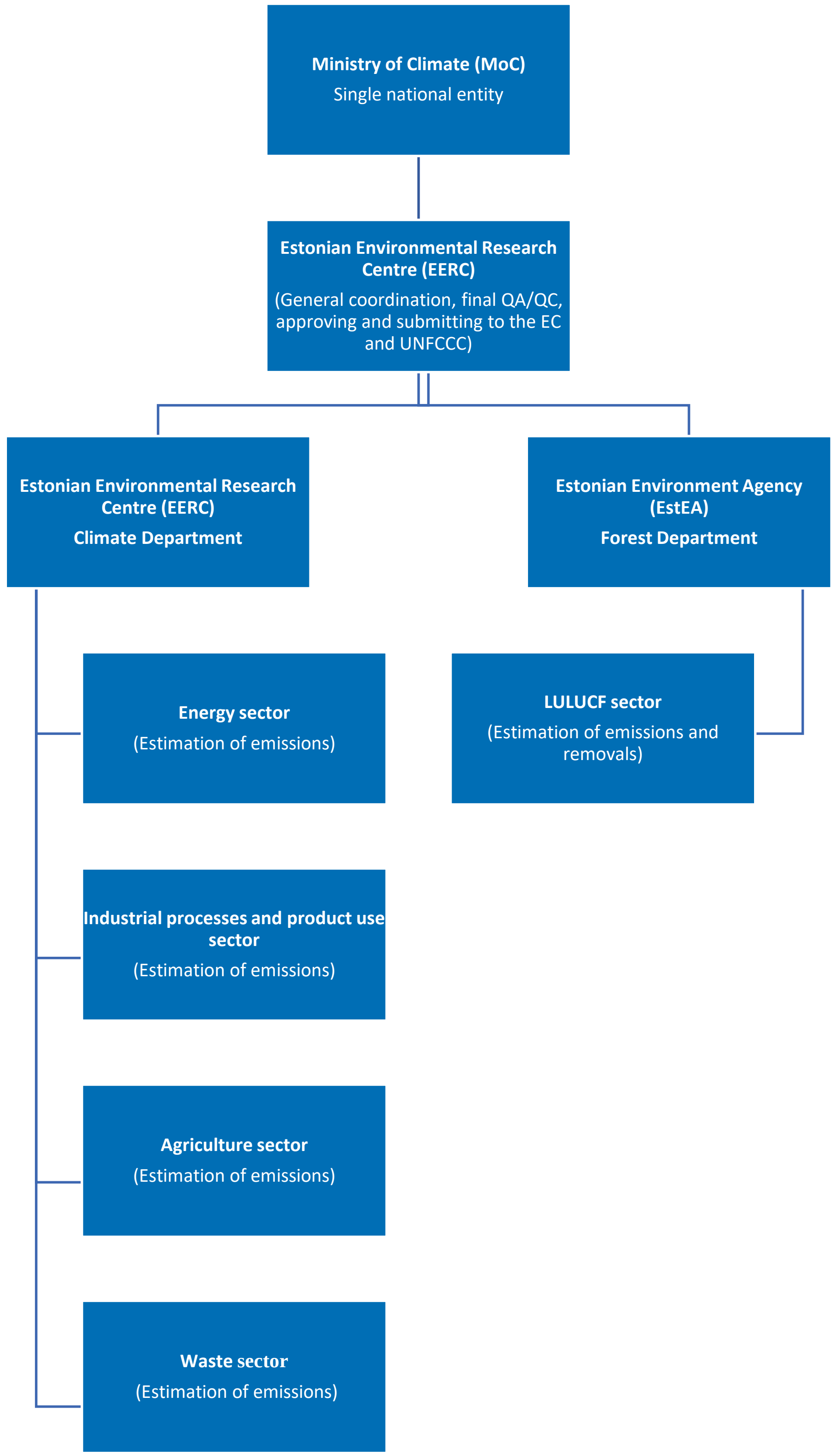


Figure 1.1. National System for GHG inventory in Estonia

Inventory preparation and management

Estonia's national GHG inventory system is designed and operated according to the guidelines for national system under article 5, paragraph 1, of the Kyoto Protocol (Decision 19/CMP.1) to ensure the transparency, consistency, comparability, completeness and accuracy of inventories. Inventory activities include planning, preparation and management of the inventories.

According to regulation (EU) 2018/1999 of the European parliament and of the council article 26 the EU member states shall report every year by 31 July to the European Commission their approximated greenhouse gas inventories for the year X-1. Therefore, data collection for the inventory compilation starts already during the summer prior to the inventory submission. However, it needs to be noted that not all activity data is available already in summer, for example energy balance (activity data for energy sector calculations) is publishes annually by Statistics Estonia not before the end of September.
The inventory preparation is an annual process and is divided into three stages: planning, preparation and management. The specific functions are described below.

Inventory planning

- Designate a single national entity with overall responsibility for the national inventory;
- Make available the postal and electronic addresses of the national entity responsible for the inventory;
- Define and allocate specific responsibilities in the inventory development process, including those related to choice of methods, data collection, particularly activity data and emission factors from statistical services and other entities, processing and archiving, and QA/QC. This definition shall specify the roles of, and cooperation between, government agencies and other entities involved in the preparation of the inventory, as well as the institutional, legal and procedural arrangements made to prepare the inventory;
- Elaborate an inventory QA/QC plan which describes specific QC procedures to be implemented during the inventory development process, facilitate the overall QA procedures to be conducted, to the extent possible, on the entire inventory and establish quality objectives;
- Establish processes for the official consideration and approval of the inventory, including any recalculations, prior to its submission and to respond to any issues raised by the inventory review process.

Inventory preparation

- Identify key source categories;
- Prepare estimates in accordance with the methods described in the 2006 IPCC Guidelines;
- Collect sufficient activity data, process information and emission factors as are necessary to support the methods selected for estimating anthropogenic GHG emissions by sources and removals by sinks;
- Make a quantitative estimate of inventory uncertainty for each source category and for the inventory in total, following the 2006 IPCC Guidelines;

- Ensure that any recalculations of previously submitted estimates of anthropogenic GHG emissions by sources and removals by sinks are prepared in accordance with the 2006 IPCC Guidelines and relevant decisions;
- Compile the national inventory;
- Implement general inventory QC procedures (*Tier 1*) in accordance with its QA/QC plan following the 2006 IPCC Guidelines;
- Implement category-specific QC procedures and provide for a basic review of the inventory of personnel that have not been included in the inventory development.

Inventory Management

- Archive information for each year in accordance with relevant decisions;
- Provide a review team with access to archived information used by to prepare the inventory;
- Respond to requests for clarifying inventory information resulting from different stages of the review process of the inventory information, and information on the national system, in a timely manner.

1.2.3. Archiving of information

It is good practice for inventory compilers to maintain the documentation for every inventory produced and provide it for the review team if requested. It is good practice to maintain and archive this documentation in a way that every inventory estimate can be fully documented and reproduced if necessary.

All institutions are responsible for archiving the data they collect and the emission calculations. EERC is responsible for Estonia's central inventory archive. When the reporting cycle ends, and all the inventory calculations are finalized all experts send their documentation to the compiler and it is stored in one place.

The data and information are archived for each submission year. The archiving includes all input data, emission calculations, corresponding letters, all partly filled-in or final CRT, recalculations of previous estimates, submissions to the UNFCCC and EC and NIR-s (since 2024 NID). The archiving system is located in EERC server which undergoes a daily backup, and the backups are securely saved.

The archiving system consists of two parts: data related (1) to the CRT and (2) to the NID. The first part contains information and documentation on activity data, emission factors and methodology used and the second part all the relevant documents that were used for the preparation of NID. Also, all submissions to the UNFCCC and EC are archived.

Estonia's archiving structure is structured in a way that all relevant materials used in the 2013–2025 inventory submission (e.g., XML and JSON files provided by the inventory compilers to the producers of the CRT tables, also relevant materials from the ftp site) are stored in the archive.

In addition to the main archive, the expert organizations contributing to the sectoral calculation archive the primary data used, internal documentation of calculations and sectoral CRT tables. These organizations keep records of their work on hard disks of individual expert's desktop workstations, with copies on backed up network servers.

Starting from autumn 2010 an ftp site has been set up to collect all important documents into one location where everybody can use them. The ftp site is used for sharing documents (xml and json files, draft NID's, QA/QC documents etc.), also pervious submissions, review reports, answers to the reviews and guidelines are available. The ftp site is accessible by sectoral experts, inventory compiler and independent experts. The ftp site has been a success, as it compiles all the latest documents into one location and through the ftp site it can be assured that you are getting the latest version. Before all information was shared through e-mails, that was not that sufficient.

1.2.4. Processes for official consideration and approval of inventory

Following the initial submission to EU in January the initial NID and CRT are sent to different departments of MoC and other relevant institutions for approval. MoC different departments and other relevant institutions carry out QA of the CRT tables and NID and submits the results to the EERC coordinators, after what the EERC and EstEA sectoral experts send their comments to the findings and possible changes according to the QA/QC (performed by the MoC, independent experts and the EU initial checks) to EERC coordinators and then to MoC. Additional QC checks are carried out before the final submission to the EU in March by EERC and the sectoral experts. Before the final official submission to the EU and UNFCCC the GHG inventory result are introduced to the MoC and other relevant institutions at a meeting after what the submission is considered finalised.

1.3. Brief general description of methodologies (including tiers used) and data sources used

The methodologies used for the Estonia's greenhouse gas inventory are consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) and in some sectors with the 2019 IPCC refinement (IPCC 2019). Detailed descriptions of the methodologies used can be found in the sectoral Chapters 3 to 8.

The main methodologies and data sources used in current inventory are given in Table 1.1.

Table 1.1. Methodology, activity data and emission factor sources used

IPCC category	Methodology	Emission factor	Activity data
1. Energy	IPCC 2006	IPCC 2006	Statistics Estonia and energy companies (Eesti Energia AS, Viru Keemia Grupp AS, Kiviõli Keemiatööstuse OÜ), Estonian Environment Agency (EstEA); The Environmental Board; Estonian Transport Administration
A. Fuel combustion	T1, T2, T3	D, CS, PS	Joint Questionnaire dataset made by Statistics Estonia; Statistics Estonia statistical database; data of energy companies, EU ETS and municipal waste fuel data from The Environmental Board, waste fuels data from EstEA
A.1. Energy industries	T1, T2, T3	D, CS, PS	Joint Questionnaire dataset made by Statistics Estonia; Statistics Estonia statistical database; data of energy companies; EU ETS and solid municipal waste data from The Environmental Board

IPCC category	Methodology	Emission factor	Activity data
A.2. Manufacturing industries and construction	T1, T2, T3	D, CS, PS	Joint Questionnaire dataset made by Statistics Estonia; Statistics Estonia statistical database; waste fuels (oils, plastics, solid waste) data from EstEA; number of off-road vehicles from Estonian Transport Administration
A.3. Transport	T1, T2, T3	D, CS	Joint Questionnaire dataset made by Statistics Estonia; Statistics Estonia statistical database; aviation activity data as well as road transport fuels activity data, including CH_4 ja N_2O emission estimations from EstEA using COPERT 5 model
A.4. Other sectors	T1, T2	D, CS	Joint Questionnaire dataset made by Statistics Estonia from statistical database; number of off-road vehicles from Estonian Transport Administration
B. Fugitive emissions	T1	D	Joint Questionnaire dataset made by Statistics Estonia
2. Industrial processes and product use	IPCC 2006	IPCC 2006	EU ETS data from The Environmental Board, Statistics Estonia; plant specific data; national and international companies; associations; public institutions; sectoral databases; Eurostat; EstEA
A. Mineral industry	T1, T2, T3	D, PS	Statistics Estonia; plant specific data; EU ETS data from Estonian Environmental Board
C. Metal industry	T3	PS	Statistics Estonia; plant specific data;
D. Non-energy products from fuels and solvent use	T1, T2	D	Statistics Estonia; EstEA; Eurostat
F. Product uses as substitutes for ODS	T2	CS	National and international companies; associations; public institutions; sectoral databases
G. Other product manufacture and use	T2, T3	CS	National and international companies, Statistics Estonia, Eurostat
3. Agriculture	IPCC 2006, 2019 Refinement	IPCC 2006, 2019 Refinement	Statistics Estonia, National Forest Inventory, EstEA, plant specific data, Agriculture and Food Board, Estonian Animal Recording Centre, Agricultural Registers and Information Board, KeMIT (waste data depository)
A. Enteric fermentation	T1, T2	D, CS, OTH	Statistics Estonia, Estonian Animal Recording Centre, EstEA, ARIB
B. Manure management	T1, T2	D, CS	Statistics Estonia, Estonian Animal Recording Centre, EstEA, ARIB, KOTKAS
D. Agricultural soils	T1	D	Statistics Estonia, EstEA; NFI, KeMIT (waste data depository)
G. Liming	T1	D	Statistics Estonia, Agriculture and Food Board
H. Urea application	T1	D	Statistics Estonia, plant specific data, Agriculture and Food Board, fertilizer producers in Estonia

IPCC category	Methodology	Emission factor	Activity data
4. LULUCF	IPCC 2006, IPCC 2014	IPCC 2006, IPCC 2014, IPCC 2019	National Forest Inventory (EstEA); Statistics Estonia; Estonian Rescue Board; Agricultural Registers and Information Board; Centre of Estonian Rural Research and Knowledge; Estonian Land and Spatial Development Board, Estonian Forest and Wood Industries Association; FAO
A. Forest land	T1, T2, T3	D, CS, OTH	National Forest Inventory; Estonian Rescue Board
B. Cropland	T1, T2, T3	D, CS, OTH	National Forest Inventory; Statistics Estonia; Agricultural Registers and Information Board; Centre of Estonian Rural Research and Knowledge
C. Grassland	T1, T2, T3	D, CS, OTH	National Forest Inventory; Estonian Rescue Board
D. Wetlands	T2, T3	D, CS, OTH	National Forest Inventory; Estonian Rescue Service; Statistics Estonia; Estonian Land and Spatial Development Board
E. Settlements	T1, T2, T3	D, CS, OTH	National Forest Inventory
F. Other land	T1, T2, T3	D, CS, OTH	National Forest Inventory
G. Harvested wood products	T2	D, CS	National Forest Inventory; Statistics Estonia; Estonian Forest and Wood Industries Association; FAO
5. Waste	IPCC 2006	IPCC 2006	EstEA; KeMIT (waste data depository); KOTKAS; Statistics Estonia; AS Vaania and SEI Tallinn sorting studies, expert opinions; plant specific data; FAOSTAT
A. Solid waste disposal	T2	D	EstEA; KeMIT; Statistics Estonia, AS Vaania and SEI Tallinn sorting studies
B. Biological treatment of solid waste	T1	D	EstEA; KeMIT
C. Incineration and open burning of waste	T1, T2a	D	EstEA; KeMIT; KOTKAS; Statistics Estonia; expert opinions, AS Vaania and Tallinn sorting studies
D. Wastewater treatment and discharge	T1	D	EstEA; KeMIT; KOTKAS, data from companies, Statistics Estonia; FAOSTAT

1.4. Brief description of key categories

Key categories are the categories of emissions/removals, which have a significant influence on the total inventory in terms of the absolute level of emissions (1990 or 2023), the trend of emissions (change between 1990 and 2023) or both. There are two alternative methods for identifying key categories: Tier 1 and Tier 2. In this report Tier 1 and Tier 2 method have been used. The results of the key category analysis are presented in Table 1.2.

Table 1.2. Key category analysis 2023

		TIER 1						TIER 2					
		Criteria identification (without LULUCF)			Criteria identification with LULUCF			Criteria identification (without LULUCF)			Criteria identification with LULUCF		
IPCC Source Category	**Gas**	**Level 1990**	**Level 2023**	**Trend**	**Level 1990**	**Level 2023**	**Trend**	**Level 1990**	**Level 2023**	**Trend**	**Level 1990**	**Level 2023**	**Trend**
1.A.1.a Energy Industries/Public Electricity and Heat Production - Gaseous Fuels	CO_2	X	X	X	X	X	X	X					
1.A.1.a Energy Industries/Public Electricity and Heat Production - Liquid Fuels	CO_2	X	X	X	X	X	X	X					
1.A.1.a Energy Industries/Public Electricity and Heat Production - Other Fuels (Waste)	CO_2		X	X		X	X		X	X		X	X
1.A.1.a Energy Industries/Public Electricity and Heat Production - Peat	CO_2	X		X	X		X						
1.A.1.a Energy Industries/Public Electricity and Heat Production - Solid Fuels	CO_2	X	X	X	X	X	X	X	X	X	X	X	X
1.A.1.c Energy Industries/Manufacture of Solid Fuels and Other Energy Industries - Solid Fuels	CO_2		X	X		X	X		X	X		X	X
1.A.2.c Manufacturing Industries and Construction/Chemicals - Gaseous Fuels	CO_2	X		X	X		X						
1.A.2.c Manufacturing Industries and Construction/Chemicals - Liquid Fuels	CO_2	X		X	X		X						
1.A.2.d Manufacturing Industries and Construction/Pulp, Paper and Print - Gaseous Fuels	CO_2			X									
1.A.2.d Manufacturing Industries and Construction/Pulp, Paper and Print - Liquid Fuels	CO_2	X		X			X						
1.A.2.e Manufacturing Industries and Construction/Food Processing, Beverages and Tobacco - Gaseous Fuels	CO_2		X	X									
1.A.2.e Manufacturing Industries and Construction/Food Processing, Beverages and Tobacco - Liquid Fuels	CO_2	X		X	X		X						
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Liquid Fuels	CO_2	X		X	X		X						
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Solid Fuels	CO_2	X		X	X		X	X			X		X
1.A.2.g Manufacturing Industries and Construction/Other - Gaseous Fuels	CO_2	X	X	X	X		X						
1.A.2.g Manufacturing Industries and Construction/Other - Liquid Fuels	CO_2	X	X	X	X	X	X						

		TIER 1						TIER 2					
		Criteria identification (without LULUCF)			Criteria identification with LULUCF			Criteria identification (without LULUCF)			Criteria identification with LULUCF		
1.A.2.g Manufacturing Industries and Construction/Other - Solid Fuels	CO_2	X		X	X		X	X					
1.A.3.b Transport/Road Transportation - Liquid Fuels	CO_2	X	X	X	X	X	X	X	X	X		X	X
1.A.3.c Transport/Railways - Liquid Fuels	CO_3		X			X							
1.A.3.e Transport/Other Transportation - Liquid Fuels	CO_2		X	X		X	X						
1.A.4.a Other Sectors/Commercial/Institutional - Gaseous Fuels	CO_2		X	X		X	X						
1.A.4.a Other Sectors/Commercial/Institutional - Liquid Fuels	CO_3		X	X		X							
1.A.4.b Other Sectors/Residential - Gaseous Fuels	CO_2		X	X		X	X						
1.A.4.b Other Sectors/Residential - Liquid Fuels	CO_2	X	X	X	X		X						
1.A.4.b Other Sectors/Residential - Peat	CO_2	X		X	X		X	X			X		X
1.A.4.b Other Sectors/Residential - Solid Fuels	CO_2	X		X	X		X	X			X		X
1.A.4.c.i Other Sectors/Agriculture/Forestry/Fishing/Stationary - Liquid Fuels	CO_2	X	X	X	X	X	X						
2.A.1 Cement production	CO_2	X		X	X		X						
2.B.1 Ammonia production	CO_2	X		X	X		X						
2.F.1.a Commercial Refrigeration	HFC		X	X		X	X						
2.F.1.c Industrial Refrigeration	HFC		X	X		X							
2.F.1.d Refrigerated Vehicles	HFC		X	X									
2.F.1.f Stationary and Room Air-Conditioning	HFC		X										
3.A.1 Enteric Fermentation - Dairy Cattle	CH_4	X	X	X	X	X	X	X	X	X	X	X	X
3.A.1 Enteric Fermentation - Non-Dairy Cattle	CH_4	X	X	X	X	X		X	X	X	X	X	
3.B.1.1 Manure Management - Dairy Cattle	CH_4		X	X		X	X						
3.B.1.1 Manure Management -Non-Dairy Cattle	CH_4		X			X							
3.B.1.3 Manure Management - Swine	CH_4		X			X							
3.B.2.5 Indirect N_2O Emissions from Manure Management	N_2O							X	X	X	X	X	
3.D.1.1 Direct Soil Emissions - Inorganic N Fertilizers	N_2O	X	X	X	X	X	X	X	X	X	X	X	X
3.D.1.2a Direct Soil Emissions - Animal Manure Applied to Soils (including manure digestates)	N_2O		X			X		X	X	X	X	X	X
3.D.1.2c Direct Soil Emissions - Compost, and Waste Digestates Applied to Soils	N_2O								X	X			X
3.D.1.3 Direct Soil Emissions Urine and Dung Deposited by Grazing Animals	N_2O							X	X	X	X		
3.D.1.4 Direct Soil Emissions - Crop Residue	N_2O	X	X	X	X	X	X	X	X	X	X	X	X
3.D.1.6 Direct Soil Emissions - Cultivation of Organic Soils	N_2O	X	X	X		X	X	X	X	X	X	X	X
3.D.2.1 Indirect Emissions - Atmospheric Deposition	N_2O		X			X		X	X	X	X	X	X

		TIER 1						**TIER 2**					
		Criteria identification (without LULUCF)			**Criteria identification with LULUCF**			**Criteria identification (without LULUCF)**			**Criteria identification with LULUCF**		
3.D.2.2 Indirect Emissions - Nitrogen Leaching and Run-off	N_2O		X	X		X		X	X	X	X	X	X
3.G Liming	CO_2		X										
4.A.1 Forest Land remaining Forest Land - dead wood	CO_2				X	X	X				X	X	X
4.A.1 Forest Land remaining Forest Land - living biomass	CO_2				X	X	X				X	X	X
4.A.1 Forest Land remaining Forest Land - mineral soils	CO_2				X	X	X				X	X	X
4.A.1 Forest Land remaining Forest Land - organic soils	CO_2				X	X	X				X	X	X
4.A.2 Land converted to Forest Land - litter	CO_2					X	X						
4.A.2 Land converted to Forest Land - living biomass	CO_2					X	X					X	X
4.B.1 Cropland remaining Cropland - mineral soils	CO_2					X	X					X	
4.B.1 Cropland remaining Cropland - organic soils	CO_2				X	X	X				X	X	X
4.B.2 Land converted to Cropland - mineral soils	CO_2					X	X					X	
4.B.2 Land converted to Cropland - organic soils	CO_2											X	
4.C.1 Grassland remaining Grassland – living biomass	CO_2					X	X					X	X
4.C.2 Land converted to Grassland – mineral soils	CO_2						X					X	X
4.D Forest Land 4(II) Emissions and removals from drainage and rewetting	N_2O				X	X	X					X	X
4.D Forest Land 4(II) Emissions and removals from drainage and rewetting	CH_4					X	X						
4.D.1.1 Peat extraction remaining Peat extraction	CO_2				X	X	X				X	X	X
4.E.2 Land converted to Settlements - living biomass	CO_2					X	X					X	
4.B.2 Land converted to Settlements - mineral soils	CO_2					X	X					X	X
4.G.1 Solid wood	CO_2				X	X	X				X	X	X
4.G.2 Paper and paperboard	CO_2					X							X
4.G.3 Semi-Chemical wood pulp	CO_2					X							
5.A Solid waste disposal	CH_4	X	X	X	X	X	X	X	X	X	X	X	X
5.D.1 Domestic wastewater	CH_4		X			X		X	X	X	X		
5.D.1 Domestic wastewater	N_2O		X						X	X			

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

The starting point in accomplishing a high-quality GHG inventory is consideration of expectations and inventory requirements. The quality requirements set for annual inventories are continuous improvement, transparency, consistency, comparability, completeness, accuracy and timeliness. The setting of concrete annual quality objectives is based on these requirements.

EERC, in collaboration with the expert organizations responsible for the inventory calculation sectors, set yearly quality objectives for the whole inventory at the inventory planning stage and design the QC procedures needed for achieving these objectives. In addition, the expert organizations set their own sector and/or category specified quality objectives and prepare their QC plans.

The next step is development of the QA/QC plan and implementing the appropriate quality control measures (e.g. routine checks, documentation) focused on meeting the quality objectives set and fulfilling the requirements. In addition, QA procedures are planned and implemented. In the improvement phase of the inventory, conclusions are made on the basis of the realized QA/QC process and its results. Please see the QA/QC plan in Annex IV.

All institutions involved in the inventory process (MoC, EERC and EstEA) are responsible for implementing QC procedures to meet the data quality objectives. EERC as the inventory coordinator is responsible for overall QC and is in charge of checking on an annual basis that the appropriate QC procedures are implemented internally in EERC and EstEA. EERC is also responsible for QC of the data of the emission inventory. EERC as the inventory coordinator is responsible for the overall QA of the national system, including the UNFCCC and EC reviews and any national reviews undertaken.

In the end of 2024 Minister of Climate signed a decree that specifies steps that the EstEA needs to do in developing LULUCF sector methodologies as well as diversifying and improving activity data for the calculations. Also, with this decree a decision was made to establish a Steering Committee whose task is to guide and approve LULUCF sector methodological developments. The Steering Committee was established with a decree signed by the Director or EstEA on the 11th of March 2025. In addition, a LULUCF coordinator position in EstEA was created since 1st of January 2025 to coordinate the work of the Steering Committee. Work of the Steering Committee was included in the QA/QC plan of Estonia for the 2025 submission.

The inventory meetings with participants from all institutes participating in the inventory preparation are held three times a year and the bilateral quality meetings between the quality coordinator (EERC) and the expert organizations are held whenever necessary.

Communication and bilateral meeting are held with Statistics Estonia as needed to discuss activity data coming from the national Statistics.

Please see additional information on QA/QC including QA/QC plan in Annex IV.

1.6. General uncertainty assessment, including data pertaining to the overall uncertainty of inventory totals

This section provides an overview of the approach to uncertainty analysis adopted for Estonia's inventory. The mandatory reporting table of the analysis is presented in Annex II.

The uncertainty estimate of the 2025 inventory submission to the UNFCCC Secretariat has been done according to the Tier 1 method presented by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). Tier 1 method combines the uncertainty inactivity rates and emission factors, for each source category and greenhouse gas, and then aggregates these uncertainties, for all source categories and greenhouse gases, to obtain the total uncertainty for the inventory. Uncertainty analyses has been done for the latest inventory year, base year and time series. In many cases uncertainty values have been assigned based on default uncertainty estimates according to IPCC 2006 guidelines or expert judgement, because there is a lack of information. For each source, uncertainties are quantified for emission factors and activity data. For base year, latest inventory uncertainty for activity data and emission factors is used unless additional information is available.

Uncertainties are estimated for direct greenhouse gases, e.g., CO_2, CH_4, N_2O, and F-gases. The uncertainty analysis was done for the sectors: Energy, Industrial processes and product use, Agriculture, LULUCF and Waste sector.

Table 1.3 shows the estimated uncertainties for total greenhouse gas emissions in 1990 and 2023 and the trend (with and without LULUCF). Experts use uncertainty estimations among other input (review recommendations etc.) when prioritizing efforts to improve the accuracy of sectoral inventory estimations. Based on the method used for a certain subcategory emission calculation (Tier 1 / Tier 2), on the share of the subcategory emission in total emissions and on the uncertainty percentage it is evaluated if it is possible to level up either the calculation methodology or specify uncertainty percentage.

Table 1.3. Uncertainty in total 2023 inventory submission

	Combined as % of total national emissions in		Introduced into the trend in total national emissions in 2023
	1990	2023	
	Uncertainty [%]		
Without LULUCF	3.55	8.89	2.03
With LULUCF	8.79	14.77	6.22

1.7. General assessment of completeness

1.7.1. Information on completeness (including information on non-reported categories or any methodological or data gaps in the inventory)

Estonia has provided estimates for all significant IPCC source and sink categories according to the detailed CRT classification. Estimates are provided for the following gases: CO_2, N_2O, CH_4, F-gases (HFC, PFC, SF_6 and NF_3), NMVOC, NO_x, CO and SO_2. The geographical coverage of the inventory is complete. Assessment of completeness is presented in Annex V.

1.7.2. Description of insignificant categories

In the LULUCF sector, C stock changes in dead organic matter (DOM) pool under the Cropland remaining cropland subcategory were not estimated and reported as "NE". Small changes in DOM pool occur due to removal or establishment of orchards, but these emissions or removals are considered insignificant in terms of the overall level and trend in national emissions (as are changes in orchards' living biomass).

CH_4 and N_2O emissions from biomass burning were not estimated for the Cropland and Settlements categories, as a disproportionate amount of effort would be required to collect the activity data about emissions that would be insignificant in terms of the overall level and trend in national emissions. This argument is based on the fact that according to the latest inventory submission, the average level of emissions from biomass burning reported in the period 1990–2023 is 0.95 kt CO_2 eq. that constitutes 0.01% of the national total GHG emissions (without LULUCF) and that the average GHG emissions from the biomass burning in Cropland and Settlements have a very low likelihood to exceed that, as the biomass density and the area in case of Settlements is considerably lower compared to the Forest land.

Estonia launched anaerobic digestion in biogas facilities in 1994 and has estimated unintentional leakages due to process disturbances or during other unexpected events by using IPCC 2006 default value of 5% of the generated CH_4. Waste as co-substrates in agricultural biogas facilities has been added from 2014. The CH_4 calculations from anaerobic digestion resulted in a percentage lower than 0.05 for each year starting from 1994. Total CH_4 emissions from anaerobic digestion in biogas facilities and leakages in 2023 comprised 2.95 kt CO_2 eq which is 0.03% of total emissions (without LULUCF). Based on the IPCC 2006 Guidelines, N_2O emissions from anaerobic digestion at biogas facilities are assumed to be negligible.

In the waste sector, the emissions from the subcategory Incineration and open burning of waste are no longer reported in a separate chapter due to the emissions from this category being insignificant. In 2023, no incineration of waste without energy recovery occurred and the emissions from open burning were 0.45 kt CO_2 eq, which was only 0.004% of the national total emissions.

1.7.3. Total aggregate emissions considered insignificant

Total aggregate emissions considered insignificant in 2023 are 4.35 kt CO_2 eq, which is 0.03% of total emissions. This comprises of emissions from Waste and LULUCF sectors reported under chapter 1.7.2.

1.8. Metrics

Estonia used in its 2025 GHG inventory calculations the 100-year time-horizon global warming potential (GWP) values from the IPCC Fifth Assessment Report (AR5), for reporting aggregate emissions and removals of GHGs, expressed in CO_2 eq.

Estonia has produced the CRT tables for the 2025 submission with the ETF GHG INVENTORY Reporting Tool (December 2024 release) and therefore also all the emissions presented in the 2025 NID are calculated using GWPs from AR5.

1.9. Summary of any flexibility applied

Estonia as a developed country Party is not using any flexibility in the implementation of the provisions of Article 13.

2. TRENDS IN GREENHOUSE GAS EMISSIONS AND REMOVALS

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

This chapter provides the trends in GHG emissions and removals by sinks in Estonia for the years 1990–2023.

The GHGs covered are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen trifluoride (NF_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Emission estimates for nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), and sulphur dioxide (SO_2).

Total emissions of greenhouse gases in Estonia (without LULUCF) decreased steadily 40 277.58 kt CO_2 eq. in 1990 to 10 862.46 kt CO_2 eq. in 2023 (Figure 2.1). From 1990 to 2023 emissions without LULUCF decreased by 73.03%. This decrease was predominantly caused by the transition from a planned economy to a market economy and the successful implementation of the necessary reforms. Total emissions including LULUCF decreased 63.20% from 35 307.53 kt CO_2 eq. in 1990 to 12 993.25 kt CO_2 eq.

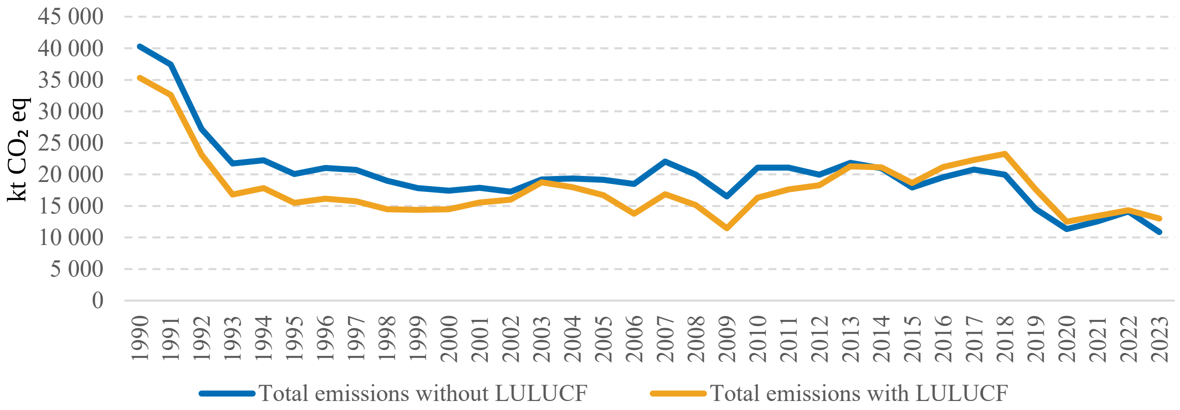
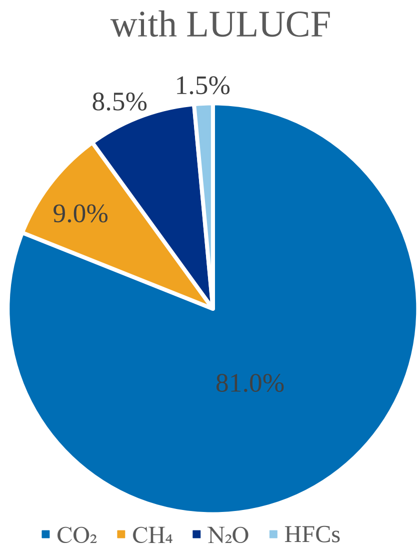


Figure 2.1. Estonia's greenhouse gas emissions in 1990–2023 (with indirect CO_2), with LULUCF and without LULUCF, kt CO_2 eq.

In 2023 the most important GHG in Estonia was carbon dioxide (CO_2), contributing 80.50% to total national GHG emissions (without LULUCF) expressed in CO_2 eq. (including indirect CO_2), followed by methane (CH_4), 10.00%, and nitrous oxide (N_2O), 7.71%. Fluorocarbons (so-called 'F-gases') account for about 1.76% of total emissions (Figure 2.2). Figure 2.2 also includes the GHG gas allocation for total GHG emissions with LULUCF.



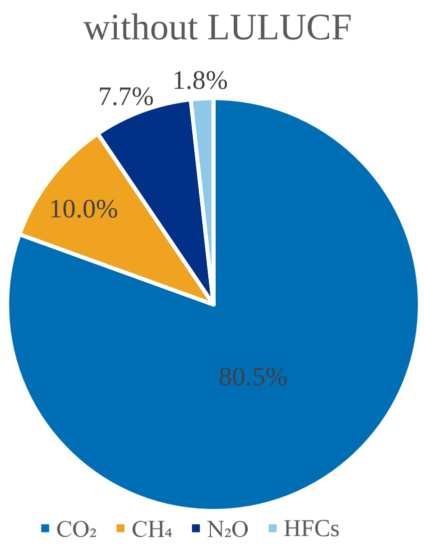


Figure 2.2. GHG emissions by gas in 2023 with and without LULUCF, %

Figure 2.3 shows GHG emission trends by gas in 1990 to 2023. CO_2 emissions (without LULUCF, with indirect CO_2) decreased by 76.31% from 36 906.19 kt in 1990 to 8744.26 kt in 2023, especially CO_2 emissions from Energy sub-sector Public electricity and heat production, which is the major source of CO_2 in Estonia.

Methane is the second most significant contributor to greenhouse gas emissions in Estonia after CO_2. Emissions of CH_4 decreased by 49.58% from 2154.79 kt CO_2 eq. in 1990 to 1086.34 kt CO_2 eq. in 2023, the downturn was especially noticeable in the Agriculture sub-sector Enteric fermentation, which is a leading source of CH_4 in Estonia.

Emissions of N_2O decreased by 31.14% from 1216.60 kt CO_2 eq. in 1990 to 837.80 kt CO_2 eq. in 2023, especially N_2O emissions from Agriculture sub-sector Agricultural soils, which is the main contributor of N_2O emissions in Estonia.

Emissions of the total F-gases (HFCs, PFCs and SF_6) increased from 0 kt CO_2 eq. in 1990 to 194.06 kt CO_2 eq. in 2023, especially HFC emissions from Refrigeration and air conditioning, which is the major source of halocarbons in Estonia. Until 2016 emissions from Refrigeration and air conditioning subsector grew rapidly because of substitution of ozone depleting substances with HFCs. In 2017–2021 emission curbing effects of EU Regulation No 517/2014 on this subsector can be seen. The second largest source is Foam blowing agents which showed relatively steady increase of emissions until 2007. In 2001 one of two big Estonian producers of one component foam replaced HFC-134a with HFC-152a, followed by the other producer starting from 2007. Due to much lower GWP of HFC-152a the emissions decreased suddenly in the corresponding years. The share of HFC emissions in 2023 was 190.85 kt CO_2 eq. and SF_6 emissions 3.21 kt CO_2 eq.

NF_3 emissions do not occur in Estonia.

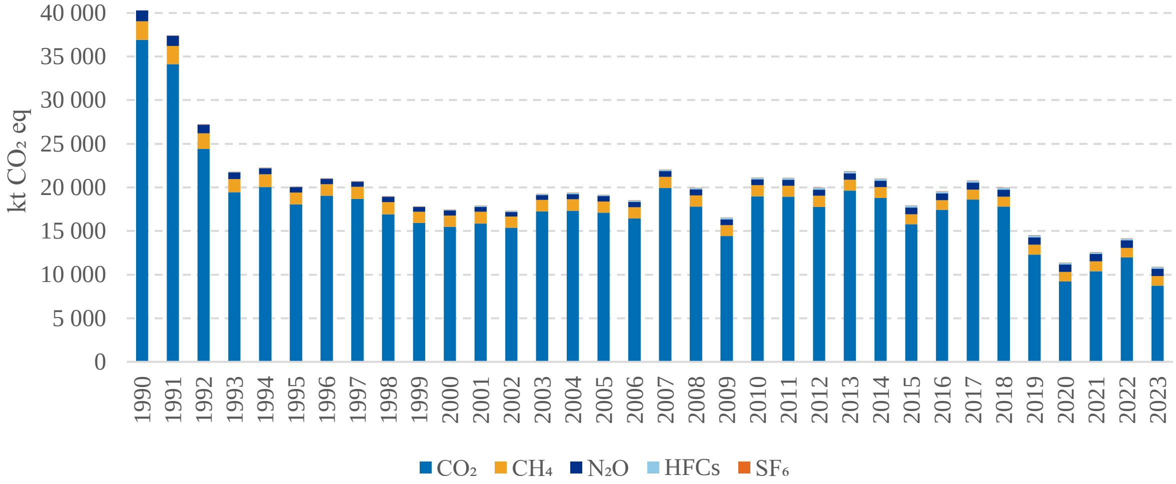


Figure 2.3. Estonia's greenhouse gas emissions by gas 1990–2023 (without LULUCF), kt CO_2 eq.

Air pollutant emissions reported in the CRT are mostly based on the data reported in UNECE/CLRTAP[5] inventories by the Estonian Environment Agency. For Energy sector, the In the air pollutant inventory emissions are mainly calculated using actual emissions data reported by the companies and also using the EMEP/EEA Guidebook[6,7] methodology. In the GHG inventory, the emissions are calculated using some country-specific emission factors and the EMEP/EEA Guidebook Tier 1 methodology; oil shale combustion emissions is the actual data reported by the companies. The emissions are mainly calculated by using actual emissions data reported by the companies as well as by using the EMEP/EEA Guidebook 2023. More detailed information about methodologies used for estimating the indirect GHG emissions are presented in relevant sectoral chapters in the NID. Figure 2.4 shows indirect GHG emission trends in 1990 to 2023.

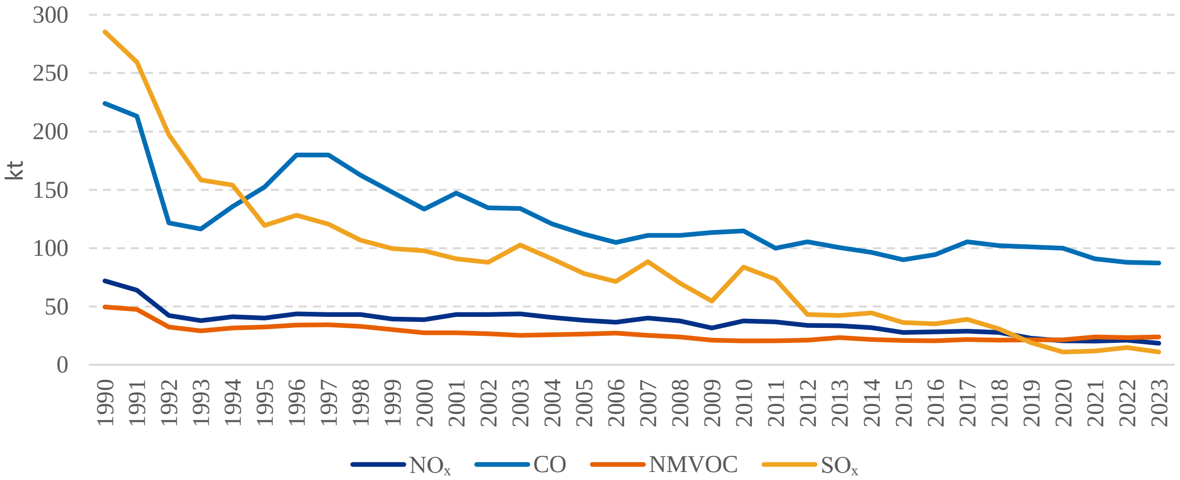


Figure 2.4. Indirect GHG emission trends in 1990 to 2023

5 United Nations Economic Commission for Europe/ Convention on Long-Range Transboundary Air Pollution
6 European Monitoring and Evaluation Programme/ European Environment Agency
7 EMEP/EEA air pollutant emission inventory guidebook 2023. [www] https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023 (07.03.2025)

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

Greenhouse gas emissions by IPCC sectors are presented in Figure 2.5. The largest contribution is the Energy sector, which contributed 80.7% of total greenhouse gas emissions in 2023 (without LULUCF). The second largest sector is Agriculture, which accounted for 14.1% of the total emissions in 2023 followed by the Waste and the Industrial processes and product use sectors accounting for 2.8% and 2.4% of total emissions in 2023.

Over the period 1990–2023 (Figure 2.5), emissions from the Energy sector decreased by 75.78%, emissions from the Industrial processes and product use sector decreased by 72.16% and emissions from the Agriculture sector decreased by 43.88%. Emissions from the Waste sector decreased by 26.54%. In 2023, the LULUCF sector acted as a CO_2 source, totalling with emissions 2130.79 kt CO_2 eq. Since 1990, net removals have decreased by 142.87%.

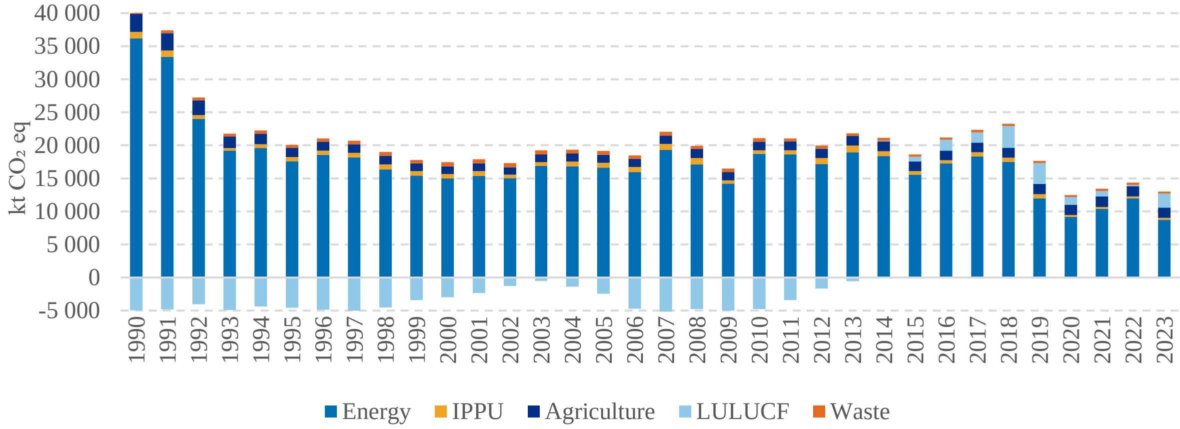


Figure 2.5. Greenhouse gas emission trends, by sectors, kt CO_2 eq.

2.2.1. Trends in Energy (CRT 1)

Emissions in from the Energy sector are divided into the following categories: Fuel combustion, which includes Energy industries, Manufacturing industries and construction, Transport, Other sectors; and Fugitive emissions. The share of emissions by sub-category is presented in Figure 2.6.

The Energy sector is the major source of GHG emissions in Estonia contributing 80.67% of total emissions in 2023, totalling 8762.44 kt CO_2 eq. 99.82% of emissions originate from fuel combustion, and only 0.18% from fugitive emissions. Energy-related CO_2 emissions vary mainly concerning the economic trend, the energy supply structure, fuel types used and weather conditions.

The decrease of GHG emissions between 1990 and 1993 is related to major structural changes in the economy as Estonia regained independence from the Soviet Union in 1991. Since then, there has been a drastic decrease in the consumption of fuels and energy in energy industries (closure of factories), agriculture (reorganisation and dissolution of collective farms), transport (the proportion of new environmentally friendly cars has increased, and the number of agricultural machines decreased), households (energy saving), and in the economy. A small increase in emissions in 1994 relates to the growing energy demand in the transport sector. After that, the emissions from the Energy sector were steady (slight decrease until 2002). In 2003 the emissions increased mainly due to the export of oil shale-based electricity. The rise in emissions between 2006-2007 is related to the overall economic upturn and the decrease of emissions between 2007-2009 to the overall economic downfall. Since 2009 the GHG emissions are strongly related to exported electricity that is mainly produced from oil shale.

The GHG emission decrease in 2023 compared to the previous two years was mainly in the Energy industries. The decrease was mainly in the energy industries because fuel prices and electricity prices were lower compared to 2022 and EU ETS allowance prices elevated, which significantly reduced competitiveness of electricity generation from oil shale in the electricity market. This resulted in a significant drop in oil shale consumption in the Public electricity and power production sector and decreased emissions by 47.56 % from 7071.52 kt CO_2 eq. in 2022 to 3708.52 kt CO_2 eq. in 2023.

Emissions from the Energy sector decreased by 75.78% compared to 1990 (incl. Energy industries – 80.65%; Manufacturing industries and construction – 93.40%; Other sectors – 77.83%; and Fugitive emissions – 78.57%). Only one subsector had greater emissions in 2023 compared to 1990 – Transport where emissions increased by 2.99%. The overall progression of GHG emissions in the Energy is presented in Figure 2.6.

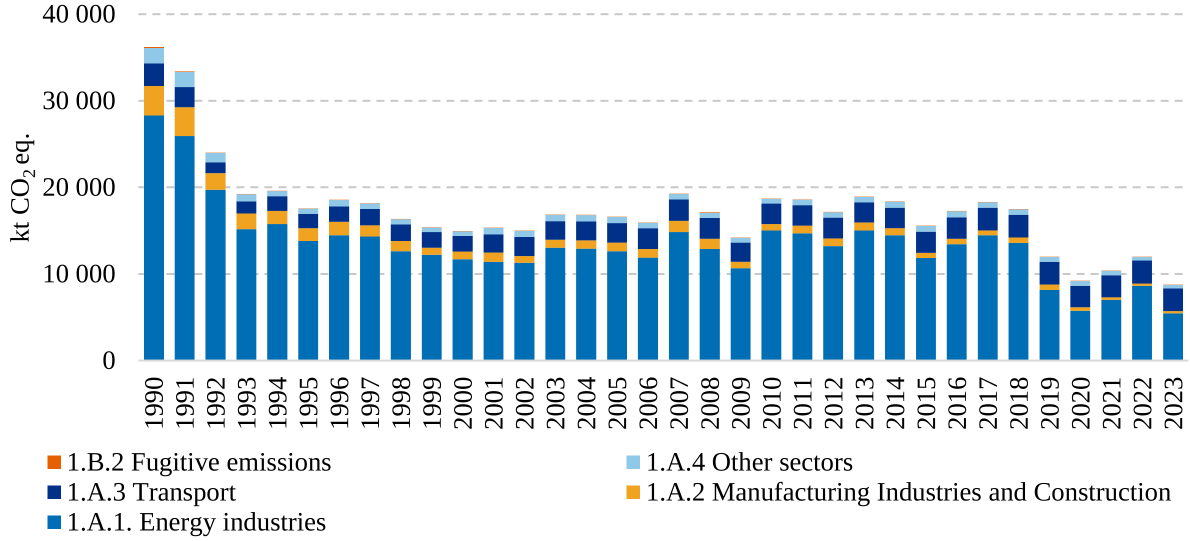


Figure 2.6. Trend in emissions from Energy sector 1990–2023, kt CO_2 eq**.**

2.2.2. Trends in Industrial processes and product use (CRT 2)

Estonia's GHG emissions from the Industrial processes and product sector are divided into the following categories:

- Mineral industry (emissions from cement until 2020, lime, glass production and other process uses of carbonates).
- Chemical industry (historically ammonia and carbamide were produced).
- Metal industry (production of secondary lead and rare earth metal compounds).
- Non-energy products from fuels and solvent use (CO_2 emissions from lubricant and paraffin wax use and urea-based catalysts for motor vehicles, as well as NMVOC emissions from solvent use and road paving with asphalt and indirect CO_2 emissions calculated from these NMVOC emissions.
- Product uses as substitutes for ODS (HFC emissions from refrigeration and air conditioning, foam blowing, fire protection and aerosols).
- Other product manufacture and use (SF_6 emissions from electrical equipment, SF_6 and PFC emissions from other product use and N_2O emissions from product uses).

In addition, NO_x, CO and SO_2 emissions from Pulp and paper are reported under 2.H Other production. The non-fuel-based CO_2 emissions from pulp and paper industry are estimated to be negligible in Estonia. All N_2O emissions from the pulp and paper and food industry are reported as fuel-based emissions under CRT 1.

In 2023 the Industrial processes and product use sector contributed 2.44% of all GHG emissions in Estonia (without LULUCF), totalling 265.16 kt CO_2 eq. with indirect CO_2 and 241.27 kt CO_2 eq. without indirect CO_2. The most significant emission sources in IPPU sector were HFC emissions from refrigeration and air conditioning at 69.82% of total emissions from the sector (with indirect CO_2). Compared to 2022, the emissions from Industrial processes and product use (with indirect CO_2) decreased by 3.55 % in 2023.

Industrial CO_2 emissions have fluctuated strongly during years 1990–2023. The decrease in emissions during the early 1990s was caused by the transition from a planned economy to a market economy after 1991 when Estonia regained its independence. This led to lower industrial production and to an overall decrease in emissions from industrial processes between 1991 and 1993. In 1994 the economy began to recover and production increased. The total emissions of HFCs have increased significantly in 1993-2016, especially HFC emissions from refrigeration and air-conditioning equipment, which is the major source of halocarbons in Estonia. The decrease in emissions in 2002 and 2003 was caused by the reduction in ammonia production, as the only ammonia factory in the country was being reconstructed. The sudden increase in emissions in 2007 was mainly caused by an increase in cement production, as the only cement factory renovated its third kiln. In 2009 the industrial processes sector was affected by economic recession. The decline in production was mainly due to insufficient demand on both the domestic and external markets. CO_2 emissions raised in 2012 and 2013, because a power plant temporarily used large amounts of limestone for flue gas desulphurisation. The increase in 2017 emissions was largely caused by an increase of cement production. Decrease in mineral (and cement) industry output was the main driver in overall decrease of industrial CO_2 emissions from 2014 to 2016. Emissions of F-gases have been halted since 2017 because of the effect of restrictions of the previous Regulation (EU) No 517/2017 followed by the new F-gas regulation (EU) 2024/573[8], in force from 11th of March 2024. In 2017-2018 emissions of HFCs have halted and in 2019-2020 significantly decreased because of bans and quota restrictions of EU Regulation No 517/2014 (the strictest ones started from 2020). Decrease in CO_2 emissions in 2023 was mainly due to decreased emissions from the decreased usage of HFC-s.

The share of emissions by category and overall progression of GHG emissions in the Industrial processes and product use sector in CO_2 eq. is presented in Figure 2.7.

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202400573 (26.12.2024)

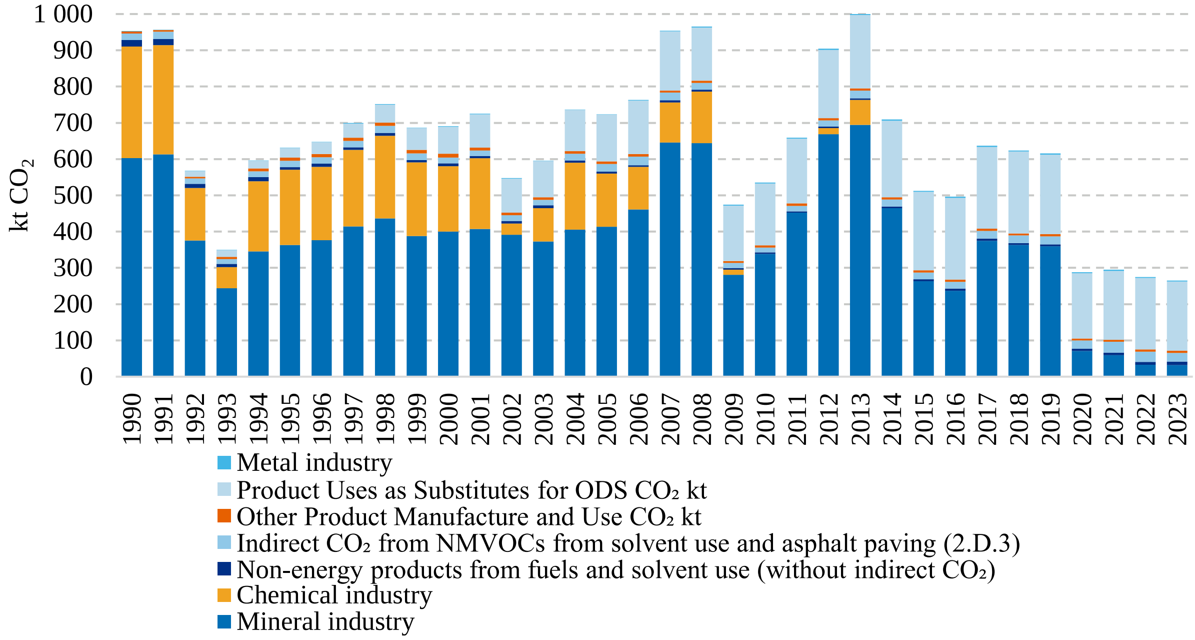


Figure 2.7. Trend in emissions from Industrial processes and product use sector, 1990–2023, kt CO_2 eq.

2.2.3. Trends in Agriculture (CRT 3)

Agricultural GHG emissions in Estonia consist of CH_4 emissions from the Enteric fermentation of domestic livestock, N_2O emissions from Manure management systems, direct and indirect N_2O emissions from Agricultural soils, CO_2 emissions from Liming and Urea application to agricultural soils. Direct N_2O emissions include emissions from synthetic fertilizers, emissions from animal waste, compost, and sludge applied to agricultural soil, emissions from crop residues and cultivation of organic soils, mineralization associated with the loss or gain of soil organic matter, and emissions from urine and dung deposited by grazing animals. Indirect N_2O emissions include emissions due to atmospheric deposition and nitrogen leaching and run-off from manure management. The trend in emissions in CO_2 eq. by category is presented in Figure 2.8.

The total GHG emissions reported in the Agricultural sector for Estonia were 1534.73 kt CO_2 eq. in 2023. The sector contributed about 14.1% to the total CO_2 eq. (without LULUCF) emissions in Estonia. In 2023, the emissions from Enteric fermentation decreased by 0.96% compared to the previous year, emissions from Manure management decreased by 0.72%. This is mostly because of the lower livestock population of cattle, sheep and goats.

As a result of the markets of the former Soviet Union collapsing in the early 1990s, Estonia was left with a large excess supply of agricultural production. Western markets remained closed to Estonian agricultural products, mostly for two reasons – high customs barriers and non-compliance of our products with the requirements and practices abroad. Producer prices in Estonia fell to a level up to 50% lower than the prices on world markets and became insufficient to cover production costs.[9] This led to a rapid decline of agricultural production in Estonia and explains why the GHG emissions from the Agricultural sector have declined by 43.88% in 2023 compared with the base year (1990). In 2002–2008, the most important driving force for

[9] ESTONICA. Encyclopedia about Estonia. Laansalu, A. Crisis in agriculture in the 1990s. [www] https://web.archive.org/web/20070610040459/http://www.estonica.org/eng/lugu.html?menyy_id=914&kateg=40&alam=94&leht=3 (28.02.2025).

Estonian agriculture was the EU accession and the application of supporting the EU's common agricultural policy, the significant effect of which could be noticed even a few years before joining.[10] The positive impact on agricultural production manifested itself years preceding the EU accession and is reflected in the turnover of a downward GHG emissions trend that began in the 1990s.

The agricultural production is in a declining trend in Estonia as the population of cattle, sheep and goats decreased in 2023 compared to the previous year. This is mostly caused by the current difficulties in the agriculture sector starting from 2021 as production costs exceed the profit. This is in turn caused by the energy crisis in EU, leading to higher prices for fertilizers, energy, and feed.[11] The dairy industry has suffered a decline in production due to economic sanctions imposed by Russia on the EU starting from August 2014, when Russia announced import restrictions for food supply coming from the EU. According to the restrictions, it is prohibited to import beef, pork, poultry, fish, milk and dairy, cheese, sausages, fruits, and nuts etc. from EU countries to Russia.[12] Consequently, the number of dairy cattle in 2023 fell by 12.9% in comparison with 2014. The number of dairy cattle was record low being only 83,300 heads in 2023.[13] The number of swine has fallen by 23.2% in 2023 compared to 2014 in Estonia because of the outbreak of African swine fever in the region in 2015. Regarding the spread of the disease, Baltic countries and Poland are a buffer zone for the whole EU, meaning it was necessary to apply measures to prevent the spreading of the African swine fever to other European countries. Prevention measures included population control, that lead to lower number of swine population in the country.[14] Then, starting from 2017, the number of swine started steadily growing again. This was mainly caused by the improved economic situation in the country. Also, a high demand for pork in both inland and foreign markets as pork being the most popular meat in Estonia helped, to some extent, to recover the number of swine after the low point that started after the African swine fever in 2015. Then, after 2020, the number of swine started decreasing again. This was caused by more outbreaks of African swine fever occurred in 2021.[15] [16] [17]What is more, as pork meat's free market purchase prices have been at least 1/3 lower than the actual production costs, several pork producers have been forced to close down their production.[7]

[10] Estonian Universtity of Life Sciences. (2011). Maaelu arengu aruanne. Tartu: AS Ecoprint, lk 86.
[11] Eesti Põllumajandus-Kaubanduskoda. Statistika toob välja ohusignaalid Eesti loomakasvatuses, sealihaturu olukord endiselt nukker. [www] https://epkk.ee/statistika-toob-valja-ohusignaalid-eesti-loomakasvatuses-sealihaturu-olukord-endiselt-nukker/ (28.02.2025)
[12] Maaeluministeerium. Venemaa sanktsioonid Euroopa Liidu toidukaupadele. [www] https://www.agri.ee/maaelu-pollumajandus-toiduturg/pollumajandus-ja-toiduturg/venemaa-sanktsioonid-euroopa-liidu (29.02.2024).
[13] Statistics Estonia. Piimalehmade arv langes Eesti kõigi aegade madalaimale tasemele. [www] https://www.stat.ee/et/uudised/piimalehmade-arv-langes-eesti-koigi-aegade-madalaimale-tasemele (29.02.2024).
[14] Ministry of Regional Affairs and Agriculture. Ministers of Agriculture and Heads of Veterinary Boards of the Baltic States discussed urgent measures to prevent the spread of African swine fever. [www] https://www.agri.ee/en/news/ministers-agriculture-and-heads-veterinary-boards-baltic-states-discussed-urgent-measures (29.02.2024)
[15]Regionaal- ja Põllumajandusministeerium, Sigade Aafrika katk. [www] https://www.agri.ee/toiduohutus-taime-ja-loomatervis/sigade-aafrika-katk (14.11.2024); ERR.ee, Seakatk võib ähvardada mitme maakonna seafarme. https://www.err.ee/1608284100/seakatk-voib-ahvardada-mitme-maakonna-seafarme (29.12.2024).
[16] Eesti Põllumajandus-Kaiubanduskoda. Käes on sigade Aafrika katku leviku kõrgaeg. [www] https://epkk.ee/kaes-on-sigade-aafrika-katku-leviku-korgaeg/ (29.12.2024).
[17] Eesti Põllumajandus-Kaubanduskoda. Statistika toob välja ohusignaalid Eesti loomakasvatuses, sealihaturu olukord endiselt nukker. [www] https://epkk.ee/statistika-toob-valja-ohusignaalid-eesti-loomakasvatuses-sealihaturu-olukord-endiselt-nukker/ (29.12.2024).

Furthermore, imported pork is cheaper for the buyer, so people have started to prefer it to domestic pork.[18] However, compared to 2022, swine numbers have risen by 2.1% in 2023.

Emissions from Agricultural soils and Liming sub-categories also decreased in 2023 compared to the previous year. This is caused by the decreased usage of lime, mineral and organic fertilizers on the fields, and a lower production of agricultural crops. Emissions from Urea application, however, increased from 0.02 kt CO_2 in 2022 to 2.28 kt CO_2 in 2023. This is in correlation with the prices of other mineral fertilizers on the market – in 2023, the prices for N-containing mineral fertilizers were higher than usual and therefore agricultural producers preferred cheaper urea fertilizers instead.

Emissions from Agricultural soils and Enteric fermentation of livestock were the major contributors to the total emissions in the sector – 43.9% and 39.7%, respectively.

The overall progression of GHG emissions in the Agriculture sector is presented in Figure 2.8.

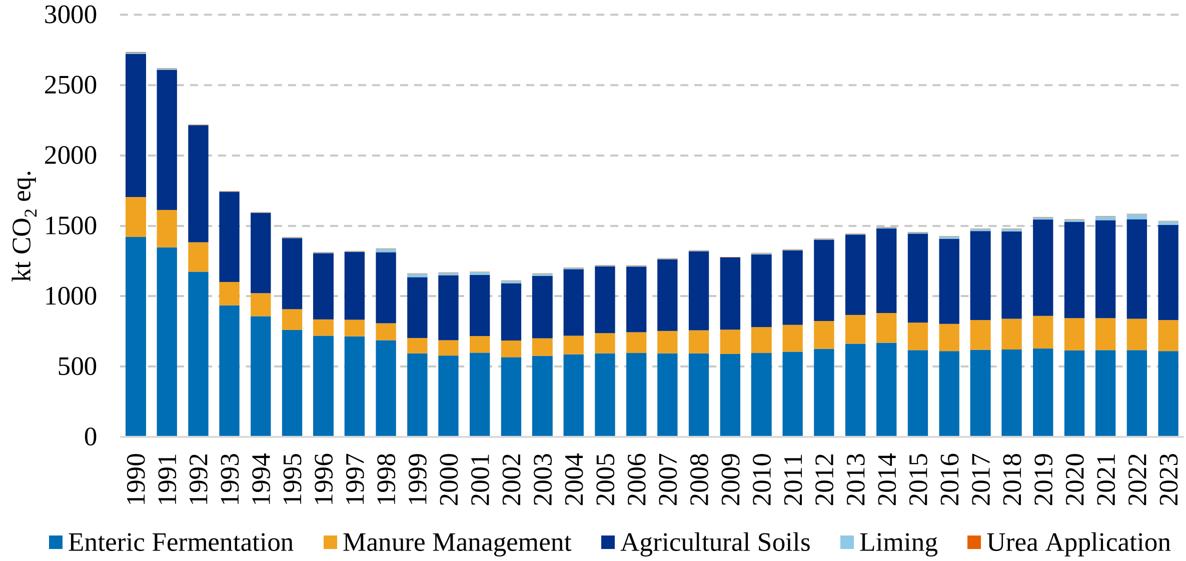


Figure 2.8. Trends in emissions from the Agriculture sector, 1990–2023, kt CO_2 eq.

2.2.4. Trends in Land use, land-use change and forestry (CRT 4)

The LULUCF sector, acting as the only possible sink of greenhouse gas emissions in Estonia, plays an important role in the national carbon cycle. Emissions and removals from the LULUCF sector are divided into the following categories: Forest land, Cropland, Grassland, Wetlands, Settlements, Other land and Harvested wood products (HWP). Each category, except HWP, is further divided into 'land remaining' and 'land converted to' subcategories.

Emissions and removals by each land use category during the period 1990–2023 is presented in Figure 2.9. In 2023 net emissions from the LULUCF sector equaled 2130.79 kt CO_2 equivalent, which is 1932.59 kt CO_2 ekv higher compared to the previous year. In the base year (1990), LULUCF sector acted as a C sink with net emissions of -4970.05 kt CO_2 eq. The LULUCF sector sink is mainly affected by the age structure of forests, management practices in forestry and agriculture, area of drained organic soils production of horticultural peat, and C sequestration in HWP.

[18] Eesti Põllumajandus-Kaubanduskoda. Kodumaine seakasvatus vajab tarbija toetust – vastasel korral hääbub. [www] https://epkk.ee/kodumaine-seakasvatus-vajab-tarbija-toetust-vastasel-korral-haabub/ (29.12.2024).

In 2023, HWP and Grassland were the only categories sequestering CO_2. Main part of the HWP sink is in the wood panels and sawnwood subcategories; grasslands sequester carbon mainly in the biomass and mineral soils following land-use change. The highest net emitter was the Wetlands category, with emissions from peat extraction areas and horticultural use of peat, followed by the Cropland category, which had high emissions from organic soils.

Forest land is the most important category that affects LULUCF sector trends. In the first half of the time series, the area of Forest land increased rapidly, and the high proportion of young and middle-aged stands led to a growing net annual increment. At the end of the 1990s, the felling volume also began to grow rapidly, but the impact of the age structure and increasing area of the forest land on the C balance was more significant. Consequently, Forest land sequestered carbon due to the rapid increase in forest growing stock.

Forest C sequestration has declined in recent years due to the high proportion of mature and near-mature forest stands and increasing proportion of forest area belonging to the first development classes (treeless area, area under regeneration and young stands). In addition, annual conversion area from other land categories to Forest land (afforestation and reforestation) has been decreasing, and the total forest area has stabilized. In 2021 and 2022, forests were sequestrating carbon due to a slightly smaller felling volume than in previous years, but in 2023 Forest land was a net emitter. C sequestration in HWP has decreased in 2022 and 2023 due to reduced production of sawnwood and wood-based panels.

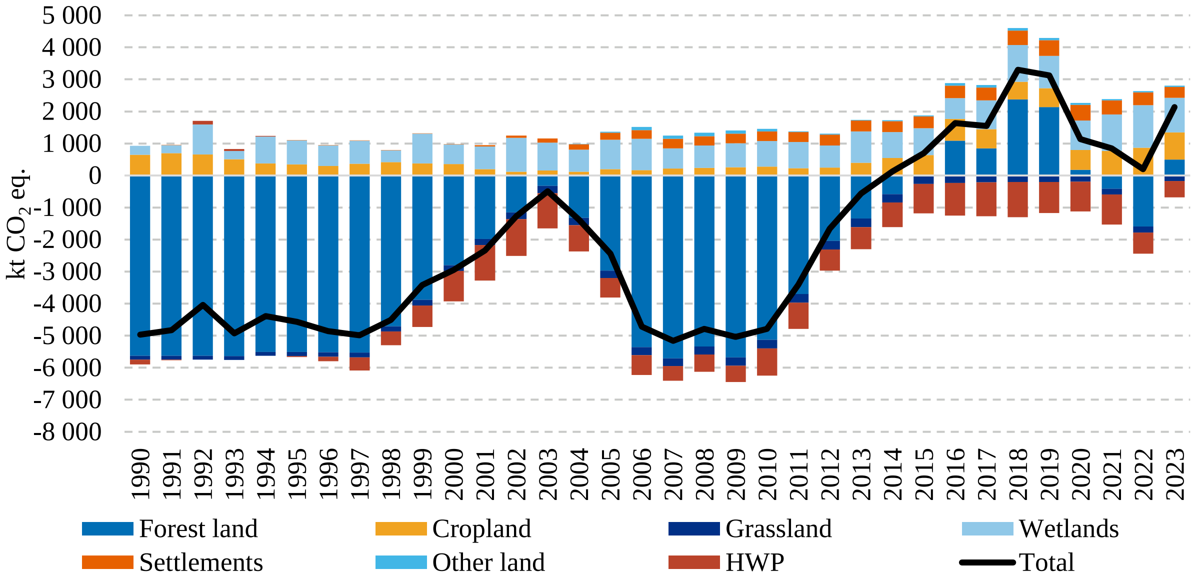


Figure 2.9. Trends in GHG emissions (+) and removals (-) from land use, land-use change and forestry sector 1990–2023, kt CO_2 eq.

2.2.5. Trends in Waste (CRT 5)

Estonia's GHG emissions from Waste sector covers solid waste disposal sites including solid municipal and industrial waste, and CH_4 and N_2O emissions from biological treatment of solid waste and wastewater treatment and discharge from domestic and industrial sector. CO_2 emissions are reported from non-biogenic incineration without energy recovery. The share of emissions by each category is presented in Figure 2.10.

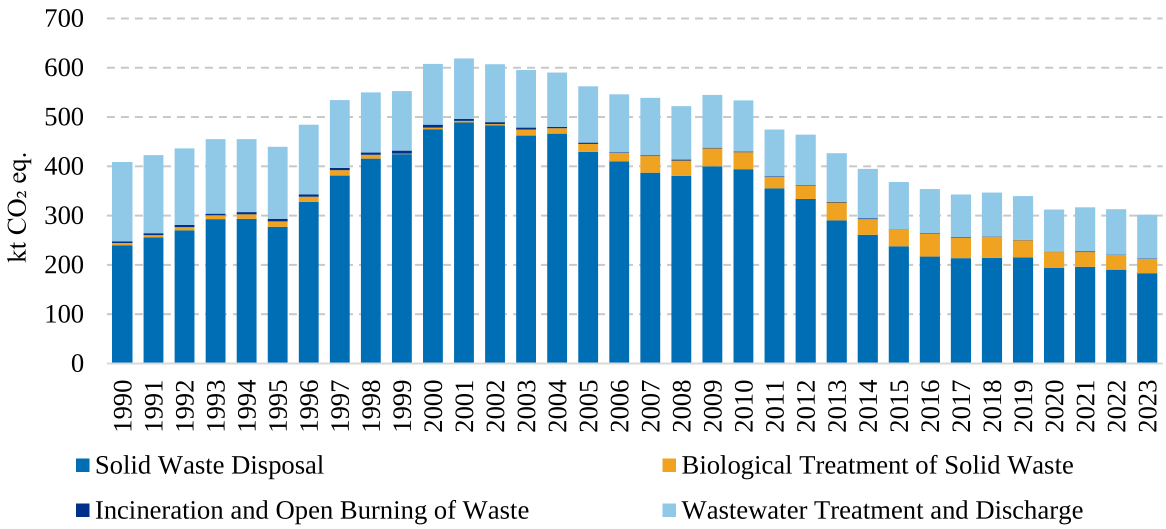


Figure 2.10. Trend in emissions from waste sector by source categories in 1990–2023, kt CO_2 eq.

CO_2 eq. emissions from the Waste sector were 300.13 kt in 2023 and contributed to 2.76% of total GHG emissions in 2023. Total CO_2 eq. emissions from the Waste sector (Table 7.2) in 2023 decreased by 4.2% compared to 2022. Compared to the base year of 1990, the amount of CO_2 eq. emissions in 2023 were 26.5% smaller. Compared to the base year, CO_2 eq. emissions from Solid waste disposal (SWD) have decreased by 23.4% and from Wastewater treatment and discharge by 44.4%. On the other hand, CO_2 eq. emissions from Biological treatment of solid waste have, compared to the base year of 1990, increased by 456.1%. Emissions from waste incineration and open burning are no longer reported as they are below the reporting threshold.

As seen from Figure 2.10, GHG emissions from the Waste sector are in decreasing trend.

Low CO_2 eq. emissions in 1995 are related to decreasing CH_4 emissions from paper and sludge disposal. The highest CO_2 eq. in 2000–2001 is related to the significant increase in emissions mainly from Solid waste disposal. The increasing trend of emission until 2001 is linked to the high amount deposited organics and food waste which were deposited due to low rate of waste sorting. Emissions from waste incineration have been marginal during the whole period compared to other activities involved. The decrease of GHG emissions from the Waste sector after 2004 relates to the increasing amount of CH_4 recovery from landfills. Emissions decrease starting from 2009 is in connection with the financial crisis during 2007–2008. The financial crisis did not affect the Waste sector immediately, because companies had a raw material reserve. The total CO_2 eq. in 2011 decreased significantly compared to previous years, mainly because of the change in the national currency, which raised prices in the country and therefore changed consumption habits and reduced waste generation. Also, opening the Iru waste incineration plant in 2013 had a decreasing effect on the amount of deposited waste trend.

Due to the COVID-19 pandemic, emissions decreased sharply in 2020, as the amount of generated waste decreased. Emissions increased a bit in 2021, but still remained below the 2019 level. The slight increase in 2021 total emissions is mainly driven by 5A (SWD) and 5D (Wastewater treatment) subcategories. In SWD emissions increased, because less landfill gas was collected and therefore methane recovery rate was lower compared to 2020. In addition, emissions in wastewater treatment subcategory increased as the population of low-density settlements increased based on recent census. The lowest CO_2 eq. emissions occurred in 2023, which was mainly connected to the decreasing amount of waste deposited in landfills.

3. ENERGY (CRT SECTOR 1)

3.1. Overview of the sector (e.g. quantitative overview and description, including trends and methodological tiers by category) and background information

The Energy sector is the main source of greenhouse gas emissions in Estonia. In 2023 the Energy sector contributed about 80.67% of total emissions, totaling 8 762.44 kt CO_2 equivalent.

Compared to the base year 1990 (36 182.03 kt CO_2 eq.), the emissions have decreased about 75.78%. Most of the Energy sector emissions (99.82%) originate from Fuel combustion and 0.18% from Fugitive emissions. A substantial amount of energy-related emissions are caused by an extensive use of fossil fuels in heat and power production, which is included in the 1.A.1 Energy industries sector – Figure 3.1.

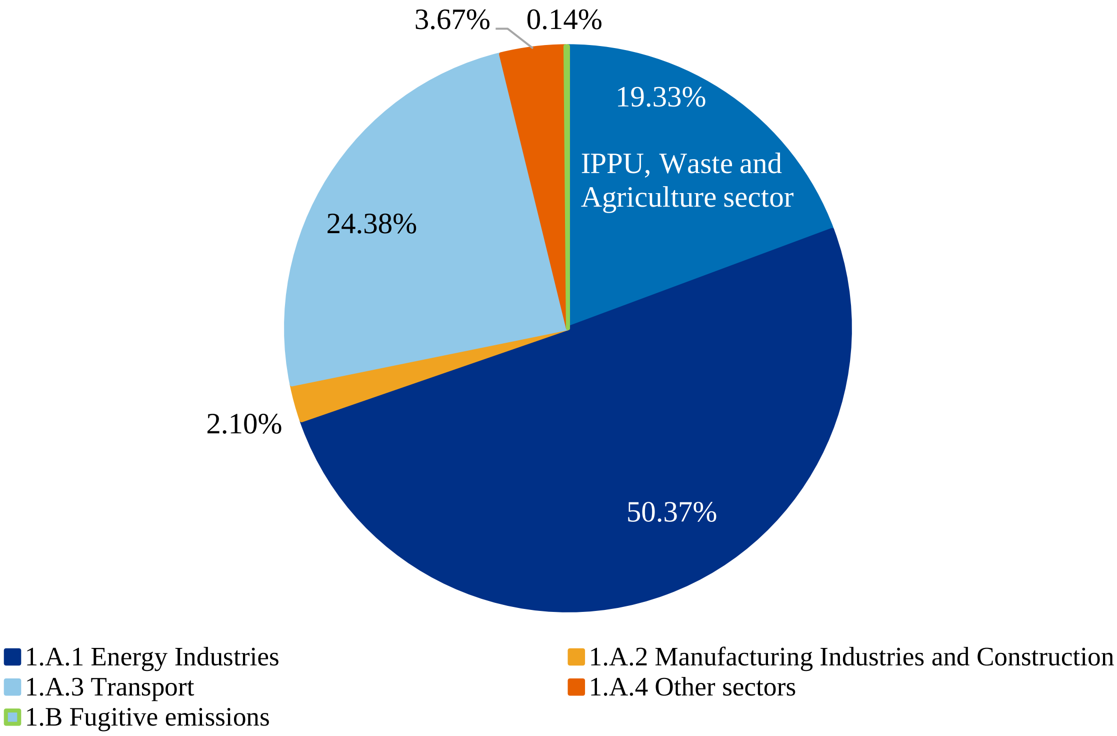


Figure 3.1. Emissions from the Energy sector compared to the total emissions in 2023, %

In 2023 inland energy consumption was 175.1 PJ, which is about 10.4% less than 2022 – Figure 3.2. Inland consumption includes 47.0% oil shale, 24.59% biomass, 19.21% liquid fossil fuels and 5.05% natural gas. Hydro, wind, and solar power formed 2.45% of inland consumption. Other fuels had smaller shares – fossil wastes 0.70%, liquid and gaseous biofuels 0.81%, peat 0.12%., and coal 0.06% - Figure 3.4. Most notable change compared to fuel consumption composition in 1990 (Figure 3.3) is significant increase in consumption of biomass-based fuels, which has decreased the overall share of liquid fossil fuels, natural gas and oil shale.

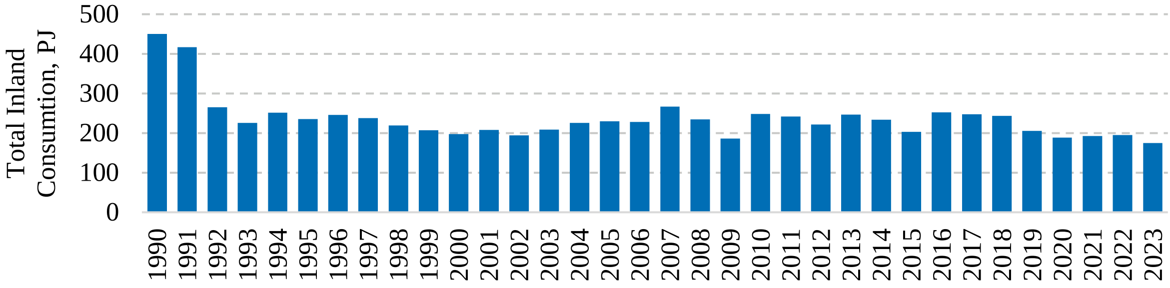


Figure 3.2. Development of inland energy consumption in Estonia in 1990–2023, PJ (Source: Statistics Estonia)

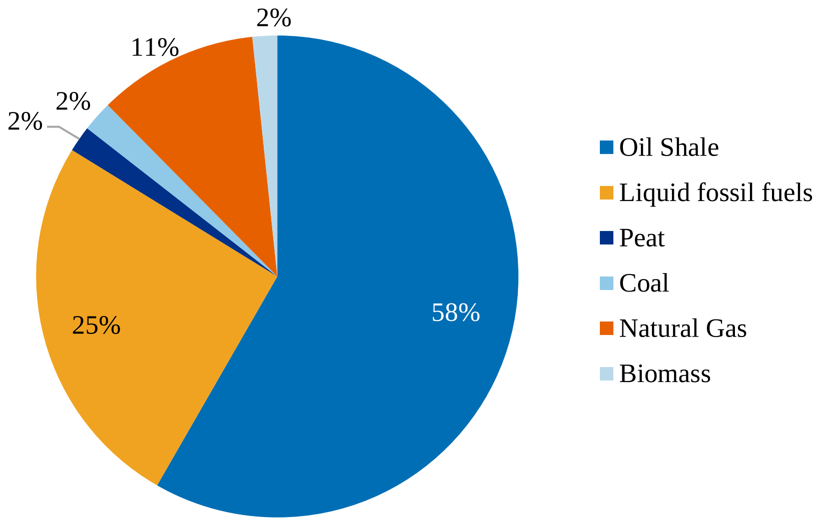


Figure 3.3. Structure of inland energy consumption in Estonia in 1990, %

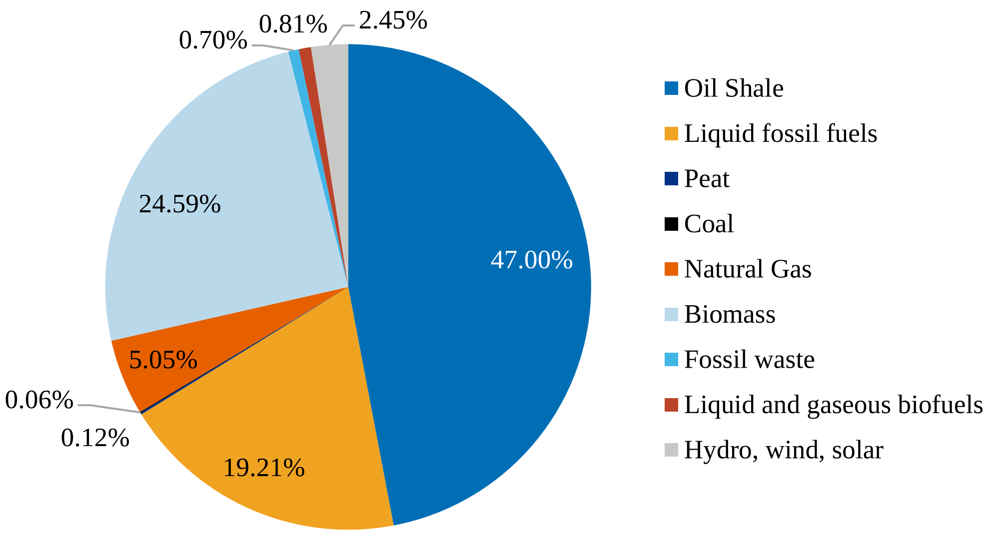


Figure 3.4. Structure of inland energy consumption in Estonia in 2023, %

Estonia´s nominal GDP has steadily grown since 2009, except in 2020 when GDP fell by 2.2% at constant prices, because of restrictions from COVID-19 pandemic, but was twice lower than EU average. In 2021 nominal GDP increased 12.9% compared to 2020 as the economy began to recover from the COVID-19 crisis. This recovery continued in 2022, with nominal GDP increasing 15.9%, compared to the previous year. Nominal GDP growth slowed in 2023 and was only 4.8% higher compared to 2022 and real GDP was 3.0% lower than 2022.

Domestic fuels have a high share in Estonia's energy resources and the primary energy balance, and it is mainly based on oil shale and biomass. Most of the oil shale is consumed in power plants and as a raw material for shale oil production. Biomass and natural gas are used in boiler houses and biomass in the public electricity and power production and residential sector (Figure 3.5).

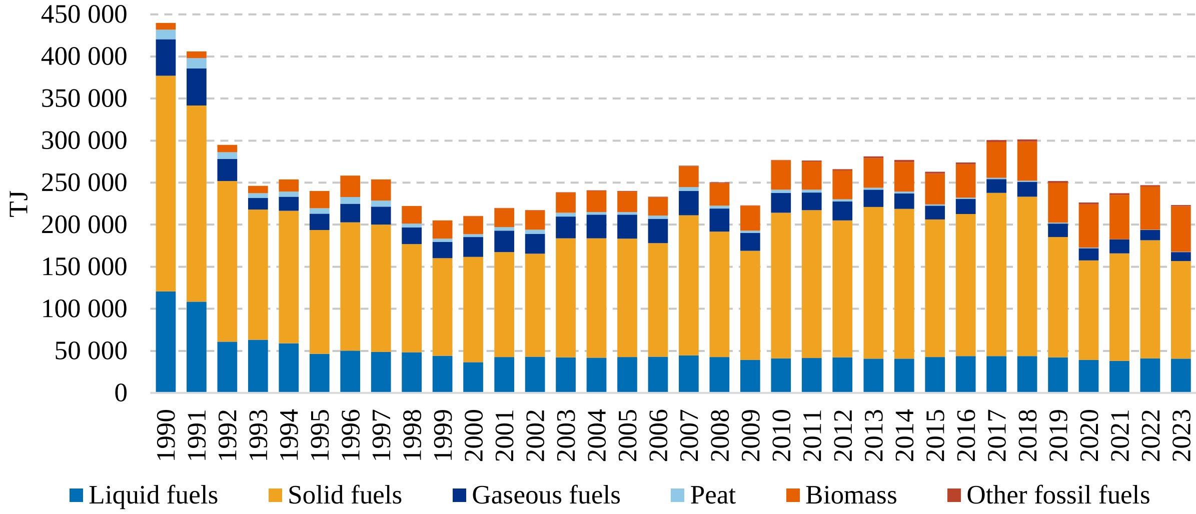


Figure 3.5. Fuel consumption in Energy sector in 1990–2023, TJ

The GHG emission and fuel consumption decreased compared to the previous year primarily in the Energy industries, as fuel prices and electricity prices were lower compared to 2022 and EU ETS allowance prices elevated, which significantly reduced competitiveness of electricity generation from oil shale in the electricity market. This resulted in a significant drop in oil shale consumption in the Public electricity and power production sector and decreased emissions by 47.56 % from 7071.52 kt CO_2 eq. in 2022 to 3708.52 kt CO_2 eq. in 2023. Emissions from the Energy sector by subcategories in 1990–2023 are presented in Figure 3.6.

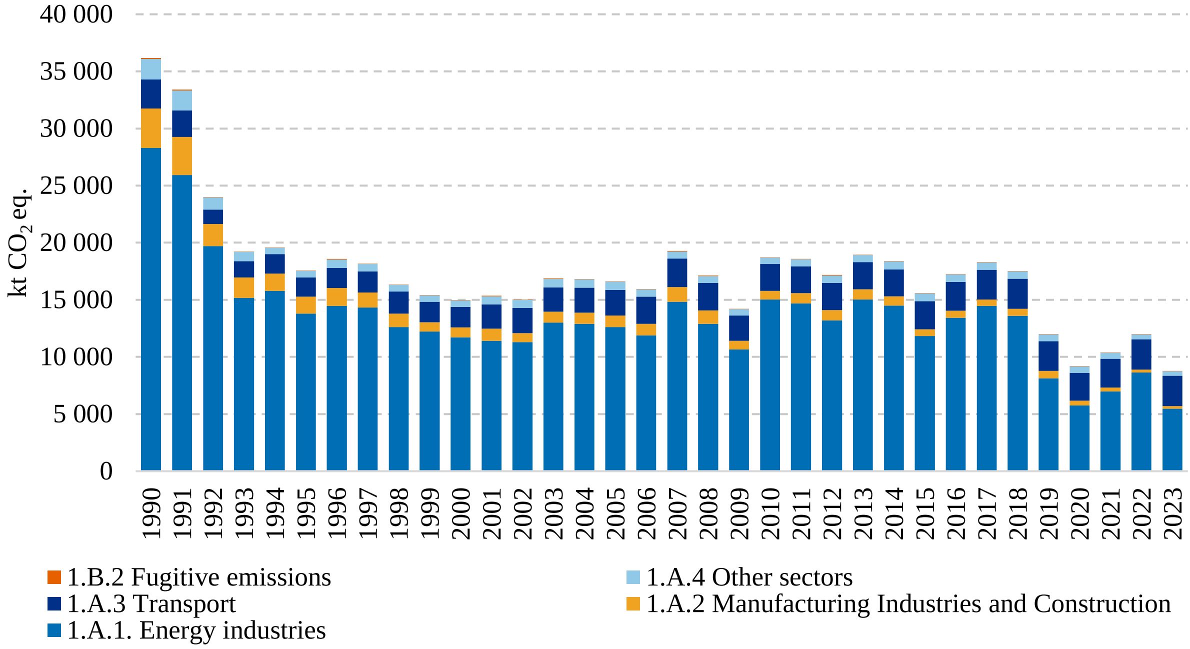


Figure 3.6. Emissions from the Energy sector by subcategory in 1990–2023, kt CO_2 eq.

The greenhouse gases emitted in the Energy sector are carbon dioxide (CO_2), small amounts of methane (CH_4), and nitrous oxide (N_2O). Energy-related CO_2 emissions vary according to the energy supply structure, electricity market dynamics and weather conditions. Electricity prices and also the price of EU ETS allowances have a significant effect on Estonian emissions, as they determine the ammount of electricity produced from oil shale. As suggested in the IPCC 2006 Guidelines, the emissions in the Energy sector are divided into Emissions from fuel combustion (CRT 1.A) and Fugitive emissions (CRT 1.B). Emissions from the Energy sector in 1990–2023 by greenhouse gas are presented in Table 3.1.

Table 3.1. Emissions from the Energy sector in 1990, 2005, and 2020–2023 by greenhouse gas, kt CO_2 eq.

Category	1990	2005	2020	2021	2022	2023
1 Energy Total, CO_2 eq.	36 182.03	16 629.14	9 192.01	10 388.63	11 978.01	8 762.44
1.A Fuel Combustion Total, kt CO_2 eq.	36 110.30	16 582.65	9 171.53	10 365.36	11 960.80	8 747.07
1.A Fuel Combustion, kt CO_2	35 943.21	16 491.23	9 079.08	10 262.60	11 858.19	8 646.13
1.A Fuel Combustion, CH_4, kt CO_2 eq	106.47	40.75	36.67	40.07	39.03	37.96
1.A Fuel Combustion, N_2O, kt CO_2 eq	60.62	50.68	55.79	62.68	63.58	62.97
1.B Fugitive Emissions, kt CO_2 eq.	71.73	46.49	20.48	23.27	17.21	15.37

3.2. Fuel combustion (CRT 1.A), including detailed information on:

3.2.1. Comparison of the sectoral approach with the reference approach

Reference approach (RA) is carried out using import–export, production, and stock change data from the Joint Questionnaire dataset reported to Eurostat by Statistics Estonia (www.stat.ee).

In the 2025 inventory submission, the difference in CO_2 emissions in 2023 between RA and Sectoral approach (SA) was 43.53%. A lot of secondary fuels that are used in final consumption are made from oil shale: shale oil, semi-coke, and oil shale gas. This brings about differences in solid fuel consumption between RA and SA. These two datasets are comparable because in SA and RA the same amount of oil shale must be theoretically consumed. But, the amount of emitted CO_2 is different, as SA considers that some of the oil shale is turned into shale oil, and this process has a smaller CEF (carbon emission factor) than the combustion of oil shale (some of the carbon is transferred into shale oil). In RA calculations entire carbon in oil shale is combusted. To conclude, the emissions in RA from solid fuels are greater than in SA.

Shale oil is reported under Liquid fuels Shale Oil in RA in CRT tables and under Other hydrocarbons in the energy balance. The production of secondary fuels (which shale oil is) is not accounted for in the energy balance and in RA and Estonia exports most of its produced shale oil. This causes a negative apparent consumption of shale oil in the energy balance. This is the reason there is a negative value reported in the stock change in RA as there is no consumption reported and the calculated consumption in CRT has to be zero.

Waste consumption and emissions allocation reported in CRT Sectoral approach and Reference approach:

- Sectoral approach
  - 1.A.1.a municipal waste fossil part in Other fossil fuels
  - 1.A.1.a municipal waste biogenic part in Biomass
  - 1.A.2.f fossil waste in Other fossil fuels
- Reference approach
  - 1.A.1.a municipal waste fossil part in Waste (non-biomass fraction)
  - 1.A.1.a municipal waste biogenic part in Other non-fossil fuels
  - 1.A.2.f fossil waste in Other fossil fuels

More detailed comparison of the sectoral approach with the reference approach is presented in the Annex III: Detailed description of the reference approach (including inputs to the reference approach such as the national energy balance) and the results of the comparison of national estimates of emissions with those obtained using the reference approach (related to a nonmandatory provision as per para. 36 of the MPGs).

3.2.2. International bunker fuels

International bunkers cover international aviation and navigation according to the IPCC 2006 Guidelines. Emissions from international bunkers for aviation and navigation are not included in the national total, but instead reported separately as a memo item in CRT 1.D.

In 2023 GHG emissions from international bunkering were 874.59 kt CO_2 eq., including international navigation 728.55 kt CO_2 eq. and international aviation 146.04 kt of CO_2 eq.

GHG emissions from navigation increased from 2005 through 2008. After 2008 a decline lasted until 2012. Due to the methodology change in activity data by Statistics Estonia, the emissions increased about two times in 2012 compared to 2011. The sharp difference in GHG emissions in 2011/2012 in International navigation remains and Statistics Estonia who provides fuel consumption data is working on data consistency issue. In 2017 LNG was introduced in this sector for the first time. In 2019 emissions from navigation fell 40.7% next to 2018 due to substituting diesel oil with LNG and a decrease in passenger traffic. In 2020 emissions from navigation increased 60.6% compared to 2019 due to an increase in fuel stocks. In 2023 emissions from international navigation decreased by 22.93% and emissions from international aviation by 15.83% compared to 2022.

The emissions trend in international aviation has been quite stable, slight increases in 2007 and 2008 were caused by lower bunker fuel prices in Estonia. In 2020 emissions from International aviation decreased 65.7% compared to 2019 because of a severly reduced international air traffic due to COVID-19 pandemic. In 2021 the emissions increased about 79.2% as passenger demand recovered due to reduced movement restrictions from COVID-19 pandemic. This trend continued in 2022 when emissions increased about 33.3%, but reveresed somewhat in 2023.

Figure 3.7 presents the trend of GHG emissions from International aviation and navigation.

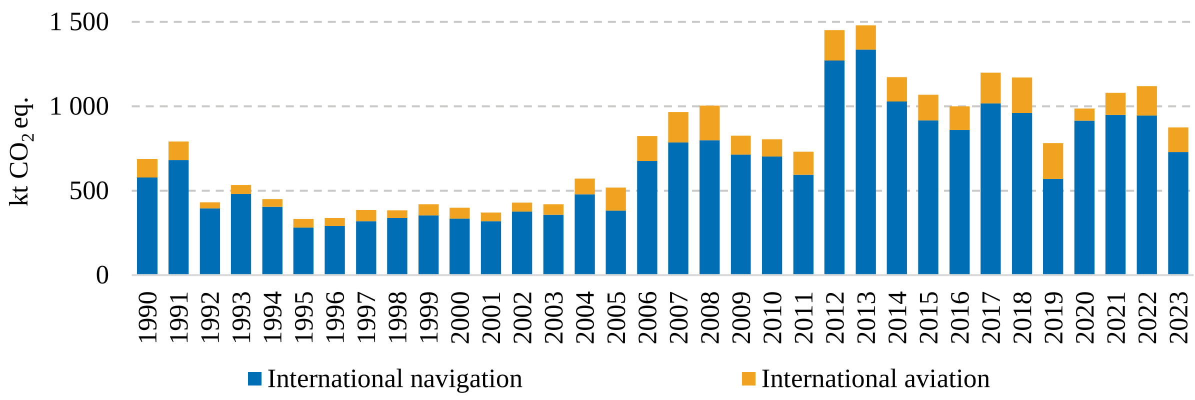


Figure 3.7. Emissions from International bunkers in 1990–2023, kt CO_2 eq.

Activity data in International navigation is taken from Joint Questionnaire made by Statistics Estonia. Statistics Estonia obtains this data from the international trade database according to the relevant merchandise code.

Activity data for the calculations in International aviation (landing and take-off cycles, fuel consumption) is obtained from the Estonian Environment Agency.

Emissions are calculated using the IPCC 2006 methodology. In international aviation the CO_2, CH_4, and N_2O emissions are calculated using IPCC 2006 default emission factors and in international navigation CO_2 emissions are calculated using country-specific emission factors for residual fuel oil, light fuel oil, and natural gas (LNG) and for CH_4 and N_2O the IPCC 2006 default emission factors are used

3.2.3. Feedstocks and non-energy use of fuels

The following fuels are reported under CRT 1.A.D Feedstocks, reductants and other non–energy use: lubricants, bitumen, natural gas, and oil shale.

Activity data on lubricants, bitumen, and natural gas consumption for non-energy use is received from Joint Questionnaire made by Statistics Estonia and is annually sent to Eurostat and IEA. Oil shale activity data is calculated using plant-specific data. The reported amount is oil shale semi-coke which is the by-product of shale oil production and contains a small amount of organic matter (carbon). Oil shale semi-coke is stored in the oil shale waste dumps (carbon stored).

Natural gas was used for non-energy purposes in ammonia production in Nitrofert AS and is reported in the CRT 2.B.1. In 2010 and 2011 the factory was temporarily closed due to low ammonia prices in the world market. The ammonia production factory has remained closed since 2013.

Lubricants are used in the Energy sector for lubrication (mainly in transport and manufacturing sub-sectors). Some used lubricants (waste oils) are incinerated, and corresponding emissions are taken into account in CRT 1.A.2.f Other fuels.

Additional information regarding CRT category 1.A(d) Feedstocks and non-energy use is presented in Annex 5 (A.V.1.3).

3.2.4. Energy industries (1.A.1)

3.2.4.1. Category description

Energy industries (CRT 1.A.1) includes GHG emissions from fuel combustion in 1.A.1.a Public electricity and heat production and in 1.A.1.c Manufacture of solid fuels and other energy industries which includes GHG emissions from shale oil production from point sources.

In 2023 Energy industries (1.A.1) contributed 62.45% of Energy sector emissions, totalling 5471.89 kt CO_2 eq. and 50.37% of total GHG emissions. Compared to the base year 1990, the emissions were 80.65% lower (28 284.61 kt CO_2 eq.). The decrease of 36.63% in 2023 in the Energy industries compared to the previous year was mainly because of energy crises caused by Russian invasion of Ukraine in 2022 begun to resolve. This led to fall in electricity prices, which in combination of high prices of EU carbon allowances resulted in reduced profitability and lower amounts of electricity generated from oil shale.

The emissions from Energy industries by relevant subcategories and gases in 1990–2023 are presented in Table 3.2 and Figure 3.8.

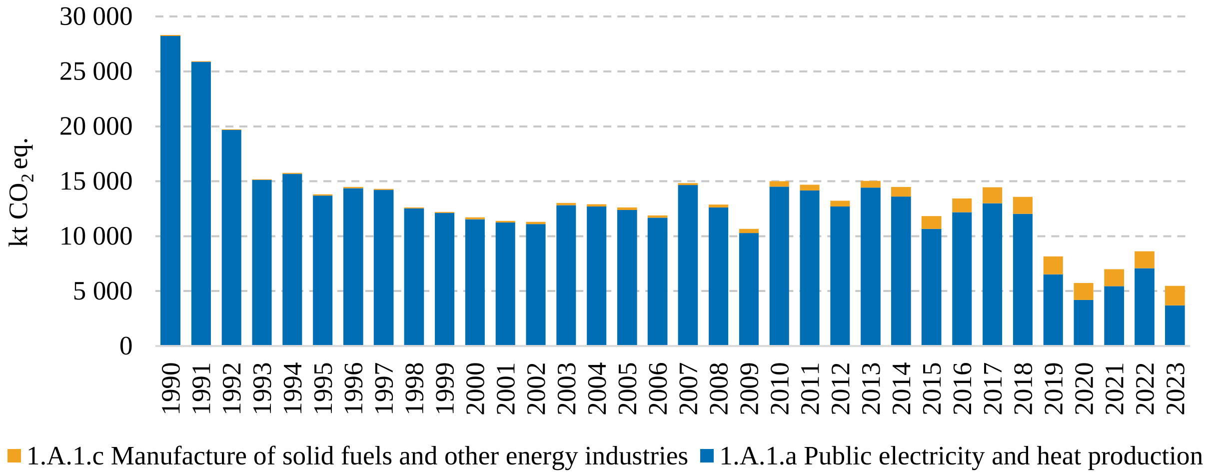


Figure 3.8. Trend of GHG emissions from Energy industries by relevant sub-categories in 1990–2023, kt CO_2 eq.

Table 3.2. GHG emissions from Energy industries by relevant subcategories in 1990, 2005, and 2020-2023, kt CO_2 eq.

	1990	2005	2020	2021	2022	2023
1.A.1 Energy Industries Total, CO_2 eq.	28 284.61	12 611.61	5 753.37	6 997.67	8 635.49	5 471.89
1.A.1.a Public Electricity and Heat Production Total, CO_2 eq.	28 206.06	12 383.43	4 190.42	5 449.05	7 071.52	3 708.52
1.A.1.c Manufacture of Solid Fuels and Other Energy Industries Total, CO_2 eq.	78.56	228.19	1 562.94	1 548.63	1 563.97	1 763.37

In general the trend of GHG emissions in Energy industries follows the trend of fuel consumption. The decrease of GHG emissions in 1.A.1.a Public electricity and power production sub-sector in 2023 compared to 1990 was 86.85%. This considerable decrease was caused by the structural changes in the economy after 1991 when Estonia regained independence. There has been a drastic decrease in the consumption of solid, liquid, and gaseous fossil fuels to produce heat and power and increase in the use of solid biofuels. At the same time, the GHG emissions from 1.A.1.c Manufacture of solid fuels and other energy industries (shale oil production) have increased over 20 times compared to 1990 due to extended production and export of shale oil.

Estonia imported natural gas, liquid fuels, coal, and solid biofuels in 2023. Natural gas imports decreased about 22.69% compared to 2022, due to decreased demand. Motor gasoline and diesel imports fell about 22.68% compared to the previous year, with majority of the decrease caused by decreased exports. Coal imports increased about 69.33% compared to 2022, but the overall quantities of coal were marginal – only 5.08 kt.

1.A.1.a Public electricity and heat production

The decrease of GHG emissions in 1.A.1.a Public electricity and power production sub-sector in 2023 compared to 1990 was 86.85%. This considerable decrease was caused by the structural changes in the economy after 1991 when Estonia regained independence. There has been a drastic decrease in the consumption of solid, liquid, and gaseous fossil fuels to produce heat and power and increase in the use of solid biofuels.

In 2023 the gross electricity production was 5 745 GWh – about 35.72% lower compared to 2022 (8 937 GWh). The electricity export decreased from 6 172 GWh in 2022 to 4 355.4 GWh in 2023 (about 29.43%). The electricity import increased from 7 183 GWh in 2022 to 7 659.7 GWh in 2023 (6.64%).

Renewable energy is generated from wind, biomass, solar and small hydroelectric plants in Estonia. The growth of wind parks, solar power, and biomass has significantly contributed to the increasing share of renewable energy in total energy production. In addition to the cheapening and availability of technology, the impulse for more active deployment of solar power plants in Estonia is provided by the support scheme for renewable electricity production.

In 2023 heat production decreased around 2.38% compared to 2022 due to decreased heating demand. Roughly 45.5% of heat was produced in heating plants and power plants produced about 54.5% of heat.

In 2013 a waste incinerator plant was opened in Estonia. These emissions are accounted for in Other fossil fuels in Energy industries sector. In 2023 Iru waste incineration plant emitted 137.35 kt CO_2 eq.

1.A.1.b Petroleum refining

There are no petroleum refining activities taking place in Estonia.

1.A.1.c Manufacture of solid fuels and other energy industries

The GHG emissions from 1.A.1.c Manufacture of solid fuels and other energy industries (includes shale oil production) have increased over 20 times compared to 1990 due to extended export of shale oil. 1227.24 kt of shale oil was produced in 2023, which was 10.06% more compared to 2022 production. The GHG emissions increased by 12.75% in 2023 from 1563.97 kt CO_2 eq in 2022 to 1763.37 kt CO_2 eq in 2023.

3.2.4.2. Methodological issues

Choice of methods

Emissions from Fuel combustion in 1.A.1 are in general calculated by using the methodology of the IPCC 2006 Guidelines. Different tiers have been applied for different fuels and greenhouse gases.

For imported fuels, which belong to key categories, mainly *Tier 2* approach is applied. For domestic fuels – oil shale, shale oil, oil shale semi-coke, oil shale semi-coke gas, generator gas, and peat – *Tier 2* and *Tier 3* approaches are used.

1.A.1.a Public electricity and heat production

Oil Shale

Oil shale is a primary indigenous fuel in Estonia, which is mainly used to produce electricity and shale oil. Estonian oil shale is characterised with a high ash (45–47%), a moderate moisture (11–13%), and sulphur content (1.5–1.7%), a low net calorific value (about 8.3–8.7 MJ/kg), and a high volatile matter in the combustible part (up to 90%). The dry matter of Estonian oil shale is considered to consist of three main parts: organic, sandy-clay and, carbonate[19].

Oil shale is produced in two qualities: with the grain size of 0÷25 mm and 25÷125 mm. The enriched lumpy oil shale (25÷125 mm) with higher calorific value is used to produce oil shale oil (shale oil) and as fuel in cement kilns. About 77% of the mined oil shale (grain size 0÷25 mm) with lower calorific value is used as boiler fuel in large power plants. The net calorific value of oil shale is decreasing because best quality oil shale layers have mostly been exhausted[15].

CO_2 is formed not only as a burning product of organic carbon during the combustion of pulverised oil shale but also as a decomposition product of the ash carbonate part. Therefore, the total quantity of carbon dioxide increases by up to 25% in flue gases of oil shale[15].

Two different combustion technologies, the older pulverised combustion of oil shale (PC) and the newer circulated fluidised bed combustion (CFBC) technology are currently used in the Estonian power plants.

The first CFBC power unit (215 MW_{el}) started at the Estonian Power Plant at the end of 2003. The conducted tests showed that the transition from pulverised combustion boilers to circulating fluidised bed boilers comes with several changes: the CFBC boiler CO_2 discharge rose from 82–84% to 75% (the carbonate decomposition rate was sometimes even less), the SO_2 atmospheric discharges stopped almost completely (k_S=0.999), the boiler efficiency increased

[19] Ots, A. (2004). Põlevkivi põletustehnika. Tallinn: Tallinna Raamatutrükikoda, page 833.

from 81–82% to ~90–95%, thus the fuel consumption also decreased, and power production efficiency at nominal load range dropped from 35–36% to 29–30% at oil shale fluidised bed combustion.

The second CFBC power unit (215 MW_{el}) started at the Narva Power Plants in 2004. The successful operation of the new CFBC units allows continuing the construction of additional units. A new CFBC power unit (300 MW_{el}) was connected to the Estonian electricity network in 2015.

A formula for the calculation of Estonian (pulverised combustion) oil shale carbon emission factor, taking into consideration the decomposition of its ash carbonate part and CO_2 binding at ash fields are presented in Equation 3.1.

Equation 3.1[20]

$$CEF_{oil\ shale} = \frac{10 \times [C_t^r + k \times (CO_2)_M^r \times 0.273]}{Q_i^r} \left[\frac{tC}{TJ}\right]$$

Where:

$CEF_{oil\ shale} =$	carbon emission factor of oil shale, tC/TJ;
$Q_i^r =$	lower heating value oil shale, MJ/kg;
$C_t^r =$	carbon content of oil shale, %;
$(CO_2)_m^r =$	mineral carbon dioxide content of oil shale, %;
K=	decomposition rate of ash carbon part (*k* = 0.64 for pulverised combustion of oil shale).

In 2017 the Regulation of Minister of Environment on ‘Calculation methods of the amount of CO_2 discharged into ambient air’[17] was updated. According to the Annex 2 of this Regulation, the carbon emission factors for oil shale combustion in power plants are:

- $CEF_{oilshalePC}$ = 27.85 tC/TJ;
- $CEF_{oilshaleCFB}$ = 26.94 tC/TJ.

CO_2 emissions from pulverised combustion and circulating fluidised bed combustion boilers are therefore calculated separately. These values have been used for most years. When available, more accurate plant-specific emission factors are used. The ranges of the emission factors are presented in Table 3.6.

Oil shale gases

Oil shale gas is a by-product of the thermal processing of oil shale. There are different types of oil shale gases depending on the technology. Semi-coke gas is the by-product of oil shale thermal processing in solid heat carrier installation (SHC), generator gas is produced in the oil shale processing in vertical reactors (gas generators), and gas gasoline is a by-product fuel in oil shale production. In Table 3.3 semi-coke gas and generator gas production data for different shale oil plants is presented.

[20] Riigi Teataja. Välisõhku väljutatava süsinikdioksiidi heite arvutusliku määramise meetodid. [www] https://www.riigiteataja.ee/akt/129122016063?leiaKehtiv (19.12.2024).

Table 3.3. Semi-coke gas and generator gas production by shale oil plants, PJ

Year	Solid Heat Carrier			Total	Gaseous Heat Carrier		Total	Total
	Narva	VKG	Kiviõli	in SHC	VKG	Kiviõli	in gas generators	Oil shale gas
1990	0.70	NO	NO	0.70	2.82	0.39	3.20	**3.90**
2005	1.60	NO	NO	1.60	2.46	0.86	3.32	**4.92**
2020	5.86	5.24	NO	11.10	1.67	0.94	2.61	**13.71**
2021	5.49	4.76	NO	10.25	1.57	1.01	2.58	**12.83**
2022	4.74	4.13	NO	8.87	1.53	0.70	2.23	**11.10**
2023	4.93	4.87	NO	9.80	1.56	0.66	2.22	**12.02**

NO – no production occurred

Description of oil shale production technologies and detailed methodology for estimation of carbon emission factors for oil shale gases is presented in Annex V (A.V.1.1). GHG emissions from the combustion of different oil shale gases are calculated separately and included into CRT 1.A.1.a Public electricity and heat production under Solid fuels.

Waste incineration

Enefit Green AS (Enefit Green Ltd. Iru incineration plant**)** uses waste in their daily activity.

Kunda Nordic Cement used waste oils, plastic waste, and other fossil-based solid waste as an alternative fuel source to produce cement, clinker, and splinters until 2020 when Kunda Nordic Cement closed down the clinker production.

Iru incineration plant uses municipal waste to produce heat and electricity since 2013. The plant uses MARTIN moving grate technology, consisting of moving grates at an angle of 26 degrees. Each part of the grate has a drive with automatically adjustable speed. The grates are made out of wear and temperature-resistant material (CrFe). The pace and speed selection of mobile grates ensure the most efficient and safe combustion process possible. A unique “reverse” reburn system ensures fuel mixing and good carbon extraction. The volatile part is lit above the grate. This operation also ensures the continuous coverage of the firing grates with a protective layer of waste or ash, preventing the grate from burning naked, giving them a longer life-span. This technology does not require cooling water for waste with high calorific values.

For the 2023 submission Estonia updated the methodology to calculate emissions from Iru waste plant. The new methodology also allowed to introduce separate carbon emission factors for imported municipal waste in the calculations. The fossil and biogenic waste fractions as well as fossil and biogenic carbon emission factors for the municipal waste have been updated for the whole timeseries. The updated fractions and emission factors are taken from the three studies conducted at the Iru waste plant in 2015[21],2019[22] and 2024[23] so the carbon emission factors and waste fractions are plant specific. For the years 2013-2018 the biogenic fraction of waste is 45% and fossil 55%, from 2019 the biogenic fraction is 32% and fossil 68%, and from 2023 biogenic fraction is 37% and fossil fraction is 63% for the local waste. Biogenic fraction of waste is 41% and fossil 59% for the imported waste throughout the timeseries.

[21] Determining the composition and properties of Estonian mixed municipal waste incinerated in the Iru electric power plant waste energy block. The study is available upon request.
[22] Determining the physical composition and characteristics of the waste incinerated in the Iru electric power plant and the CO_2 emission coefficient produced during combustion. The study is available upon request.
[23] Determining the physical composition and characteristics of the waste incinerated in the Iru electric power plant and the CO_2 emission coefficient produced during combustion. The study is available upon request.

1.A.1.b Petroleum refining

There are no petroleum refining activities taking place in Estonia.

1.A.1.c Manufacture of solid fuels and other energy industries

Shale Oil

In Estonia shale oil production (reported under other energy industries) takes place in three companies: **Kiviõli Keemiatööstuse OÜ** (Kiviõli Oil Shale Processing and Chemicals Plant Ltd.) in Kiviõli, **Viru Keemia Grupp AS (VKG)** (Viru Chemistry Group Ltd.) in Kohtla-Järve, and **Enefit Power AS** (Enefit Power Ltd.) in Auvere.

There are two different technologies now in use: since 1924 processing large-particle oil shale in vertical retorts with gaseous heat carrier, and since 1980 processing fine-grained oil shale with solid heat carrier (SHC). Both technologies are in operation in Kohtla-Järve and Kiviõli, and the solid heat carrier technology is used in the Narva Oil Plant since 2010.

The technology of processing oil shale in vertical retorts with a **gaseous heat carrier (GHC)** is a universal technology and is suitable for retorting high-calorific oil shale. The vertical retort is a metal vessel lined on the inside with refractory bricks. The oil shale charging device, spent shale discharge chute, and extractor are arranged on the top, and in the lower part of the retort vessel, respectively. Thermal processing of oil shale takes place in retorting chambers in the cross-flow of a gaseous heat carrier. By the influence of gases, the oil shale is warmed and dried up, and after achieving a necessary temperature for retorting, the organic part of the oil shale starts to decompose quickly. The mixture of the heat carrier with oil and water vapour moves into collector chambers, semi-coke (retorted oil shale) moves downward to cooling chambers. Oil vapour and gas exit the retort via outlet connections to condensation system. Cleaned generator gas is delivered to heating boilers for burning. Thermal processing of oil shale in vertical retorts occurs without any contact with the ambient atmosphere; therefore no pollutants are emitted[24]. As GHC plants have no direct emissions from the shale oil production process, the CEF is effectively 0. This causes the IEF of Energy industries to be very low.

In **solid heat carrier installation (SHC)** hot oil shale dust as a heat carrier is used. Pre-dried fine-grained oil shale with hot oil shale dust (800 ^{o}C) is delivered to a horizontal rotating reactor where the retorting process occurs in just a few minutes. The mixture of heat carrier with oil and water vapours moves into the dust separation chamber. Oil vapours and gas move to the condensation chamber where the condensed oil is separated and semi-coke gas is sent to the power plant. The mixture of semi-coke and dust will be delivered to an aero fountain combustor chamber, where semi-coke is burned and flue gases separated. The flue gases are used for drying and pre-heating the raw oil shale in the dryer and then they are entirely emitted into the atmosphere. Some of the dust is delivered back to the reactor[21] and the rest to the ash hill.

In 2023 83.25 PJ of oil shale was consumed for shale oil production in total and processing of 62.37 PJ of oil shale caused direct CO_2 emissions at the solid heat carrier-type plants (see Table 3.4). This occurs because of a difference in technologies as no CO_2 is emitted directly from gas generator-type plants (all gases produced in the process are burned in the electric plants), however, CO_2 is emitted in solid heat carrier-type plants.

[24] Soone, J., Doilov, S. (2003). Sustainable utilisation of oil shale resources and comparison of contemporary technologies used for oil shale processing. Oil Shale, Vol. 20. No. 3S. pages 311-323.

Table 3.4. Oil shale consumption for shale oil production by different technologies, PJ

Year	Solid Heat Carrier			Total	Gaseous Heat Carrier		Total	Total
	Narva	VKG	Kiviõli	in SHC	VKG	Kiviõli	in gas generators	Oil shale
1990	3.24	NO	NO	3.24	21.56	5.55	27.11	**30.36**
2005	8.87	NO	NO	8.87	17.78	4.21	22.00	**30.86**
2020	29.36	28.30	1.74	59.40	16.13	4.99	21.13	**80.53**
2021	28.90	27.09	1.88	57.86	15.62	4.82	20.45	**78.31**
2022	29.15	24.23	2.00	55.38	15.73	5.60	21.33	**76.70**
2023	31.85	28.53	1.99	62.37	15.72	5.15	20.87	**83.24**

NO – no consumption occurred

Activity data

Activity data for GHG emission calculations are collected from several sources. The final fuel consumption data by sectors, including sub-sectors, is recieved from Joint Questionnaire (JQ) dataset made by Statistics Estonia. This data is also presented in the SE database[25] and added to Annex 3 (A.3.2). Some detailed data (i.e. pulverised and fludised bed combustion of oil shale consumption; shale oil, and semi-coke gas production) is obtained from the energy company Enefit Power AS. Information on oil shale, shale oil, semi-coke, and generator gas consumption in Kiviõli and VKG oil plants is obtained directly from the oil plant operators.

Municipal solid waste incineration data in 1.A.1.a is plant specific and taken from The Environmental Board database KOTKAS.

Fuel consumption in Energy industries (CRT 1.A.1) in 1990–2023 is presented in Figure 3.9 and Table 3.5.

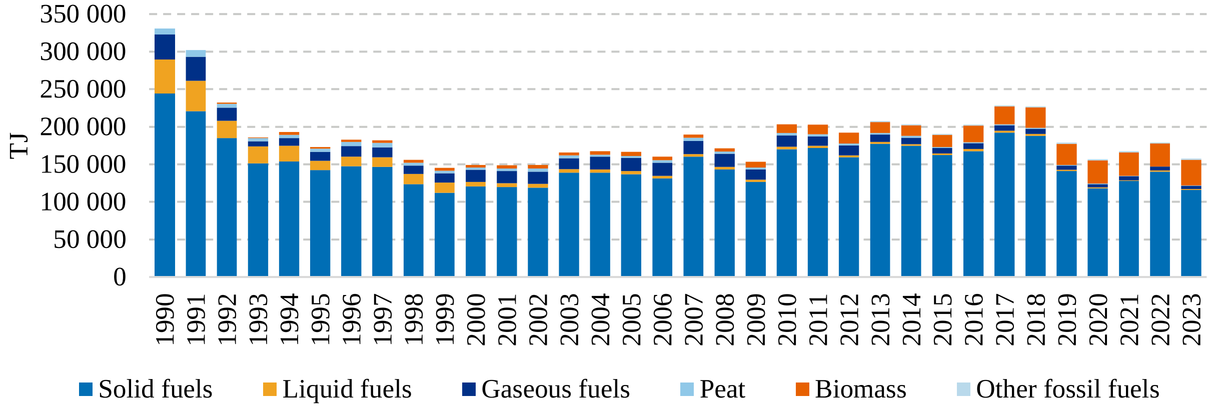


Figure 3.9 Trend of fuel consumption in Energy industries, TJ

[25]Eesti Statistikaameti andmebaas. [www] https://andmed.stat.ee/et (10.01.2025).

Table 3.5. Fuel consumption in Energy industries in 1990, 2005, and 2020–2023, TJ

Category/activity data	1990	2005	2020	2021	2022	2023
1.A.1 Energy Industries Total, TJ.	**330 776**	**166 794**	**156 622**	**167 411**	**178 951**	**157 608**
Liquid fuels	45 263	4 342	1 442	817	1 672	1 387
Solid fuels	244 766	136 734	117 849	127 767	140 203	115 960
Gaseous fuels	32 792	17 551	4 336	5 734	5 080	4 282
Peat	7 956	2 525	641	199	246	149
Biomass	NO	5 642	30 752	31 249	30 296	34 339
Other fossil fuels	NO	NO	1 602	1 646	1 455	1 491

Emission factors

Carbon emission factors, oxidation factors, and net calorific values used in the emission calculations in 1.A.1 are presented below in Table 3.6.

Table 3.6. Carbon emission factors, oxidation factors, and net calorific values in 2023

Fuels	NCV average	Unit	CEF, tC/TJ	Oxidation factor	Source of emission factor
Liquid fuels					
LPG	45.5	GJ/t	17.22	1	CS (Estonia)
Motor gasoline	44	GJ/t	19.20	1	CS (Estonia)
Light fuel oil	42.3	GJ/t	19.91	1	CS (Estonia)
Diesel oil	42.3	GJ/t	19.91	1	CS (Estonia)
Residual fuel oil (heavy fuel oil)	39.25	GJ/t	21.09	1	CS (Estonia)
Solid fuels					
Coal	24.94	GJ/t	25.81	1	CS (Estonia)
Coke oven coke	28.5	GJ/t	29.02	1	CS (Estonia)
Oil shale	8.42	GJ/t	26.42 – 27.25	1	PS (Estonia)
Milled&sod peat[26]	10.33	GJ/t	28.9	1	D, IPCC 2006
Peat briquette	16	GJ/t	26.45	1	FI (Finland)
Oil shale semi-coke gas (SHC technology, Narva Enefit 140 plant)	36.51	GJ/1000 m^3	19.68	1	PS (Estonia)
Oil shale semi-coke gas (SHC technology, Narva Enefit 280 plant)	45.15	GJ/1000 m^3	19.03	1	PS (Estonia)
Oil shale semi-coke gas (VKG Petroter I plant)	42.00	GJ/1000 m^3	19.17	1	PS (Estonia)
Oil shale semi-coke gas (VKG Petroter II plant)	42.00	GJ/1000 m^3	19.17	1	PS (Estonia)
Oil shale semi-coke gas (VKG Petroter III plant)	42.00	GJ/1000 m^3	19.17	1	PS (Estonia)
Oil shale semi-coke gas (Kiviõli plant)	50.06	GJ/1000 m^3	17.78	1	PS (Estonia)
Oil shale generator gas (Kiviõli plant)	2.35	GJ/1000 m^3	53.01	1	PS (Estonia)
Oil shale generator gas (VKG plant)	2.65	GJ/1000 m^3	52.46	1	PS (Estonia)
Gas gasoline	44	GJ/t	19.81	1	CS (Estonia)
Municipal solid waste (MSW, fossil part) (CRT 1.A.1.a)	9.5	GJ/t	25.11	1	PS, Iru incineration plant
Natural gas	35.43	GJ/1000 m^3	14.73	1	CS (Estonia)
Biomass fuels					

[26]A processed form of peat that is compressed into mall (40–70 mm) pieces.

Fuels	NCV average	Unit	CEF, tC/TJ	Oxidation factor	Source of emission factor
Solid biomass (solid, includes e.g. firewood, wood chips, sawdust pellets, briquettes, etc.)	6.9 – 16.9	GJ/t	30.5	1	D, IPCC 2006
Municipal solid waste (MSW, biogenic part) (CRT 1.A.1.a)	9.5	GJ/t	44.08	1	PS, Iru incineration plant
Biogas (landfill gas and biogas from wastewater treatment)	17.4	GJ/1000 m^3	14.89	1	D, IPCC 2006

D – IPCC default value; CS – country-specific; PS – plant-specific;

CH_4 and N_2O emission factors for 1.A.1 Energy industries for different fuels are presented in Table 3.7. In 2021 Estonia developed country-specific CH_4 and N_2O emission factors for 1-50 MW combustion plants for natural gas, biogas, light fuel oil, residual fuel oil, peat, biomass, and municipal solid waste. The emission factors are used in the Energy Industry sector 1.A.1.a, Manufacturing industries and construction subsectors, 1.A.4.a, and 1.A.4.c. CH_4 and N_2O emission factors for less than 1 MW and larger than 50 MW combustion plants are IPCC 2006 default values.

Table 3.7. CH_4 and N_2O emission factors by fuel, kg/TJ

Fuels	Energy industries		Manufacturing industries and construction		Source
	CH_4	N_2O	CH_4	N_2O	
Liquid fuels					
LPG (liquefied petrol gas)	1	0.1	1	0.1	D, IPCC 2006
Motor gasoline	3	0.6	3	0.6	D, IPCC 2006
Light fuel oil	3/0.003*	0.6/0.17*	3/0.003*	0.6/0.17*	D, IPCC 2006/CS[27]
Diesel oil	3	0.6	3	0.6	D, IPCC 2006
Residual fuel oil (heavy fuel oil)	3/0.003*	0.6/0.17*	3/0.003*	0.6/0.17*	D, IPCC 2006/CS[24]
Waste oil	30	0.6	30	0.6	D, IPCC 2006
Solid fuels					
Oil shale $_{PC}$[15]	0*	0*	10	1.5	CS (A.Ots); D, IPCC 2006
Oil shale $_{FBC}$	0*	0.82*	10	1.5	CS/ D, IPCC 2006
Milled&sod peat	1/1.7*	1.5/2.5*	2/1.7*	1.5/2.5*	D, IPCC 2006/CS
Peat briquette	1/1.7*	1.5/2.5*	2/1.7*	1.5/2.5*	D, IPCC 2006/CS[24]
Oil shale gases (semi-coke gas and generator gas)	1	0.1	1	0.1	D, IPCC 2006 (natural gas)
Municipal solid waste	0.004*	0.17*	–	–	CS[22]
Gaseous fuels					
Natural gas	1/0.003*	0.1/0.12*	1/0.003*	0.1/0.12*	D, IPCC 2006/ CS[24]
Biomass fuels					
Solid biomass (solid, includes e.g. firewood, bark, chips, sawdust, and other industrial wood residues, pellets, and briquettes)	30/0.29*	4/0.21*	30/0.29*	4/0.21*	D, IPCC 2006/CS[24]
Biogas (landfill gas and biogas from wastewater treatment)	1/0.0025*	0.1/0.12*	–	–	D, IPCC 2006/CS[24]

D – IPCC default value; CS – country-specific; * – country-specific

[27]Country-specific emission factors for 1-50 MW are based on “Control measurements and updating of data for specific emissions of GHGs and air pollutants from households and large and medium-sized combustion plants in the energy sector” The report is available upon request.

The NO_x, CO, and NMVOC emissions are calculated by Estonian Environmental Agency. Emission factors come from different sources. If possible, a country-specific and plant-specific emission factor is used, if not, the emission factors from EMEP/EEA Guidebook 2023 are used[28]. The oil shale direct combustion data is plant-specific. The NO_x, CO, and NMVOC emissions are calculated by using Equation 3.2.

Equation 3.2.

$$EF_{pollutant} = AR_{activity} \times EF_{pollutant}$$

Where:

$E_{pollutant}$ =	the emission of the specific pollutant;
$AR_{activity}$ =	the activity rate;
$EF_{pollutant}$ =	the emission factor for this pollutant.

3.2.4.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Energy industries subcategory, please see Annex A.II.1 Energy, 1.A.1 Energy industries chapter.

3.2.4.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.5. A complete Quality Assurance (QA) and Quality Control (QC) was carried out for Energy industries according to the IPCC *Tier 1* method.

There are several QC procedures. The most resource-demanding is checking the fuel consumption data in Joint Questionnaires received from Statistics Estonia:

Fuel consumption data in natural units (tons or thousand cubic meters) and energy units (TJ) is available in Joint Questionnaires from Statistics Estonia (www.stat.ee). Year average net calorific values are received from Statistics Estonia. Before entering the fuel consumption data into emission calculation tables, the expert first checks the current year data by multiplying fuel amounts in natural units with NCV and compare the results with fuel consumption data in TJ presented in the statistical database. Sometimes there are some small differences due to the rounding the values. The second step is to check all activity data on previous years because Statistics Estonia sometimes corrects old data. The third step is to verify national energy balance data with IEA data. IEA uses constant NCV-s but national energy data uses TJ that are calculated using year-specific NCV-s. Some differences also occur in produced heat. IEA reports only fuels used for sold heat produced by district heating power plants and auto-producers in the Energy conversion sector, but fuels used for heat production by auto-producers (used for their own consumption) are reported under the final consumption.

[28]EMEP/EEA air pollutant emission inventory guidebook – 2023.
[www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion (05.03.2024).

Next the fuel emission factors can be checked. If there is some new research on the estimation of country-specific emission factors available, all necessary corrections will be made for the whole time-series.

In the 2025 inventory submission Energy sector CO_2 emissions were compared against the emissions of European Union Emission Trading Scheme (EU ETS) enterprises (for the year 2023). The consistency of EU ETS data and the inventory submission has improved since the 2016 submission. Firstly, the methodology of calculating the emissions of shale oil production has improved. Inventory compilers receive additional information from shale oil producers which make inventory emissions data more precise and reliable. Estonia has unified the oil shale combustion data presented in the EU ETS and in the energy balance of Statistics Estonia and continues to do so.

There is a more comprehensive list of *Tier 1* and *Tier 2* QC activities in the Energy sector in the internal documentation (in Estonian).

3.2.4.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

Recalculation for year 2022 in 1.A.1.a sub-category was carried out and this increased 2022 emission by 209.11 kt CO_2 eq (Table 3.8.). The reason for this recalculation was an error in the oil shale generator gas emission calculations.

Table 3.8. Recalculations for 1.A.1.a sub-sector.

Year 2022 1.A.1.a emission in 2024 submission (kt CO_2 eq)	Year 2022 1.A.1.a emission in 2025 submission (kt CO_2 eq.)	Difference (kt CO_2 eq.)
6862.41	7071.52	209.11

3.2.4.6. Category-specific planned improvements, if applicable including tracking of those identified in the review process

Verification measurements of specific CH_4 and N_2O emission factors (e.g. for solid biomass) for large combustion plants (over 50 MW) in the energy sector are planned for 2025.

3.2.5. Manufacturing industries and construction (1.A.2)

3.2.5.1. Category description

Manufacturing industries and construction (CRT 1.A.2) include emissions from industrial sectors (power plants, boilers, and industrial plants with boilers, and/or other combustion). In 2023 the Manufacturing industries and construction contributed about 2.60% of Energy sector emissions, totalling 228.07 kt CO_2 eq., and about 2.10 % of total GHG emissions.

The structural changes in the economy after regaining independence in 1991 caused the relevant decrease from 1992. Compared to 1990 the emissions have decreased by 93.40% in 2023. Emissions decreased in the Manufacturing industries and construction sector by 14. 48% compared to 2022, mainly because of reduced natural gas consumption, which was substituted by increased consumption of solid biomass.

According to the structure of CRT tables Manufacturing industries and construction sub-sectors are presented in the following CRT sub-categories: 2.a Iron and steel; 2.b Non-ferrous metals; 2.c Chemicals; 2.d Pulp, paper, and print; 2.e Food processing, beverage, and tobacco; 2.f Non-metallic minerals, and 2.g Other. Table 3.9 and Figure 3.10 represent the emissions from Manufacturing industries and construction by relevant subcategories.

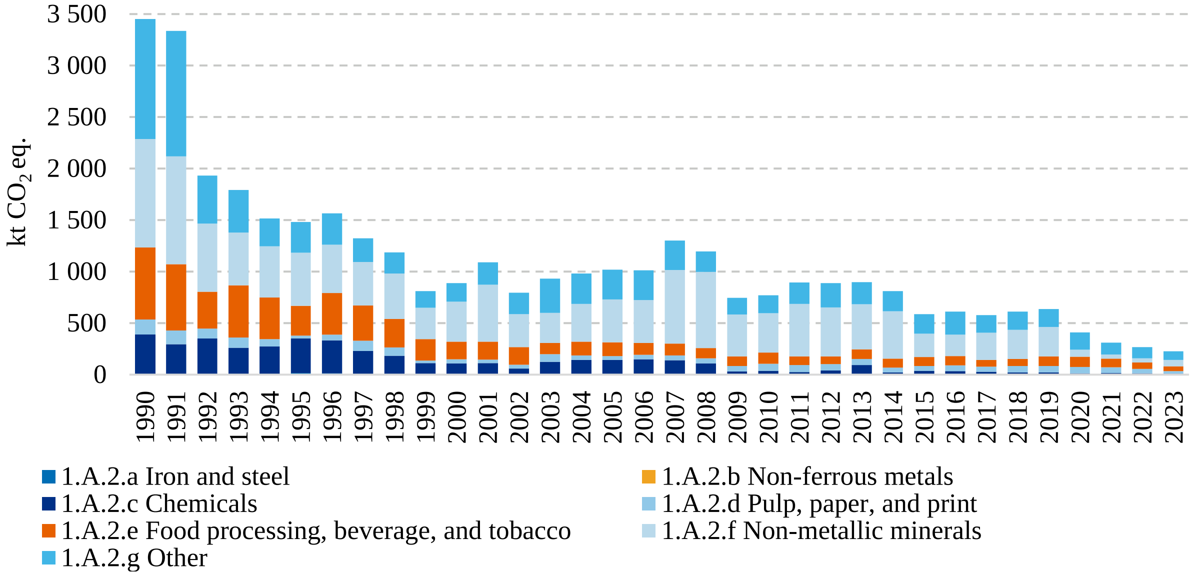


Figure 3.10. Trend of GHG emissions from Manufacturing industries and construction by relevant sub-categories in 1990–2023, kt CO_2 eq.

Table 3.9. GHG emissions from Manufacturing industries and construction by relevant subcategories 1990, 2005, and 2020-2023, kt CO_2 eq.

Category	1990	2005	2020	2021	2022	2023
1.A.2 Manufacturing Industries and Construction Total, CO_2 eq.	3454.24	1017.78	411.49	309.33	266.70	228.07
1.A.2.a Iron and Steel, CO_2 eq.	NO	1.24	0.48	0.73	0.69	0.47
1.A.2.b Non-Ferrous metals, CO_2 eq.	NO	1.00	1.24	0.50	NO	0.76
1.A.2.c Chemicals, CO_2 eq.	389.90	139.32	10.77	14.66	12.93	6.82
1.A.2.d Pulp, Paper and Print, CO_2 eq.	145.35	38.60	63.08	56.49	42.26	25.40
1.A.2.e Food Processing, Beverages and Tobacco, CO_2 eq.	697.01	132.62	98.16	82.48	61.92	46.48
1.A.2.f Non-Metallic Minerals, CO_2 eq.	1 057.16	418.62	67.41	42.02	40.73	61.96
1.A.2.g Other, CO_2 eq.	1 164.83	286.38	170.34	112.45	108.17	86.17

1.A.2.a Iron and steel

The 1.A.2.a Iron and steel CRT sub-category has a very small share in Estonia. This category consists largely of factories using fuel for manufacturing goods from imported iron and steel. Estonia imported the raw material (iron and steel) from Russia and after regaining independence in 1991 all iron- and steel-using factories were closed. In 1994 those factories started working again. As the production of goods depends on the raw material supply and final production export possibilities, the production decrease in 1997–1999 was directly caused by the economic crisis in Russia during the same period. Production stabilized from 2000 to 2006 and the decrease in emissions from 2007 to 2009 relates to the last economic depression. Since 2007 the annual emissions have been below 1 kt CO_2 eq., in 2023 the emissions were 0.47 kt CO_2 eq. which is 32.0% decrease as activity levels in the sector continue to shrink.

The trend of GHG emissions in 1.A.2.a Iron and steel in 1990–2023 is presented in Figure 3.11.

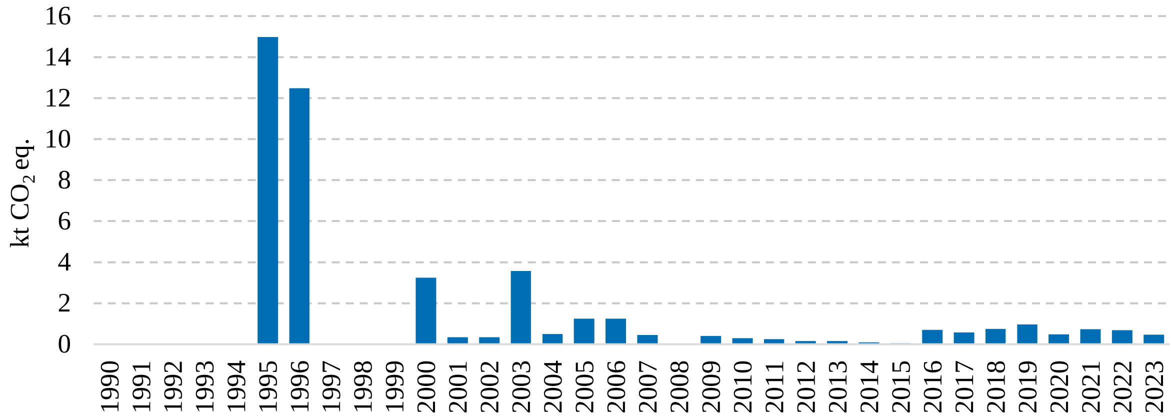


Figure 3.11. Trend of GHG emissions from Iron and steel in 1990–2023, kt CO_2 eq.

1.A.2.b Non-ferrous metals

The 1.A.2.b Non-ferrous metals sub-sector is small-scale in Estonia consisting only of 2–3 enterprises. The growth of GHG emissions in 2006 compared to previous years is connected to fuel consumption increase and is probably caused by large order(s) by some of these enterprises. In 2022 the emissions from Non-ferrous metals were 0 kt CO_2 eq. since no fuel consumption for 2022 was reported for this sector by the Estonian Statistical Agency. In 2023 the emissions from Non-ferrous metals were 0.76 kt CO_2 eq.

Figure 3.12 presents the trend of GHG emissions in 1.A.2.b Non-ferrous metals in 1990–2023.

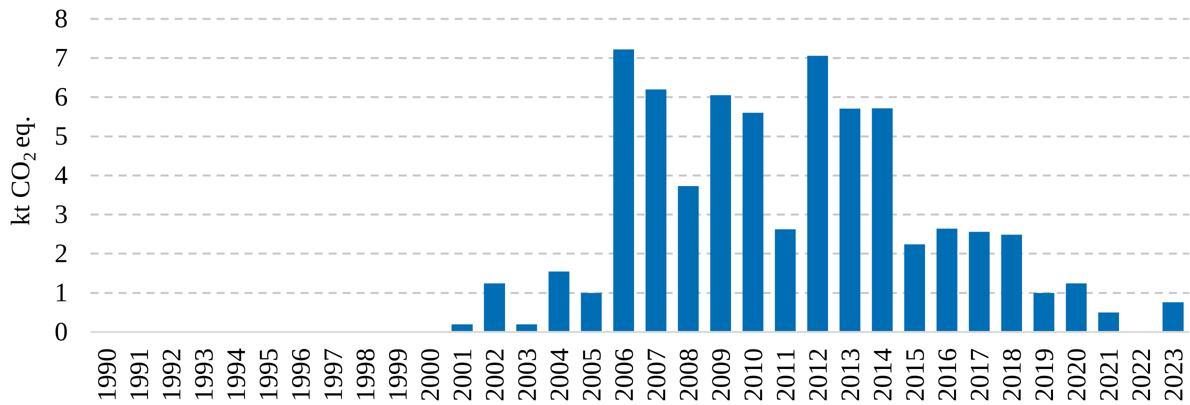


Figure 3.12. Trend of GHG emissions from Non-ferrous metals in 1990–2023, kt CO_2 eq.

1.A.2.c Chemicals

In 1.A.2.c Chemicals sub-category emissions from several chemical factories are reported. The biggest fuel consumer (mainly natural gas) was historically the ammonia and urea producer Nitrofert AS. This sub-sector formed about 2.99% of the Manufacturing industries and construction sector GHG emissions in 2023 and were 6.82 kt CO_2 eq and decreased 47.24% compared to the previous year due to decreased overall fuel usage and significant drop in LPG usage – from 75.1 TJ to 0.18 TJ.

The first decrease in the trend of GHG emissions in 1993 was caused by privatisation of chemical enterprises after regaining independence in 1991, and by a transition from eastern to western markets. The second decrease in 1999 was resulting from the extensive restructuring of Estonia’s biggest chemical enterprise Kiviter AS. The main product of Kiviter AS is shale oil (a liquid fuel made from oil shale), but since 1999 the shale oil production is reported under the Energy sector. Only the by-products of oil shale industry, like formalin, toluene, etc are still reported under chemical industry. In 2002 and 2009 the production of Nitrofert AS was very small, in 2010 and 2011 the factory was temporarily closed due to low ammonia prices in the world market. In 2013 the factory was reopened. Since the GHG emission trend follows the fuel consumption trend, and the fluctuations are determined by the ammonia export possibilities of Nitrofert AS. From 2014 the production facilities of Nitrofert AS is closed, so the overall emissions are noticeably lower.

Figure 3.13 presents the trend of GHG emissions from 1.A.2.c Chemicals in 1990–2023.

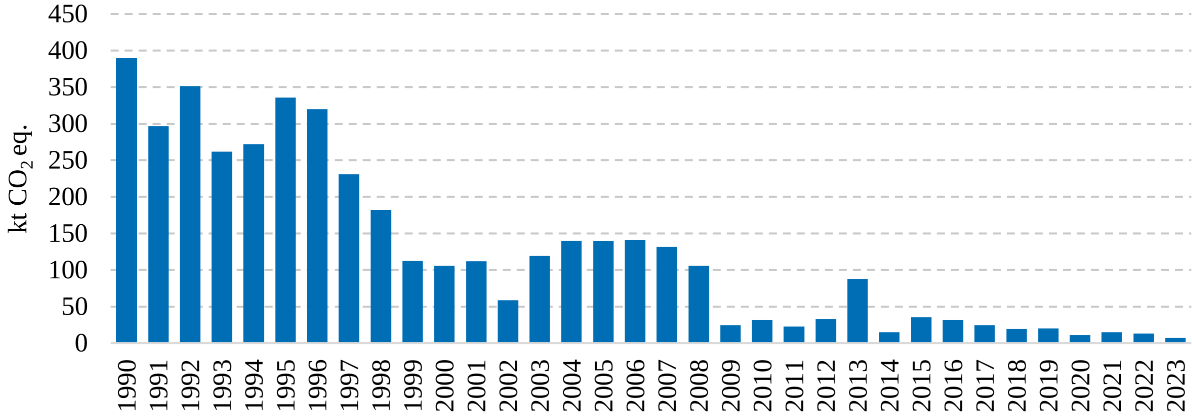


Figure 3.13. Trend of GHG emissions from Chemicals in 1990–2023, kt CO_2 eq.

1.A.2.d Pulp, paper and print

The CRT sub-category 1.A.2.d Pulp, paper, and print formed about 11.14% of the Manufacturing industries GHG emissions in 2023 with emissions of 25.40 kt CO_2 eq.

There are only a few pulp and paper factories in Estonia: Horizon Tselluloosi ja Paberi AS (Horizon Pulp and Paper Ltd), Kohila Paber AS (Kohila paper Ltd), and Räpina Paberivabrik AS (Räpina paper factory Ltd). In 2006 a new aspen pulp factory Estonian Cell AS was opened.

During 1992–1998 the production of paper fluctuated because some factories halted, and ownerships changed. During 1999–2003 the production of paper grew every year. In 2004 manufacturing of wood pulp lowered. In 2005 paper and paper products manufacturing increased due to lively investments and export growth. Sector production levels have stabilized since 2010 and are mostly affected by market volatility. The emissions decreased about 39.89% compared to the previous year due to significant substitution from natural gas to solid biofuels.

The trend of GHG emissions of 1.A.2.d Pulp, paper, and print in 1990–2023 is presented in Figure 3.14.

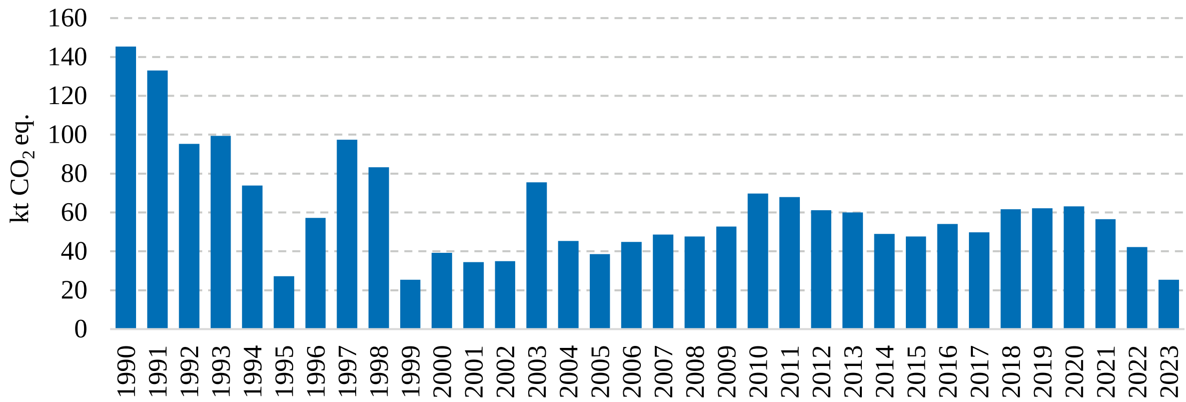


Figure 3.14. Trend of GHG emissions from Pulp, paper and print in 1990–2023, kt CO_2 eq.

1.A.2.e Food processing, beverages and tobacco

The 1.A.2.e Food processing, beverage, and tobacco CRT sub-category shares about 20.38% of the Manufacturing industries and construction with GHG emissions of 46.48 kt CO_2 eq. in 2023 and decreased 24.94% compared to the previous year because of significant substitution from natural gas to solid biofuels.

Compared with other branches of industry, the manufacture of food products has been one of the most stable ones. While before the economic crisis the production growth was 3–4% a year, in 2007 production slowed down and during the following three years the volume of output at constant prices decreased a bit. The economic crisis influenced the manufacture of food products somewhat less than other branches because food products are basic commodities directed mainly to the domestic market. The sector still remains cyclical and is influenced by evolving import and export dynamics of food and beverage products..

Figure 3.15 describes GHG emissions trend in 1.A.2.e Food processing, beverages, and tobacco in 1990–2023.

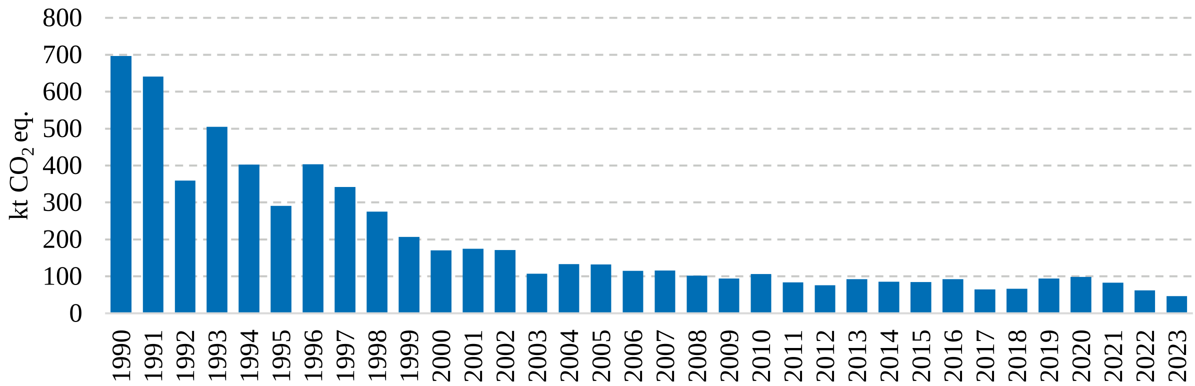


Figure 3.15. Trend of GHG emissions from Food processing, beverages, and tobacco in 1990–2023, kt CO_2 eq.

1.A.2.f Non-metallic minerals

The 1.A.2.f Non-metallic minerals CRT category has the e second largest share in Manufacturing industries and construction with 27.17% and 61.96 kt CO_2 eq. in 2023. The main share of GHG emissions in this sub-category was historically cement production. Therefore, the trend of GHG emissions follows the trend of fuels used in cement production. In 2015, the emissions decreased about 50.47% compared to 2014 due to an unfavorable cement market. In

2020 emissions decreased about 76.29% compared to the previous year as a decrease of waste and solid fuel consumption due to an unprofitable production, since EU ETS allowance prices increased. Clinker production in Kunda Nordic Cement was ceased in 2020 as it wasn´t economically feasible anymore, as the EU ETS price was increasing. In 2023 the emissions increased 52.13% due to reduction in solid biomass waste use and increased usage of natural gas, coal, peat, diesel oil and waste oils.

The trend of GHG emissions in 1.A.2.f Non-metallic minerals in 1990–2023 is presented in Figure 3.16.

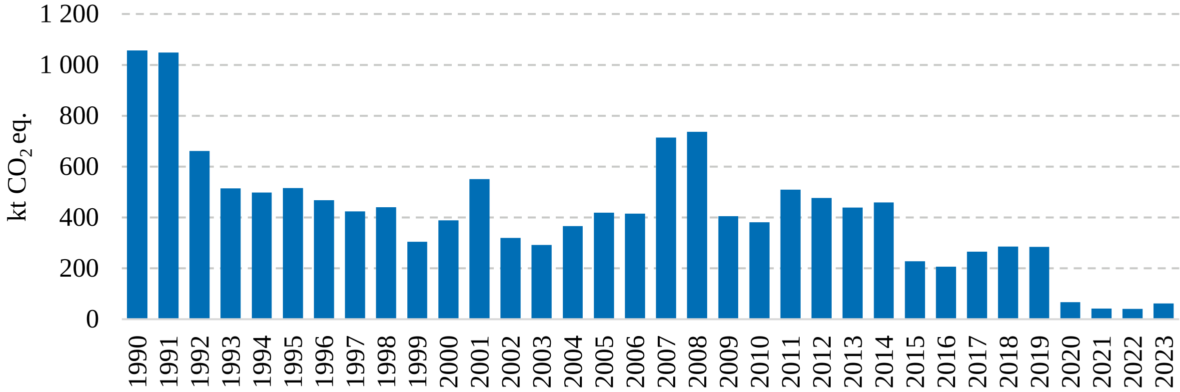


Figure 3.16. Trend of GHG emissions from Non-metallic minerals in 1990–2023, kt CO_2 eq.

1.A.2.g Other

The 1.A.2.g Other sub-category has the biggest share in Manufacturing industries and construction sector with close to 37.78% share in 2023, 86.17 kt CO_2 eq.

In Estonia the Manufacturing industries and construction sector's sub-category 1.A.2.g Other includes following sub-sectors: 'Transport equipment'; 'Machinery'; 'Mining and quarrying'; 'Wood and wood products; 'Textiles leather, and clothing industry', 'Construction', and 'Other industry'. Emissions from other miscellaneous mobile equipment (Excavators, loaders, road work machines, etc) are reported in Chapter 1.A.3.e Other transportation.

In general, the GHG emission trend matches the trend of fuel consumption. The fluctuations are determined by the export possibilities of the factories. The decrease in emissions in 2009 and 2010 relates to the economic depression which started in 2008. Despite the recovery of the economy in some branches of manufacturing industries, the total volume of output in the manufacturing industry decreased in 2010. There was still a recession in the construction market, which caused a low demand for building materials in the domestic and international markets. This was the main reason for the decline in emissions. In 2011 GHG emissions increased about 18.86% compared to 2010 because of overall economic upturn. Emission downtrend from 2016 in Wood and wood products industry sub-sector is due to introduction of new economical technologies in wood processing and switching to a different fuel (mainly using wood residues instead of fossil fuels). In 2023 emissions decreased 20.34% compared to 2022 due to switching from fossil fuels (natural gas, residual fuel oil and diesel oil) to solid biofuels.

Figure 3.17 presents the trend of GHG emissions of 1.A.2.g Other in 1990–2023.

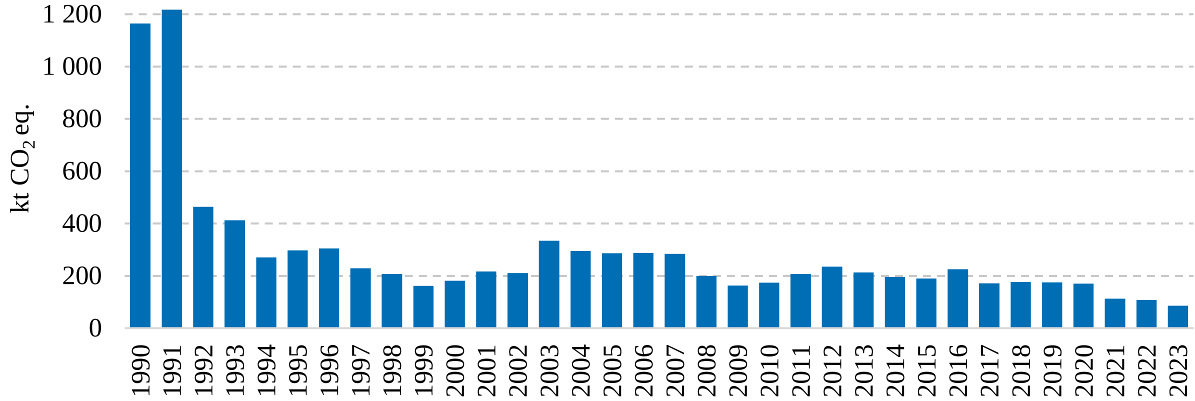


Figure 3.17. Trend of GHG emissions from Other in 1990–2023, kt CO_2 eq.

3.2.5.2. Methodological issues

Choice of methods

Emissions from Fuel combustion 1.A.2 are in general calculated by using the methodology of the IPCC 2006 Guidelines. Different tiers have been applied for different fuels and greenhouse gases.

For imported fuels, which belong to key categories, mainly *Tier 2* approach is applied. For domestic fuels – oil shale and peat – *Tier 1* approach is used for milled and sod peat CO_2 and oil shale CH_4 and N_2O.

1.A.2.a Iron and steel

Tier 2 method is used for CO_2, CH_4 and N_2O emission calculations for natural gas; for CH_4 and N_2O emission calculations for solid biofuels; and for CO_2 emission calculations for coal and coke oven coke *Tier 1* method is used for CH_4 and N_2O emission calculations for coal and coke oven coke and for CO_2 emission calculations for solid biofuels.

1.A.2.b Non-ferrous metals

Tier 2 method is used for CO_2, CH_4 and N_2O emission calculations for natural gas and gas oil (LFO) and for CO_2 emission calculations for coal. *Tier 1* method is used for CH_4 and N_2O emission calculations for coal.

1.A.2.c Chemicals

Tier 2 method is used for CO_2, CH_4 and N_2O emission calculations for natural gas, gas oil (LFO) and residual fuel oil; for CH_4 and N_2O emission calculations for solid biofuels; and for CO_2 emission calculations for LPG.

Tier 1 method is used for CH_4 and N_2O emission calculations for coal and LPG and for CO_2 emission calculations for solid biofuels.

1.A.2.d Pulp, paper and print

Tier 2 method is used for CO_2, CH_4 and N_2O emission calculations for natural gas, gas oil (LFO), residual fuel oil and peat briquette; for CH_4 and N_2O emission calculations for solid biofuels, milled peat, and biogases; and for CO_2 emission calculations for LPG and gasoline.

Tier 1 method is used for CH_4 and N_2O emission calculations for LPG and gasoline and for CO_2 emission calculations for solid biofuels, biogases, and milled peat.

1.A.2.e Food processing, beverages and tabacco

Tier 2 method is used for CO_2, CH_4 and N_2O emission calculations for natural gas, residual fuel oil and peat briquette; for CH_4 and N_2O emission calculations for solid biofuels and milled peat; and for CO_2 emission calculations for LPG, coal, diesel oil and gasoline.

Tier 1 method is used for CH_4 and N_2O emission calculations for LPG, diesel oil, coal and gasoline; and for CO_2 emission calculations for solid biofuels and milled peat.

1.A.2.f Non-metallic minerals

Tier 2 method is used for CO_2, CH_4 and N_2O emission calculations for natural gas, residual fuel oil, solid biomass waste and peat briquette; for CH_4 and N_2O emission calculations for solid biofuels and milled peat; and for CO_2 emission calculations for LPG, coal, coke oven coke, diesel oil, waste oils, plastics solid waste, oil shale and gasoline.

Tier 1 method is used for CH_4 and N_2O emission calculations for LPG, diesel oil, coal, coke oven coke, oil shale, plastics, waste oils, solid waste, and gasoline; and for CO_2 emission calculations for solid biofuels and milled peat.

1.A.2.g Other

Tier 2 method is used for CO_2, CH_4 and N_2O emission calculations for natural gas, residual fuel oil, gas oil (LFO), and peat briquette; for CH_4 and N_2O emission calculations for solid biofuels and milled peat; and for CO_2 emission calculations for LPG, coal, coke oven coke, diesel oil, plastics solid waste, and gasoline.

Tier 1 method is used for CH_4 and N_2O emission calculations for LPG, coal, coke oven coal, solid waste, and gasoline; and for CO_2 emission calculations for solid biofuels and milled peat.

Activity data

Activity data for GHG emission calculations are collected from several sources. The final fuel consumption data by sectors, including sub-sectors, is recieved from Joint Questionnaire (JQ) dataset made by Statistics Estonia. This data is also presented in the SE database[29] and added to Annex V (A.V.2.4).

Other fossil fuels, plastics, and waste oils incinerated in 1.A.2.f Non-metallic minerals is taken from Estonian waste database (Tableau).

Fuel consumption in Manufacturing industries and construction (CRT 1.A.2) in 1990–2023 is presented in Figure 3.18 and in Table 3.10. Sharp reduction of biomass use from 2016 is due to the fact that several CHP plants using wood were completed in the wood industry (1.A.2.g sector) and this means that any wood burned in these CHP plants were no longer reported under 1.A.2.g, but in the transformation sector (1.A.1.a) instead.

[29]Eesti Statistikaameti andmebaas. [www] https://andmed.stat.ee/et (04.01.2025)

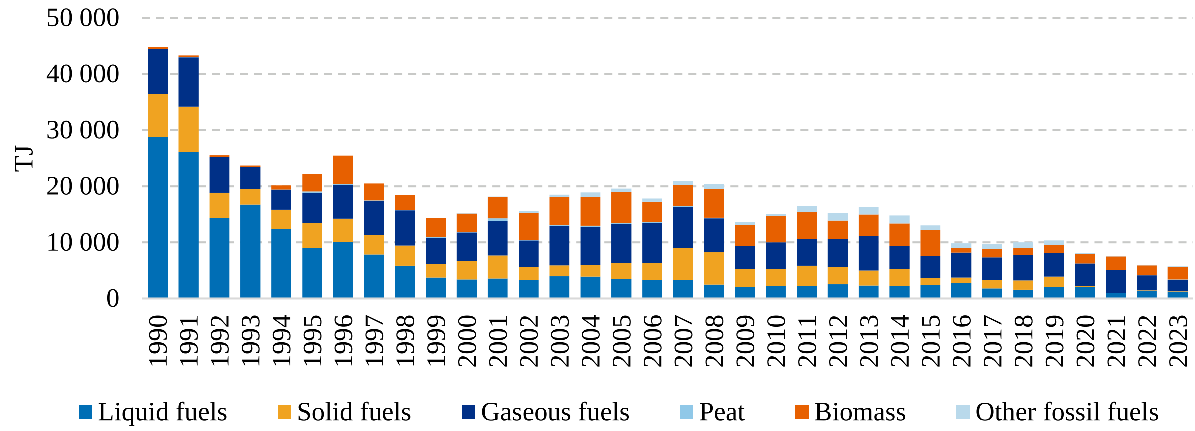


Figure 3.18. Trend of fuel consumption in Manufacturing and construction, TJ

Table 3.10. Fuel consumption in Manufacturing industries and construction in 1990, 2005, and 2020–2023, TJ

Category/activity data	1990	2005	2020	2021	2022	2023
1.A.2 Manufacturing and construction Total, TJ.	**44 759**	**19 575**	**8 106**	**7 540**	**5 985**	**5 832**
Liquid fuels, TJ	28 817	3 495	2 000	962	1 372	1 321
Solid fuels, TJ	7 585	2 884	260	7	67	105
Gaseous fuels, TJ	8 004	6 934	3 965	4 134	2 679	1 967
Peat, TJ	90	148	NO	NO	40	96
Biomass, TJ	264	5 509	1 648	2 371	1 755	2 254
Other fossil fuels, TJ	NO	606	233	66	73	90

Emission factors

Carbon emission factors, oxidation factors, and net calorific values used in the emission calculations in 1.A.2 are presented below in Table 3.11.

Table 3.11. Carbon emission factors, oxidation factors, and net calorific values in 2023

Fuels	NCV average	Unit	CEF, tC/TJ	Oxi-dation factor	Source of emission factor
Liquid fuels					
LPG	45.5	GJ/t	17.22	1	CS (Estonia)
Motor gasoline	44	GJ/t	19.20	1	CS (Estonia)
Light fuel oil	42.3	GJ/t	19.91	1	CS (Estonia)
Diesel oil	42.3	GJ/t	19.91	1	CS (Estonia)
Residual fuel oil (heavy fuel oil)	39.25	GJ/t	21.09	1	CS (Estonia)
Solid fuels					
Coal	24.94	GJ/t	25.81	1	CS (Estonia)
Coke oven coke	28.5	GJ/t	29.02	1	CS (Estonia)
Oil shale	8.42	GJ/t	28.9	1	PS (Estonia)
Milled&sod peat[30]	10.33	GJ/t	28.9	1	D, IPCC 2006
Peat briquette	16	GJ/t	26.45	1	FI (Finland)
Gas gasoline	44	GJ/t	19.20	1	CS (Estonia)
Waste oils (CRT 1.A.2.f)*	25.67	GJ/t	20.18	1	PS, Kunda Nordic Cement
Other fossil based solid waste (MSW) (CRT 1.A.2.f)	17.79	GJ/t	21.82	1	PS, Kunda Nordic Cement
Plastic waste (CRT 1.A.2.f)	21.12	GJ/t	20.45	1	PS, Kunda Nordic Cement
Natural gas	35.43	GJ/1000 m^3	14.73	1	CS (Estonia)
Biomass fuels					
Solid biomass (solid, includes e.g. firewood, wood chips, sawdust pellets, briquettes, etc.)	6.9 – 16.9	GJ/t	30.5	1	D, IPCC 2006
Solid biomass waste (CRT 1.A.2.f)	16.69	GJ/t	21.82	1	PS, Kunda Nordic Cement
Biogas (landfill gas and biogas from wastewater treatment)	17.4	GJ/1000 m^3	14.89	1	D, IPCC 2006

D – IPCC default value; CS – country-specific; PS – plant-specific; *biogenic and non-biogenic origin

CH_4 and N_2O emission factors for 1.A.2 Manufacturing industries and construction for different fuels are presented in Table 3.12. In 2021 Estonia developed country-specific CH_4 and N_2O emission factors for 1-50 MW combustion plants for natural gas, biogas, light fuel oil, residual fuel oil, peat, biomass, and municipal solid waste.[24] The emission factors are used in the Energy Industry sector 1.A.1.a, Manufacturing industries and construction subsectors, 1.A.4.a, and 1.A.4.c. CH_4 and N_2O emission factors for less than 1 MW and larger than 50 MW combustion plants are IPCC 2006 default values.

Table 3.12. CH_4 and N_2O emission factors by fuel, kg/TJ

Fuels	CH_4	N_2O	Source
LPG (liquefied petrol gas)	1	0.1	D, IPCC 2006
Motor gasoline	3	0.6	D, IPCC 2006
Light fuel oil	3/0.003*	0.6/0.17*	D, IPCC 2006/CS
Diesel oil	3	0.6	D, IPCC 2006
Residual fuel oil (heavy fuel oil)	3/0.003*	0.6/0.17*	D, IPCC 2006/CS
Waste oil	30	0.6	D, IPCC 2006

[30]A processed form of peat that is compressed into mall (40–70 mm) pieces.

Fuels	CH_4	N_2O	Source
Coal	10	1.5	D, IPCC 2006
Coke oven coke	10	1.5	D, IPCC 2006
Oil shale	10	1.4	CS/ D, IPCC 2006
Milled&sod peat	2/1.7*	1.5/2.5*	D, IPCC 2006/CS
Peat briquette	2/1.7*	1.5/2.5*	D, IPCC 2006/CS
Waste oils	30	4	D, IPCC 2006
Other fossil based waste (MSW)	30	4	D, IPCC 2006
Plastic waste	30	4	D, IPCC 2006
Natural gas	1/0.003*	0.1/0.12*	D, IPCC 2006/ CS
Solid biomass (solid, includes e.g. firewood, bark, chips, sawdust, and other industrial wood residues, pellets, and briquettes)	30/0.29*	4/0.21*	D, IPCC 2006/CS
Biogas (landfill gas and biogas from wastewater treatment)	1.75	0.11	CS

D – IPCC default value; CS – country-specific; * – country-specific

In 1.A.2.g Other emissions from off-road vehicles such as excavators, loaders, and road work machines are reported under 1.A.3.e Other transportation, starting from 2024 submission and this change is made for the whole timeseries. Activity data of off-road vehicles and emission factors used for estimating GHG emissions can be found in Chapter 3.2.6.2. In Table 3.31, Table 3.32 and Table 3.33 the respective carbon, CH_4 and N_2O emission factors of motor fuels used for off-road vehicles are presented.

The NO_x, CO, and NMVOC emissions are calculated by Estonian Environmental Agency. Emission factors come from different sources. If possible, a country-specific and plant-specific emission factor is used, if not, the emission factors from EMEP/EEA Guidebook 2023 are used.[25] The oil shale direct combustion data is plant-specific. The NO_x, CO, and NMVOC emissions are calculated by using Equation 3.3.

Equation 3.3

$$EF_{pollutant} = AR_{activity} \times EF_{pollutant}$$

Where:

$E_{pollutant}$ = the emission of the specific pollutant;
$AR_{activity}$ = the activity rate;
$EF_{pollutant}$ = the emission factor for this pollutant.

3.2.5.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Energy industries subcategory, please see Annex A.II.1 Energy, 1.A.2 Manufacturing industries and construction chapter.

3.2.5.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.5. A complete Quality Assurance (QA) and Quality Control (QC) was carried out for Manufacturing industries and construction sectors according to the IPCC *Tier 1* method.

There are several QC procedures. The most resource-demanding is checking the fuel consumption data in Joint Questionnaires received from Statistics Estonia:

Fuel consumption data in natural units (tons or thousand cubic meters) and energy units (TJ) is available in Joint Questionnaires from Statistics Estonia (www.stat.ee). Year average net calorific values are received from Statistics Estonia. Before entering the fuel consumption data into emission calculation tables, the expert first checks the current year data by multiplying fuel amounts in natural units with NCV and compare the results with fuel consumption data in TJ presented in the statistical database. Sometimes there are some small differences due to the rounding the values. The second step is to check all activity data on previous years because Statistics Estonia sometimes corrects old data. The third step is to verify national energy balance data with IEA data. IEA uses constant NCV-s but national energy data uses TJ that are calculated using year-specific NCV-s. Some differences also occur in produced heat. IEA reports only fuels used for sold heat produced by district heating power plants and auto-producers in the Energy conversion sector, but fuels used for heat production by auto-producers (used for their own consumption) are reported under the final consumption.

Next the fuel emission factors can be checked. If there is some new research on the estimation of country-specific emission factors available, all necessary corrections will be made for the whole time-series.

There is a more comprehensive list of *Tier 1* and *Tier 2* QC activities in the Energy sector in the internal documentation (in Estonian).

3.2.5.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

There were no category-specific recalculations.

3.2.5.6. Category-specific planned improvements, if applicable including tracking of those identified in the review process

There are no category-specific improvements planned.

3.2.6. Transport (1.A.3)

3.2.6.1. Category description

In 2023 the greenhouse gas emissions from Transport sector amounted for 2647.95 kt CO_2 eq. The share of the Transport sector in the Energy sector was 30.22% and approximately 24.38% of the total greenhouse gas emissions (without LULUCF) in 2023. Emissions from Transport include all domestic transport sectors, including 1.A.3.e Other transportation, which was added starting from 2024 submission (change was made for the whole time series) (Table 3.13):

- Domestic aviation (CRT 1.A.3.a)
- Road transportation (CRT 1.A.3.b)
- Railways (CRT 1.A.3.c)
- Domestic navigation (CRT 1.A.3.d)
- Other transportation (CRT 1.A.3.e)

Table 3.13. Reporting categories in the Transport sector

CRT category	Description	Remarks
CRT 1.A.3		
1.A.3.a Domestic aviation	Jet and turboprop powered aircraft (turbine engine fleet), and piston engine aircraft.	Emissions from helicopters are not calculated separately.
1.A.3.b Road transportation	Transportation on roads by vehicles with combustion engines: passengers cars, vans, buses, lorries, motorcycles, and mopeds.	Military vehicles are included in 1.A.4.a Commercial/institutional.
1.A.3.c Railways	Railway transport operated by steam and diesel locomotives.	Coal was used in steam locomotives in 1990–1998.
1.A.3.d Domestic navigation	Merchant ships, passenger ships, technical ships, leisure, tour ships, and other inland vessels.	-
1.A.3.e Other transportation	Tractors, excavators, loaders, road work machines, ATV-s, forklifts, cranes, harvesters, forestry machines.	Includes emissions from off-road vehicles from 1.A.2.g Other, 1.A.4.a Commercial/institutional, and 1.A.4.c Agriculture/forestry/fisheries – starting from 2024 submission. Before 2024 submission emissions from off-road vehicles were reported under the respective subcategories 1.A.2.g, 1.A.4.a and 1.A.4.c.

Emission trends from Transport sector by subcategories are given in Figure 3.19.

GHG emissions decreased strongly after 1991 because of the fast growing fuel prices after regaining independence in 1991 and also difficulties in fuel supply. At the beginning of the 1990s Estonia imported all transport fuels from Russia. The low hit in 1992 and after that the increase has been fairly constant reaching the 1990 emission levels in 2007. The increase has taken place mainly in road transport. In 2010 emissions from transportation sector grew comparing to the previous year. The reason for this advance was the expansion of the economic environment after the economic depression in 2008 and 2009.

In 2009 the emissions dropped about 7.3% compared to 2008 as a consequence of economic recession that caused a sharp decline in a number of transported goods a lower number of public transport users. In 2020 emissions decreased in all Transport subsectors because of the internal movementrestrictions due to COVID-19 pandemic and decreased fuel consumption in Road transport sector. In 2021 the GHG emissions from Transport sector increased 3.1% compared to the previous year due to increased diesel use in Road transport and aviation gasoline in Domestic aviation, and lifting the moving restrictions. Normalization to the pre-pandemic trends continued in 2022, which resulted in an increase of GHG emissions by 4.3%, mainly due to increased use of diesel and gasoline in Road transport and diesel in Other transportation (formerly reported under 1.A.2.g, 1.A.4.a and 1.A.4.c). Transport sector emissions in 2023, remained on the same level as in 2022, and were just 0.15% higher compared to previous year.

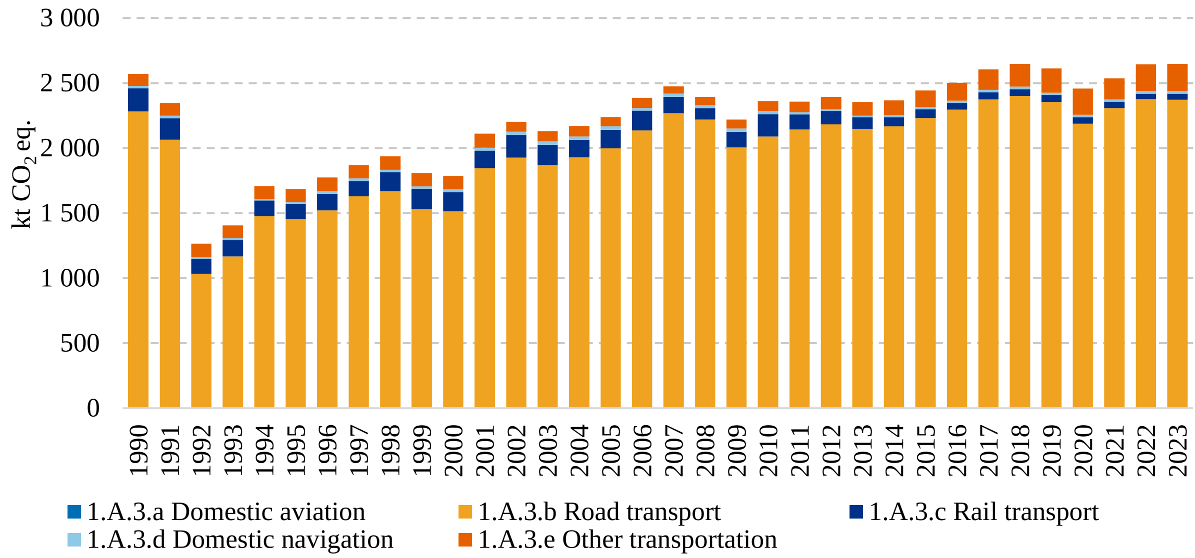


Figure 3.19. Emissions from Transport sector by subcategory in 1990–2023, kt CO_2 eq.

Road transportation is an essential emission source in the Transport sector covering 89.32% of the sector's emissions (see Figure 3.19). The fuel consumption and the emissions from the Transport sector are presented in Table 3.14 and Table 3.15. Significant drop in other fossil fuel consumption in 2022 was due to extensive replacement of FAME biodiesel (which contains fossil part that is counted under other fossil fuels) with HVO renewable diesel by fuel retailers. No FAME consumption was reported for 2023.

Table 3.14. Emissions from the Transport sector by subcategories in 1990, 2005, and 2020–2023, kt CO_2 eq.

Category	1990	2005	2020	2021	2022	2023
1.A.3 Transport Total, CO_2 eq.	**2 571.10**	**2 239.35**	**2 458.32**	**2 535.39**	**2 643.98**	**2 647.95**
1.A.3.aii Domestic aviation	5.56	4.71	3.59	5.62	4.86	5.55
1.A.3.b Road transport, CO_2 eq.	2 278.43	1 993.18	2 182.89	2 303.21	2 371.76	2 365.18
1.A.3.c Rail transport, CO_2 eq.	174.41	143.60	49.07	47.54	42.75	46.90
1.A.3.d.ii Domestic navigation, CO_2 eq.	21.87	24.99	20.02	18.47	17.95	20.14
1.A.3.e Other transportation, CO_2 eq.	90.84	72.87	202.75	160.55	206.67	210.18

Table 3.15. Fuel consumption in Transport sector in 1990, 2005, and 2020–2023, TJ

Activity data	1990	2005	2020	2021	2022	2023
1.A.3.a Domestic aviation						
Aviation gasoline	78	66	50	78	68	78
1.A.3.b Road transport						
Gasoline	21 567	12 522	8 840	8 234	8 712	8 643
Diesel oil	9 473	14 709	20 170	22 281	22 991	23 125
LPG	9	62	423	437	455	348
CNG	NO	NO	618	721	426	440
Biomass*	NO	3	1 487	1 920	1 650	1 613
Other fossil fuels*	NO	3	464	439	1	NO
1.A.3.c Railways						
Coal	179	NO	NO	NO	NO	NO
Light fuel oil	1946	1777	607	587	529	581
1.A.3.d Domestic navigation						
Diesel oil	296	338	271	250	243	273
1.A.3.d Other transportation						

Activity data	1990	2005	2020	2021	2022	2023
Gasoline	26	18	67	82	88	64
Diesel oil	1 201	967	2 676	2 088	2 707	2 783

NO - no consumption occurred, * - under Other fossil fuels the fossil part of liquid biofuels (biodiesel and bioethanol) are presented and under biomass the biogenic part of liquid biofuels and biomethane (bio-CNG) is presented.

1.A.3.a Domestic aviation

The emissions from Domestic aviation (CRT 1.A.3.a) include all domestic aviation transport within Estonian flight regions, generally islands (Figure 3.20). Helicopters are not included in the calculations due to the small number of flights and the lack of emission factors, however, the fuel consumption is included as part of sector 1.A.3.a.

The share of Domestic aviation in Transport sector was only 0.21% with 5.55 kt CO_2 eq. in 2023, which was 14.25% higher compared to last year. The increase compared with the previous year was on account of a increased fuel consumption in cruise mode, which is a result of using larger and more powerful turboprop aircrafts. The corresponding emissions were 5.56 kt CO_2 equivalent in 1990.

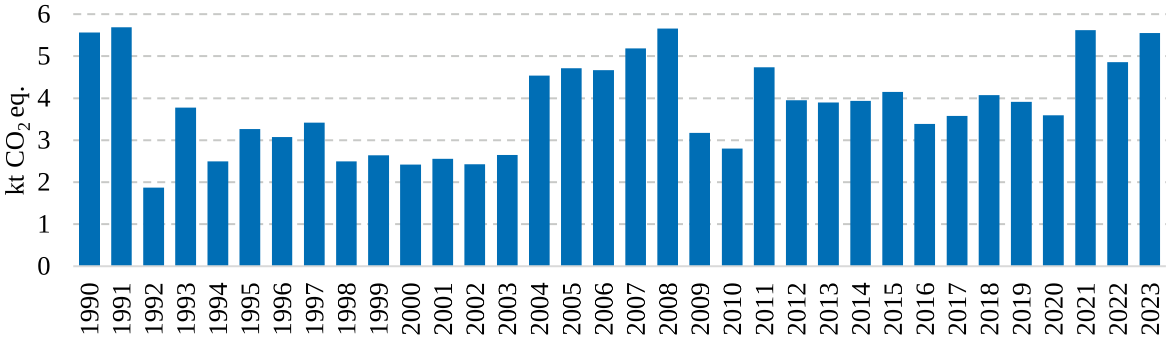


Figure 3.20. GHG emissions from Domestic aviation in 1990–2023, kt CO_2 eq.

1.A.3.b Road transportation

Road transport (CRT 1.A.3.b) includes all transportation on the roads in Estonia. The types of vehicles with combustion engines are passenger cars, vans, buses, lorries, motorcycles, and mopeds. The category does not cover farm and forest tractors driving occasionally on the roads, since they are included starting from 2024 submission in the CRT category 1.A.3.e Other transportation.

Road transport is the most important emission source in the Transport sector. The emissions from Road transportation of 2 365.18 kt CO_2 eq. in 2023 is about 89.32% of total Transport sector emissions and 26.99% of the Energy sector. In 2023 the GHG emissions of the Road transport sector were about 3.81% higher than in 1990 (2 278.43 kt CO_2 eq.).

The trend of GHG emissions follows, in general, the fuel consumption trend in the Road transport sector. The total emissions of Road transport can be seen in Figure 3.21. The lowest emissions in Road transportation were reached in 1992, caused by the rapid increase of fuel prices after regaining independence in 1991 and difficulties in fuel supply (at the beginning of the 1990s Estonia imported all transport fuels from Russia). The second decrease in the emissions was in 1999-2000 and it was connected with an economic crisis in Russia (fuel supply problems). In 2007 the emissions from Road transport were on the level of 1990, but since 2008 a slight decline of emissions (in 2008/2007 about 2.2% and in 2009/2008 9.5%) started which reflects the overall economic depression in Estonia. Since 2014 the GHG emissions have gradually increased reaching their peak in 2018.

The GHG emission decrease in 2020 was due to the extended consumption of biofuels and a fall in total mileage compared to the previous year as decreased usage of fuels due to the state of emergency established by the Government of Estonia. In 2021 the emissions in Road transport sector increased 5.5% due to increased use of diesel oil and increased mileage of heavy duty trucks. In 2022 the recovery from Covid-19 pandemic continued and the increased consumption of of diesel and gasoline in Road transport and diesel in Other transportation resulted in 3.0% GHG emission increase. There was a slight decrease of 0.28% in 2023 emissions compared to previous year, mainly due to more efficient vehicle fleet and increase in number of electric vehicles, which offset higher traffic mileage of road vehicles (Table 3.).

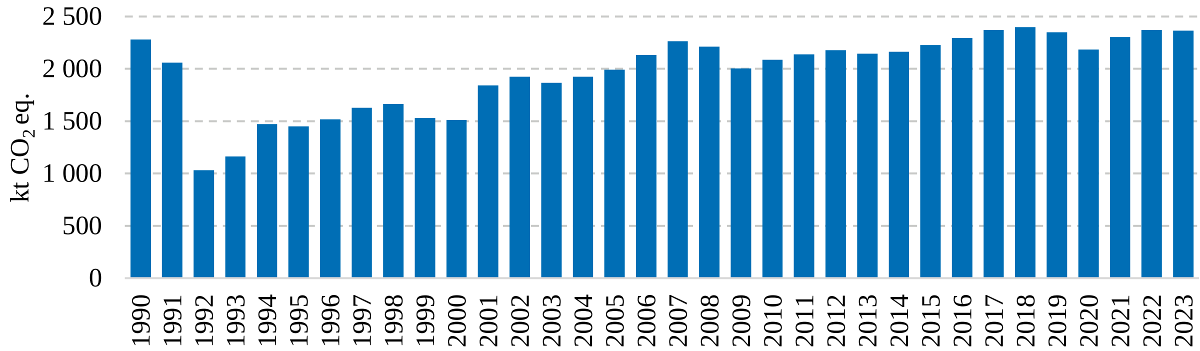


Figure 3.21. Emissions from the Road transport in 1990–2023, kt CO_2 eq.

1.A.3.c Railways

New trains started to run on Estonian railways in 2013 after several years of railway reconstructions. All non-electric locomotives use diesel oil in Estonia. From 1990 to 1998 also coal-burning locomotives were used in Estonia.

Railway transportation in Estonia has a small share of emissions in the Transport sector. The emissions were 46.90 kt CO_2 eq. in 2023 with the share of 1.77% in the Transport sector. In 1990 the corresponding figure was 174.41 kt CO_2 eq.

The passenger rail transport in Estonia is not so widely used compared to other countries. Also, the rail network density (meters per km^2) is one of the smallest in Europe.

In general, the CO_2 emissions trend matches the fuel consumption trend in the Rail transport sector (Figure 3.22). Rail transport is principally used for transporting goods. The lowest emission level in Rail transport before 2016 was reached in 2008, because of a rapid decrease in the amount of goods carried by Estonian transport enterprises. The decrease in the goods transported by rail started in 2007 and continues falling. In 2023 the emissions from Rail transport increased 9.72%, compared to 2022.

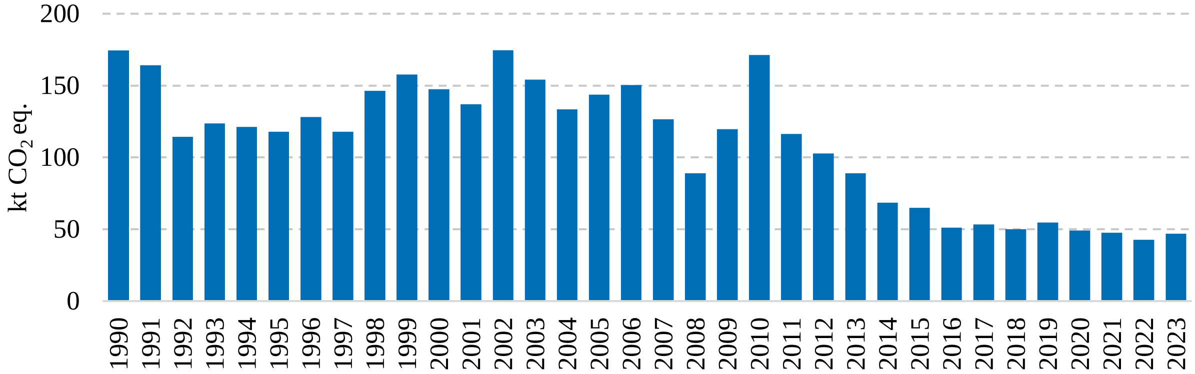


Figure 3.22. Emissions from Railways in 1990–2023, kt CO_2 eq.

1.A.3.d Domestic navigation

Estonian Transport Administration manages Ship Register that listed 208 seagoing ships (gross weight 100 tons or more) and 30 inland ships at the end of 2023. In addition, 10 merchant ships were listed in the register of bareboat character ships.

Domestic navigation in Estonia is also a minor emission source in Transport sector. The emissions of Domestic navigation were 20.14 kt CO_2 eq. in 2023 (0.76% of Transport sector emissions). The increase of 12.17% comparing to the previous year was due to a increase in diesel oil consumption caused by increased number of passenger ferry trips to Estonian islands. In 1990 the corresponding figure was 21.87 kt CO_2 eq.

Emissions from deep sea fishing are not included in the reporting of Domestic navigation.

The trend of GHG emissions is presented in Figure 3.23.

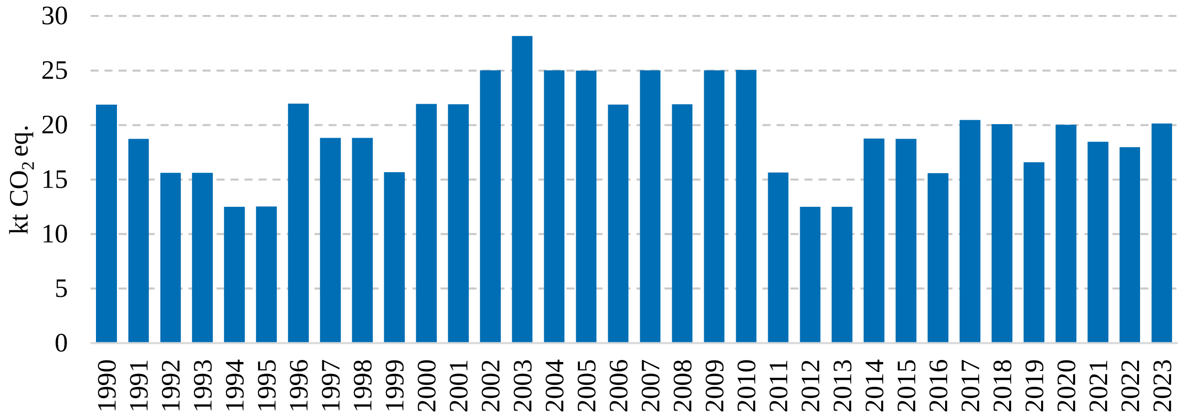


Figure 3.23. Emissions from Domestic navigation in 1990–2023, kt CO_2 eq.

1.A.3.e Other transportation

Off-road vehicles are used in industry, agriculture, forestry, and for household purposes (Table 3.16).

Table 3.16. Reporting categories of off-road vehicles sources reported under 1.A.3.e Other transportation (until 2023 submission reported under different categories)

Previous CRT category	Description
1.A.2.g Other	Excavators, loaders, road work machines
1.A.4.a Commercial/institutional	Other miscellaenous equipment (e.g. ATV-s, forklifts, cranes, etc.)
1.A.4.c Agriculture/forestry/fisheries	Tractors, harvesters, forestry machines

Emissions of off-road mobile equipment in 1990-2023 are shown in Figure 3.24. The overall GHG consumption trend follows the fuel consumption trend (Figure 3.25). The biggest share of emissions from off-road vehicles comes from 1.A.4.c since most of the fuel (mostly diesel oil) is consumed in tractors in agriculture. Gasoline is only consumed in tractors in Agriculture/forestry/fisheries sector.

The GHG decrease in from 1999 was directly caused by the economic crisis in Russia. In 2007 economic crisis in Estonia showed the downwards trend in GHG emissions. Since 2010 the GHG emissions have increased together with the growth of the economy. The trend of GHG emissions matches the trend of fuel consumption. In 2023 emissions from off-road vehicles accounted for 210.18 kt CO_2 eq., which is a 1.70% increase compared to the previous year (Table 3.17).

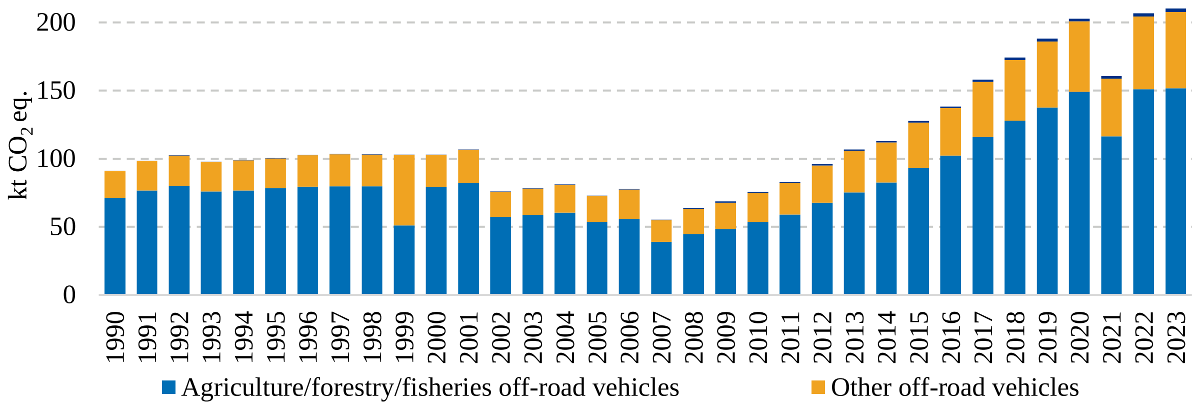


Figure 3.24 Emissions from off-road vehicles in Estonia in 1990-2023, kt CO_2 eq.

Table 3.17 Emissions from off-road vehicles by subcategories in 1990, 2005, and 2020–2023, kt CO_2 eq.

Category	1990	2005	2020	2021	2022	2023
1.A.3.e Other transportation Total, CO_2 eq.	**90.84**	**72.87**	**202.75**	**160.55**	**206.67**	**210.18**
Other off-road vehicles, CO_2 eq.	19.84	18.96	51.66	42.37	53.44	55.94
Commercial/institutional off-road vehicles, CO_2 eq.	0.12	0.34	2.02	1.89	2.30	2.56
Agriculture/forestry/fisheries off-road vehicles, CO_2 eq.	70.88	53.57	149.07	116.29	150.93	151.68

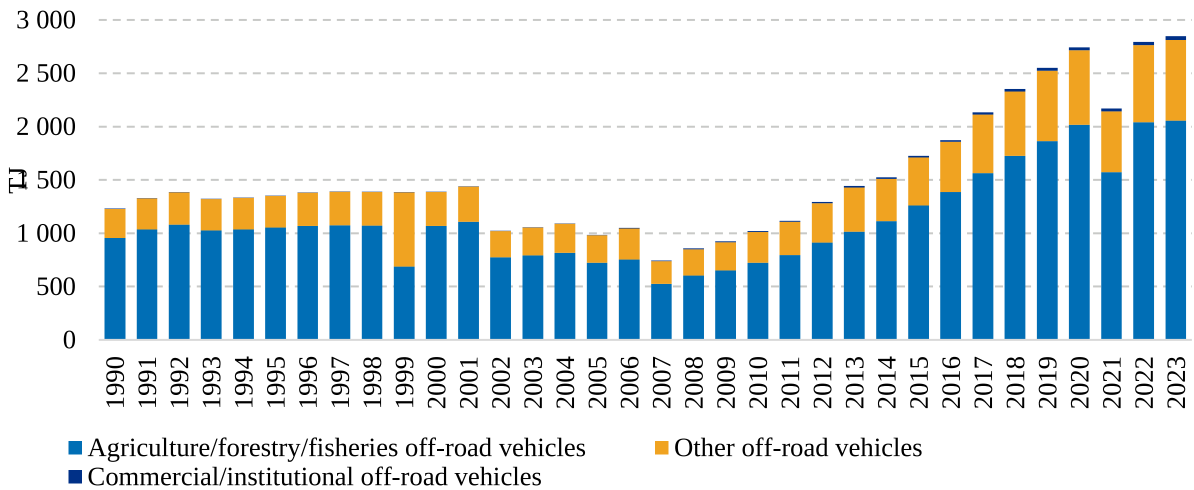


Figure 3.25 Fuel consumption of off-road vehicles in Estonia in 1990-2023

3.2.6.2. Methodological issues

Choice of methods

1.A.3.a Domestic aviation

Tier 2 approach is used to estimate emissions from Domestic aviation operations of aircraft which is divided into LTO and cruise phases. *Tier 2* separates the calculation of emissions from aviation into the following steps using Equation 3.4, Equation 3.5, and Equation 3.6:

Equation 3.4[31]

1. *Total Emissions = LTO Emissions + Cruise Emissions*

Equation 3.5[32]

2. *LTO Emissions = Number of LTOs ×Emission Factor of LTOs*

Equation 3.6[33]

3. *Cruise Emissions = (Total Fuel Consumption – LTO Fuel Consumption)× EF Cruise*

1.A.3.b Road transportation

CO_2 emissions from Road transport are estimated using the IPCC 2006 *Tier 2* methodology.

In the current inventory report the emissions of CO_2 is calculated on basis of combusted fuels and their carbon content. *Tier 2* calculates CO_2 emissions by multiplying the estimated fuel sold times a country-specific emission factor. This approach is expressed in Equation 3.7:

Equation 3.7[34]

$$Emission = \sum_a [Fuel_a \times EF_a]$$

Where:

Emission =	emissions of CO_2, kt;
$Fuel_a$ =	fuel sold, TJ;
EF_a =	emission factor; this is equal to the carbon content of the fuel multiplied by 44/12, kg/TJ;
A =	type of fuel (e.g. petrol, diesel, LPG, etc).

CH_4 and N_2O emissions are calculated separately using the COPERT 5 model in accordance with the IPCC 2006 *Tier 3* methodology for fossil diesel, gasoline, LPG, and liquid biofuels, which is based on EMEP/EEA air pollutant emission inventory guidebook 2023 sector 1.A.3.b Road transport[35]. The calculations in the COPERT 5 model are done in the Estonian Environment Agency The mileage (km/y) of each vehicle type and model on different road types and in different speed classes are multiplied with corresponding CH_4 and N_2O emission factors. CO_2, CH_4, and N_2O emissions from CNG in Road transport are calculated using the IPCC *Tier 2* method and country-specific emission factors.

From 2023 submission Estonia also reports the fossil part of biofuels consumption and CH_4 and N_2O emissions in CRT tables under Other fossil fuels in 1.A.3.b.

COPERT 5 is a software tool used worldwide to calculate air pollutants and GHG emissions from road transport. The development is coordinated by the European Environment Agency, in the framework of the European Topic Centre for Air Pollutant and Climate Change Mitigation.

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[31] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.2.
[32] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.3.
[33] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.5.
[34] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.12, equation 3.2.1.
[35] EMEP/EEA air pollutant emission inventory guidebook – 2019 1.A.3.b.i-iv Exhaust emissions from road transport. [www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view (29.01.2025).

Necessary input for the model to calculate emissions is number of vehicles, annual mileage per vehicle, annual statistical fuel consumption, speed (urban, rural, highway), driving share (urban, rural, highway), monthly minimum and maximum average temperatures, monthly reid vapour pressure (RVP), etc. COPERT 5 contains 240 individual vehicle types. The vehicle classes are defined by the vehicle category (passenger car, light-duty vehicle, etc.), fuel type, weight class, environmental class, and in some instances the engine type and/or the emission control technology (e.g. 'Euro' standards). Estonia divides its vehicle stock into 159 vehicle types.

Road vehicles are classified according to their level of emission control technology that is defined in emission legislation. Therefore, the emission factors are differentiated per vehicle category and Euro standard. N_2O emission factors depend on vehicle category and on fuel sulphur content[32] .

The emission equation of *Tier 3* for CH_4 and N_2O is described in the Equation 3.8:

Equation 3.8[36]

$$Emission = \sum_{a,b,c,d} \left[Distance_{a,b,c,d} \times EF_{a,b,c,d}\right] + \sum_{a,b,c,d} C_{a,b,c,d}$$

Where:

Emission =	emission of CH_4 or N_2O, kt CO_2 eq.;
EF $_{a.b.c.d}$ =	emission factor, kg/km;
Distance $_{a.b.c.d}$ =	distance traveled (VKT) during thermally stabilized engine operation phase for a given mobile source activity, km;
C $_{a.b.c.d}$ =	emissions during warm-up phase (cold start);
a =	fuel type (e.g. diesel, g asoline, etc);
b =	vehicle type;
c =	emission control technology (such as uncontrolled, catalytic converter, etc);
d =	operating conditions (e.g. urban or rural road type, climate, or other environmental factors).

The NO_x, CO, and NMVOC emissions are calculated by Estonian Environmental Agency using COPERT 5 model and EMEP/EEA air pollutant emission inventory guidebook 2023 sector 1.A.3.b Road transport methodology. The NO_x, CO, and NMVOC emissions are calculated by using Equation 3.9.

Equation 3.9

$$EF_{pollutant} = AR_{activity} \times EF_{pollutant}$$

Where:

$E_{pollutant}$ =	the emission of the specific pollutant;
$AR_{activity}$ =	the activity rate;
$EF_{pollutant}$ =	the emission factor for this pollutant.

[36] IPCC 2006 Guidelines, Volume 2, Chaper 3; Mobile Combustion, page 3.15, equation 3.2.5.

1.A.3.c Railways

CO_2 emissions from Railways are calculated by multiplying the estimated fuel consumption with a country-specific emission factor using IPCC 2006 *Tier 2* method.CH_4 and N_2O emissions are calculated using emission factors from 2006 IPCC Guidelines and *Tier 1* method.

1.A.3.d Domestic navigation

CO_2 emissions from Domestic navigation are calculated by multiplying the estimated fuel consumption with a country-specific emission factor for light fuel oil using IPCC 2006 *Tier 2* method. CH_4 and N_2O emissions are calculated using emission factors from 2006 IPCC Guidelines and *Tier 1* method.

1.A.3.e Other transportation

Emissions from Off-road vehicles are estimated using IPCC 2006 *Tier 2* methodology for CO_2 emissions and the EMEP/EEA air pollutant inventory guidebook 2023 1.A.4 Non road mobile machinery *Tier 3* methodology[37] for CH_4 and N_2O emissions, and fuel consumption. The emissions of CO_2 is calculated on the basis of combusted fuels and their carbon content. *Tier 2* calculates CO_2 emissions by multiplying the estimated fuel consumed times a country-specific emission factor.

CH_4 and N_2O emissions are calculated separately for gasoline and diesel vehicles. Workload of each vehicle type and model on different road types and in different speed classes are multiplied with corresponding CH_4 and N_2O emission factors. Off-road mobile vehicles are classified according to their level of emission control technology that is defined in emission legislation. Therefore, the emission factors are differentiated per vehicle category and Euro standard.

Activity data

1.A.3.a Domestic aviation

The activity data on aviation gasoline used in civil aviation is provided by Statistics Estonia and Tallinn Airport. Aviation fuel is not presented separately in the national energy balance for national and international flights. This data is collected from different fuel supply companies by special statistical questionnaire 'Transport Fuels' where fuel use has to be reported separately for national and international use.

Estonia separates the fuel consumption further into the landing and take-off (LTO) phase and the cruise phase using the following principle: in LTO phase fuel consumption is based on representative aircraft type. The energy use by aircraft is calculated for both domestic and international LTOs by multiplying the LTO fuel consumption factor for each representative aircraft type with the corresponding number of LTOs (Equation 3.10). The cruise energy use is estimated as the difference between the total fuel use from aviation fuel sale statistics and the total calculated LTO fuel use (Equation 3.11).

Equation 3.10[38]

$$LTO_{\text{Fuel Consumption}} = \text{Number of LTOs}_{\text{by aicraft type}} \times \text{Fuel Consumption per LTO}_{\text{by aicraft type}},$$

[37] EMEP/EEA air pollutant emission inventory guidebook – 2019 1.A.4. Non road mobile machinery. [www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-4-non-road-1/view (29.02.2024).

[38] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.4.

Equation 3.11[39]

$$Cruise_{\ Fuel\ Consumption} = Total_{\ Fuel\ Consumption} - LTO_{\ Fuel\ Consumption\ Cruise},$$

Detailed aircraft data with take-off and landing activity is provided by airports. Estonian aircraft movement statistics consider landing and take-offs as two different activities. However, the methodology defines both one landing and one take-off as a full LTO cycle. Therefore statistical aircraft movement data is divided by two.

The methodology requires information on the number of LTOs grouped by representative aircraft types. This kind of detailed knowledge is hard to obtain (individual aircraft with their specific engines) and, therefore, data is aggregated for practical reasons. Assumptions are made if there is missing data in some situations.

Despite of the different levels of aviation statistics it is possible to divide the air traffic activity into the number of LTOs per aircraft type by using different statistical sources. Estonian emission calculations are based on the EMEP/EEA 2023 methodology and other referred sources in guidebook (IPCC, FOCA, ICAO engine database etc.).

A complete calculations have been carried out by Estonian Environment Agency for the years 1992–2023 (Table 3.18). An extrapolation has been made for 1990 and 1991.

Table 3.18. Number of LTO cycles

Year	Domestic LTO	International LTO
1992	2 249	5 247
2005	7 740	17 907
2019	8 014	21 391
2020	7 095	8 678
2021	7 676	10 265
2022	7 683	16 336
2023	6 962	16 453

1.A.3.b Road transportation

The activity data for calculating the CO_2 emissions is based on the amount of fuel consumed in road traffic. The data is received from Statistics Estonia. The consumption of fuel on the country level is based on fuel sales.

For obtaining more detailed activity data (distance travelled, emission control technology, vehicle type, operating conditions, etc.) for CH_4 and N_2O emission calculations the Estonian Environment Agency has concluded a contract with the Estonian Transport Administration.

In Estonia a small amount of liquid biofuels are used since 2005. The liquid biofuels inland consumption data and information regarding the types of bioethanol and biodiesel is collected from the Estonian Environment Agency. The Estonian Environment Agency is making its calculations based on assumption that biodiesel is marked as B7 (7% of biodiesel) and bioethanol as E5 (5% of bioethanol). Bioethanol is only allowed mixed with petrol and biodiesel both mixed and pure form.

According to the Estonian Liquid Fuel Act[40] from the 1st of April 2020 the total energy content of the petrol, diesel, and biofuel released for consumption, as well as of the electricity supplied

[39] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.5.
[40] Riigi Teataja. Liquid fuel act. [www] https://www.riigiteataja.ee/en/eli/516122024007/consolide (12.03.2025)

for use in road transport, by any seller of fuel or for the import of fuel must include a total energy content of biofuels, biomethane or electricity supplied for final consumption, at the value, as a weighted average for the calendar year, of 10 percent by the end of that year. Since 1st of January 2022 the total energy content is 7.5% since a revision of Liquid Fuel Act was adopted.

The biofuel consumption is reported in Table 3.19.

Table 3.19. Consumption of bioethanol, biodiesel, and biomethane in Estonia in 2005–2023, TJ

Year	Bioethanol	Biodiesel	Biomethane
2005	NO	6.50	NO
2019	308.87	838.00	210.90
2020	259.08	1370.73	320.73
2021	176.16	1735.23	446.34
2022	84.99	1088.30	478.31
2023	95.0	841.39	676.70

NO – no consumption occurred

The activity data for CNG and biomethane (bio-CNG) is taken from Joint Questionnaire provided by Statistics Estonia.

LPG vehicles run on bi-fuel system that uses diesel or gasoline as a second fuel. Therefore, vehicles that are using LPG are not extracted from the total number of vehicles used in the COPERT 5 model to ensure the accounting of the emissions from the second fuel.

In Table 3.20 the number of vehicles and in Table 3.21 road traffic mileage are presented following COPERT 5 model.

Table 3.20. Number of vehicles in Estonia, thousand vehicles

Number of vehicles	Passenger cars	Light Commercial Vehicles	Heavy Duty Trucks and Buses	Motorcycles and Mopeds	Total Vehicles
1990	241	31	45	2	**319**
2005	355	34	26	9	**423**
2019	628	74	32	42	**775**
2020	625	76	31	44	**777**
2021	635	80	31	45	**791**
2022	642	84	31	52	**809**
2023	661	86	31	48	**826**

Table 3.21. Road traffic mileage in Estonia, million km/y

Road traffic mileage	Passenger cars	Light Commercial Vehicles	Heavy Duty Trucks and Buses	Motorcycles and Mopeds	Total Mileage
1990	5729	696	1601	7	8032
2005	5822	954	892	29	7697
2019	8495	1252	796	65	10 608
2020	8122	1252	719	53	10 146
2021	8086	1395	906	82	10 469
2022	7988	1479	1050	83	10 601
2023	8531	1448	963	77	11 019

Until 2021 submission the Statistics Estonia's number of motorcycles was used, which included motorcycles that had been demolished, but were not taken out from the national registry by the owners. Since the 2022 submission data from COPERT 5 model is used (as in the model demolished motorcycles have been deducted and the data is more precise). An analysis of high statistical number of motorcycles in use during the period 1990-1994 was carried out, and as a result the number of vehicles was corrected to ensure that the data no longer reflects vehicles which have not been in use and technically inspected. The number of mopeds was adjusted for 1995-2012 based on the corrections for 1990-1994 period. Also, the timeseries for the number of motorcycles has been updated according to COPERT 5 model.

The number of vehicles increased between 1991 and 1992 by 5.3% while the kilometers driven decreased by 53.9%. This surge in the number of vehicles and decrease in mileage is the result of Estonia regaining independence in 1991. Before, only people with special permits could buy a vehicle. Since 1992 no permits were needed anymore. Still, there was a shortage of motor fuels and the prices were rather high. Therefore, there was a significant decrease in the mileage. Since 2010 there has been an increase in the number of passenger cars, which is attributable to the increment of economic wealth in Estonia.

1.A.3.c Railways

The activity data on fuel consumption used in Railways is obtained from Joint Questionnaire dataset managed by Statistics Estonia and is presented in Table 3.15.

1.A.3.d Domestic navigation

The activity data on fuel consumption used in Domestic navigation is gained from the Statistics Estonia and presented in Table 3.15.

Statistics Estonia acquires the amounts of fuel used from relevant reports that are presented by water transport companies. Statistics Estonia is aware about the large variation in the activity data and looking into the matter to improve consistency.

1.A.3.e Other transportation

The number of off-road vehicles is obtained from different sources. The data for the years 2010-2023 is obtained from Estonian Transport Administration that provides the number of vehicles by vehicle category, brand, model, type, year of first registration, engine type, engine capacity, engine power, and mass. To construct the number of vehicles by emission technology for the whole time series of 1990-2023, the 1990-2009 timeline needed to be established. The total number of off-road vehicles was obtained from Statistics Estonia for the years 1990-2009. A linear interpolation was made between 1990 and 2009 based on the trend of distribution of emission technology for the years 2010-2023. In Figure 3.26 number of vehicles by vehicle type is presented[41].

[41] Number of vehicles are based on "Revision of calculation principles for emissions from other mobile sources". The report is available upon request.

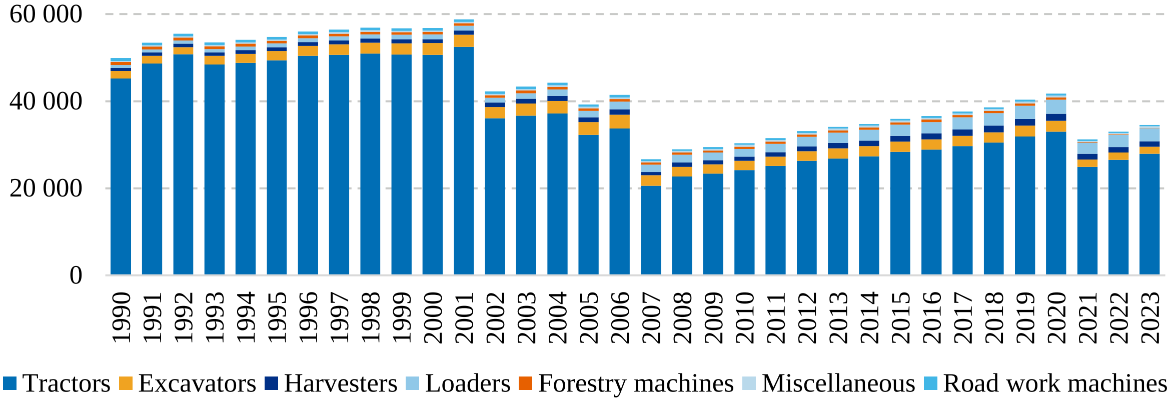

Figure 3.26. Number of off-road vehicles in 1990-2023

The NCVs for the fuels used for off-road vehicles are for diesel 42.3 GJ/kg and gasoline 44.0 GJ/kg. In Table 3.22 the consumption of fuels in off-road vehicles is presented.

Table 3.22. Consumption of fuels from off-road vehicles, TJ

Year	Diesel	Gasoline
1990	1201	26
2005	967	18
2020	2676	67
2021	2088	82
2022	2707	88
2023	2783	64

Emission factors

1.A.3.a Domestic aviation

Cruise and LTO emission factors of CO_2, CH_4, and N_2O used in the emission calculations from national aviation are taken from the IPCC 2006 Guidelines.

Cruise emission factors of NO_x, CO, NMVOC, and SO_2 used in the emission calculations from national aviation are taken from the EMEP/EEA 2023 air pollutant emission inventory guidebook (Ch. 1.A.3.a Aviation, Table 3–3, p. 21).

LTO emission factors of NO_x, CO, NMVOC, and SO_2 used in the emission calculations from national aviation are taken from the EMEP/EEA 2023 air pollutant emission inventory guidebook (Ch. 1.A.3.a Aviation, table 3–3, p. 21) and other referred sources in guidebook (IPCC, FOCA, ICAO engine database etc). The share of different aircraft types varies every year and the average emission factor changes from year to year. Average emission factors used for 2022 emission calculations are presented in Table 3.23.

Table 3.23. Emission factors used in the calculations of emissions from Civil aviation (1.A.3.a)

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
Cruise[42]	70 000 kg/TJ	0 kg/TJ	2 kg/TJ	10.3 kg/t	2.0 kg/t	0.1 kg/t	1.0 kg/t
LTO	3 160 kg/t	5 kg/TJ	2 kg/TJ	6.0 kg/t	103.3 kg/t	5.1 kg/t	0.0 kg/t

[42] EMEP/EEA air pollutant emission inventory guidebook 2023, Table 3-3, p.21 (average fleet).

Emission factors in kg/tonne of aviation gasoline are converted to kg/TJ using net average calorific value of aviation gasoline. The results for 2023 are presented in Table 3.24.

Table 3.24. Emission factors from Civil aviation (1.A.3.a)

	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
	t/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Cruise	70	0	2.0	239.5	46.5	2.3	23.3
LTO	73.5	5	2.0	128.9	2 708.1	202.1	21.0

1.A.3.b Road transportation

CO_2 emission factors of gasoline, LPG, and diesel oil for Road transport are presented in Table 3.25. In 2013 Estonia developed country-specific CEF calculation methodology for gasoline, LPG, and diesel oil for Road transport. The CEFs are calculated using weighted average method using CEFs of countries that Estonia imports the fuel from. Since there was no import data for the years 1990–1994, these values are calculated based on 1995–1997 data. All submissions after 1997 are based on these CEFs.

Table 3.25. Carbon emission factors, tC/TJ; CH_4 emission factors, kg/TJ; and N_2O emission factors, kg/TJ for fuels used in Road transport

Year	Gasoline			Diesel			LPG		
	CEF	CH_4 EF	N_2O EF	CEF	CH_4 EF	N_2O EF	CEF	CH_4 EF	N_2O EF
1990	19.50	36.86	2.26	20.01	7.47	2.53	17.72	19.07	0.00
2005	19.27	22.89	3.51	19.95	6.15	1.59	17.75	17.89	3.47
2020	19.22	7.56	0.87	19.94	1.07	2.77	17.39	10.63	1.34
2021	19.14	6.90	0.70	19.98	0.89	2.85	17.31	10.54	1.13
2022	19.22	5.95	0.59	19.95	0.71	3.05	17.23	10.56	1.04
2023	19.20	5.73	0.57	19.91	0.58	3.05	17.22	10.03	0.91

The amounts of fuels imported in 2023 are presented in Table 3.26.

Table 3.26. Imported fuel amounts in 2023 by country

	Gasoline (kg)	Diesel (kg)	LPG (kg)
Belgium	-	1 380 907	-
Czechia	-	-	1 101
Cyprus	-	-	20 780
Denmark	-	1 650	-
Finland	3 6967 183	20 522 6625	842 443
France	-	68 962	80
Germany	-	4 185	3 323
Greece	-	-	351
Ireland	-	-	102
Italy	-	-	7 548
Kazakhstan	-	-	6 211 200
Latvia	11 450	39 127 795	3 340 060
Lithuania	164 542 655	427 206 839	26 460
Netherlands	4 2944	5 181 570	3 677
Poland	3 524	103 747	21 271
Russia	1 069	2 171	3 945 580
Sweden	159 096	9 875 781	29 260
United States	-	25 847 694	

Oxidation factors for all fuels in Road transport are equal to 1. The NCVs for the fuels used in Road transport are following: diesel – 42.3 GJ/kg, LPG – 45.5 GJ/kg, and gasoline – 44.0 GJ/kg. The CEFs used for the calculation of the country-specific CO_2 emission factor in 2023 by country are presented in Table 3.27.

Table 3.27. Carbon emission factors used in the calculation of the country-specific CO_2 emission factor for liquid fuels in Road transport, tC/TJ

	Gasoline	Diesel	LPG
Belgium	-	20.20	-
Czechia	-	-	17.97
Cyprus	-	-	17.20
Denmark	-	20.21	-
Finland	19.50	20.00	17.70
France	-	20.32	17.21
Germany	-	20.19	18.09
Greece	-	-	17.20
Ireland	-	-	17.37
Italy	-	-	17.20
Kazakhstan	-	-	17.20
Latvia	18.91	20.40	17.13
Lithuania	19.13	19.85	18.22
Netherlands	19.69	19.77	18.19
Poland	19.19	19.76	17.04
Russia	19.64	20.27	17.21
Sweden	19.64	20.25	17.75
United States	-	19.16	-

* Countries for whom CEF data was not available, the defaults have been used.

CH_4 and N_2O emissions from liquid fossil fuels are calculated using COPERT 5 model. CH_4 and N_2O emission factors are described in the EMEP/EEA air pollutant emission inventory guidebook 2023[41]. Since every EURO class has different emission factors, the CH_4 and N_2O emissions are highly dependent on the share of vehicles used in road transport.

Gaseous fuels

In 2021 Estonia developed CNG country-specific emission factors for CH_4 and N_2O for passenger cars, buses, and light duty vehicles. The EFs are calculated using Handbook Emission Factors for Transport[43] (HBEFA) database which aggregates emission factors for different types of vehicles by emission technologies and fuel types taking into account the road type and weather conditions. The database includes emission factors for Austria, Germany, Switzerland, France, Norway, and Sweden.

The activity data for Estonia is available from 2010 as CNG was first used in passenger cars in 2010 and in buses in 2011. The first biomethane buses started to run in Estonia in 2018.

The arithmetic mean of the specific emission factors of the emission technologies was taken for each road type: urban road, rural road, and motorway. In order to make the specific emission factors as closely as possible comparable to Estonian conditions, the specific emission factors

[43]Handbook Emission Factors for Transport. [www] https://www.hbefa.net/e/index.html (08.01.2024).

were calculated using the weighted average method for the years 2010-2022 using the existing shares of Estonian road types available at COPERT 5 model. To conclude the selection a comparison of weather conditions between Estonia and selected countries was made. The metheorological data was taken from HBEFA database and for Estonia from COPERT 5. In GHG inventory, the emission factors for passenger cars and buses are used. HBEFA includes N_2O emission factors for city buses from the EMEP/EEA 2023 guidebook[32], which lists the specific N_2O emission factors for city buses as 0 or n.a. The same emission factors for CNG and biomethane are used in estimating CH_4 and N_2O emissions in Road transport using IPCC *Tier 3* method.

The CEF used for calculating CO_2 emissions from CNG and biomethane is country-specific for natural gas. According to the Regulation No. RT I, 29.07.2017, 6[44] of the Minister of Economic Affairs and Infrastructure biomethane used in transport must meet the quality requirements of natural gas. Table 3.28 presents the CEF-s, CH_4 and N_2O emission factors for CNG and biomethane.

Table 3.28. Carbon emission factors, tC/TJ; CH_4 and N_2O emission factors, g/km for CNG and biomethane used in passenger cars and buses in Road transport

Year	CNG					Biomethane		
	CEF	Passenger cars		Buses		CEF	Buses	
		CH_4 EF	N_2O EF	CH_4 EF	N_2O EF		CH_4 EF	N_2O EF
2010	15.07	0.028	0.0004	–	–	–	–	–
2011	15.07	0.028	0.0004	0.028	0.0004	–	–	–
2012	15.07	0.029	0.0004	0.029	0.0004	–	–	–
2013	15.07	0.029	0.0004	0.029	0.0004	–	–	–
2014	15.07	0.029	0.0004	0.029	0.0004	–	–	–
2015	15.07	0.027	0.0004	0.027	0.0004	–	–	–
2016	15.07	0.027	0.0004	0.027	0.0004	–	–	–
2017	15.07	0.027	0.0004	0.027	0.0004	–	–	–
2018	15.07	0.027	0.0004	0.027	0.0004	15.07	0.26	0
2019	15.07	0.027	0.0004	0.027	0.0004	15.07	0.26	0
2020	15.07	0.027	0.0004	0.027	0.0004	15.07	0.26	0
2021	15.07	0.027	0.0004	0.027	0.0004	15.07	0.26	0
2022	15.07	0.027	0.0004	0.027	0.0004	15.07	0.26	0
2023	14.73	0.027	0.0004	0.027	0.0004	14.73	0.26	0

Liquid biofuels

The emissions from bioethanol and biodiesel use are reported separately from fossil-based diesel oil and gasoline emissions. The fossil CO_2, CH_4 and N_2O emissions are reported under Other Fossil Fuels and biogenic CO_2, CH_4 and N_2O emissions under Biomass in 1.A.3.b Road Transportation in CRT tables. The biogenic CH_4 and N_2O emissions are accounted for in national total. CH_4 and N_2O emissions from biofuels are calculated using COPERT 5 model. CH_4 and N_2O emission factors in COPERT 5 are described in the EMEP/EEA air pollutant emission inventory guidebook 2023, Chapter 1.A.3.b Road transport[32].

[44]Riigi Teataja. Gaasituru toimimise võrgueeskiri. [www] https://www.riigiteataja.ee/akt/129122020033?leiaKehtiv (29.02.2024).

In 2022 Estonia carried out a development work to specify CO_2 emissions from fossil part of liquid biofuels. The fossil carbon origin of FAME (fatty-acid methylether) and ETBE (ethyl tert-butyl ether) was specified and the distribution of biodiesel into FAME and HVO (hydrotreated vegetable oil) and the ETBE part of bioethanol was taken into account in calculations. The shares of FAME and HVO in biodiesel and ETBE in bioethanol are taken from the COPERT 5 model which are calculated by Estonian Environment Agency. ETBE is consumed only in 2019 in Estonia and its share in bioethanol is very small. The consumption data of liquid biofuels in Estonia is available from 2005.

Bioethanol is 100% bio-origin. ETBE is a bioether that is synthesized by mixing bioalcohols and isobutylene over a catalyst. Isobutylene is currently derived from fossil sources and and therefore is considered to have a fossil part. The CO_2 emission factor for bioethanol and ETBE are based on the stochiometric C-contents of 52% for bioethanol (C_2H_6O) and 71% for ETBE The CO_2 emissions factors for bioethanol and ETBE ($C_6H_{14}O$). The fossil part of ETBE is considered to be 66.7% and is taken from the fossil carbon content calculation method prepared by Sempos[45]. The calorific value for bioethanol is 27.7MJ/kg is taken from COPERT 5 model and is country-specific. For ETBE it is 36.2MJ/kg which is taken from EMEP/EEA 2023 Guidebook[46].

FAME is also considered to have a fossil carbon part since fossil derived methanol is used in production. For analysing FAME composition, the fossil diesel fuel samples (since FAME is always blended into fossil diesel) were analysed in gas chromatography in Estonian Environmental Research Centre fuel laboratory. Based on the results the country-specific fossil part of FAME was calculated which is 5.28%. The country-specific calorific value of 37.5MJ/kg was also calculated based on these results. The results are available upon request[47].

HVO is also considered 100% bio-origin. For the HVO the average carbon content of 84.8% and calorific value of 44 MJ/kg.[48]

In 2023 the fossil CO_2, CH_4, and N_2O emissions from transportation biofuels totalled 1.08 kt CO_2 eq., constituting 0.01% of Estonia's total GHG emissions.

1.A.3.c Railways

The CO_2 emissions from Railway transportation are calculated using the country-specific carbon emission factors of diesel oil. This emission factor is calculated using the weighted average method using CEFs of countries that Estonia imports fuels from. Emission factors of CH_4, and N_2O are taken from the IPCC 2006 Guidebook. NO_x, CO, and NMVOC for coal from EMEP/EEA Guidebook 2023, and SO_2 EF is country-specific (expert estimation). Emission factors are presented in Table 3.29.

Table 3.29. Emission factors used in the calculation of emissions from Railways

Fuel	GHG	EF	Source
Diesel Oil	CO_2	19.91 tC/TJ	CS
	CH_4	4.15 kg/TJ	IPCC 2006, Vol.2, Chapter 3, Table 3.4.1

45 Note on fossil carbon content in biofuels. Ioannis Sempos, 2019
46 EMEP/EEA 2023 Guidebook, Part B, 1. Energy, 1.A Combustion, 1.A.3.b.i-iv Road Transport, Table 3-28
47 The fossil part of FAME and other parameters used in liquid biofuels is based on development work: Analysis of biofuels in the transport sector. The report is available upon request.
48 Hydrotreated Vegetable Oil (HVO) as a Renewable Diesel Fuel: Trade-off between NOx, Particulate Emission, and Fuel Consumption of a Heavy Duty Engine. H. Aatola, M. Larmi, T. Sarjovaara, 2008

Fuel	GHG	EF	Source
	N_2O	28.6 kg/TJ	IPCC 2006, Vol.2, Chapter 3, Table 3.4.1
	NOx	52.4 kg/t	EMEP/EEA Guidebook 2023
	CO	10.7 kg/t	EMEP/EEA Guidebook 2023
	NMVOC	4.65 kg/t	EMEP/EEA Guidebook 2023
	SO_2	141.2 kg/t	CS
Coal	CO_2	25.75 tC/TJ	CS
	CH_4	2 kg/TJ	IPCC 2006, Vol.2, Chapter 3, Table 3.4.1
	N_2O	1.5 kg/TJ	IPCC 2006, Vol.2, Chapter 3, Table 3.4.1
	NOx	173 kg/TJ	EMEP/EEA Guidebook 2023
	CO	931 kg/TJ	EMEP/EEA Guidebook 2023
	NMVOC	88.8 kg/TJ	EMEP/EEA Guidebook 2023
	SO_2	1 028 kg/TJ	CS

CS – country-specific

1.A.3.d Domestic navigation

CO_2 emissions from Domestic navigation are calculated using the country-specific carbon emission factor for diesel oil. This emission factor is calculated with weighted average method using CEFs of countries from which Estonia imports this fuel. CH_4 and N_2O emission factors for diesel oil are taken from the IPCC 2006 guidelines. NO_x, CO, and NMVOC emission factors for diesel oil are taken from the EMEP/EEA Guidebook 2023[25]. SO_2 EF is country-specific. All emission factors are presented in Table 3.30.

Table 3.30. Emission factors used in the calculation of emissions from Domestic navigation

Fuel	GHG	EF	Source
Diesel Oil	CO_2	19.91 tC/TJ	CS
	CH_4	7 kg/TJ	IPCC 2006
	N_2O	2 kg/TJ	IPCC 2006
	NO_x	9.4 kg/t	EMEP/EEA Guidebook 2023
	CO	573.9 kg/t	EMEP/EEA Guidebook 2023
	NMVOC	181.5 kg/t	EMEP/EEA Guidebook 2023
	SO_2	141.2 kg/TJ	CS

CS – country-specific

1.A.3.e Other transportation

Carbon emission factors for gasoline and diesel oil for off-road vehicles are presented in Table 3.31. In 2013 Estonia developed country-specific CEF calculation methodology for gasoline, LPG, and diesel oil for Road transport. The CEFs are calculated using weighted average method using CEFs of countries that Estonia imports the fuel from. Since there was no import data for the years 1990–1994, these values are calculated based on 1995–1997 data. All submissions after 1997 are based on these CEFs. The same fuels are also used in Road transport sector.

Table 3.31. Carbon emission factors for fuels used for off-road vehicles, tC/TJ

Year	Gasoline CEF	Diesel CEF
1990	19.50	20.01
2005	19.27	19.95
2020	19.22	19.94
2021	19.14	19.98
2022	19.22	19.95
2023	19.20	19.91

CH_4 emission factors by vehicle type used in calculations are presented in Table 3.32 and N_2O emission factors in Table 3.33

Table 3.32. CH_4 emission factors used for off-road vehicles, kg/TJ

Year	Gasoline		Diesel						
	Tractors	Other	Tractors	Excavators	Harvesters	Loaders	Forestry	Other	Road work
1990	15.0	28.8	4.3	4.4	3.0	3.6	3.9	3.8	3.2
2005	13.0	24.4	4.0	2.8	1.6	2.4	2.1	2.2	2.6
2020	10.5	24.7	1.4	0.9	0.4	0.7	0.8	3.3	1.2
2021	10.1	24.4	3.3	0.7	0.4	0.6	0.5	0.5	0.9
2022	9.8	24.5	0.9	0.6	0.3	0.6	0.4	0.5	0.9
2023	9.68	24.8	0.9	0.6	0.3	0.6	0.4	0.4	0.9

Table 3.33. N_2O emission factors used for off-road vehicles, kg/TJ

Year	Gasoline		Diesel						
	Tractors	Other	Tractors	Excavators	Harvesters	Loaders	Forestry	Other	Road work
1990	1.3	1.1	3.0	2.9	3.1	3.0	3.0	3.0	3.1
2005	1.4	1.1	3.0	3.2	3.2	3.1	3.2	3.2	3.1
2020	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.1	3.2
2021	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.3	3.3
2022	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.3	3.3
2023	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.3	3.3

CH_4, N_2O, NO_x, CO, and NMVOC emission are estimated using EMEP/EEA air pollutant inventory guidebook 2023 1.A.4 Non road mobile machinery *Tier 3* methodology. Emissions are estimated for gasoline and diesel separately and for each vehicle type[38]. Emissions are calculated by using Equation 3.12.

Equation 3.12

$$EF_{pollutant} = AR_{activity} \times EF_{pollutant}$$

Where:

$E_{pollutant}$ = the emission of the specific pollutant;
$AR_{activity}$ = the activity rate;
$EF_{pollutant}$ = the emission factor for this pollutant.

3.2.6.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Transport subcategory, please see Annex A.II.1 Energy, 1.A.3 Transport chapter.

3.2.6.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.5. A complete Quality Assurance (QA) and Quality Control (QC) was carried out in the Transport sector according to the IPCC *Tier 1* method.

COPERT 5 model includes vehicle data and annual mileage per vehicle and is collected from the Estonian Transport Administration and the fuel consumption by Statistics Estonia. A check for fuel and mileage statistics is performed by the inventory compiler and data is adjusted, if necessary. The calculated fuel consumption in COPERT 5 model is compared against the statistical fuel conusmption data in Joint Questionnaires. This data is also presented in the SE database[20] and added to Annex 3 (A.3.2).

The statistical fuel consumption is fitted into the COPERT 5 model by distributing it between vehicle categories based on annual mileage per vehicle category from odometer readings taken during the annual technical inspection to maintain a balance between calculated and statistical fuel consumption levels as calculated by COPERT 5 model. Meteorological data is provided by Estonian Weather Service.

3.2.6.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

There were no category-specific recalculations.

3.2.6.6. Category-specific planned improvements, if applicable including tracking of those identified in the review process

There are no category-specific improvements planned.

3.2.7. Other sectors (1.A.4)

3.2.7.1. Category description

Sub-categories of CRT 1.A.4 includes emissions from the small combustion of fuels in stationary equipment:

- 1.A.4.a Commercial/institutional
- 1.A.4.b Residential
- 1.A.4.c Agriculture/forestry/fisheries

These sectors cover mainly fuels used in heating commercial, institutional, and agriculture buildings. Off-road vehicles used in 1.A.4.a Commercial/institutional and 1.A.4.c Agriculture/forestry/fisheries sectors are covered under 1.A.3.e Other transportation since 2024 submission.

In 2023 emissions in CRT 1.A.4 Other sectors were 399.16 kt CO_2 eq., about 4.56% of the Energy sector’s emissions and 3.67% of total GHG emissions in Estonia. Corresponding emissions in 1990 were 1800.34 kt CO_2 equivalent (see Figure 3.27 and Table 3.34). Fuel consumption in Other sectors in 1990, 2005, and 2020-2023 is presented in Table 3.35.

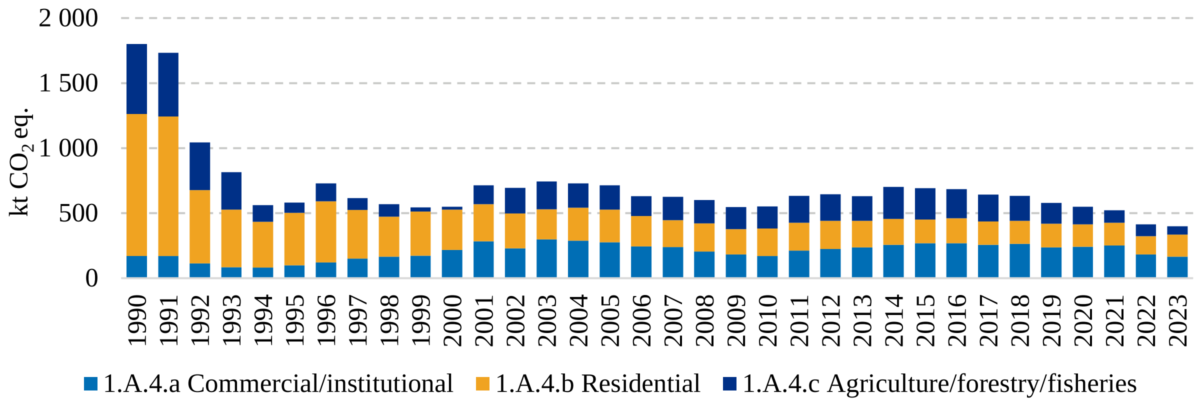

Figure 3.27. Trend of GHG emissions from Other sectors, kt CO_2 eq.

Table 3.34. Emissions from Other sectors by relevant subcategories in 1990, 2005, and 2020-2023, kt CO_2 eq.

Sector	1990	2005	2020	2021	2022	2023
1.A.4 Other sectors Total, CO_2 eq.	**1800.34**	**713.91**	**548.35**	**522.96**	**414.62**	**399.16**
1.A.4.a Commercial/institutional, CO_2 eq.	172.22	276.62	242.06	252.22	182.30	164.32
1.A.4.b Residential, CO_2 eq.	1090.14	251.40	171.56	174.14	141.42	170.33
1.A.4.c Agriculture/forestry/fisheries, CO_2 eq.	537.98	185.89	134.74	96.60	90.90	64.50

Table 3.35. Fuel consumption in Other sectors in 1990, 2005, and 2020-2023, TJ

Category/activity data	1990	2005	2020	2021	2022	2023
1.A.4 Other Total, TJ.	**29 453**	**23 140**	**25 989**	**25 341**	**24 224**	**22 117**
Liquid fuels, TJ	12 053	4 476	2 803	2 222	2 212	2 213
Solid fuels, TJ	3 749	1 086	89	80	NO	30
Gaseous fuels, TJ	2 786	4 089	5 653	5 986	4 095	3 997
Peat, TJ	3 264	227	NO	NO	41	NO
Biomass, TJ	7 601	13 263	17 444	17 053	17 875	15 877

1.A.4.a Commercial/institutional

GHG emissions from CRT 1.A.4.a Commercial and institutional sub-sector include wholesale and retail trade, repair of motor vehicles, hotels and restaurants, financial intermediation, real estate, renting and business activities, public administration, and defence, compulsory social security, education, health and social work, other community, social and personal service activities, fuel terminals, etc.

The decreasing trend of GHG emissions in Commercial/institutional at the beginning of the 90s (from 1992 up to 1994) reflects the general economic development trend after regaining independence in 1991 (Figure 3.28). The increase of emission trend in 2001 is connected to a large growth of some sub-sectors like financial intermediation, real estate, hotels, and restaurants, etc. The faster decrease in 2006 was caused by structural changes in the use of wood fuels which increased about 16.2% and liquid fuels which decreased about 29.6%. From 2007 to 2010 the economic crisis showed a downwards trend in GHG emissions. In 2022 the GHG emissions decreased 27.72 %, compared to previous year, being 182.30 kt CO_2 eq. as natural gas consumption decreased significantly due to high prices. In 2023 emissions continued to decrease by 9.86% to 164.32 kt CO_2 eq., caused mainly by overall decrease in fuel consumption.

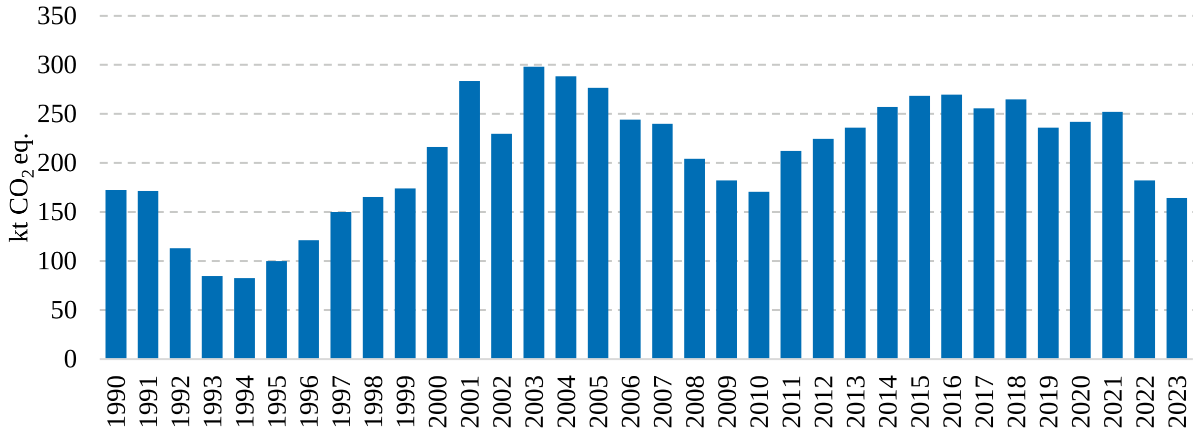

Figure 3.28. Trend of GHG emissions from Commercial and institutional sector, kt CO_2 eq.

1.A.4.b Residential

The category 1.A.4.b Residential sub-sector includes GHG emissions from fuel combustion in households. Emissions from other miscellaneous mobile equipment (ATV-s, forklifts, cranes, etc) are reported in Chapter 1.A.3.e Other transportation. The overall trend of GHG emissions is decreasing and follows the fuel consumption trend in the sector. The decreasing trend is a consequence of energy efficiency and saving measures, renovation, and building more new energy efficient houses, weather conditions, etc (Figure 3.29). Foremost, the decrease shows a relevant change in the fuel consumption structure in the Residential sector. Consumption of fuel oils decreased rapidly after 1991, but consumption of wood fuels has been increasing since 1990 and increased in 2023 more than three times in comparison with 1990/1991 (Figure 3.33). In 2022 the emissions in Residential sector were 141.42 kt CO_2 eq. which is about 18.79% decrease compared to the previous year as natural gas consumption decreased significantly due to high prices. In 2023 the emissions in Residential sector were 170.33 kt CO_2 eq. which is about 20.44% increase compared to the previous year as natural gas consumption increased and solid biofuels consumption decreased as natural gas prices were substantially lower compared to extremely high levels in 2022.

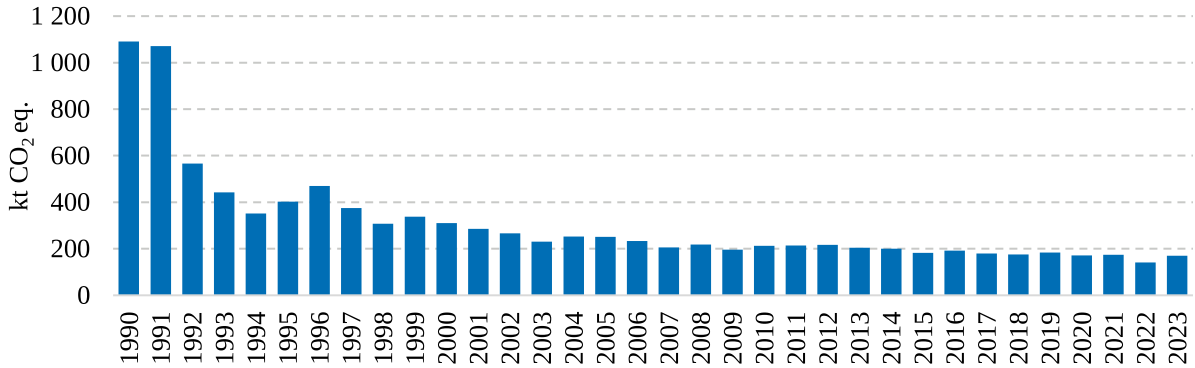

Figure 3.29. Trend of GHG emissions from Residential sector, kt CO_2 eq.

1.A.4.c Agriculture/forestry/fishing

Under category 1.A.4.c Agriculture/forestry/fisheries GHG emissions from stationary fuel combustion are reported. Emissions from mobile sources include tractors, harvesters, and forestry machines and are reported in Chapter 1.A.3.e Other transportation. The trend of GHG emissions follows the fuel consumption trend and reflects the development trend in the sector.

The number of farms decreased since 1994 drastically and reached a bottom in 1999 as well as the agricultural production decreased. Since 2002 the production in agriculture stabilized and small fluctuations in different years is explained mainly with different weather conditions (Figure 3.30). The increase in emissions and use of fuels in 2011 is explained by the growth in the production of agricultural products. In 2012 and 2013 the emissions stayed about the same level as in 2011.

In 2014 a rise in emissions occurred, about 28,9% compared to the previous year. This was related to an increase in diesel consumption. In 2016 emissions fell 7.8% compared to the previous year mainly due to the falling consumption of light fuel oil and the same trend continued until 2020 when the GHG emissions decreased 14.7% compared to 2019. In 2021 emissions decreased about 28.3% compared to previous year as production in agriculture sector decreased (decrease in farm animals, and large-scale price increase of production inputs). In 2022 the emissions in agricultural sector were 90.90 kt CO_2 eq. which is about 5.90% decrease compared to the previous year as the sector stabilized. In 2023 the emissions in Agriculture/forestry/fisheries sector were 64.50 kt CO_2 eq. which is about 29.04% decrease compared to the previous year as fertilizer use and overall crop yields fell in 2023, compared to 2022.

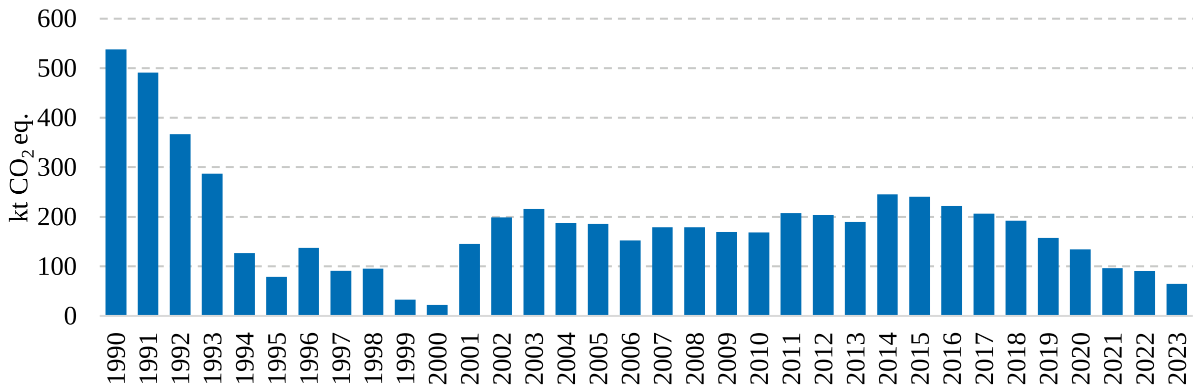

Figure 3.30. Trend of GHG emissions from Agriculture/forestry/fisheries sector, kt CO_2 eq.

3.2.7.2. Methodological issues

Choice of methods

CO_2 emissions from 1.A.4.a Other sectors are estimated using the IPCC 2006 *Tier 2* methodology. The emissions of CO_2 is calculated on basis of combusted fuels and their carbon content. *Tier 2* calculates CO_2 emissions by multiplying the estimated fuel sold times a country-specific emission factor.

For CH_4 and N_2O emission calculations country-specific and IPCC 2006 default emission factors are used (Table 3.37).

Activity data

The activity data is taken from Joint Questionnaire (JQ) dataset made by Statistics Estonia (also sent to IEA and Eurostat). It covers fuels used in Commercial/institutional, Residential, and Agricultural/forestry/fisheries sectors. Statistics Estonia gathers data from energy and fuel producers and consumers. In the case of energy consumers, sampling questionnaire is used. The general assembly of participants includes economically active companies/organisations. Furthermore, companies with at least 50 employees are questioned; a random selection is made from smaller companies. There are separate questions for liquid fuel consumption in road, water, air, and rail transport, other use (industrial production, construction works, etc.), and consumed fuel on the territory of the company (e.g. in agriculture on the fields, in greenhouses, etc.). The fuel for other uses is observed through EMTAK (The Estonian Classification of Economic Activities) categories. This data is also presented in the SE database[20] and added to Annex III.

The fuel consumption data by main fuel groups is presented in Figure 3.31.

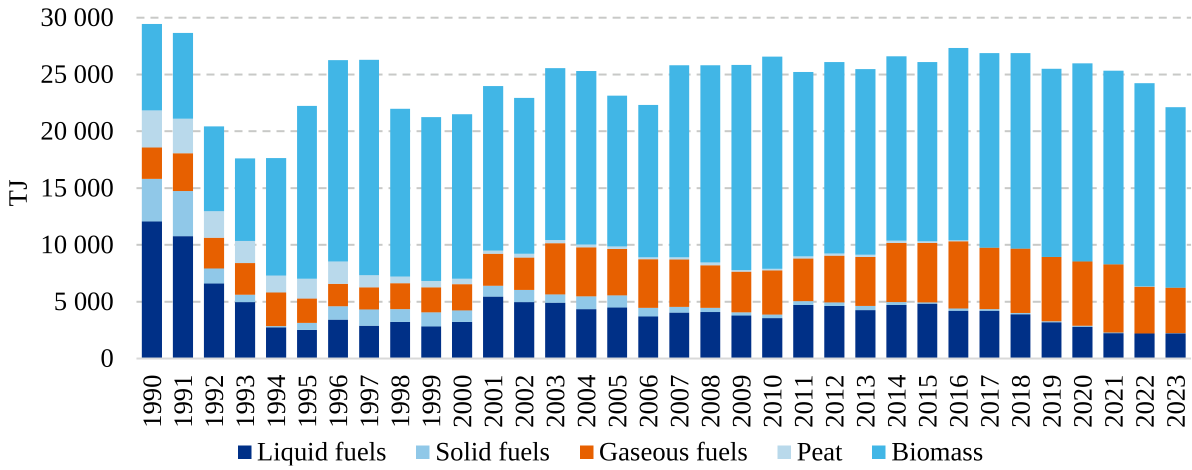

Figure 3.31. Fuel consumption in CRT 1.A.4 Other sectors, TJ

The trend of fuel consumption in Commercial/institutional sector shows a big increase of natural gas use since 2002 as the construction boom started in Estonia. Many new logistics buildings and hypermarkets (using gas heating) were built. Consumption of other fuels: liquid, solid, and biomass fuels was steady, some fluctuations are in the liquid fuel consumption trend in 1992, 2001, and 2002. The decrease of fuel consumption in 2009/2010 corresponds to the consequence of economic recession and increase from 2011 the upturn of economy. In 2022 natural gas consumption decreased significantly due to high prices (Figure 3.32). In 2023 natural gas consumption decrease continued, although the price of gas was lower compared to the previous year. This is mostly related to the special permits received in 2022 to burn residual fuel oil in heating plants instead of natural gas. Residual fuel consumption increased more than 15 times from 16.5 TJ to 284.5 TJ. Use of residual fuel oil usage is expected to decrease in the future as special permits will expire.

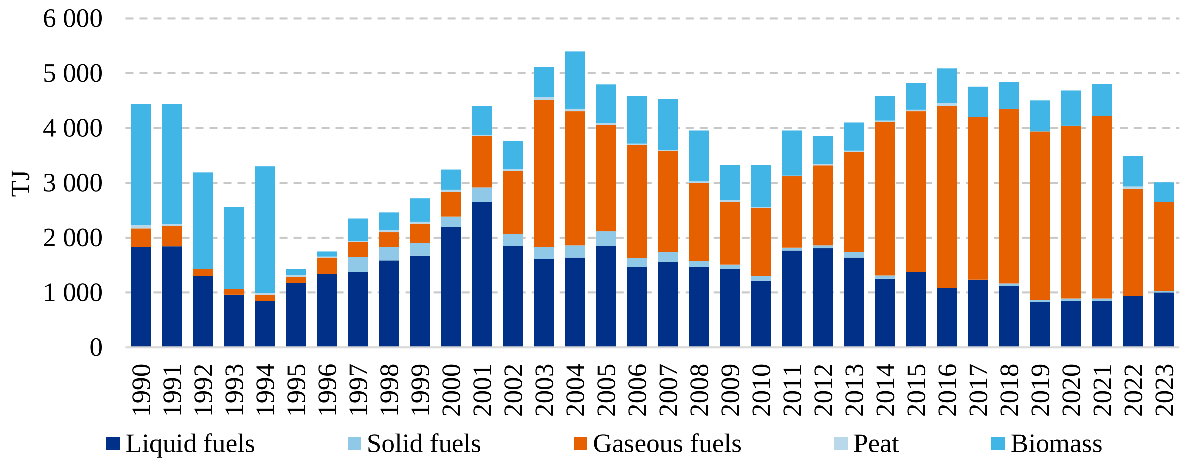

Figure 3.32. Fuel consumption in Commercial/institutional sector, TJ

Figure 3.33 presents the fuel consumption in Residential sector. The most defining fuel is biomass (used for space heating). The major increase of biomass is most likely caused by the methodologies used to estimate household fuel use in the post-controlled economy in Estonia, as great changes were occurring in the economy of the country while collected data might have been slightly incomplete. The increase of the biomass consumption trend in 1996/1997 relates to the methodology change of the Statistics Estonia and decreases in 2005/2006 with warm winters. Since 2007 the use of biofuels in residential sector has been slightly increasing. Considering the warmer-than-average winter, the use of biomass in households for heating decreased in 2011 compared to 2010. In recent years, fuel consumption in the Residential sector has stayed on a stable level with solid fuels being substituted with liquid fuels and biomass. Biomass use increased and natural gas consumption decreased significantly due to high natural gas prices in 2022. In 2023 natural gas consumption increased to levels similar to the period before 2022 energy crises in Europe. At the same time biomass consumption decreased, which can be explained by switching back to natural gas as more convenient source of heat, compared to biomass heating, as natural gas prices normalized. Overall decrease in fuel consumption in the sector was influenced by warmer then usual winter months, with January being the warmest and 2º C warmer than long-term norm. Another reason could be the result of wider adoption and usage of heat pumps, which was supported by reconstruction grant for small households, which was opened in second half of 2022.

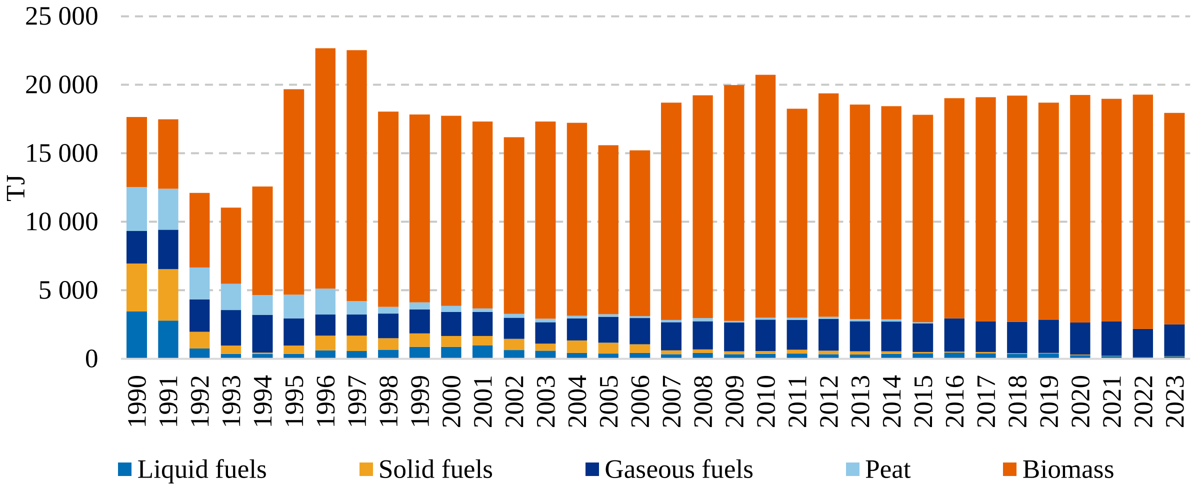

Figure 3.33. Fuel consumption in Residential sector, TJ

Figure 3.34 presents the fuel consumption trend of the Agriculture/forestry/fisheries sector. The largest fuel group in agriculture is liquid fuels, other fuel groups have smaller shares. The liquid fuels use decreased since 1990 up to 1995 almost 85%, mostly due to the decreasing of the agricultural production caused by the structural changes in the economy after Estonia became independent in 1991. After 2000 the agricultural production started to increase, bringing on the increase of liquid fuel consumption. Fuel consumption has been quite stable through the years 2005–2010. Due to the growth in the production of agricultural products, the use of liquid fuels also increased in 2011. In 2012 and 2013, the GHG emissions stayed at the same level as in 2011. Compared to the 2011-2013 stability, in 2014 the fuel consumption grew about 27.8% next to 2013. In 2019 fuel consumption decreased by 18.3% and in 2020 11.6% compared to the respective previous year mainly because of decreased use of diesel oil. In 2021 fuel consumption decreased about 24.5% because of decreased production in Agriculture sector and the same trend continued to 2022, with fuel consumption decreasing by 5.63%. Downtrend in gas oil consumption continued in 2023 – consumption was 29.11 % lower than previous year, because fertilizer use and overall crop yields fell in 2023, compared to 2022.

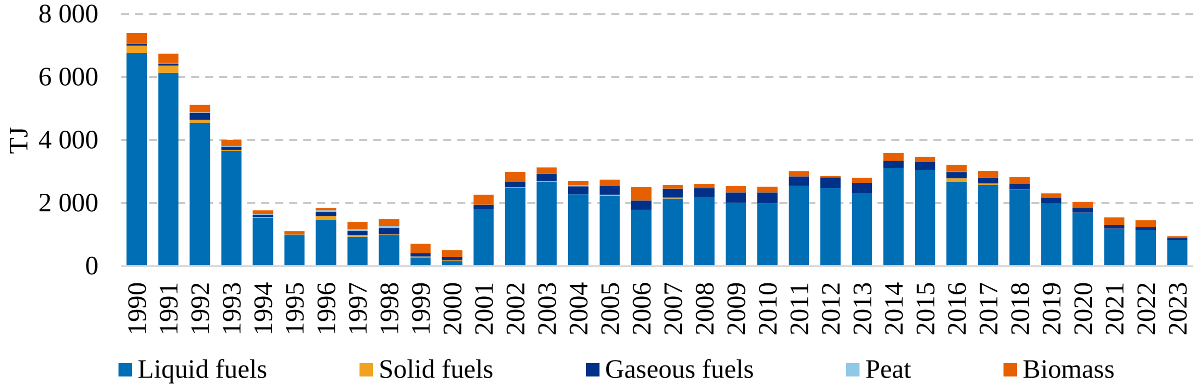

Figure 3.34. Fuel consumption in Agriculture/forestry/fisheries sector, TJ

Emission factors

Both IPCC default and country-specific emission factors are used. Estonia uses the country-specific weighted average CEFs for LPG, light fuel oil, diesel oil, gasoline, residual fuel oil, and coal, and IPCC 2006 default emission factors for solid biomass to calculate CO_2 emissions.

For CH_4 and N_2O emission calculations country-specific and IPCC 2006 default emission factors are used (Table 3.36).

In 2023 a project (2020-2023) on developing country-specific factors for heating appliances in households in 1.A.4.b Residential sector was finalized, and Estonia has now developed country-specific CH_4 and N_2O emissions factors for solid biomass in 1.A.4.b Residential sector.

Table 3.36. CH_4 and N_2O emission factors for stationary combustion in 1.A.4 by subsector and fuel, kg/TJ

Fuel	Sector	CH_4	N_2O	Source
Natural gas	1.A.4.a	1.25	0.11	CS[24]
	1.A.4.b	5	0.1	IPCC 2006
	1.A.4.c	1.00	0.12	CS[24]
Biogases	1.A.4.a	1.75	0.11	CS[24]
	1.A.4.c	5	0.10	CS[24]
Light fuel oil, residual fuel oil	1.A.4.a	9.38	0.57	CS[24]
	1.A.4.b	10	0.6	IPCC 2006
	1.A.4.c	8.16	0.52	CS[24]
Diesel oil	1.A.4.b	10	0.6	IPCC 2006
Gasoline	1.A.4.a	3	0.6	IPCC 2006
	1.A.4.b	10	2	IPCC 2006
	1.A.4.c	10	0.6	IPCC 2006
LPG	1.A.4.a, 1.A.4.b, 1.A.4.c	5	0.1	IPCC 2006
Coal	1.A.4.a	10	1.5	IPCC 2006
	1.A.4.b, 1.A.4.c	300	1.5	IPCC 2006
Milled&sod peat, peat briquette	1.A.4.a	6.69	1.82	CS[24]
	1.A.4.b, 1.A.4.c	300	1.4	IPCC 2006
Solid biomass	1.A.4.a	69.23	1.08	CS[24]
	1.A.4.b	29.64	1.12	CS[24]
	1.A.4.c	177.12	2.45	CS[24]

CS – country-specific

3.2.7.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Energy industries subcategory, please see Annex A.II.1 Energy, 1.A.4 Other sectors chapter.

3.2.7.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.5. A complete Quality Assurance (QA) and Quality Control (QC) was carried out for 1.A.4 Other sectors according to the IPCC *Tier 1* method. The same QA/QC procedures are used as in 1.A.1 and 1.A.2 categories as described in Chapter 3.2.4.4 and Chapter 3.2.5.4.

3.2.7.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

There were no category-specific recalculations.

3.2.7.6. Category-specific planned improvements, if applicable including tracking of those identified in the review process

There are no category-specific improvements planned.

3.2.8. Other (1.A.5)

3.2.8.1. Category description

No emissions are reported under category 1.A.5 Other.

3.3. Fugitive emissions from fuels (CRT 1.B)

3.3.1. Solid Fuels (1.B.1)

There are no coal mines in Estonia. Oil shale is mined for energy generation and shale oil production.

Unlike coal mines, there are no fugitive emissions (CO_2 and CH_4) from oil shale mines, because methane is non-existent in Estonian oil shale (see Explanation Letter from the Department of Mining of Tallinn University of Technology in Annex V.1.1).

3.3.2 Oil and Natural Gas and other emissions from energy production (1.B.2)

3.3.2.1. Category description (e.g. characteristics of sources)

Sources of fugitive emissions within oil and gas systems include releases during normal operation, such as emissions associated with maintenance, during system upsets, and accidents. Liquid fossil fuels and natural gas are mainly imported as only shale oil is produced in Estonia.

Estonia reports CO_2 and CH_4 emissions from natural gas venting, transmission, and distribution. which are reported in following sub-sectors in CRT 1.B.2 Oil and Natural gas sector:

- 1.B.2.c.i Venting
- 1.B.2.b.iv Transmission and storage
- 1.B.2.b.v Distribution

Reported emissions, calculation methods, and type of emission factors for the subcategory Fugitive Emissions in the Estonian GHG inventory can be found in Table 3.37.

Table 3.37. Reported emissions, calculation methods, and type of emission factors

CRT	Source	Emissions	Method	Emission factor
1.B.2.c.i	Venting	CO_2	T1	D
		CH_4		
1.B.2.b.iv	Transmission and storage	CO_2	T1	D
		CH_4		
1.B.2.b.v	Distribution	CO_2	T1	D
		CH_4		

T1 – *Tier 1* method, D – IPCC 2006 default

In 2023 fugitive emissions from oil and natural gas were 15.37 kt CO_2 eq, of which CO_2 is 0.02 kt and CH_4 15.35 kt CO_2 eq. It is about 0.18% of the Energy sector's emissions and 0.14 % of total GHG emissions in Estonia. Corresponding emissions were 71.73 kt CO_2 eq. in 1990.

1.B.2.a Oil

The fugitive emissions from oil distribution are not estimated, as no valid methodology for calculations is currently available.

1.B.2.b Natural gas

Historically natural gas was imported into Estonia from Russia and the Inčukalns underground gas storage in Latvia. AS Eesti Gaas has two gas metering stations on the border of Estonia (in Värska and Karksi) which measure the imported gas volumes. In 29.09.2022 Estonian Government decided to sanction Russian gas imports, but the enforcement date was 31.12.2022. From 2023 Estonia imports its natural gas via pipeline connections with Finland and Latvia. Most of the natural gas in 2023 originated from Norway and the second biggest supplier was USA (Table 3.38).

Table 3.38. Imported natural gas amounts in 2023 by country

-	Natural gas (TJ)
Austria	95
European Union	121
Finland	283
Germany	3
Latvia	4
Lithuania	246
Norway	18396
Poland	5
Russia	309
United States	16116

In 2020 a new pipeline Balticconnector was opened between Estonia and Finland with a new gas metering and compression station in Paldiski, and a compression station in Kiili, allowing two-way natural gas movement. Gas is distributed to customers through gas pipelines, distribution stations, and gas pressure reducing stations.

Figure 3.35 presents the map of the natural gas distribution network in Estonia.

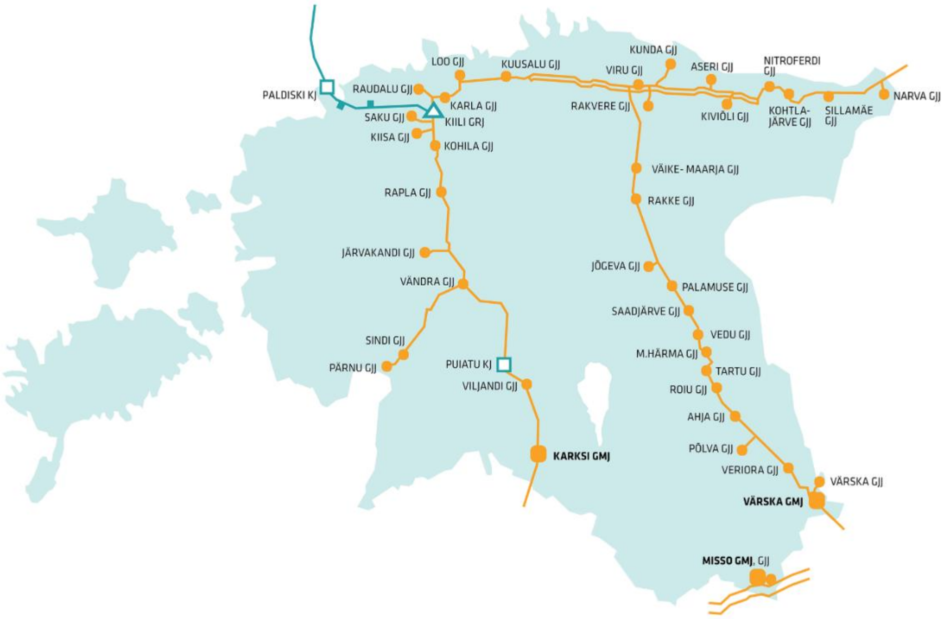

Figure 3.35. Natural gas distribution network in Estonia

Natural gas inland consumption decreased about 12.98% in 2023 compared to 2022, due to elevated prices (compared to longer term averages), lower economic activity, warmer weather and fuel switching (Table 3.39).

Table 3.39. Natural gas consumption in 1990, 2005, and 2020-2023, TJ

Activity Data	1990	2005	2020	2021	2022	2023
Natural gas consumption, TJ	51 174	33 481	14 572	16 575	12 280	10 686

Table 3.40 shows CO_2 and CH_4 emissions from natural gas transmission, and Table 3.41 from natural gas distribution.

Table 3.40. CO_2 and CH_4 emissions from natural gas transmission in 1990, 2005, and 2020-2023

Sector	1990	2005	2020	2021	2022	2023
Natural gas transmission total, kt CO_2 eq.	**8.21**	**5.32**	**2.35**	**2.67**	**1.97**	**1.76**
Natural gas transmission CO_2, kt	0.002	0.001	0.0004	0.001	0.0004	0.0003
Natural gas transmission CH_4, kt	0.29	0.19	0.08	0.10	0.07	0.06

Table 3.41. CO_2 and CH_4 emissions from natural gas distribution in 1990, 2005, and 2020-2023

Sector	1990	2005	2020	2021	2022	2023
Natural gas distribution total, kt CO_2 eq.	**54.51**	**35.33**	**15.57**	**17.69**	**13.08**	**11.68**
Natural gas distribution CO_2, kt	0.09	0.06	0.03	0.03	0.02	0.02
Natural gas distribution CH_4, kt	1.94	1.26	0.61	0.63	0.47	0.42

1.B.2.c Venting and flaring

Table 3.42 shows CO_2 and CH_4 emissions from natural gas venting.

Table 3.42. CO_2 and CH_4 emissions from natural gas venting in 1990, 2005, and 2020-2023

Sector	1990	2005	2020	2021	2022	2023
Natural gas venting total, kt CO_2 eq.	**9.01**	**5.84**	**2.57**	**2.92**	**2.16**	**1.93**
Natural gas venting CO_2, kt	0.01	0.004	0.002	0.002	0.001	0.001
Natural gas venting CH_4, kt	0.32	0.21	0.09	0.10	0.08	0.07

3.3.2.2. Methodological issues

Choice of methods

The calculation of CH_4 emissions from oil and gas activities is presented in Equation 3.13:

Equation 3.13[49]

$$Emissions = \frac{Activity \times EF}{10^6}$$

Where:

Emissions = CH4 emissions, kt
Activity = activity data of natural gas activities, PJ;
EF = emission factor of fugitive emissions from natural gas activities, kg/PJ.

Activity data

The activity data for category CRT 1.B.2 is taken from the Joint Questionnaire dataset made by Statistics Estonia.

Emission factors

CO_2 and CH_4 emission factors for calculating natural gas venting, transmission and distribution emissions are taken from the IPCC 2006 Guidelines (developed countries and economies in transition).

There were two new gas compression stations added to the system in 2020. This does not affect the emission factors since the new compressors are of the same type as the previous compressors (centrifugal compressors) according to which the emission factors are used. Therefore, the emission factors remain the same.

Emissions from natural gas storage are not occurring since there are no natural gas storage facilities in Estonia. Estonia uses storage facilities located in Latvia.

3.3.2.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Energy industries subcategory, please see Annex A.II.1 Energy, 1.B.2 Oil and Natural Gas and other emissions from energy production chapter.

3.3.2.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.5. A complete Quality Assurance (QA) and Quality Control (QC)

[49] IPCC 2006 Guidelines, Volume 2, Chapter 2; Stationary Combustion, page 2.11, equation 2.1.

was carried out for 1.B.2 Oil and Natural Gas and other emissions from energy production according to the IPCC *Tier 1* method. The same QA/QC procedures are used as in 1.A.1 category as described in Chapter 3.2.4.4.

3.3.2.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

There were no category-specific recalculations.

3.3.2.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

There are no category-specific improvements planned.

3.4. Carbon dioxide transport and storage (CRT 1.C)

Up to 2023 no CO_2 transport and storage has been used in Estonia.

4. INDUSTRIAL PROCESSES AND PRODUCT USE (CRT SECTOR 2)

4.1. Overview of the sector (e.g., quantitative overview and description, including trends and methodological tiers by category) and background information

Greenhouse gas emissions from the Industrial processes and product use sector contributed 2.44 % the total anthropogenic greenhouse gas emissions in 2023 (Figure 4.1), totalling 265.16 kt CO_2 eq. with indirect CO_2 and 241.27 kt CO_2 eq. without indirect CO_2. Indirect CO_2 emissions in the sector is 23.89 kt CO_2 eq.

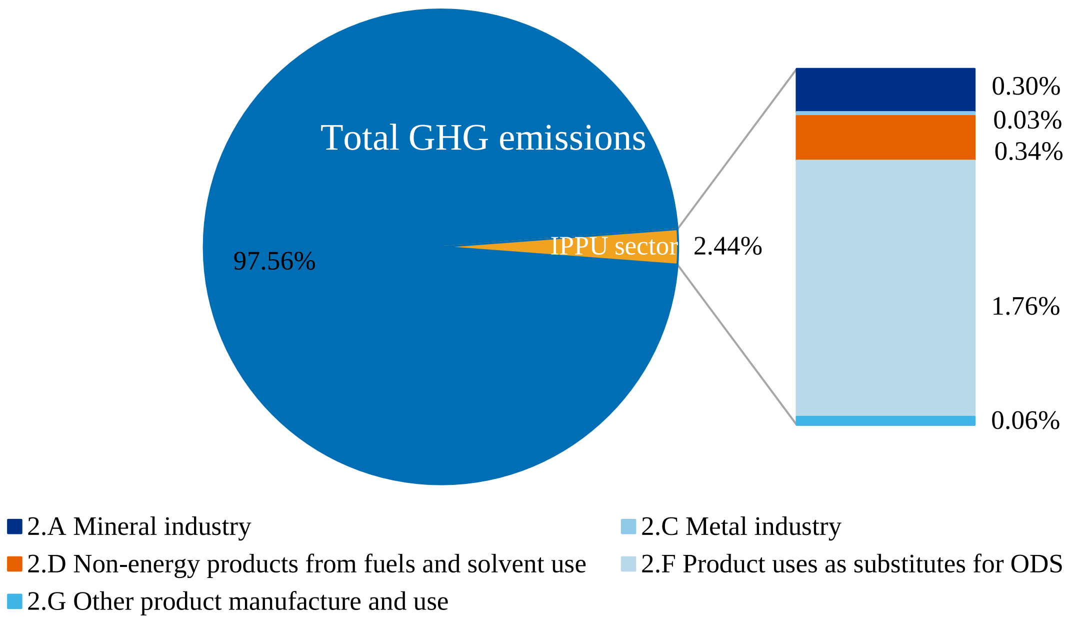

Figure 4.1. Emissions from Industrial processes and product use compared with total emissions in 2023, %

Estonia’s emissions from the Industrial processes and product use sector are divided into following emission categories:

- Mineral industry (CRT 2.A) including CO_2 emissions from cement (historical data), lime and glass production, other process uses of carbonates (ceramics);
- Historical chemical industry’s emissions (CRT 2.B) – CO_2 emissions from ammonia production;
- Metal industry (CRT 2.C) including CO_2 emissions from secondary lead production (aggregated with CO_2 emissions from soda ash used by rare metals and rare earth metal industry);
- Non-energy products from fuels and solvent use (CRT 2.D) including CO_2 emissions from use of 1) lubricants 2) paraffin waxes and 3) urea-based catalysts for motor vehicles, NMVOC emissions from solvent use and road paving with asphalt;
- Products used as substitutes for ODS (CRT 2.F) including HFC emissions from refrigeration and air conditioning, foam blowing agents, fire protection and aerosols.

- Other product manufacture and use (CRT 2.G) including SF_6 emissions from electrical equipment, SF_6 and PFC emissions from other product use and N_2O emissions from product uses;
- Other (CRT 2.H) including NOx, CO, NMVOC and SO_2 emissions from pulp and paper and NMVOC emissions from food and beverages;
- Indirect CO_2 emissions calculated from NMVOC emissions from CRT 2.D.3.

Reported greenhouse gas emissions, used methods and type of emission factors are listed in Table 4.1.

Table 4.1. Reported GHG emissions, calculation methods and type of emission factors for Industrial processes and product use sector in 1990–2023.

	Method applied/EF used				
GHG SOURCE AND SINK CATEGORIES	**CO_2**	**HFCs**	**N_2O**	**SF_6**	**Indirect CO_2**
2.A.1 Cement production (historically)	T2/PS				
2.A.2 Lime production	T1,T2/D,PS				
2.A.3 Glass production	T1,T3/D,PS				
2.A.4 Other process uses of carbonates	T1,T2/D,PS				
2.B.1 Ammonia production (historically)	T3/PS				
2.C.5 Lead production	T3/PS				
2.D.1 Lubricant use	T1/D				
2.D.2 Paraffin wax use	T1/D				
2.D.3 Other (Urea based catalysts for motor vehicles)	T2/D				
2.D.3 Solvent use					T1/D
2.D.3 Road paving with asphalt					T1/D
2.F.1 Refrigeration and air conditioning		T2/CS			
2.F.2 Foam blowing agents		T2/CS			
2.F.3 Fire protection		T2/CS			
2.F.4 Aerosols		T2/CS			
2.G.1 Electrical equipment				T3/CS	
2.G.2 SF_6 and PFCs from other product use				T2,T3 /CS	
2.G.3 N_2O from product uses			T2/CS		

T1 – *Tier 1* method, T2 – *Tier 2* method, T3 – *Tier 3* method, D – IPCC default, PS – plant specific, CS – country-specific

Compared to 2022, the emissions from the Industrial processes and product use sector (with indirect CO_2) decreased by -3.55 % in 2023.

Regarding chemical industry (2.B) – ammonia production has completely ceased since 2014 and the company has announced that it has sold all production equipment and no longer plans to continue with ammonia production.

Industrial CO_2 emissions have fluctuated strongly since 1990 (Figure 4.2 and Table 4.2) reaching their lowest level in 1993. The decrease in emissions during the early 1990s was caused by the transition from a planned economy to a market economy after 1991 when Estonia regained its independence. This led to lower industrial production and to an overall decrease in emissions from industrial processes between the years 1991 and 1993. In 1994, the economy began to recover, and production increased. Since 1995 (the base year for F-gases under the Kyoto Protocol) F-gas emissions have significantly increased. The decrease in CO_2 emissions in 2002 and 2003 was caused by the reduction in ammonia production, as the only ammonia factory in the country was being reconstructed. The sudden increase in CO_2 emissions in 2007 was mainly caused by a rise in cement production, as the only cement factory renovated its third kiln. In 2009, the industrial processes sector was affected by the global economic recession. The decline in production was mainly due to insufficient demand on both the domestic and external markets. The increase in 2011 emissions was attributable to rising cement production. CO_2 emissions grew in 2012 and 2013, because a power plant used large quantities of limestone for flue gas desulphurisation. Decrease in mineral industry output was the main driver in overall decrease of industrial CO_2 emissions from 2014 to 2016. Decrease in 2020 was caused by the closure of clinker production in the only cement plant in Estonia in March 2020. Decrease in 2022 was mainly due to decreased lime production caused by higher prices of natural gas. Following decrease in 2023 was due to the decrease in the usage of HFCs. The biggest decrease was in the commercial refrigeration sector because there was less F-gas in total in the 15 year old equipment (installed in 2008) that was decommissioned in 2023. The other factor is that environmentally friendly alternatives are used instead of F-gases in the commercial sector.

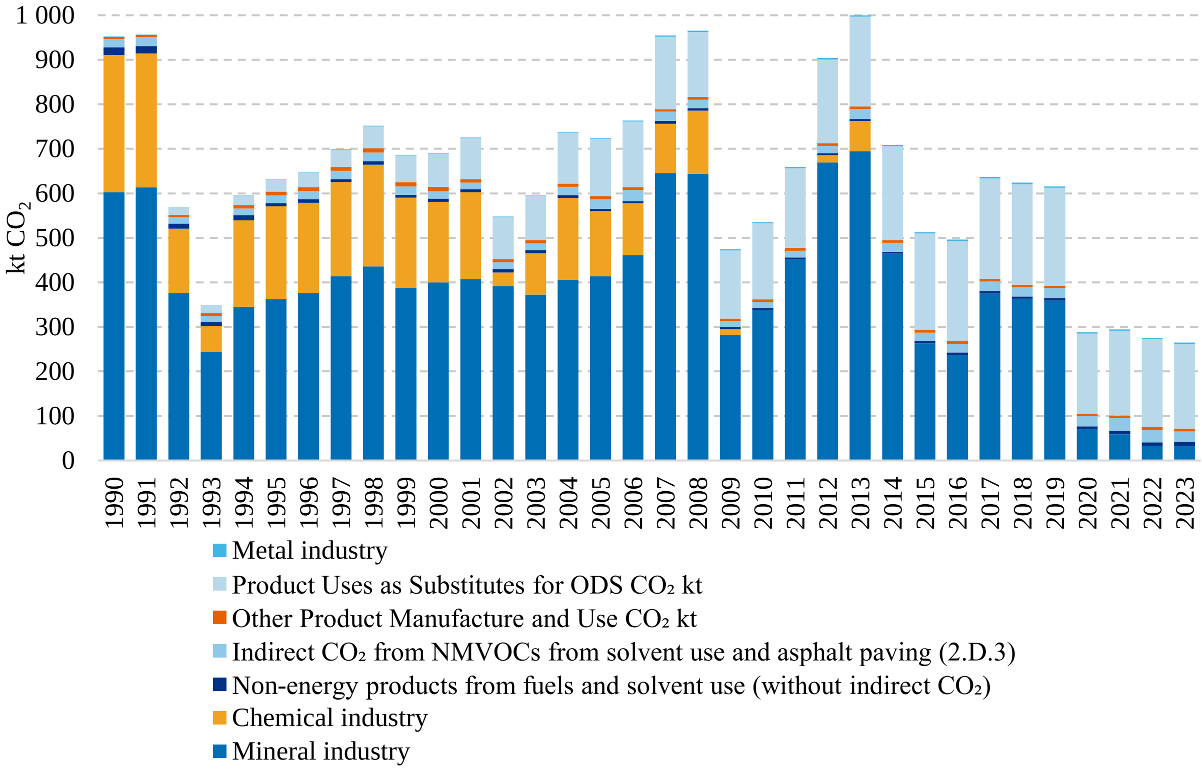

Figure 4.2. Emissions from Industrial processes and product use in 1990–2023 (with indirect CO_2), kt CO_2 eq.

Table 4.2. Trends in the greenhouse gas emissions from Industrial processes and product use in 1990–2023, kt CO_2 equivalent

	1990	**2005**	**2020**	**2021**	**2022**	**2023**
Mineral industry	603.1	413.6	70.3	58.8	32.6	32.2
Chemical industry	307.7	146.4	NO	NO	NO	NO
Metal industry	0.8	1.5	2.9	3.0	2.7	3.0
Non-energy products from fuels and solvent use (without indirect CO_2)	17.4	5.1	6.6	7.9	8.3	9.3
Indirect CO_2 from solvent use and road paving with asphalt	18.5	21.9	22.5	29.3	28.0	23.9
Other product manufacture and use (from N_2O use)	4.9	6.0	2.8	2.4	3.1	2.8
HFCs	NO*	128.2	179.9	190.2	197.1	190.9
PFCs	NO**	NO	NO	NO	NO	NO
SF_6	NO***	1.1	3.0	3.1	3.1	3.2
Total (with indirect CO_2)	**952.4**	**723.7**	**288.1**	**294.6**	**274.9**	**265.2**
Total (without indirect CO_2)	**933.8**	**701.8**	**265.5**	**265.3**	**246.9**	**241.3**

*The use of HFCs started in 1992 in Estonia
**The use of PFCs took place in 2006-2008 in Estonia
***The use of SF_6 started in 1991 in Estonia

4.2. Mineral industry (CRT 2.A)

In this category Estonia reports non-fuel emissions from:

- Cement production (2.A.1);
- Lime production (2.A.2);
- Glass production (2.A.3);
- Other process uses of carbonates (2.A.4):
    - Ceramics (2.A.4.a) – bricks and tiles, lightweight gravel;
    - Emissions that previously were reported under subcategory 2.A.4.b Other uses of soda ash have been relocated to 2.C.5 Lead production and recalculated.
    - Other (2.A.4.d) – use of limestone for flue gas desulphurisation at power plant until 2017;

CO_2 emissions from the Mineral industry have fluctuated since 1990 (Figure 4.3 and Table 4.3) decreased in 1993, 2009–2010, 2015–2016 and continued to decrease in 2020-2023. The decrease in the emissions during the early 1990s was caused by the transition from a planned economy to market economy after 1991 when Estonia became independent. This led to a decrease in industrial production and to an overall decrease in emissions from the Mineral industry between 1991 and 1993. In 1994, the economy began to recover, and production increased.

The increase in the mineral industry during 2007–2008, 2010–2011 and 2017 is attributable to an increase in cement production. In 2009, the Mineral industry sector was affected by economic recession. The decrease in 2015–2016 was mainly caused by insufficient demand in cement markets. In 2017, the output of cement industry recovered, and emissions were higher. In 2020 emissions decreased sharply as in March 2020 clinker production was ceased. The wet process technology was causing high CO_2 emissions and as the CO_2 quota prices started to rise, cement production using previously mentioned technology was not economically feasible anymore.

CO_2 emissions increased in 2012 and 2013 as a power plant used limestone for flue gas desulphurisation. Since 2014 they have been using novel integrated desulphurisation (NID), which uses lime as a reagent. From the year 2014, the use of limestone for flue gas desulphurisation has decreased every year and the last power plant ceased its use in 2017.

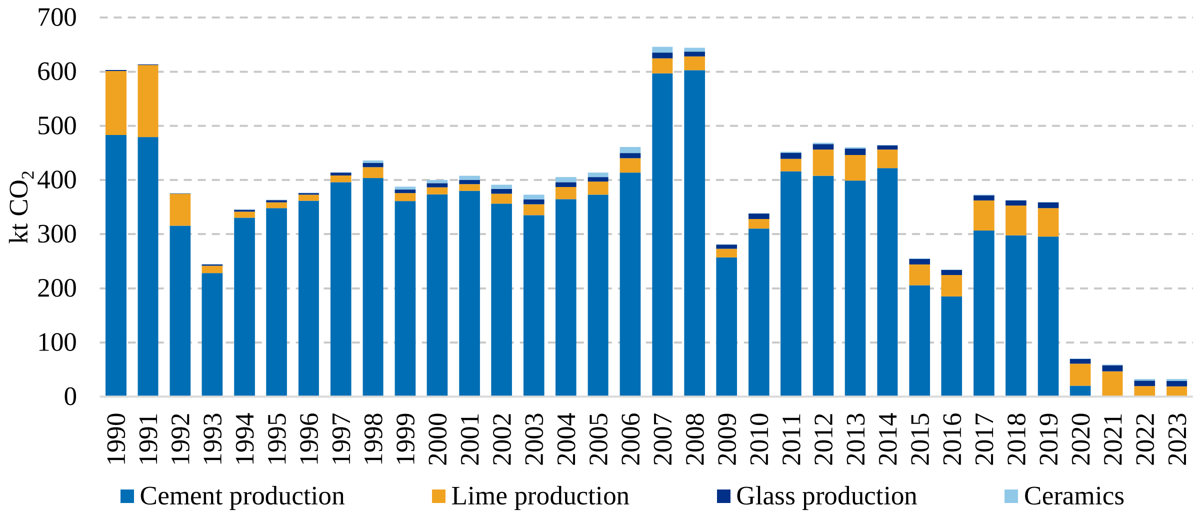

Figure 4.3. CO_2 emissions from Mineral industry in 1990–2023, kt

Table 4.3. CO_2 emissions from Mineral industry in 1990–2023, kt

	1990	2005	2020	2021	2022	2023
2.A.1 Cement production	483.0	372.9	20.1	NO	NO	NO
2.A.2 Lime production	118.8	24.1	40.7	46.8	19.3	18.8
2.A.3 Glass production	1.2	8.1	9.0	11.1	10.2	9.9
2.A.4.a Ceramics	NA	8.5	0.5	1.0	3.2	3.6
2.A.4.b Soda ash use	IE[50]	IE	IE	IE	IE	IE
2.A.4.d Other - Use of limestone for flue gas desulphurization	NO	NO	NO	NO	NO	NO
Total	**603.1**	**413.6**	**70.3**	**58.8**	**32.6**	**32.2**

4.2.1. Category description

2.A.1 Cement production[51]

In cement production, CO_2 is emitted when an intermediate product, clinker, is produced. In that process, limestone is heated to high temperature, which results in emissions, as the main component of limestone, calcium carbonate, breaks down and calcinates into calcium oxide and carbon dioxide. Limestone contains small amounts of magnesium carbonate ($MgCO_3$), which will also calcinate in the process causing CO_2 emissions.

In Estonia, there was only one plant producing clinker and cement until March 2020. Clinker production with wet process was not economically feasible anymore as EU ETS CO_2 price rose rapidly in 2019 and in 2020, therefore clinker production was ceased.

[50] All emissions previously reported under 2.A.4.b are now included into emissions reported under 2.C.5
[51] Historical category

In previous years clinker burning process took place in rotary kilns. Dust caught with rotary kilns electric filters was partly directed into a kiln and partly into dust silo. Oil shale, coal and refuse-derived fuels were the most important fuels in the production process.

SO_2 emissions from cement production were also reported in the CRT and were calculated by the plant and reported to the Estonian Environmental Decisions Information System (KOTKAS[52]).

2.A.2 Lime production

CO_2 emissions from lime production are due to calcination of calcium and magnesium carbonates at high temperatures. In 2023 two plants reported that they have not produced lime and therefore currently there is only one lime production plant.

Production in 2020 decreased because of decreased consumption. Main reason for the decreased consumption was the price increase of lime mainly due to EU ETS CO_2 price increase. In 2022 production decreased due to the high prices of natural gas and remained at the same level in 2023.

2.A.3 Glass production

Under this category, Estonia reports CO_2 emissions from flat glass and container glass production. Currently only container glass is produced in Estonia in one production plant. The plant started to produce container glass in 1992. Flat glass was produced in Estonia from 1990 to 1996.

2.A.4 Other process uses of carbonates

Other process uses of carbonates (CRT category 2.A.4) consists of

- 2.A.4.a Ceramics;
- 2.A.4.d Other – Limestone use for flue gas desulphurization.

2.A.4.a Ceramics

Subcategory 2.A.4.a Ceramics consists of

- Bricks and roof tiles production;
- Lightweight gravel production.

The emissions from different ceramic products are aggregated in the CRT.

Process-related CO_2 emissions result from the calcination of carbonates in clay or additives, e.g., limestone filler. Carbonates are heated to high temperatures in a kiln, producing oxides and CO_2.

Bricks and roof tiles production

Historically in Estonia there have been multiple plants that have produced either bricks or roof tiles or both. Starting from 2012 here has been only one big producer. The output has been fluctuating a lot because of the variance in export demand.

Lightweight gravel production

In lightweight gravel production process-related CO_2 emissions result from the calcination of carbonates in clay. The carbonates are heated to high temperatures in a kiln, producing oxides

[52] https://kotkas.envir.ee/, (12.11.2024)

and CO_2. In the lightweight gravel production plant dolomite is used as a flux. Therefore, CO_2 emissions occur from carbonates in the clay as well from dolomite used as a flux. In 2009–2021, there was no production of lightweight gravel in Estonia. In 2022 and 2023 one company was producing lightweight gravel.

2.A.4.d Other – Limestone use for flue gas desulphurisation

The limestone used for flue gas desulphurisation is one of the by-products from oil shale mining and therefore may contain organic carbon, which is oxidised to CO_2, the majority of which comes from the $MgCO_3$ and $CaCO_3$ contained in the limestone.

Limestone was used by:

1. One of Estonian oil shale firing power plant in large quantities (up to 491 kt yearly) for flue gas desulphurisation only in 2012 and 2013 (afterwards the operator discontinued burning lime in the desulphurisation process and replaced this with novel integrated desulfurisation (NID) technology using quicklime (CaO) as sorbent). The quicklime was purchased from an Estonian lime producer;
2. Two other power plants in 2015–2017 (up to 18 kt yearly).

In 2023 no limestone was used for flue gas desulphurisation in power plants. Instead, oil shale with higher calcium carbonate content was used. Because this calcium carbonate-rich oil shale is fueling the emissions arising from it are accounted for under the Energy sector.

4.2.2. Methodological issues

Choice of methods

2.A.1 Cement production

Emissions from the cement production were calculated using a method compliant with the *Tier 2* method (Equation 4.1) from the IPCC 2006 Guidelines.

Equation 4.1[53]

$$Emissions = EF_{clinker} \times Clinker\ Production \times CKD\ Correction\ Factor$$

Activity data, emission factor and cement kiln dust (CKD) correction factor were given by the cement plant. All measurements and calculations were done according to Regulation (EU) 2018/2066[54] on the monitoring and reporting of greenhouse gas emissions and verified according to EU Directive 2003/87/EC. The plant operators calculated emissions with special software (Cement CO_2 and Energy Protocol software from the World Business Council for Sustainable Development[55]).

[53] IPCC 2006 Guidelines, Volume 3, Chapter 2: Mineral Industry, page 2.9, equation 2.2.
[54] Regulation (EU) 2018/2066. [www] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018R2066 (22.12.2024)
[55] Cement CO_2 and Energy Protocol software from the World Business Council for Sustainable Development [www] https://docs.wbcsd.org/2011/05/CSI-CO2-Protocol.pdf (22.12.2024)

2.A.2 Lime production

The methods for calculating emissions from lime production are consistent with the Tier 2 level method (Equation 4.2) from the IPCC 2006 Guidelines.

Equation 4.2[56]

$$CO_2\ emissions = \sum_i \left(EF_{lime,i} \times M_{l,i} \times CF_{lkd,i} \times C_{h,i}\right)$$

Where:

CO_2 emissions =	emissions of CO_2 from lime production, tonnes;
$EF_{lime,i}$ =	emission factor for lime of type *i*, tonnes CO_2/tonne lime;
$M_{l,i}$ =	lime production of type *i*, tonnes;
$CF_{lkd,i}$ =	correction factor for LKD for lime of type *i*, dimensionless;
$C_{h,i}$ =	correction factor for hydrated lime of the type *i* of lime, dimensionless;
i =	each of the specific lime types.

2.A.3 Glass production

There are two methods in use for calculating CO_2 emissions from glass production.

1. For flat glass production Tier 1 method according to the IPCC 2006 Guidelines is used (Equation 4.3).

According to the Tier 1 method:

Equation 4.3[57]

$$CO_2\ emissions = M_g \times EF \times (1 - CR)$$

Where:

CO_2 emissions =	emissions of CO_2 from glass production, tonnes;
M_g =	mass of glass produced, tonnes;
EF =	default emission factor for manufacturing of glass, tonnes CO_2/tonne glass;
CR =	cullet ratio for process (default), fraction.

Tier 1 method was used since the carbonates used in flat glass manufacturing are not known and only national-level production statistics were available.

2. For container glass production Tier 3 method is used (Equation 4.4).

Equation 4.4[58]

$$CO_2\ emissions = \sum_i (M_i \times EF_i \times F_i)$$

[56] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.21, equation 2.6.
[57] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.28, equation 2.10.
[58] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.28, equation 2.12.

Where:

M_i = weight or mass of the carbonate i consumed, tonnes;
EF_i = emissions factor for the particular carbonate i, tonnes CO_2/tonne carbonate;
F_i = fraction calcination achieved for the carbonate i, fraction.

Emissions from coke that is a component of the glass batch, are accounted in addition to carbonate materials.

2.A.4 Other process uses of carbonates

2.A.4.a Ceramics

The emissions from different brick producers are calculated according to the *Tier 1* (small producers) and *Tier 2* method (large producer). The emissions from lightweight gravel are calculated according to the *Tier 1* method of the IPCC 2006 Guidelines. Data collection and processing is described below by different products (for transparency).

Bricks and roof tiles production

Emissions from ceramic bricks and roof tiles production were calculated using the *Tier 1* (emissions of small producers) and *Tier 2* (large producer) methodology from the IPCC 2006 Guidelines. In the case of the large production plant, from the years 2001-2020 the emissions arose only from limestone filler. From 2021 the emissions are calculated based on the amount of organic carbon used in the clays and $BaCO_3$, as well as on the $CaCO_3$ content of the limestone filler. The organic carbon content of the clay and $BaCO_3$ were declared in the EU ETS report for the first time. The plant uses the same method for reporting their process emissions for EU ETS.

According to the *Tier 1* method (Equation 4.5):

Equation 4.5[59]

$$CO_2\ emissions = M_c \times (0.85 \times EF_{ls} + 0.15 \times EF_d)$$

Where:

CO_2 emissions = emissions of CO_2 from other process uses of carbonates, tonnes;
M_c = mass of carbonates consumed, tonnes;
EF_{ls} or EF_d = emission factor for limestone or dolomite calcinations, tonnes CO_2/tonne carbonate.

and *Tier 2* method (Equation 4.6):

Equation 4.6[60]

$$CO_2\ emissions = M_{ls} \times EF_{ls} + M_d \times EF_d$$

Where:

CO_2 emissions = emissions of CO_2 from other process uses of carbonates, tonnes;

[59] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34, equations 2.14-2.15.
[60] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34, equations 2.15

M_{ls} = mass of limestone consumed, tonnes;
M_d = mass of dolomite consumed, tonnes;
EF_{ls} or EF_d = emission factor for limestone or dolomite calcinations, tonnes CO_2/tonnes carbonate.

Lightweight gravel production

Emissions from lightweight gravel production were calculated using the *Tier 1* methodology from the IPCC 2006 Guidelines (Equation 4.7). According to the *Tier 1* method:

Equation 4.7[61]

$$CO_2\ emissions = M_c \times (0.85 \times EF_{ls} + 0.15 \times EF_d)$$

Where:

CO_2 emissions = emissions of CO_2 from other process uses of carbonates, tonnes;
M_c = mass of carbonate consumed, tonnes;
EF_{ls} or EF_d = emission factor for limestone or dolomite calcinations, tonnes CO_2/tonne carbonate.

2.A.4.d Other – Limestone use for flue gas desulphurization

Emissions from limestone use for flue gas desulphurisation were calculated by multiplying the number of carbonates (e.g., $CaCO_3$) and organic carbon in limestone with respective emission factors and oxidised fractions.

Activity data was gathered directly from the industry. The method for calculating emissions from limestone is consistent with the *Tier 3* level method according to the IPCC 2006 Guidelines[62].

Activity data

2.A.1 Cement production

During emissions calculating from the cement production, the annually produced amount of clinker was used as activity data. The data on clinker production, kiln dust (not recycled to the kiln) and CO_2 emitted from both materials was received directly from the plant for the years 1990-2020. The cement producing plant has calculated uncertainties of EF-s of clinker and kiln dust since weighted average CaO, MgO and free lime content according to the WBCSD Cement Sustainability Initiative standard. The cement kiln dust (CKD) correction factor calculation done by the plant is compliant with the *Tier 2* method from the IPCC 2006 Guidelines[63].

The plant has stated that each year the CKD correction factor differed mainly due to different quantities of cement kiln dust, but also calcination rate of CKD, CaO and organic content of the clinker and ash content of the alternative fuels used in kilns are slightly different in various years. The plant followed the national legislation on the best available technology[64] and European Commission's best available techniques (BAT) reference document[65] to reduce

[61] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34, equation 2.14.
[62] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.36.
[63] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.13, equation 2.5.
[64] https://www.riigiteataja.ee/en/eli/ee/510012019010/consolide/current, (22.12.2024)
[65] https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CLM_Published_def_0.pdf, (22.12.2024)

emissions and continuously improve the dust control technology of the production. There is no BAT reference document nor any legal act that specifies how much kiln dust should be recycled. The plant optimised clinker burning process to recycle maximal amounts of dust to kiln. In 1990–2006 the calcination rate of CKD was 82% and in 2007–2020 the corresponding rate was 79%.

Data on clinker production as well as CKD correction factors between 1990–2020 are presented in Table 4.4.

Table 4.4. Activity data for clinker production in 1990–2020

2.A.1 Cement production	**1990**	**2005**	**2015**	**2019**	**2020**
Clinker production, kt	790.3	635.4	356.3	503.6	35.0
CKD correction factor	1.113	1.073	1.034	1.055	1.037

2.A.2 Lime production

Activity data for lime production is collected mainly directly from industry and taken partly from industrial statistics (1990–1996). From 1990–1996 several lime producing plants were operating in Estonia and industrial statistics together with direct activity data from the industry have been used to calculate emissions. From 1997 two lime producing plants continued operation and a third one started operation in 2014 and their activity data has been collected directly from the industry and EU ETS reports (1997–2023).

Data on lime production between 1990–2023 is available in Table 4.5.

Table 4.5. Activity data for lime production in 1990–2023

2.A.2 Lime	**1990**	**2005**	**2020**	**2021**	**2022**	**2023**
Lime production, kt	185.0	37.2	54.8	63.8	24.9	23.9

2.A.3 Glass production

The consumption of limestone, sodium carbonate and coke has been used as activity data when calculating emissions from container glass production. Activity data (1993-2023) was collected directly from the glass producing plant and EU ETS reports.

Activity data for calculating emissions from the flat glass production is based on national statistics, however the numbers were corrected for the quantity of cullet used in glass production. The default cullet ratio of 50% was considered and national level data on the mass of flat glass produced was multiplied by $0.20 \times (1 - 0.50) = 0.10$ tonnes CO_2/tonnes glass produced.

Data on glass production between 1990–2023 are available in Table 4.6.

Table 4.6. Activity data and emission factors for container and glass production in 1990–2023

2.A.3 Glass	**1990**	**2005**	**2020**	**2021**	**2022**	**2023**
Container glass production, kt	NO	62.1	76.7	76.9	78.6	68.8
Limestone consumption, kt	NO	8.6	10.5	12.85	11.73	11.23
Sodium carbonate consumption, kt	NO	10.20	10.55	12.92	11.97	11.60
Coke consumption, t	NO	36.33	24.51	26.86	24.4	20.8
Flat glass production, kt	12.3	NO	NO	NO	NO	NO

2.A.4 Other process uses of carbonates

2.A.4.a Ceramics

Bricks and roof tiles production

Mass of carbonates in consumed clay has been used as activity data when calculating CO_2 emissions from small brick plants.

The emissions from the large plant were calculated based on limestone filler, which is in line with the method used by the plant calculating the emissions from the years 2001-2023. For calculation based on limestone filler, the exact $CaCO_3$ content of the limestone filler used is provided by the plant. The same goes for barium carbonate and the organic C content of the clays, which were declared by the larger producer for the first time in 2021. The EF and process-related emissions from the Estonian bricks and tiles industry result from the calcination of carbonates in the clay or used additives, e.g., limestone filler, the content of which is small and fluctuates depending on customer request (e.g., a higher limestone filler content produces more yellowish bricks and tiles). The $MgCO_3$ content is negligible.

Data on the amount of clay, organic carbon content of the clays used (in case of the larger producer), barium carbonate (in case of the larger producer), and limestone filler used in brick production were directly collected from the plants in 1992 to 2023. The amount of clay consumed in brick production in 1990–1992 was calculated by multiplying production with a default loss factor of 1.1. In 1993, only two small plants produced ceramic bricks in Estonia. Data on the amount of clay used in the production of roof tiles has been directly collected from the plant since 1997 (production of ceramic roof tiles began in 1997).

As no other information was available, the default carbonate content of 10%[66] was applied for the clays used by small producers. It was assumed that 85% of the carbonates consumed are limestone and 15% of the carbonates consumed are dolomite[67].

For the years 1992–2023 data about bricks production was directly collected from the plants. This includes the precise amounts of the organic carbon used in the clays, $BaCO_3$ and limestone filler used by one producer and amounts that are estimated by the *Tier 1* method for other producers. The amounts of bricks produced between the years 1990–2000 was taken from industrial statistics for one company. Data on the production of ceramic roof tiles were received directly from the plant for all the years (Table 4.7).

As in 1990–1991, the only operational tile producer used a type of clay that did not contain carbonates, there was no CO_2 emission from production.

Table 4.7. Activity data of bricks and tiles and lightweight gravel production in 1990–2023

	1990	2005	2020	2021	2022	2023
Production of ceramics, kt including:	251.1	184.6	36.9	36.2	107.7	119.1
Production of bricks and tiles, kt	251.1	69.0	36.9	36.2	47,2	17.0
Production of lightweight gravel, kt	NO	115.6	NO	NO	60.5	102.1
High-calcium limestone consumption for all ceramics (limestone filler + 85% of carbonate component of some type of clay), kt	NO	14.13	1.16	1.28	0.63	0.21
Dolomite consumption (15% of carbonate component of some type of clay), kt	NO	4.8	0.0002	0.0001	1.1	1.6

[66] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34
[67] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.36.

Lightweight gravel production

Mass of carbonates consumed has been used as an activity data when calculating CO_2 emissions from lightweight gravel production (see Table 4.7). Data about the amount of clay used for lightweight gravel production was directly collected from the plant from 1998 to 2008. As no other information was available, the default carbonate content of 10% was applied to clays. It was assumed that 85% of the carbonates consumed are limestone and 15% are dolomite[68]. In 2022-2023 data about the amount of clay used was received from the EU ETS report.

Data on production of lightweight gravel was received directly from the plant for all years in 1998–2008 and in 2022-2023 (Table 4.7).

2.A.4.d Other – Limestone use for flue gas desulphurization

Activity data on limestone use was provided by the three power plants.

Data on limestone use for flue gas desulphurisation in 2012–2013 and 2015–2017 is presented in CRT.

Emission factors

2.A.1 Cement production

Emission factors used in calculating the emissions from cement production were provided by the plant. Emission factors varied slightly due to the parameters (i.e., amount of kiln dust, CaO and MgO content of the clinker) affecting them from year to year.

Emission factors from cement production were based on the actual CaO and MgO contents of clinker. Cement kiln dust and bypass dust as well as the amounts of CaO and MgO that were already calcinated before the process (and therefore do not cause emissions) were considered at the plant.

Data on emission factors between 1990–2020 are presented in Table 4.8.

Table 4.8. Emission factors for clinker production in 1990–2020

2.A.1 Cement production	1990	2005	2015	2019	2020
EF, t/t	0.549	0.547	0.558	0.556	0.555
$EF_{default}$	0.52				
CKD correction factor	1.113	1.073	1.034	1.055	1.037
CKD correction $factor_{default}$	1.02				

2.A.2 Lime production

Four different emission factors were used to calculate emissions from lime production. The first of them is used for historical lime plants (for the years 1990-1996). For the years 1990-1996 activity data was collected directly from plants producing lime and industrial statistics were used to calculate emissions from plants closed during 1990-1996. For the years 1990-1996 we used production data from Statistics Estonia and the implied emission factor to calculate emissions for those plants for which we did not receive company-based information. This data was combined with data received from lime plants from which we did get information from and for which we used company-based emission factors.

From 1997 onwards we have received data from all lime producing plants working in Estonia and have thereafter used company-based data. The emission factors used for all the lime plants

[68] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.36.

from which we have received company-based data have stayed the same throughout the time series. Two bigger plants that have had the obligation to submit their EU ETS reports have calculated emission factors: 1) using values from national regulation as allowed by EU Regulation (EU) No 601/2012 on monitoring and reporting. The Estonian Minister of the Environment Regulation No 86 of 27th December 2016 on calculation methods of the amount of CO_2 discharged into the ambient air[69] or 2) based on chemical analyses of carbonate content. Since 2005 the biggest plant started giving emission factors based on actual CaO and MgO contents. The EFs of CaO and MgO are calculated based on the ratio of molecular weight of CO_2 to CaO/MgO.

Table 4.9. Emission factors used in 1990-2023 and comparison with IPCC default values

2.A.2 Lime	**Emission factors (years)**						
IEF, t/t*I	0.64 (1990-1996)						
$EF_{plant-specific}$, t/t**	0.79 (2014-2023)						
$EF_{plant-specific}$, t/t***	0.64 - 0.70 (1990-2022)						
$EF_{plant-specific}$, t/t****	0.82 (1994-2022)						
Year	1990	2005	1999	2020	2021	2022	2023
IEF_{lime},t/t	0.70	0.65	0.72	0.74	0.73	0.77	0.79
IPCC default values[70]:	0.77						

*For historical lime plants in 1990–1996 the implied emission factor was used
**One of the bigger plants uses value from national regulation as allowed by EU Regulation (EU) No 601/2012 on monitoring and reporting. The Estonian Minister of the Environment Regulation No 86 of 27th December 2016 on calculation methods of the amount of CO_2 discharged into the ambient air stipulates the emission factor 0.7857 t CO_2/t for lime. This emission factor is appropriate for producing lime from Estonian limestone, which has high calcium content and contains maximally 3% of magnesium oxide.
***The biggest plant's emission factors of CaO and MgO are calculated based on the ratio of molecular weight of CO_2 to CaO/MgO and have been available since 2005. As this emission factor differs from the default emission factor, emission factors for 1990–2004 are established as a mean value from the emission factors in 2005–2008.
****The smallest lime plant has been estimating their emission factor since 1994.

The recalculations done in the 2010 submission of the NIR (chapter 4.2.2.5. Source-specific recalculation) on the recommendation of the UNFCCC Review Team show differences in the emissions using company-based data and default emissions. Source-specific recalculations on page 130 (NIR 2010) stated that emissions from lime production were recalculated throughout the time series. Emissions in 1990-1996 were recalculated due to applying plant specific emission factors to two production plants. Emissions in 1997-2007 were recalculated due to better activity data and plant specific emission factors available. Those recalculations were recommended by 2009 UNFCCC Review Team and in the results of Twinning Light Project EE06-IB-TWP-ENV06.The same EFs have been used also for later years.

Correction factor for the lime kiln dust is 1 in case of both bigger lime plants.

Historically, the operator of the biggest (until 2021) plant explained that all products that leave the kiln (including kiln dust) are sold, and these products have already been considered when calculating CO_2 emissions. One part of dust is returned to the kiln, and another part is sold as a product. Product of low quality is sold for filling mines. In the environmental permit of the plant (number 20971[71]) it is explained that lime kiln dust is captured in different stages of production by flue gas filters, bag filters and aspiration system more efficiently than required by BREF[72]. This complies with the fact that in their annual waste report the plant reports no mineral waste.

[69] https://www.riigiteataja.ee/akt/108032019006?leiaKehtiv, (22.12.2024)
[70] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.22
[71] Database of Estonian environmental permits, https://kotkas.envir.ee/permits/public_view?permit_id=129739, (22.12.2024).
[72] https://eippcb.jrc.ec.europa.eu/reference, (13.11.2024).

The environmental permit and e-mail from the plant operators can be provided to reviewers on request.

The only operator in 2023 confirms that almost all of kiln dust arises from crushing the burnt lime after the lime is weighed. CO_2 emissions are calculated based on this weight. If there is inferior lime generated it is recycled to the kiln. The operator confirms that CO_2 emission from the calcination process of inferior lime (including kiln dust) is accounted for in their EU-ETS report.

The correction factor for hydrated lime is 1 because all plants give data on produced quicklime before it is hydrated.

Glass production (CRT 2.A.3)

Emission factors for calculating emissions from limestone use are based on the actual $CaCO_3$, $MgCO_3$ content of limestone and this data is provided by the plant. The plant operators provided exact carbonate content of limestone for the years 2006–2023. The plant operators estimated that the carbonate content of the limestone used in 1992–2005 was approximately the same as in the later years. Therefore, the average values of the $CaCO_3$ and $MgCO_3$ contents of the limestone used in 2006–2012 were applied for 1992–2005. The emission factors used for $CaCO_3$, $MgCO_3$ and Na_2CO_3 are the ones from the IPCC 2006 Guidelines and are based on stoichiometric ratios. The emission factor for limestone is then (Equation 4.9):

Equation 4.9[73]

$$EF_{limestone} = EF_{CaCO3} \times part\ of\ CaCO_3 + EF_{MgCO3} \times part\ of\ MgCO_3$$

Where:

part of $CaCO_3$/$MgCO_3$ = fraction of $CaCO_3$ or $MgCO_3$ in limestone.

The emission factors for calculating emissions from flat glass production are based on the IPCC default factors[74]. For the calculation of CO_2 emissions from flat glass, an emission factor 0.20 t of CO_2 per tonne of glass is used.

The emission factors for coke are provided by the plant and are based on the carbon content of the coke.

2.A.4 Other process uses of carbonates

2.A.4.a Ceramics

Bricks and roof tiles production

Data on emission factors are available in Table 4.10 and as it can be seen from there that IPCC default EF-s for calcium carbonate (0.43971) and dolomite (0.47732) are used. The proportion of these substances in raw material is actually small – corresponding amounts are shown in Table 4.7 row 'High-calcium limestone consumption for all ceramics (limestone filler + 85% of carbonate component of some type of clay), kt.

[73] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.
[74] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.29, equation 2.13.

Table 4.10. Emission factors for bricks and roof tiles production in 1990–2023

	1990	2005	2020	2021	2022	2023
IEF of bricks and roof tiles, t CO_2/t products	NA	0.008	0.014	0.029	0.030	0.017
$EF_{default}$ t/t ($CaCO_3$)	0.43971					
$EF_{default}$ t/t ($CaMg(CO_3)_2$)	0.47732					

Lightweight gravel production

Emission factors for calculating emissions from limestone and dolomite use are based on the IPCC default factors[75]. For the calculation of CO_2 emissions from limestone use, the emission factor 0.43971 t of CO_2 per tonne of limestone is used. For the calculation of CO_2 emissions from dolomite use, emission factor the 0.47732 t of CO_2 per tonne of dolomite is used. In 2022-2023 emission factor from ETS report was used as it was received with the laboratory analysis.

Table 4.11. Emission factors for lightweight gravel production in 1990–2023

	1990	2005	2019	2020	2021	2022	2023
IEF of lightweight gravel, t CO_2/t product	NO	0.068	NO	NO	NO	0.029	0.032
$EF_{default}$ t/t ($CaCO_3$)	0.43971						
$EF_{default}$ t/t ($CaMg(CO_3)_2$)	0.47732						

2.A.4.d Other – Limestone use for flue gas desulphurization

Calculation methods for emission factors are adapted from verified EU ETS reports from three power plants and modified in the case of two plants. All EF-s are based on the carbonate content of the limestone. As EU Regulation No 601/2012 allows several methods for emission factor calculations and due to differences in burning processes (e.g., temperatures), the methodology applied for the different plants vary somewhat.

The plant which used large quantities of limestone has done chemical analyses for determination of $CaCO_3$, $MgCO_3$ and organic carbon content of limestone. For CO_2 from $CaCO_3$ the default emission factor of 0.43971 t CO_2 per tonne and for $MgCO_3$ the respective default emission factor of 0.52197 t CO_2/t was used[76]. The oxidised fraction was provided by the plant and was 100% (because of high temperature burning). For CO_2 from the oxidation of organic carbon, the emission factor was based on relation of molecular weights of carbon dioxide and carbon (44/12=3.66667) and data on the oxidised fraction was provided by the plant.

The smaller plants have determined the carbonate content of limestone by chemical analysis. They have used either plant-specific oxidation factor of the carbonates (because of low-temperature burning) or default oxidation factor best suitable for their burning process as stipulated in the relevant national regulation ("Calculation methods of CO_2 emitted to ambient air")[77].

4.2.3. Uncertainty assessment and time-series consistency

For uncertainty assessment please see Annex A.II.2 IPPU, 2.A Mineral industry chapter.

[75] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.
[76] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.
[77] https://www.riigiteataja.ee/akt/108032019006?leiaKehtiv, (22.12.2024)

4.2.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for Industrial processes and product use sector according to the IPCC *Tier 1* method.

2.A.1 Cement production

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the Industrial processes and product use sector according to the IPCC *Tier 1* method.

Activity data was compared with the data from Statistics Estonia to exclude the possibility of other cement production plants. The completeness of the category was also checked from the Estonian Environmental Decisions Information System (KOTKAS[49]).

The emissions of 2005–2020 were compared to the EU ETS data. Differences were zero to 0.00009 % at the most during this period. The cause of the differences was that the emissions in the EU ETS reports were rounded to the nearest ton (according to the Regulation (EU) 2018/2066 the emissions must be submitted with the accuracy of 1 ton).

In 2021-2023 the plant had no obligation to submit its EU ETS report as no production took place during that year.

2.A.2 Lime production

The completeness of the category was checked from the Estonian Environmental Decisions Information System (KOTKAS[49]), national database of environmental permits and EU-ETS reports. No other lime production plants were found.

Lime production reported in the GHG inventory was compared with data from Statistics Estonia. Statistics Estonia has somewhat different methodology regarding lime production.

The emissions been compared with EU ETS data in the period of 2005-2023. Differences between emissions reported to the EU ETS and GHG inventory have been 0.005% at the most in this period. The cause of the differences was that the emissions in the EU-ETS reports were rounded to the nearest ton (according to the Regulation (EU) 2018/2066 the emissions must be submitted with the accuracy of 1 ton) but the emissions in the GHG inventory are not rounded.

2.A.3 Glass production

The completeness of the category was checked from the Estonian Environmental Decisions Information System (KOTKAS[49]), national database of environmental permits and EU-ETS reports.

Data on produced glass provided by the plant was compared with data on produced glass from Statistics Estonia. The data from both sources agreed. It can be concluded that there are no other glass production plants in Estonia.

The CO_2 emission from glass production and amounts of raw materials used as reported in 2025 submission were compared with respective data from EU ETS. The amounts of limestone, soda ash and coke were identical in ETS and GHG inventory.

2.A.4 Other process uses of carbonates

2.A.4.a Ceramics

Bricks and roof tiles production, Lightweight gravel production

For completeness check, the Estonian Environmental Decisions Information System (KOTKAS[49]) was checked and no other plants were found.

The activity data was compared with the data from Statistics Estonia but as some plants are providing aggregated data on their production and imports to Statistics Estonia, the data does not match 100%.

2.A.4.d Other – Limestone use for flue gas desulphurisation

The Estonian Environmental Decisions Information System (KOTKAS) and EU ETS reports were checked and no other plants that use limestone for flue gas desulphurisation, were found.

CO_2 emission reported in the CRT were compared with emissions reported to EU ETS. The differences are caused by the conformation of different emission factor calculation methods of different companies (more information in paragraph Emissions factors).

4.2.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

Recalculations were done for the years 1990-1996 due to the change in the emission factor values. The UNFCCC 2022 review suggested to use implied emission factor for the plants for which company based data was not available. Implied emission factors were calculated based on the data received from other companies operating in 1990-1996 (Table 4.12).

Table 4.12. Recalculations in the emissions from lime production for the years 1990-1996

Emissions	1990	1991	1992	1993	1994	1995	1996
kt CO_2 , 2024 submission	129.69	141.78	63.84	15.62	13.51	12.38	12.31
kt CO_2 , 2025 submission	118.84	132.97	59.10	13.49	11.58	10.82	11.20
Difference, kt CO_2	10.85	8.81	4.74	2.14	1.93	1.57	1.11

4.2.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

There are no planned category-specific improvements.

4.3. Chemical industry (CRT 2.B)

4.3.1. Category description

2.B.1 Ammonia production

This category of the inventory includes the non-fuel emissions from natural gas used for ammonia production. In Estonia, there has been one ammonia production plant.

In 2014–2023, no NH_3 production took place at this plant. The plant operator has announced that it has sold all its production equipment and no longer plans to continue ammonia production activities, as ammonia production in Estonia has not been profitable since 2014 due to low global market prices for ammonia and rising natural gas prices.

Regarding earlier years, CO_2 emissions from ammonia production have decreased considerably since 1990, having the lowest values in 1993, 2002 and 2009. In 2009, the plant temporarily stopped production at the beginning of February. In 2010–2011, there was no production of ammonia in Estonia. The plant restarted ammonia production at the beginning of December in 2012 and production continued until September 2013. The decrease in the emissions during the early 1990's was caused by the transition from planned economy to a market economy after 1991 when Estonia became independent. This led to a decrease in industrial production, and to an overall decrease in emissions from industrial processes between 1991 and 1993. In 1994, the economy began to recover, and production started to increase, emissions stabilised till 2002 and 2003 when there was a sudden decrease in emissions. In 2002, 2003 and 2008, reconstructions of the plant took place that strongly affected production. The lowest point in production and in emissions was in 2009.

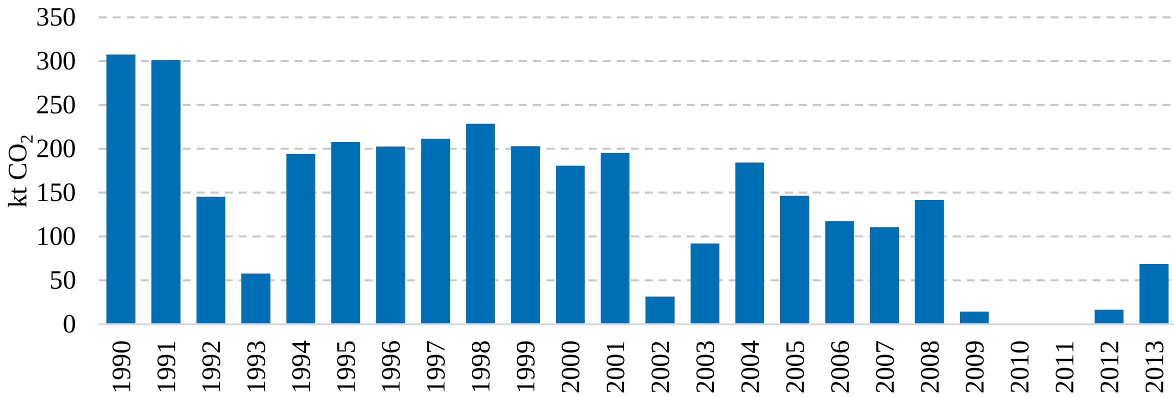

Figure 4.4. CO_2 emissions from Chemical industry in 1990–2013, kt

4.3.2. Methodological issues

Choice of methods

2.B.1 Ammonia production

Estonia has accounted under Industrial processes and product use sector only the natural gas used as feedstock for primary steam reforming. The amount of natural gas combusted was reported under Energy sector 1.A.2.c. The reason for such accounting is that it would be very difficult to subtract the combusted gas from the Joint Questionnaire dataset. In the Joint Questionnaire dataset provided by Statistics Estonia, it is not possible to split by single plants.

Emissions of CO_2 depend on the amount and composition of gas used in the technological process and whether and how much carbon is captured in produced urea.

A part of the CO_2 from ammonia production was captured for urea (carbamide) production. The most part of CO_2 captured in urea is subtracted as following:

1. Since 2015 submission the carbon dioxide captured in urea which was sold in Estonia as fertilizer is subtracted from emissions. It is accounted for under the Agriculture sector, 3.H. Urea application together with imported urea that was used as fertilizer.
2. CO_2 captured in produced urea that was exported thereafter was subtracted. The most part of the produced urea was exported each year. Imported urea solutions that are

used as catalysts in motor vehicles exhaust gas systems are accounted for under subsector 2.D.3 Other.

Estonia uses method Tier 3 in calculating CO_2 emissions from ammonia production (Equation 4.10. According to the Tier 3 method:

Equation 4.10[78]

$$CO_2\ emissions = \sum_i (TFR_i \times CCF_i \times COF_i \times 44/12) - R_{CO2}$$

Where:

TFR_i = total fuel requirement for fuel type i, GJ;
CCF_i = carbon content factor of the fuel type i, kg C/GJ;
COF_i = carbon oxidation factor of the fuel type i, fraction;
R_{CO2} = CO_2 recovered for downstream use (urea production, CO_2 capture and storage (CCS)), kg.

The plant-specific consumption of CO_2 for urea production is 0.75 t CO_2/t urea.

Activity data

2.B.1 Ammonia production

The annual ammonia production figures for the years 1990–2013 have been provided by the production plant. Consumption of natural gas feedstock in millions m^3 at 1 atm pressure and 20 degrees C and in terajoules (TJ) in the years 1990–2003 and 2005–2013 have been provided by the production plant to Statistics Estonia. This data was included in the energy balance (category "non-energy use of fuels") by Statistics Estonia. Concerning gas feedstock quantity used in 2004, the plant provided retrospectively corrected data to the inventory compiler, however no correction has been made concerning statistical data. Corrected gas feedstock quantity for the year 2004 was used in the GHG inventory.

The plant also provided data on the amount of the urea exported and the urea sold in Estonia as fertilizer in years 2004–2013, but data in 1990–2003 were not available.

- It was assumed, that the urea sold in Estonia as fertiliser between 1990–2003 constituted the same per cent from total yearly production of urea as the average of the years 2004–2009.

It was assumed that urea exported between 1990–2003 constituted the same per cent from the total production of urea each year than in 2003–2005.

Activity data from ammonia production in 1990–2023 are in Table 4.13.

Table 4.13. Activity data (and its differences to statistical data ammonia production in 1990–2023)

2.B.1	1990	2005	2010–2011	2012	2013	2014–2023
Ammonia production, kt	294.0	212.6	NO	17.2	120.9	NO
Amount of natural gas used as feedstock, million m^3	227	146	NO	13	83	NO
Amount of natural gas used as feedstock, TJ	7 657	4 915	NO	448	2789	NO
Carbon content of natural gas, t C/TJ	15.1	15.0	NO	14.8	15.1	NO
Difference of natural gas feedstock AD (TJ) to statistical data, %	0.0	0.0	NO	0.0	0.0	NO

[78] IPCC 2006 Guidelines, Volume 3, Chapter 3, page 3.13.

Emission factors

2.B.1 Ammonia production

Emission factors were calculated by dividing CO_2 emissions (without subtracting recovered amounts) from technological process with the amount of ammonia produced.

Emissions were calculated based on the amount of natural gas used as feedstock and the carbon content of gas. Data on the carbon content of the gas was provided by the industry directly to the inventory compilers. The amount of gas feedstock was provided by the industry to Statistics Estonia and from Statistics Estonia to inventory compilers. The emission factors for calculations of CO_2 emissions from ammonia production were plant specific throughout time series. In Estonia, ammonia production emission factors have varied between 1.276–1.516 t CO_2/tonne of NH_3 produced.

The carbon content of the gas was calculated by the gas supply network operator using the results of monthly gas compositional analyses. The carbon content was determined at gas parameters at 0 degrees Celsius and 1 atmosphere of pressure and recalculated to 20 degrees and 1 atm pressure for emission calculations.

For carbon oxidation factor the default value 1 was used.

Emission factors from ammonia production in 1990–2023 are in Table 4.14.

Table 4.14. Emission factors for ammonia production in 1990–2023

2.B.1	1990	2005	2010–2011	2012	2013	2014–2023
$EF_{ammonia}$, t/t (recovered amounts subtracted)	1.4	1.3	NO	1.4	1.3	NO

4.3.3. Uncertainty assessment and time-series consistency

For uncertainty assessment please see Annex A.II.2 IPPU, 2.B Chemical industry chapter.

4.3.4. Category-specific QA/QC and verification, if applicable

Ammonia production (CRT 2.B.1)

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for Industrial processes and product use sector according to the IPCC Tier 1 method.

The emissions in 2008–2013 have been compared with respective EU ETS reports. The differences in quantities of natural gas used as feedstock (converted to 20 degrees C and 1 atm) were 0.5% or less in 2008–2009 and 2013. In 2012, the difference was 2.5% because the consumption of natural gas was very small, and statistical data is rounded to millions m^3. Quantitative comparison can be provided to the ERT on request.

The completeness of the category was checked from the Estonian Environmental Information Decisions Information System (KOTKAS) and no other ammonia production plants were found.

The 2016 UNFCCC Review Team also asked Estonia to provide an outcome of the comparison between operator data on gas feedstock AD and the allocation of non-energy use of fuels in the Joint Questionnaire dataset from Statistics Estonia[79]. The differences in gas feedstock AD that Statistics Estonia used in the Joint Questionnaire dataset non-energy use of fuels and that is used for GHG inventory 2.B.1 are included in Table 4.12. For 1990–2003 and 2005–2013

[79] ARR2016/ Table 5. I.9 IPPU

Estonia uses the data provided by the operator to Statistics Estonia and for that dataset and there are no differences. The difference in year 2004 is because the plant operator retrospectively corrected natural gas quantity – recalculated from 0 degrees C and 1 atm to 20 degrees C and 1 atm. In the GHG inventory the corrected gas amount is used for emission calculation.

4.3.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

2.B.1 Ammonia production

No category-specific recalculations were done.

4.3.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

2.B.1 Ammonia production

There are no planned category-specific improvements.

4.4. Metal industry (CRT 2.C)

In this category Estonia reports emissions from:

1. production of secondary lead;
2. soda ash and ammonium bicarbonate use and from calcination of rare earth metal carbonates into oxides in rare metals and rare earth metals and compounds industry.

In CRT CO_2 emissions from both categories are aggregated and reported under 2.C.5 – Lead production. Most emissions arise from lead production.

In CRT, on the row Activity Data, the production volume of secondary lead aggregated with production volume of rare earth element (REE) compounds is provided. Before 2003 when the lead recycling plant production started, the rare metals and rare earth metals production plant was the only one in this category. Its production volumes are confidential and notation key 'C' is reported in CRT for the years 1990–2002.

The reason why emissions from soda ash used in rare metals and rare earth element production are aggregated with emissions from lead production is that there is only one plant in each category and majority of their data on production volumes, intermediates, hints to technologies (e.g., process reactions) are confidential. Estonia has reported emissions solely from the beforementioned two production plants under category 2.A.4.b Other uses of soda ash in submissions before 2017. The reason why these emissions are now reported under subsector 2.C is that coal used as reducing agent could not be reported in category 2.A.4.b.

The methodology of calculation of emissions from secondary lead production and soda ash use in rare metals and rare earth metals and compounds industry is described separately in following subparagraphs.

4.4.1. Category description

2.C.5 Lead production

In Estonia lead is produced only by one plant which started production in 2003.

Lead is produced from scrapped lead acid batteries using soda ash desulphurisation and pyrometallurgical process.

Spent batteries are scrapped and sulphuric acid is drained. Lead paste ($PbSO_4$) is desulphurised with Na_2CO_3. Desulphurised lead paste consisting mainly of $PbCO_3$ is subjected to thermal reduction with anthracite in rotary furnace and metallic lead is produced.

Sulphuric acid drained from batteries and residual solutions are neutralised with Na_2CO_3.

The lead battery recycling plant was launched in autumn 2003 and therefore emissions were small in the first year.

Emissions arise from:

1) neutralisation of sulphuric acid with soda ash and;

2) reduction-oxidation reaction between coal and lead carbonate in the smelting process.

In 2023 emissions from the category 2.C were 3.0 kt CO_2.

Emissions from rare metals and rare earth metals and compounds industry (reported under CRT category 2.C.5 Lead production aggregated with emissions from lead production)

Separation and production of rare metals and rare earth metals and compounds started in 1970 in Estonia in one production plant. The same plant is operating to this day. Rare earth metal raw material is dissolved in acid and then precipitated with sodium carbonate and ammonium bicarbonate. Some of the produced rare earth metal carbonates are calcinated to oxides.

4.4.2. Methodological issues

Choice of methods

2.C.5 Lead production

Estonia uses the *Tier 3*[80] method in calculating CO_2 emissions from lead production. Data on raw materials and products is supplied by the production plant. The plant does not have to submit EU ETS report on GHG and therefore calculations are done by the GHG inventory compiler. This is done by considering the following:

1. Emissions from soda ash reaction with sulphuric acid in neutralisation process are calculated by multiplying the stoichiometric ratio of CO_2/Na_2CO_3 with the amount of used carbonates (Equation 4.11). 100% of soda ash is reacting with acid;
2. Emissions from anthracite used for the reduction of lead paste are calculated by multiplying the stoichiometric ratio of CO_2/C with quantity of used anthracite and carbon content of anthracite.

[80] IPCC 2006 Guidelines, Volume 3, Chapter 4, page 4.73

The summarised reaction can be described by the following equation:

Equation 4.11

$$PbSO_4 + Na_2CO_3 + C = Pb + CO + CO_2 + Na_2SO_4$$

Emissions from rare metals and rare earth metals and compounds industry (reported under CRT category 2.C.5 Lead production aggregated with emissions from lead production)

Emissions are calculated based on soda ash and ammonium bicarbonate consumption in: 1) rare earth element (REE, mostly La and Ce) separation (mostly) and 2) neutralisation of residual solutions and gases in rare metals production. In addition, there are emissions arising from calcination of rare earth metal carbonates to oxides.

Estonia uses the *Tier 3* method of category 2.A.4 Other process uses of carbonates for calculating CO_2 emissions from soda ash and ammonium bicarbonate used in rare metals and REE compounds production. Emissions from soda ash use are calculated by multiplying emission factor (0.41492) with the amount of used soda ash. Emissions from ammonium bicarbonate are calculated by multiplying the emission factor with the amount of used ammonium bicarbonate (the EF – 0.278481013 is the same for precipitating La as well as Ce(III) carbonates). The emission factor is derived based on chemical equation of ammonium bicarbonate reacting with rare earth metal nitrates. The exact calculation can be provided to the review when requested.

Emissions from rare earth metal carbonate calcination occur according to the formula:

Equation 4.12

$$La_2(CO_3)_3 = La_2O_3 + 3CO_2$$

Activity data

2.C.5 Lead production

The quantity of soda ash used for sulphuric acid neutralisation as well as the quantity and carbon content of anthracite used as a reducing agent are provided by the plant. Table 4.15 presents the quantities of consumed anthracite in lead production and aggregated quantities of soda ash and ammonium bicarbonate used in lead and rare metals and rare earth metals production. Aggregation is because of confidentiality reasons.

Table 4.15. Quantities of anthracite consumed in lead production and soda ash and ammonium bicarbonate consumed in lead production and rare and rare earth metal production

Material use	**1990**	**2005**	**2020**	**2021**	**2022**	**2023**
Anthracite use kt	NO	0.309	0.668	0.676	0.554	0.670
Soda ash and ammonium bicarbonate use, kt	1.87	1.48	2.26	2.44	2.51	2.38

Emissions from rare metals and rare earth metals and compounds industry (reported under CRT category 2.C.5 Lead production aggregated with emissions from lead production)

The quantities of soda ash used by the plant in 1998, 2002-2021 (the rest of the years the quantities are interpolated) and the production volume of REE compounds since 1995 are supplied by Statistics Estonia. Quantities of ammonium bicarbonate used in 2000 and 2006-

2021 were obtained from the air pollution reports (supplied by the Environmental Board) and the possible quantities consumed in 1990-2005 were derived from the relation of REE concentrate use as raw material and quantity of ammonium bicarbonate used in 2000. In 2022-2023 quantities of ammonium bicarbonate and REE concentrate was asked from the manufacturing plant.

The quantities of REE concentrate in 2004-2021 are from reports on air pollution and quantities in 1990-2006 are from old newspaper articles (e.g., Äripäev, 1995[81], Äripäev, 1998[82]).

Emission factors

2.C.5 Lead production

The emission factor of soda ash is 0.41492[83]. The emission factor of anthracite is carbon content multiplied with EF of the carbon – 44/12.

Emissions from rare metals and rare earth metals and compounds industry (reported under CRT category 2.C.5 Lead production aggregated with emissions from lead production)

The emission factor of ammonium bicarbonate is 0.278481013. The fractions of reacted soda ash and ammonium bicarbonate are assumed to be 1.

The emission factor of rare earth metal carbonate calcination is 0.139240506. This is calculated as follows:

Equation 4.13

$$\frac{44(M_{CO2}) * 3(stoich.coeffiecient) * 0.5\ (50\%\ of\ carbonates\ are\ calcined)}{79\ \left(M_{NH4(HCO3)}\right) * 6(stoich.coefficient)}$$

where M is molecular mass.

4.4.3. Uncertainty assessment and time-series consistency

2.C.5 Lead production

For uncertainty assessment please see Annex A.II.2 IPPU, 2.C Metal industry chapter.

4.4.4. Category-specific QA/QC and verification, if applicable

2.C.5 Lead production

The inventory compiler asked Statistics Estonia if anthracite use is accounted in the national energy balance, and it was not the case.

The quantities of consumed soda ash and anthracite were checked from the Estonian Environmental Decisions Information System (KOTKAS). No differences were found.

[81] Äripäev, 1995 https://www.aripaev.ee/uudised/1995/12/03/silmet-otsib-uusi-partnereid, (22.12.2024).
[82] Äripäev, 1998 https://www.aripaev.ee/uudised/1998/11/19/silmet-ootab-kasumit, (22.12.2024).
[83] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1

Emissions from rare and rare earth metals and compounds industry (reported under CRT category 2.C.5 Lead production aggregated with emissions from lead production)

The quantities of consumed soda ash and volumes of REE compounds were checked from the Estonian Environmental Decisions Information System (KOTKAS). No significant differences were found.

4.4.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

2.C.5 Lead production

No category-specific recalculations were done.

Emissions from rare metals and rare earth metals and compounds industry (reported under CRT category 2.C.5 Lead production aggregated with emissions from lead production)

No category-specific recalculations were done.

4.4.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

2.C.5 Lead production

There are no planned category-specific improvements.

Emissions from rare metals and rare earth metals and compounds industry (reported under CRT category 2.C.5 Lead production aggregated with emissions from lead production)

There are no planned category-specific improvements.

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

This category includes:

- 2.D.1 – CO_2 emissions from the use of lubricants (industrial and motor oils) during their use time;
- 2.D.2 – CO_2 emissions from paraffin waxes;
- 2.D.3 Other – CO_2 emissions from urea-based catalysts for motor vehicles;
- 2.D.3 – NMVOC emissions from 1. Solvent use and 2. Road paving with asphalt. Indirect CO_2 emissions are calculated from NMVOC emissions from this category and reported under 2.D.3 on the row of CO_2 emissions.

CO_2 emissions from lubricants, paraffin waxes and urea based catalytic converters for motor vehicles are shown in Figure 4.5.

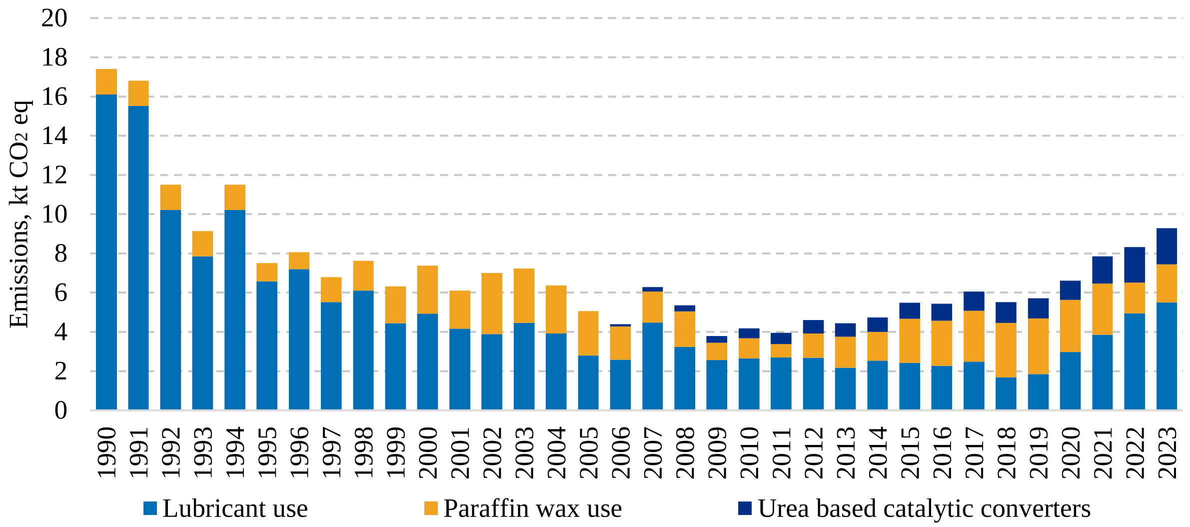

Figure 4.5. CO_2 emissions from lubricants, paraffin waxes and urea based catalytic converters for motor vehicles in 1990–2023, kt

Table 4.16. CO_2 emissions from lubricants, paraffin waxes and urea based catalytic converters for motor vehicles

	1990	2005	2020	2021	2022	2023
2.D.1 Lubricant use						
CO_2 emission, kt	16.11	2.80	2.96	3.85	4.94	5.51
2.D.2 Paraffin wax use						
CO_2 emission, kt	1.29	2.26	2.66	2.62	1.57	1.94
2.D.3 Urea based catalysts for motor vehicles						
CO_2 emission, kt	NO	NO	0.99	1.38	1.82	1.84
Sum of CO_2 emissions from 2.D.1-2.D.3, kt (excl. indirect CO_2)	17.40	5.06	6.62	7.85	8.33	9.29

More information about subcategories is found in the following paragraphs.

4.5.1. Category description

2.D.1 Lubricant use

Lubricant use covers industrial and motor oils and greases that were produced from fossil fuels. This paragraph is about emissions from the primary use of lubricants in industry, households, and vehicles. The lubricants that are lost during primary use are oxidised and result in CO_2 emissions. The waste oils that are incinerated are accounted under the Energy sector´s sectoral approach.

2020 -2023 data show an increase in usage of lubricants and therefore rise in CO_2 emissions.

In 2023 the apparent consumption of lubricants was 9.3 kt and the CO_2 emission from this category (2.D.1) was 5.5 kt.

2.D.2 Paraffin wax use

The category includes such products as candles, petroleum jelly, paraffin waxes and other waxes, including osokerite. Most of the CO_2 emissions in this category derive when the waxes or derivatives of paraffin are combusted during use (e.g., candles). In Estonia, candles are produced from paraffin waxes. No production of paraffin waxes has occurred.

In Estonia, there is one major candle producer, which started production in 1997 and has produced most of the total candle production in Estonia since 1998. Before 1998 there was another candle producer, which was closed in 1998. Candle production in Estonia has multiplied after 2005 and exports constitute approximately 90% of the producers' turnover.

In 2023, the apparent consumption of paraffin waxes (including candles) was 3.3 kt and the CO_2 emission from this category (2.D.2) was 1.9 kt.

2.D.3 Other

The subsector 2.D.3 covers:

- Other – CO_2 emissions from urea-based catalysts for motor vehicles;
- NMVOC and indirect CO_2 emissions from use of solvents and other products;
- NMVOC and indirect CO_2 emissions from road paving with asphalt.

Urea based catalysts for motor vehicles

The consumption of urea-based DEF (AdBlue) was 7.7 kt and the CO_2 emission from this category (2.D.3) was 1.84 kt.

Directive 2005/55/EC of the European Parliament and of the Council introduced Euro IV maximum limit of NO_x for exhaust gases of new heavy vehicles with diesel engines registered after 01.10.2006. Euro V applied for new heavy vehicles registered since 01.10.2009 and Euro VI since 31.12.2013.

Regulation 692/2008/EC and Regulation (EU) 2016/427 (of 10 March 2016) stipulate requirements for type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6). New light vehicles placed on the EU market and registered after 1st September 2015 must meet strict limits of exhaust NO_x and need a catalyst system. Euro 6 upper limit on NO_x is over twice smaller than Euro 5 upper limit.

SCR is the dominant technology in the market of trucks and buses, constituting 75% of sales[84]. Larger trucks have been equipped with SCR+EGR (exhaust gas recirculation). Most of Euro 6 compliant light commercial vehicles were SCR-equipped in 2019. The market share of passenger cars equipped with SCR was estimated at *ca* 40% in 2014[85].

Solvent use

The use of solvents and products containing solvents results in emissions of non-methane volatile organic compounds (NMVOCs) when emitted into the atmosphere. Indirect CO_2 emissions are calculated from NMVOCs.

NMVOC-s are not greenhouse gases but air pollutants which are reported in the Air pollutant emission inventory according to the NEC Directive and the UNECE CLRTAP (United Nations Economic Commission for Europe's Convention on Long-Range Transboundary Air Pollution). The Air pollutant emission inventory is compiled by the Estonian Environmental Agency every year by 15th of February.

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[84] EAA air pollutant inventory emission guidebook 2023, page 63 https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view (22.12.2024)

[85] Yang,L., Franco,V et al. 2015. NOx control technologies for Euro 6 diesel passenger cars. https://www.theicct.org/sites/default/files/publications/ICCT_NOx-control-tech_revised%2009152015.pdf, (22.12.2024).

In CRT Estonia also reports CO which arises mainly from tobacco use, fireworks and less from some processes using solvents.

Use of solvents and other products covers emissions from:

SNAP 0601: Coating application;

SNAP 0602: Degreasing, dry cleaning and electronics;

SNAP 0603: Chemical products, manufacturing or processing;

SNAP 0604: Other use of solvents and related activities. Including such activities as 'enduction' (i.e., coating) of glass wool and mineral wool, printing industry, fat and oil extraction, uses of glues and adhesives, wood preservation, domestic solvent use (other than paint application) and vehicle underseal treatment and vehicle dewaxing.

SNAP 0606: Other product use (e.g., tobacco, fireworks) (SNAP 060602). Under this SNAP emissions from lubricant use are also reported in the NEC/CLRTAP inventory but not in the GHG inventory because emissions from lubricants are already reported under category 2.D.1.

Under categories of paint application (SNAP 0601), degreasing and dry cleaning (SNAP 0602), chemical products, manufacture, and processing (SNAP 0603) and other (SNAP 0604 and SNAP 0606), Estonia reports indirect greenhouse gas emissions (NMVOCs) and indirect CO_2 emissions from NMVOC emissions (Table 4.16).

The NMVOC and indirect CO_2 emissions from solvents by the EMEP/EEA Air pollutant emission inventory NRF code are shown in Table 4.16. Indirect CO_2 emissions from: 1) paint application (2D3d; SNAP 0601); 2) domestic solvent use (e.g., fungicides) (2D3a; SNAP 0604); 3) other solvent use (2D3i; SNAP 0604) and 4) printing (2D3h; SNAP 0604) made up the main share of total emissions from the sector 1) 47.4%; 2) 33.7%; 3) 13.8% and 4) 2.6%, respectively, in 2023 (Table 4.7).

Table 4.17. Reported emissions from Solvent use in 2022

SNAP	NRF	Source	Emissions
0601	2D3d	Coating application (e.g., paint)	NMVOC, indirect CO_2, CO
0602	2D3e	Degreasing	NMVOC, indirect CO_2
0602	2D3f	Dry cleaning	NMVOC, indirect CO_2
0603	2D3g	Chemical products, manufacturing and processing	NMVOC, indirect $CO_{2,}$ CO
0604	2D3h	Printing	NMVOC, indirect $CO_{2,}$
0604	2D3a	Domestic solvent use (e.g., fungicides)	NMVOC, indirect CO_2
0604	2D3i	Other solvent use	NMVOC, indirect $CO_{2,}$
0606	2G	Other product use (e.g., tobacco, fireworks)	NMVOC, indirect CO_2, CO

A large increase in NMVOC emissions in 2021 has been in paint application (industrial and domestic) and the amounts were similar in 2022. In 2023 The increase of emissions from paint application has been somewhat curbed by decreasing emission factors. Content of NMVOCs in paints and therefore emission factors have decreased mainly as an effect of Directive 2004/42/CE on limitation of VOCs in paints. Emission factors of domestic solvent use (other than paints) have not been decreased in time series because according EMEP/EEA Air Pollutant Inventory Guidebook 2023 they should remain constant during time series. In real life it could be that the emission factors might have decreased as effect of Regulation (EC) No 1223/2009 on cosmetic products (requirement of safety assessment and bans of certain hazardous components) and Regulation (EU) No 528/2012 concerning the making available on the market and use of biocidal products (imposing bans of certain hazardous components). Compared to the base year 1990 the emissions from indirect CO_2 from Solvent use category in 2023 were 29.2% larger because emissions from coating applications (e.g paint) have increased.

The fluctuation of total NMVOC emissions during the period 1990–2023 has mostly occurred due to the economic condition of the country. The decrease in the emissions between 1992 and 1993 was attributable to the economic crisis that was conditioned by the fall of the Soviet Union and the regaining of independence of the Republic of Estonia. Between 1993 and 1998 economic growth induced the growing usage of NMVOC containing paints in decorative and industrial coating application. At the end of 1998, the world was struck by economic crisis, which affected the construction sector and as a consequence the usage of decorative coatings diminished. From 2001 the economy turned again into growth until in 2008 when Estonia suffered badly from the global economic depression. Because of that, compared with the year 2007, the NMVOC emissions and indirect CO_2 emissions decreased respectively in 2008 and 2009 (please see Figure 4.6). From 2018-2021 there were an increase mostly in the use of coating applications following decrease in 2023 that resulted in overall decrease of NMVOC emissions.

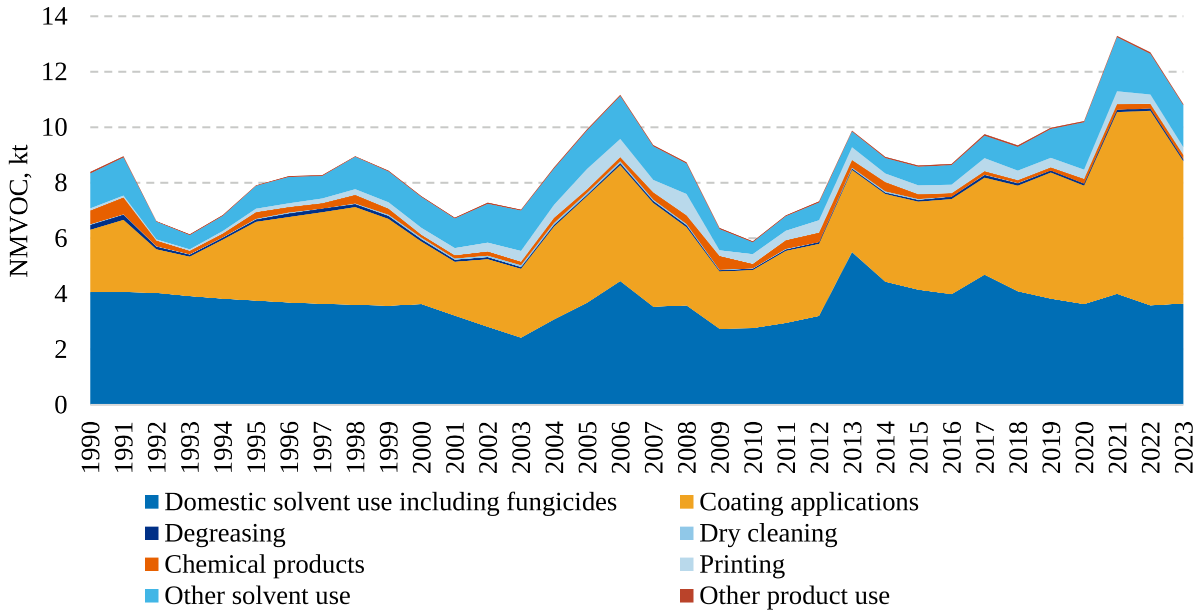

Figure 4.6. Total NMVOC emissions from Solvent use in 1990–2023, kt

Table 4.18 Emissions from Solvent use and Road paving with asphalt in 1990–2023, kt

Emissions from Solvent use and Road paving with asphalt, kt		**1990**	**2005**	**2020**	**2021**	**2022**	**2023**
2D3a	NMVOC emissions from Domestic solvent use (e.g., fungicides), kt	4.07	3.68	3.62	3.99	3.58	3.65
2D3d	NMVOC emissions from Coating applications (e.g., paint), kt	2.24	3.84	4.27	6.55	7.01	5.13
2D3e	NMVOC emissions from Degreasing, kt	0.18	0.05	0.07	0.08	0.08	0.07
2D3f	NMVOC emissions from Dry cleaning, kt	0.01	0.06	0.01	0.01	0.004	0.004
2D3g	NMVOC emissions from Chemical products, manufacture, and processing, kt	0.50	0.13	0.17	0.21	0.17	0.16
2D3h	NMVOC emissions from Printing, kt	0.08	0.75	0.33	0.45	0.34	0.28
2D3i	NMVOC emissions from Other solvent use, kt	1.26	1.38	1.71	1.95	1.47	1.50
2G	NMVOC emissions from Other product use (e.g. tobacco), kt	0.05	0.04	0.05	0.05	0.05	0.05
Total NMVOC from solvent use, kt		8.40	9.93	10.23	13.30	12.70	10.85

Emissions from Solvent use and Road paving with asphalt, kt	**1990**	**2005**	**2020**	**2021**	**2022**	**2023**
Indirect CO_2 emissions from NMVOCs from Solvent use, kt	18.48	21.85	22.50	29.25	27.94	23.86
NMVOC emissions from Road paving with asphalt, kt	0.03	0.02	0.03	0.03	0.02	0.02
Indirect CO_2 emissions from NMVOCs from Road paving with asphalt, kt	0.05	0.03	0.05	0.04	0.04	0.03
Total indirect CO_2 emissions from Solvent use and Road paving with asphalt, kt	18.45	21.88	22.55	29.29	27.98	23.89

Road paving with asphalt

In this source category NMVOC emissions from road paving with asphalt are reported. The NMVOC emissions are calculated at the Estonian Environment Agency.

Indirect CO_2 emissions from road paving with asphalt: 0.03 kt.

NMVOC and indirect CO_2 emissions in 1990–2023 are shown in Table 4.8

4.5.2. Methodological issues

Choice of methods

2.D.1 Lubricant use

Emissions from lubricants were calculated using the Tier 1 method according to the IPCC 2006 Guidelines (Equation 4.14). Total consumption of solid and liquid lubricants (TJ) is multiplied with the emission factor. The emission factor is based on default values of carbon content and oxidation during use (ODU) factor[86].

Equation 4.14[87]

$$CO_2\ emissions = \sum (LC \times CC_{lubricant} \times ODU_{lubricant}) \times 44/12$$

Where:

CO_2 emissions = CO_2 emissions from lubricants, tonne CO_2;
LC = total lubricant consumption, TJ;
$CC_{Lubricant}$ = carbon content of lubricants (default), tonne C/TJ (= kg C/GJ);
$ODU_{Lubricant}$ = ODU factor (based on default composition of oil and grease), fraction;
44/12 = mass ratio of CO_2/C.

2.D.2 Paraffin wax use

Emissions from paraffin waxes were calculated using the *Tier 1* method according to the IPCC 2006 Guidelines (Equation 4.15), because no sufficient data on oxidation factors of different paraffin wax products were found.

Total consumption of paraffin waxes (TJ) is multiplied with the emission factor.

Equation 4.15[88]

[86] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.9, section 5.2.2.2.
[87] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.7, equation 5.2.
[88] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.11, equation 5.4.

$$CO_2\ emissions = PW \times CC_{wax} \times ODU_{wax} \times 44/12$$

Where:

CO_2 emissions =	CO_2 emissions from waxes, tonne CO_2;
PW =	total wax consumption, TJ;
CC_{wax} =	carbon content of paraffin wax (default), tonne C/TJ (= kg C/GJ);
ODU_{wax} =	ODU factor for paraffin wax, fraction;
44/12 =	mass ratio of CO_2/C.

2.D.3 Other

Urea based catalysts for motor vehicles

Summary reaction of urea in SCR systems (Equation 4.16):

Equation 4.16

$$4NO + 2(NH_2)_2CO + O_2 = 4N_2 + 4H_2O + 2CO_2$$

The *Tier 2* method from the IPCC 2006 Guidelines was used.

According to the *Tier 2* methodology:

Equation 4.17[89]

$$Emission = Activity \times 12/60 \times Purity \times 44/12$$

Where:

12/60 = stoichiometric coefficient of carbon in urea;
44/12 = stoichiometric coefficient of conversion of carbon to CO_2.

Solvent use

The compiling of NMVOC emission data from the Solvent use category is performed by the Estonian Environment Agency. An inventory of air pollutants is being carried out to meet the obligations of UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP).

NMVOC emission estimations from Solvent use are based on several data sources and methods. Emissions from point sources are gathered from the Estonian Environmental Decisions Information System (KOTKAS) and the emissions for diffuse sources are calculated from the data received and gathered from Statistics Estonia and Eurostat using international emission factors and expert opinions. The main database of emission factors is the EMEP/EEA Guidebook 2023.

Indirect CO_2 emissions from Solvent use were calculated using methodology from the IPCC 2006 Guidelines (Equation 4.18). According to the method:

[89] IPCC 2006 Guidelines, Volume 2, Chapter 3 page 3.12.

Equation 4.18[90]

$$CO_2\ emissions = Emissions_{NMVOC} \times \%\ carbon\ in\ NMVOCs\ by\ mass \times 44/12$$

It was assumed that the average carbon content of NMVOCs is 60% by mass for all categories under the sector of Solvent use according to the IPCC 2006 Guidelines.

Road paving with asphalt

NMVOC emissions from road paving with asphalt were calculated using the *Tier 1* default approach from the renewed EMEP/EEA Guidebook 2023 (Equation 4.19).

According to the *Tier 1* method:

Equation 4.19[91]

$$E_{pollutant} = AR_{production} \times EF_{pollutant}$$

Where:

$E_{pollutant}$ =	the emissions of the specified pollutant;
$AR_{production}$ =	the activity rate for the road paving with asphalt;
$EF_{pollutant}$ =	the emission factor for this pollutant.

Indirect CO_2 emissions from road paving with asphalt were calculated using methodology from the IPCC 2006 Guidelines (Equation 4.18).

Activity data

2.D.1 Lubricant use

Data on production of lubricants in 1990–2023 was provided by Statistics Estonia. No production of motor and industrial oils was present in Estonia during 1990–2023 according to Statistics Estonia and the Eurostat database[92].

The apparent consumption of lubricants was calculated with the formula: import minus export, as no lubricant production occurred.

The quantities in tones were converted into TJ using the default net calorific value – 40.2 TJ/kt in line with the IPCC 2006 Guidelines[93].

Activity data on lubricants are presented in Table 4.19.

[90] IPCC 2006 Guidelines, Volume 1, Chapter 7, page 7.6, box 7.2.
[91] EMEP/EEA air pollutant emission inventory guidebook 2023, page 9, https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/2-industrial-processes-and-product-use/2-d-2-l-other/2-d-3-b-road/view (22.12.2024)
[92] https://ec.europa.eu/eurostat/web/main/data/database (22.12.2024)
[93] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.18, table 1.2.

Table 4.19. Activity data concerning lubricants

	1990	2005	2020	2021	2022	2023
2.D.1 Lubricant use, kt	27.3	4.8	5.0	6.5	8.4	9.3
Lubricant use, TJ	1 098	191	202	262	337	374

2.D.2 Paraffin wax use

According to Statistics Estonia, no production of paraffin waxes has taken place in Estonia, instead, candles are produced from paraffin waxes. The data on candle production in 2006–2023 was obtained from Eurostat database. No data was available for the years 1990–2005 and therefore the average apparent candle consumption (import minus export) of the years 2006–2013 was used for the years 1990–2005.

The apparent consumption of paraffin waxes was calculated with formula: import minus export plus production. The amounts of paraffin waxes which were processed into candles were excluded because the consumption of candles was already accounted, and the exported candles do not contribute to Estonia's emissions.

Data on import and export of paraffin waxes for the years 1995–2023 was obtained from the Eurostat database. For the years 1990–1995 the average import and export data from the years 1995–1999 was used for calculating the apparent consumption.

The quantities of total consumed paraffin waxes in tons were converted into TJ using the default net calorific value – 40.2 TJ/kt[94].

Activity data on paraffin waxes are presented in Table 4.20.

Table 4.20 Activity data concerning paraffin waxes

	1990	2005	2020	2021	2022	2023
2.D.2 Paraffin wax use, kt	2.2	3.8	4.5	4.4	2.7	3.3
Paraffin wax use, TJ	88	154	182	179	107	133

2.D.3 Other

Urea based catalysts for motor vehicles

Activity data consists of:

- diesel fuel consumption of vehicles (data from Estonian Environmental Agency);
- consumption of urea containing diesel exhaust fluid (DEF) per fuel consumption.

Data on diesel fuel consumption by new vehicles complying with Euro standards were compiled by the Estonian Environment Agency (EstEA). The EstEA has obtained data on diesel fuel consumption from Statistics Estonia and vehicle data (passenger cars, light and duty vehicles, buses, motorcycles) and annual mileage per vehicle from the Estonian Transport Administration.

Until 2015 only heavy vehicles were accounted for, from 2015 light vehicles have also been accounted for.

Solvent use

NMVOC emission estimations from Solvent use are based on several data sources and methods. Emissions from point sources are gathered from the Estonian Environmental Decisions Information System (KOTKAS) and the emissions for diffuse sources are calculated from the

[94] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.18, table 1.2.

data received and gathered from Statistics Estonia and Eurostat using international emission factors and expert opinions. The main database of emission factors is the EMEP/EEA Guidebook 2023.

Road paving with asphalt

The annual weight of asphalt produced for road paving was used as activity data when calculating NMVOC emissions from this source category. Activity data was received from the Estonian Infra Construction Association (ESTICA) for the years 1990–2023.

Emission factors

2.D.1 Lubricant use

According to Tier 1 the weighted average ODU factor 0.2 for lubricants is used[95].

The default carbon content for lubricants 20.0 t C/TJ was applied[96].

Table 4.21 Emission factors concerning lubricants

2.D.1 Lubricant use	1990	2005	2020	2021	2022	2023
$EF_{lubricants}$, t/t	0.5896 for all years					

2.D.2 Paraffin wax use

Default oxidation factor (ODU) of 0.2 and carbon content 20.0 t C/TJ were applied according to the IPCC 2006 Guidelines[97].

Table 4.22 Emission factors concerning paraffin waxes and urea based catalytic converters for motor vehicles

2.D.2 Paraffin wax use	1990	2005	2020	2021	2022	2023
$EF_{paraffin\ waxes}$, t/t	0.5896 for all years					

2.D.3 Other

Urea based catalysts for motor vehicles

The default average consumption of DEF per fuel consumption is 1–3%. Estonia uses 3% when calculating emissions because Estonia wholesalers of catalyst fluid estimate that it is not under 3%.

The emission factor consists of the concentration of urea in it (purity) and stoichiometric coefficient of conversion of C in urea into CO_2.

The emission factor is the concentration of urea in DEF (32.5%) multiplied with 0.73333 - stoichiometric coefficient for conversion of C from urea into CO_2 (44/60). EF = 0.325 x 0.73333 = 0.238332255.

Solvent use

The main database of emission factors for NMVOC emissions is the EMEP/EEA Guidebook 2023.

[95] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.9, table 5.2.
[96] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.21, table 1.3.
[97] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.21, table 1.3.

Road paving with asphalt

Default NMVOC factors are taken from EMEP/EEA Guidebook 2023. For the calculations of NMVOC emissions from road paving with asphalt, emission factor 16 g of NMVOC per Mg of asphalt was used.

When calculating indirect CO_2 emissions from road paving with hot asphalt mix it was assumed that the average carbon content of NMVOCs is 45% which is between the default values of 40–50%.

4.5.3. Uncertainty assessment and time-series consistency

For uncertainty assessment please see Annex A.II.2 IPPU, 2.D Non-energy products from fuels and solvent use chapter.

4.5.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the Industrial processes and product use sector according to the IPCC Tier 1 method.

2.D.1 Lubricant use

All possible CN 8-digit codes for lubricants were checked to make sure that all relevant lubricants were included (waste oils were not included).

The number of vehicles with 2-stroke engines was estimated using data from the Estonian Transport Administration. Approximately 40 000 motor scooters that are not over 20 years old (a large part of them are with 2-stroke engines) are registered in the Estonian Transport Administration. It was concluded that the use of lubricants in 2-stroke engines is marginal.

Activity data on lubricants are obtained from Statistics Estonia and Eurostat; both data sources have similar information on imports and exports.

The amount of lubricants used shows that less lubricants are needed on the market. 2020-2023 data show an increase in usage of lubricants and therefore rise in CO_2 emissions.

2.D.2 Paraffin wax use

All possible CN 8-digit codes for paraffin waxes were checked from Eurostat to make sure that all of them were included.

2.D.3 Other

Urea based catalysts for motor vehicles

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the Industrial processes and product use sector according to the IPCC Tier 1 method.

Solvent use

Normal statistical quality checking related to the assessment of magnitude and trends is carried out. Calculated emissions and emission data from the KOTKAS database are compared to previous years to detect calculation errors, errors in the reported data or in allocation of data under subcategories. The reasons behind any fluctuation in the emission figures are studied. The data reported and entered the KOTKAS database by operators are first checked by specialists from the Estonian Environmental Board and then by the specialists in the Estonian Environment Agency.

Road paving with asphalt

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the Industrial processes and product use sector according to the IPCC *Tier 1* method.

4.5.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

Recalculations have been made in Solvent use NMVOC emissions and therefore also changes in indirect CO_2 emissions 2006-2014 and 2017-2022 (Table 4.23) in the categories 2D3a (2020, 2022), 2D3d (2022), 2D3g (2006-2014), 2D3i (2020-2022) and 2G (2017-2022). Recalculations were due to moving SNAP codes under correct SNAP and changes in the data from the Statistics Estonia for several years.

Table 4.23. Recalculations in NMVOC emissions and therefore in indirect CO_2 emissions for the years 2006-2014, 2017-2022

Year	2024 submission NMVOC, kt	2024 submission Indirect CO_2, kt	2025 submission NMVOC, kt	2025 submission, Indirect CO_2, kt	Difference in indirect CO_2 emissions, kt
2006	11.1782	24.592044	11.17622	24.587684	-0.00436
2007	9.368514	20.610731	9.366976	20.607347	-0.00338
2008	8.741333	19.230933	8.740692	19.229522	-0.00141
2009	6.379164	14.034161	6.379135	14.034097	-0.00006
2010	5.898934	12.977655	5.898921	12.977626	-0.00003
2011	6.833476	15.033647	6.833434	15.033555	-0.00009
2012	7.334456	16.135803	7.334442	16.135772	-0.00003
2013	9.886336	21.749939	9.886264	21.749781	-0.00016
2014	8.933968	19.654730	8.933937	19.654661	-0.00007
2017	9.752405	21.455291	9.752342	21.455152	-0.00014
2018	9.351719	20.573782	9.351664	20.573661	-0.00012
2019	9.989923	21.977831	9.989827	21.977619	-0.00021
2020	10.22798	22.501552	10.22751	22.500529	-0.00102
2021	13.21801	29.079613	13.29504	29.249090	0.16948
2022	12.73234	28.011152	12.70114	27.942501	-0.06865

Recalculations have been made in the emissions of urea-based catalysts for motor vehicles for the years 2006, 2008-2022 due to changes in the activity data.

Table 4.24. Recalculations in urea based catalysts for motor vehicles for years 2006, 2008-2022

Year	2024 submission, kt CO_2	2025 submission, kt CO_2	Difference CO_2, kt
2006	0.106757	0.11	-0.003243
2008	0.318904	0.32	-0.001096
2009	0.335379	0.33	0.005379
2010	0.510173	0.5	0.010173
2011	0.5704	0.6	-0.029600
2012	0.679953	0.68	-0.000047
2013	0.693442	0.69	0.003442
2014	0.739595	0.74	-0.000405
2015	0.815912	0.79	0.025912
2016	0.874165	0.87	0.004165
2017	0.975517	0.99	-0.014483

Year	2024 submission, kt CO_2	2025 submission, kt CO_2	Difference CO_2, kt
2018	1.047849	1.09	-0.042151
2019	1.034435	1.09	-0.055565
2020	0.994788	1.06	-0.065212
2021	1.380067	1.5	-0.119933
2022	1.816606	1.76	0.056606

4.5.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

There are no planned category-specific improvements.

4.6. Product uses as substitutes for ODS (CRT 2.F)

In 2023 greenhouse gas emissions under the category CRT 2.F Product uses as substitutes for ODS amounted to 190.9 kt CO_2 equivalent, which was about 1.76% of the total greenhouse gas emissions in Estonia.

Under this category, Estonia reports HFC emissions from refrigeration and air-conditioning equipment (CRT 2.F.1), HFC emissions from foam blowing agents (CRT 2.F.2), HFC emissions from fire protection (CRT 2.F.3) and HFC emissions from aerosols (CRT 2.F.4).

The consumption of halocarbons in Estonia depends on import. F-gases are imported either in bulk by trade or industry for domestic productive consumption (manufacturing) – filling of newly manufactured products, refilling of equipment – or in imported preliminary and final products respective equipment already filled with F-gases.

In recent years, imports of F-gases to Estonia have decreased due to the EU phasedown (and related diminishing HFC quotas) (related to previous F-gas Regulation (EU) No 517/2014[98]). In addition, wholesalers have bought more HFC-s from other EU countries. An exemption is the high-GWP R-404A which sales have fluctuated in recent years but has decreased in 2022 and 2023. R-404A previously was almost the only gas used in commercial refrigeration but not anymore. Imported quantities in pre-filled equipment have not decreased. Importers of pre-filled equipment purchased HFC quota authorizations mostly from companies trading with quotas and therefore this did not affect the Estonian wholesalers of HFC-s.

The total emissions of HFCs increased rapidly between 1993-2015, especially HFC emissions from refrigeration and air-conditioning equipment, which is the major source of halocarbons in Estonia (Figure 4.7).

As it can be seen from Figure 4.7, the increase of HFC emissions have halted two times – in 2008 and 2016-2018 reaching highest emissions in 2018. In 2023 there was a decrease in HFC emissions – 2.91 % compared to 2022.

In 2008, one-component polyurethane foams with R-134a were banned by Regulation (EU) No 842/2006[99] and large foam producers in Estonia replaced propellant R-134a (GWP 1300, AR5) with R-152a (GWP 138, AR5), which has a significantly lower GWP, thus emissions decreased sharply. This has been elaborated in 4.6.2. Methodological issues under

[98] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014R0517&from=en (22.12.2024)
[99] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32006R0842&from=EN (22.12.2024)

‘One-component PU foam’. HFC use and emissions also declined in 2008 due to the global economic recession that affected Estonia severely.

The reason for a halt in emissions growth in 2016 was that fewer new commercial and industrial refrigeration equipment were installed. The probable cause for this could be the EU HFC phasedown and other restrictions of Regulation (EU) No 517/2014 on placing on the market certain commercial refrigeration systems with high-GWP HFCs (GWP 2500 and more) and ban to top up existing equipment with virgin HFCs with a GWP 2500 and more.

The cause for the second halt in emissions growth in 2016-2018 is the effect of the EU HFC phasedown and other restrictions of Regulation (EU) No 517/2014 on placing on the market certain commercial refrigeration systems with high-GWP HFCs (GWP 2500 and more) and ban to refilling existing equipment with virgin HFCs with a GWP 2500 and more. Since the refilling ban in 2020 the service companies reported much lower refilling rates and explain that the most leaking equipment has been decommissioned and that only minimal amounts of refrigerants needed for functioning were filled into equipment. Hence the steep decrease in HFC emissions in 2020. There has been an increase in emissions in 2021-2022 because decommissioning emissions of 15 years old equipment consisting of higher amount of F-gases than in previous years. The emission factor of decommissioning older equipment is 50% (from the amount of F-gases filled into equipment originally). In 2023 there was a decrease in emissions, because there were less amounts of HFCs in decommissioned equipment reaching their end-of-life emissions.

Since 2015, alternative and lower GWP refrigerants, e.g., CO_2-based systems for larger commercial systems have increasingly gained market in Estonia and the stock of HFCs has declined. In 2020 a quarter of supermarkets had CO_2 equipment (this information is based on data collected from service companies for the GHG inventory; for methods, please see section 4.6.2. Methodological issues).

Concerning industrial refrigeration, the Regulation (EU) No 517/2014 did not impose such strict bans on HFC-s like for commercial refrigeration equipment. That is the main reason why the decrease of R-404A stock and emissions have been slower than in commercial refrigeration. New F-gas Regulation (EL) 2024/573 does not distinguish commercial or industrial use in the bans of placing on the market.

In mobile air conditioning the MAC Directive´s (2006/40/EC) ban on bringing onto market new passenger cars and vans with HFC-134a in their air conditioners since 2017 has had a pronounced effect on emissions. In comparison to 2017 the emissions from mobile air conditioning have decreased 27%.

HFC emissions from the A/C and HP sector have not decreased yet but use of lower GWP refrigerant R-32 is slowly increasing.

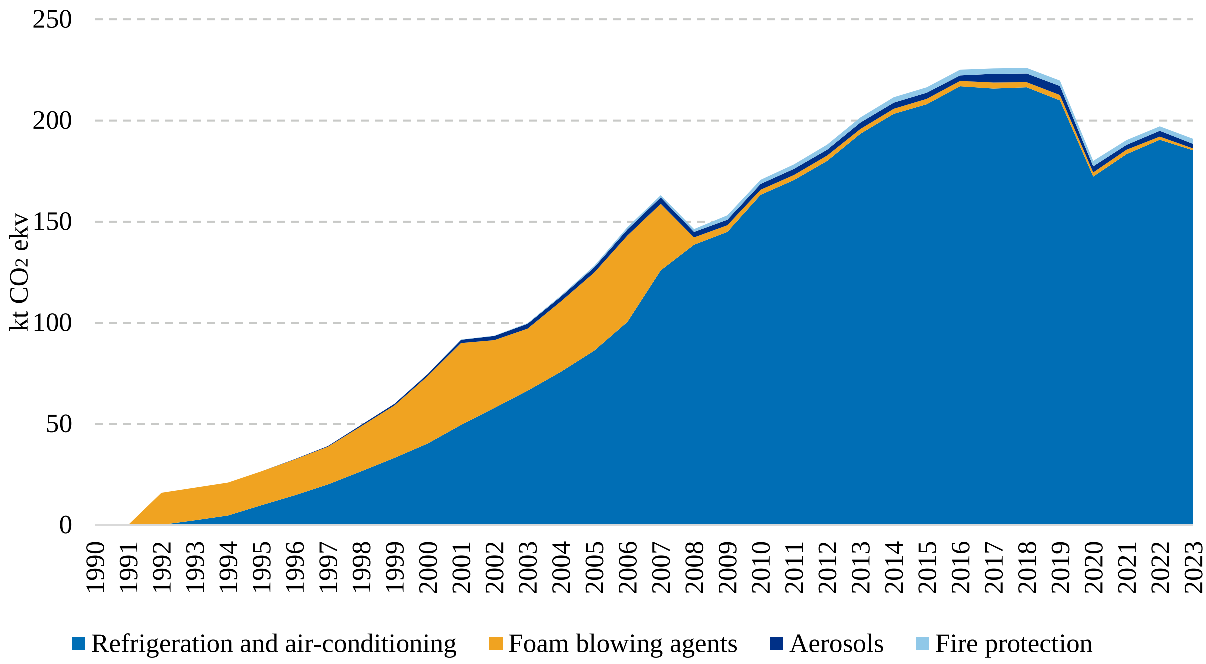

Figure 4.7. Actual emissions of HFCs by subcategory in 1990–2023, kt CO_2 equivalent

4.6.1. Category description

2.F.1 Refrigeration and air-conditioning

Refrigeration and air-conditioning (RAC) are responsible for about 97.0% of the Estonian F-gas emissions (185.14 kt CO_2 eq. in 2023). The important subsectors are:

a) Commercial refrigeration (refrigeration units of supermarkets and smaller shops, restaurants etc.);

b) Domestic refrigeration (fridges and freezers for domestic use);

c) Industrial refrigeration (refrigeration units in the food and other industries);

d) Transport refrigeration (refrigerated vehicles and reefer containers);

e) Stationary air-conditioning (heat pumps and room air-conditioning systems);

f) Mobile air-conditioning (AC systems for passenger cars, trucks, buses, ships, railcars, wheel tractors/mobile machinery).

2.F.1.a Commercial refrigeration (CRT 2.F.1.a)

Commercial refrigeration and its main subsector, supermarkets, is one of the big application sectors of fluorinated refrigerants and emissions in Estonia. This category distinguishes between:

- Supermarkets and other food retail shops with mostly on-site assembled centralised systems; small shops and institutions with comparable refrigeration units (only one compressor and/or less than 15 kg refrigerant, including standalone equipment as well as plus and/or minus compartments of refrigeration systems). About one quarter of supermarkets are equipped with new CO_2 systems. The main HFC refrigerant in other supermarkets is R-404A, but also R-448A, 449A, R-134a (the latter mostly in standalone equipment).

- Refrigeration equipment for restaurants, hotels, pubs, canteens, etc. (mostly small stand-alone equipment for kitchens and cold rooms, on average 350 g/device). The main HFC refrigerants are R-134a and R-404A.
- Stand-alone or plug-in equipment (mostly vending machines for shops, filling stations, etc., on average 250 g R-134a/device).

The commercial refrigeration sector´s HFCs are dominated by the refrigerants R-404A, which make 84% of the 2023 HFC stock (mostly used in supermarket systems), R-134a – about 10% (mainly used in vending machines, small shops and restaurants) and R-407F – 3% (substitute for R-404A).

The number of food retail supermarkets in Estonia – hypermarkets, supermarkets, discounters, department stores – was according to the Estonian Traders Association about 600. The number of small commercial and public customer-orientated service institutions with refrigeration equipment (like small shops, hotels, restaurants, canteens, etc.) was according to other statistical sources more than 10 000. This includes according to expert calculation from refrigeration service companies about 7 000 small shops with less than 3 kg refrigerant charge, plus about 4 000 hotels, bars, restaurants, pubs, canteens, etc. The number of vending machines for cooling beverages and other goods (stand-alone equipment) was estimated at ca 15 000 units.

In 2023 the total quantity of HFCs filled into new commercial refrigeration equipment was 0.32 t (with non-HFC components) and 0.28 t (without non-HFC components). The manufacturing emissions from this filling were 0.0014 t. The HFC stock amounted to 68.81t (57.54 t of R-404A, 6.84 t of R-134a and smaller amounts of R-407F, R-407C, R-410A, R-448A, R-449A, R-417A, R-422D and R-452A). Emissions from stock were in total 6.75 t R-404A and 0.61 t R-134a, constituted the largest part of them.

The amount of R-404A, R-134a and R-407C filled in new equipment in 2008 was decommissioned according to 15 years lifetime in 2023.

In 2023, the amount of HFC refrigerant remaining in products at decommissioning amounted to 11.18 t of R-404A, 0.65 t of R-134a and a small amount of other refrigerants – 11.85 t of HFCs total. The emissions from disposal were in total 5.92 t (5.59 t of R-404A, 0.32 t of R-134a and small amount of other refrigerants).

Total HFC emissions from commercial refrigeration in 2023 amounted to 13.78 t (50.84 kt CO_2 eq.).

2.F.1.b Domestic refrigeration

Refrigerators (fridges and freezers) for domestic use that are containing HFCs are not manufactured in Estonia but were imported from 1993–2009 (new and second hand). To some degree, R-134A was used as a refrigerant and in foam insulating gas. R-134A as a refrigerant was introduced by industry at the end of 1993 as a replacement for CFC-12. In the following years, its replacement by R-600A (isobutane), which is a functional replacement for refrigerants R-12, R-22 and R-134A in this category, started in some countries (e.g., Germany) but not in all countries in Europe and North America. According to Estonian experts, there has been no import of domestic refrigerators with refrigerant R-134a since 2009. The stock of domestic refrigeration equipment consists of all the afore-mentioned types of refrigerants.

The total 2023 amount of R-134A emissions in this subcategory was 1.08 t (stock emissions: 0.004 t, end-of-life emissions: 1.08 t) representing 1.41 kt CO_2 equivalent.

2.F.1.c Industrial refrigeration

Industrial refrigeration is a big application sector of fluorinated greenhouse gases, mainly of HFC blend R-404A. The dominant application area is the food industry (fish, meat, dairy, beverage industries, breweries, etc.), which is Estonia's one of the most important industrial sectors. The output of the food industry has decreased 5% compared to 2022. The HFC consumption of other industries (process cooling in plastics, printing, chemical industries, etc.) is comparably small.

In contrast to commercial refrigeration, in industrial refrigeration non-HFC/HCFC refrigerants – especially NH_3 – play a major role. The number of industrial refrigeration systems operating with NH_3 is ca 50 while the number of these containing more than 250 kg HFCs is in the same magnitude. Regarding the HFC stock, R-404A is still the prevailing refrigerant with about 79.8% of the stock. HFC-134a makes up 4.5% of the stock. Other HFC refrigerants (R-407C, R-410A, R-407F, R-448A etc.) are of minor importance. The new equipment is with lower GWP HFC-s R-448A, R-452A and R-134A.

The refrigeration systems are very often serviced by bigger service companies. However, self-maintenance and cooperation with smaller (locally based) service companies are more used compared to the supermarket and food retail sectors.

The total quantity of HFCs filled into new industrial refrigeration equipment in 2023 amounted to 0.37 t (0.20 t of R-448A, 0.04 R-407C, 0.01 t of R-134a, 0.003 t R-404A). The manufacturing emissions from filling were 0.002 t of HFCs (3.40 kt CO_2 eq.).

The HFC stock amounted to 76.7 t (3.46 t of R-134a, 61.20 t of R-404A, 2.25 t of R-407C, 2.39 t of R-407F, 1.39 t of R-410A, 1.05 t of R-448A and small volumes of R-452A, R-422A, R-422D, R-417A). The emissions from stock totaled 6.98 t of HFCs (24.79 kt CO_2 eq.).

The amount of refrigerants left in products at decommissioning amounted to 4.23 t (4.05 t of R-404A, 0.18 t of R-407C). The disposal emissions totaled 2.12 t of HFCs (8.13 kt CO_2 eq.).

In 2023, total HFC emissions from industrial refrigeration amounted to 9.10 t (32.93 kt CO_2 eq.).

2.F.1.d Transport refrigeration

Total HFC emissions from transport refrigeration was 25.70 kt CO_2 eq. in 2023.

Refrigerated vehicles

As of 31.12.2023, 1830 refrigerated vans and trucks and 1603 refrigerated trailers were registered in Estonia. Most of these vehicles are second-hand vehicles imported from Western Europe. Many of the refrigeration units fitted to the imported second-hand trucks and trailers are replaced with new pre-filled equipment but some are refilled within the country. Mostly pick-up trucks are fitted with empty refrigeration units first in Estonia and first filled in the country. The refrigerants in use are R-452A in all types of vehicles, R-134a in the case of vans and smaller trucks, and the blend R-404A in bigger trucks and trailers.

The total 2023 quantity of HFCs filled in the equipment of newly registered refrigerated vehicles in Estonia amounted 101.5 kg of R-452A. The 'manufacturing' emissions of these first fills were 1.02 kg of R-452A. The HFC stock in refrigerated vehicles amounted to 0.49 t of R-134A, 17.97 t of R-404A and 2.44 t of R-452A. The emissions from stock were 0.15 t of R-134A 5.39 t of R-404A and 0.73 t of R-452A. The amount of refrigerant left in products at decommissioning from 2013 (10 years old refrigerated vehicles) amounted to 1.03 t of R-404A and 0.002 t of R-134A. The disposal emissions were 0.001 t of R-134A and 0.012 t of R-404A. According to national experts, the lifetime of refrigerated vehicles is about 10 years.

Total HFC emissions from refrigerated vehicles amounted to 6.36 t (24.10 kt CO_2 eq) in 2023.

Reefer containers

Reefer containers are being transported on sea ships around the world and HFC emissions from their refrigeration systems do not occur inside a particular country. Consequently, it is plausible to attribute the emissions of the worldwide reefer container fleet to a particular nation according to the share of this country in world trade. According to the World Trade Organization, Estonia's share in the world trade amounted to 0.082% in 2023[100], thus Estonian reefer containers constituted 0.082% of the world HFC stock and HFC emissions of the worldwide reefer container fleet in the same year.

In 2023 the HFC stock in reefer containers amounted to 6.25 t of R-134A and 0.05 t of R-404A. The 2023 HFC stock emissions from reefer containers attributable to Estonia were 0.62 t of R-134A and 0.005 t of R-404A. In 2023, the emissions from decommissioning of reefer containers attributable to Estonia were 0.12 t of R-134A and 0.0008 t of R-404A.

The lifetime for reefer containers is according to experts about 14 years.

Total HFC emissions from reefer containers amounted to 0.92 t (1.60 kt CO_2 eq) in 2023.

2.F.1.e Mobile air-conditioning (CRT 2.F.1.e)

Total MAC HFC emissions from mobile air-conditioning in 2023 amounted to 32.83 kt CO_2 eq.

Passenger cars

In Western Europe, systematic air-conditioning (A/C) of passenger cars with refrigerant HFC-134A started in 1994. As the lifetime of passenger cars is estimated to be 12 years, most cars are supposed to have an air conditioner. According to EU directive 2006/40/EC (MAC Directive), since 1 January 2017, the air conditioning systems of new types of M_1 and N_1 category vehicles placed on the EU market shall be filled with a refrigerant that has a GWP 150 or less. The most common refrigerant meeting this criterion is HFO-1234yf. Type approval end of series vehicles were exempted until end 2018. Individually reconstructed vehicles approvals allow A/C with HFC-134A in the future. New cars with HFO-1234yf were already marketed in Estonia in 2013–2014 and their proportion has increased until 100% in 2019.

The relevant MAC properties (equipment quota, refrigerant charge, leakage rate) depend on car makes and models and refrigerant type. The refrigerant charge of passenger car MAC systems ranges from 0.39 kg to 1.24 kg, the emission rate is estimated at 10%.

The total HFC-134a stock in passenger car MACs in Estonia amounted to 56.03 t in the year 2023. The HFC-134a emissions from the Estonian passenger car fleet in 2023 totaled 5.60 t (10%) (7.28 kt CO_2 eq.).

The amount of HFC-134a in the passenger cars MACs disposed in 2023 was estimated at 4.31 t (5.60 kt CO_2 eq). Disposal emissions from the Estonian passenger car fleet in 2023 totaled 2.16 t (EF=50%), the CO_2 equivalent of which was 2.80 kt.

Total MAC HFC emissions from passenger cars in 2023 amounted to 7.76 t (10.09 kt CO_2 eq.).

Trucks

In Western Europe, systematic air-conditioning of trucks with the refrigerant R-134a had started in 1994/95. Therefore, about half of Estonian trucks are potentially air-conditioned. Equipment

[100] https://stats.wto.org/ (22.12.2024)

of these newer vehicles with air-conditioners is relatively high – 79-100% of new trucks depending on the category.

In 2023, the total R-134a stock in truck MACs in Estonia amounted to 21.43 t and R-134a emissions from the Estonian truck fleet totalled 2.69 t (3.49 kt CO_2 eq.).

The amount of R-134a in the truck MACs disposed of in Estonia in 2023 was estimated at 1.65 t. Disposal emissions from the Estonian truck fleet in 2023 totalled 0.82 t (EF=50%), the CO_2 equivalent of which is 1.07 kt.

Total MAC HFC emissions from trucks in 2023 amounted to 3.51 t (4.56 kt CO_2 eq.).

Buses

In Western Europe, the large-scale use of buses with HFC-134a A/Cs (air conditioners) started in 1995. Most Estonian buses were built in 1995 or later and are therefore potentially equipped with HFC containing A/Cs. The proportion of newer buses with A/Cs is relatively high (e.g., ca 74% of buses initially registered in 2011–2020). The relevant MAC (mobile air conditioners) properties (equipment quota, refrigerant charge, leakage rate) depend on whether a bus is a city, intercity or a tourist bus. City buses can be subdivided into single and articulated buses. Intercity and tourist buses are usually single vehicles, with a small part of tourist buses being double-deckers. MAC systems in buses are big, containing 10-18 kg of refrigerant. The emission rate is high mainly because of the up to 50 meters long refrigerant pipes but also due to vibration.

The total R-134A stock in bus MACs in Estonia amounted to 20.54 t in the year 2023. The operating emissions from the Estonian bus fleet in 2023 totaled 2.84 t of R-134a, the CO_2 equivalent of which was about 3.69 kt.

The amount of HFC-134a in the bus MACs disposed of in 2023 was estimated at 1.58 t. Disposal emissions from the Estonian bus fleet in 2023 totaled 0.74 t (EF=50%), the CO_2 equivalent of which is 0.96 kt.

Total MAC HFC emissions from buses in 2023 amounted to 3.56 t (4.65 kt CO_2 eq.).

Ships

Usually, merchant ships >100 Gross Tonnage (GT) are equipped with air-conditioning systems and provision refrigeration, tugs with air-conditioning only, and fishing vessels >18 m with refrigeration. Ship air-conditioning with HFC started from 1996 onwards substituting HCFC-22. The refrigerants in use are R-407C, R-404A, R-407F, R-507A, R-442A and HFC-134a. Other HFC refrigerants (R-427A, R-417A, R-434A, R-438A) are of minor importance. Most HFC-refrigerants are used for air-conditioning (R-134a). A smaller part is used for provision cooling (R-134a, R-407F, R-404A, R-407C). The cooling and freezing systems of most Estonian deep-sea freezer trawlers operate without HFC, instead, ammonia is used.

In 2023, the total MAC HFC emissions from ships amounted to 4.61 t (7.63kt CO_2 eq.).

Railcars

The relevant MAC properties (refrigerant charge, leakage rate) do not depend on the type of the railcars. The refrigerant charge of railcar MAC systems ranges from 1.30 kg to 11.09 kg.

The total HFC-134a stock in railcar MACs in Estonia amounted to 1.37 t in 2023.

Total MAC HFC emissions from railcars in 2023 amounted to 3.27 kg (0.004 kt CO_2 eq.).

Wheel tractors and mobile machinery

The first agricultural machines (wheel tractors, combine harvesters) equipped with mobile air-conditioners on the Estonian market were sold in 1997/1998. Regarding construction machines (excavators, loaders) and other mobile machinery (forestry vehicles, roadwork machines) A/C equipment appeared later, in 2000.

The A/C equipment quota of the new agricultural machines has been estimated to be at least 75% since 2005.

The refrigerant used was HFC-134a. The relevant MAC properties (equipment quota, refrigerant charge, leakage rate) depend on the type and purpose of a specific machine. The refrigerant charge of tractors and mobile machinery MAC systems ranges from 1.0 kg to 2.3 kg. The emission rate is high due to the powerful vibration of these machines causing amongst others the connections in the MAC system to become loose.

In 2023, the total HFC-134a stock in tractor and mobile machinery MACs in Estonia amounted to 16.58 t. The HFC-134a emissions from the entire Estonian fleet totalled 4.27 t, the CO_2 equivalent of which is about 5.56 kt.

The amount of HFC-134a in the tractor/mobile machinery MACs disposed of in 2023 was estimated at 1.28 t. Disposal emissions from the respective Estonian fleet totalled 0.26 t (EF=20%), the CO_2 equivalent of which is 0.33 kt.

In 2023, the total MAC HFC emissions from wheel tractors and mobile machinery amounted to 4.53 t (5.89 kt CO_2 eq.).

2.F.1.f Stationary air-conditioning

Total HFC emissions from stationary and room air-conditioning in 2023 amounted to 25.09 t (41.44 kt CO_2 eq).

Heat pumps

The use of heat pumps with HFC refrigerants – ground and air heat pumps – started in Estonia in 1995. Ground heat pumps generally operate with HFC-407C, older air heat pumps with HFC-410A and the newer ones with R-32. In general, heat pumps are imported to the country and are already charged with refrigerant. In 2023, no heat pumps were manufactured and filled with refrigerant in Estonia.

In 2023, operating stock amounted to 35.74 t of R-407C (ground and other HP), 154.91 t of R-410A and 71.57 t of R-32 (air HP). Respective operating emissions totalled 0.89 t of R-407C, 3.87 t of R-410A and 1.79 t of R-32. The amount of refrigerant in HP at decommissioning was 0.21 t of R-407C. Disposal emissions in 2023 totalled 0.063 t of R-407C.

Total HFC emissions from heat pumps in 2023 amounted to 6.61 t (10.20 kt CO_2 eq.).

Stationary and room air-conditioning

Stationary and room air-conditioning systems including chillers, ventilation and split systems are generally imported to Estonia. Split systems are imported prefilled with HFC, newly installed chillers and ventilation systems are first filled inside the country. In these cases, emissions from filling (manufacturing) must be considered. The most common refrigerant used for new chillers is R-134a and most chillers contain it. Some new chillers are installed with R-410A and some with R-1234ze. In older equipment, smaller amounts R-407C remains, whereas in newer equipment R-410A can be found. The usual refrigerants for ventilation systems and split systems are mainly R-410A. In 2018 the first split systems with R-32 came to the Estonian market and now the majority of new equipment is with this refrigerant.

Manufacturing emissions in 2023 were: 0.005 t of R-134a, 0.004 t of R-32 and 0.004 t of R-125.

The operating stock in 2023 amounted to 162.22 t of R-134a, 83.06 t of R-32 and 71.13 t of R-125 and operating emissions were: 1.92 t of R-134a, 4.84 t of R-32 and 3.94 t of R-125.

As 1995 was the starting point of using HFCs in stationary air-conditioning equipment in Estonia, the first decommissioning emissions occurred in 2010. The disposal emissions in 2023 were: 1.10 t of R-134a, 1.13 t of HFC-32 and 1.18 t of HFC-125.

Table 4.25. Activity data and emissions from the stationary and room air-conditioning in 2023

	Operating stock, t	Operating emissions, t	Disposal emissions, t
R-134a	162.22	1.92	1.10
R-32	83.06	1.84	1.13
R-125	71.13	3.94	1.18

Total HFC emissions from heat pumps in 2023 amounted to 18.48 t (31.24 kt CO_2 eq.).

Total HFC emissions from 2.F.1.f subcategory in 2023 amounted to 25.09 t (41.44 kt CO_2 eq.).

2.F.2 Foam blowing agents

Total HFC emissions from foam blowing agents in 2023 amounted to 5.62 t (1.01 kt CO_2 eq).

2.F.2.a Closed cells

Total HFC emissions from closed cell foams in 2023 amounted to 0.24 t (0.27 kt CO_2 eq).

PU insulation panels

In 2023, HFC blown and containing insulation panels made of polyurethane rigid foam were neither manufactured nor used in Estonia. Imported products had been used in the past. In 2001, one Estonian company manufacturing PU sandwich panels (consisting of facings and a rigid polyurethane foam core) had substituted the blowing agent CFC directly by the water/CO_2 reaction. The only manufacturer of industrially prefabricated insulation panels for buildings (some type of sandwich element) combining PU spray foam with polystyrene changed the blowing agent in 2004 from HCFC-141b to CO_2/water and methyl formate. From 1998 onwards, a certain amount of PU sandwich elements manufactured with HFC-134a as a blowing agent had been imported from abroad. Although the use of these products in Estonia stopped in 2006, the HFCs enclosed in the foam cells of these panels form a small bank that is a source of emissions in the long run.

The 2023 Estonian HFC-134a bank in PU insulation panels amounted to 14.12 tons, the annual use-phase emissions were 0.071 tons (0.092 kt CO_2 eq.).

Spray and injection PU foam

PU spray foam systems are used for in-site insulation of buildings and soil-laid heating pipes. This sector of on-site insulation with spray and respectively injection foam blown with HFC-365mfc (with HFC-227ea add-on to reduce the flammability) is small. In Estonia HFC-containing spray foam was used in 2006-2008 and 2017-2019. For the period 2009-2018 I who sold this foam were interviewed and they answered that they sold water- or air- or HFO-based foams.

The inventory compilers in Estonia have searched for enterprises who insulate buildings with spray polyurethane foam and manufacturers of polyurethane (PU) foam products. The companies reported that they use air as a propellant.

In 2023 the stock constituted of 10.84 t of HFC-365mfc, 0.70 t of HFC-227ea and 0.027 t of HFC-134a. Stock emissions were: 108.36 kg HFC-365mfc, 7.01 kg HFC-227ea and 0.27 kg HFC-134a.

XPS insulation foam

The 2023 basic research showed that XPS foam was not manufactured in Estonia whereas imported XPS board for thermal insulation was of some importance in the country. Inventory compilers checked websites of imported foam products that are sold in markets for construction/gardening goods and found information that no HFCs are used. The European manufacturers have stepwise shifted from HCFC blowing agents to HFC-134a/152a and to CO_2. The main XPS suppliers to the Estonian market are using CO_2. One international manufacturer currently using both CO_2 and HFC-134a blowing agents supplies the Estonian market from a Scandinavian factory with CO_2 blown foam. From 2001 to 2006, this company sold a considerable amount of HFC-134a containing XPS panels to Estonia where these panels were used. There is data from producers that in case of HFC-134a some 27% of the blowing agent is released to the atmosphere on manufacturing (EF_{manu} = 27%). Therefore, 73% of the blowing agent remains in the panels as insulating cell gas, in the long term. Thus, in Estonia, a HFC bank in the XPS board stock was considered as a source of domestic emissions.

- 2023 HFC-134a bank: 7.75 t;
- 2023 use-phase emissions: 0.051 t (0.66%) (0.066 kt CO_2 eq.).

2.F.2.b Open cells

Total HFC emissions from open cell foams in 2023 amounted to 5.38 t (0.74 kt CO_2 eq).

One component PU foam

Estonia is amongst the biggest polyurethane one-component foam (OCF) producers in the EU. To a considerable part, the propellant gases in the foam cans are HFCs (R-152a) that are added to halogen-free flammable gases. By far most of the domestically used fluorinated greenhouse gases (HFCs) are imported for filling more than 4.5 million OCF cans that are, on their part, predominantly exported, especially to Eastern Europe. There is, however, also a considerable domestic market for OCF, which is supplied by both domestic manufacturers and – to a lesser degree – foreign companies. Due to the restrictions of one of the previous F-gas Regulation (EU) No 842/2006 on marketing HFCs in OCF both Estonian producers, in 2008, have stopped marketing OCF with R-134a in the EU, using mainly hydrocarbons instead, but also R-152a for some special applications. In 2010–2012, one Estonian producer manufactured OCF with R-134a as propellant but all the R-134a products were exported from the EU. From 2013 onwards R-134a has not been used in OCF production in Estonia and no emissions have occurred.

Manufacturing emissions: 0.29 t of R-152a (0.04 kt CO_2 eq.);
Stock = use-phase emissions: 5.09 t of HFC-152a (0.70 kt CO_2 eq.).

Total HFC emissions from One component PU foams in 2023 amounted to 5.38 t (0.74 CO_2 eq.).

PU integral skin foam

In Estonia, the PU Integral Skin Foam production started in 2004 with HFC-365mfc. Beforehand, ozone-depleting HCFC-141b was used, which is no longer allowed from 2004 onwards. All blowing agents applied in manufacturing are supposed to emit to the atmosphere the same year. Until 2009, one company in Estonia used HFC-365mfc and HFC-227ea for manufacturing of a very small amount of PU integral skin products. In 2010–2023, PU Integral Skin Foam was neither manufactured nor used in Estonia, thus no emissions were occurring.

2.F.3 Fire protection

In Estonia, different types of HFC are used for substituting halons in fire protection (flooding equipment): mostly HFC-227ea (FM-200), the blend FS49C2 (R-866) consisting of HFC-134a, HFC-125 and CO_2, and furthermore HFC-23.

The popularity of HFCs in fire protection systems has a decreasing trend and in the last six years no or very little new systems were installed. HFC-23 in fire extinguishing system was banned by the Regulation (EU) no 517/2014 in 2018. Another reason for decreasing popularity is that HFCs are much more expensive than environmentally friendlier substances for firefighting in indoor flooding systems (e.g., nitrogen, argon). The latter are characterized as gases under pressure of 200-300 bar. Compared to them, the advantage of HFCs is their lower pressure (30-50 bar) and that is one reason why in some applications HFC-s could be a better choice for smaller rooms where the higher pressure of e.g., argon could cause damage. Another alternative is Novec 1230 extinguishing fluid with GWP 1 and pressure of ca 30-40 bar. HFCs for fire protection are still popular on aircraft and some military vehicles.

HFCs for fire protection are brought to Estonia in closed cylinders from European manufactories. Installation is carried out by connecting the cylinder with the piping system. The cylinder has, according to the supplying companies, no valve outside but only inside so that a mistake upon installation (e.g., opening of the wrong valve) is hardly possible. In case of false alarm or fire, the whole charge of the cylinder is blown out. Refilling on site does normally not take place. Emptied cylinders are replaced by full cylinders.

In Estonia, the total 2023 quantity of F-gases in installed firefighting systems amounted to 30.68 t (21.97 t of R-227ea, 3.03 t of R-23 and 6.17 t of R-866 (FS49C2), the latter containing 8% CO_2 in mixture with R-134a and R-125). The emissions from this stock are calculated with 2%: 0.06 t of R-23, 0.01 t of R-125, 0.1 t of R-134a and 0.44 t of R-227ea.

Total HFC emissions from fire protection in 2023 amounted to 0.61 t (2.39 kt CO_2 eq.).

2.F.4 Aerosols

Total HFC emissions from aerosols in 2023 amounted to 1.77 t (2.30 kt CO_2 eq.).

2.F.4.a Metered dose inhalers

Under the category of Metered Dose Inhalers (MDI) with HFCs of pharmaceutical-grade two aerosol applications are discussed: aerosols for the treatment of asthma/COPD (chronic obstructive pulmonary diseases) and aerosols for natural medicine.

- Natural medicines: In 2023 the amount of HFC-134a used in domestic production was 0.68 t, of which 3% were manufacturing emissions (0.02 t or 0.03 CO_2 eq. kt). 100% of the products (0.68 t of HFC) was sold to the domestic market, resulting in use-phase emissions of the same amount of 0.88 kt CO_2 eq
- Anti-Asthma MDIs: The 2023 domestic market was 1.09 t of HFC-134a with the same quantities of emissions. The emissions of are 1.09 t HFC-134 (1.42 kt CO_2 eq). There were no HFC-227ea containing MDI-s on Estonian market in 2023.
- Total HFC emissions from Metered-dose inhalers in 2023 amounted to 1.77 t (2.30 kt CO_2 eq.).

2.F.4.b Technical aerosols

R-134a is used as a propellant in some technical aerosols like solvent and cleaning sprays, but in recent years HFC-free sprays with alternative gases are marketed in Estonia. Regulation (EU) No 842/2006 banned placing on the market of novelty aerosols such as signal horns for sports events or hunting. The Estonian manufacturer stopped producing signal horns in 2009. Solvent and cleaning sprays with R-134a were imported until 2010. The use of HFC-134a in solvent and cleaning sprays then stopped in Estonia due to supplier exchange and changes in product prescription. Placing technical aerosols containing HFC-s with GWP value of 150 or more on the EU market has been banned since 2018.

4.6.2. Methodological issues

Choice of methods

The first assessment of F-gas consumption in Estonia was made in 2006 under the Twinning Project EE2005/IB/EN/01 'Enhancing the capacity to reduce the emissions of fluorinated greenhouse gases in Estonia' (Twinning project between the Estonian Ministry of Environment and the German Ministry for the Environment, Nature Conservation and Nuclear Safety). Within the project, all sectors of possible F-gas consumption as described in the IPCC Guidelines for National Greenhouse Gas Inventories (2006 edition) were investigated in detail. The methods developed during the Twinning Project are used until today and the validity of the methods is evaluated each year with quality assessment activities.

Compiling of the Estonian F-gas inventory is bottom-up orientated. The main sources of information are manufacturers and traders of F-gas containing equipment and products, bulk F-gas suppliers as well as consumers of such goods in industry and tertiary sector and the F-gas trade itself, including experts from domestic and international companies, from associations and public institutions (e.g., Statistics Estonia, Estonian Transport Administration etc.).

Data collection and examination of data quality is carried out in direct contact with the sources and from databases. By this activity data, emission factors and emissions are determined methodologically as far as possible in a country-specific way (*Tier 2a* and *Tier 3* according to IPCC 2006 Guidelines).

In the Product uses as substitutes for ODS categories 2.F.1, 2.F.2 and 2.F.4 the method used is *Tier 2a* with country-specific determination of EF as described in the IPCC 2006 Guidelines.

Activity data

Refrigeration and air-conditioning (CRT 2.F.1)

2.F.1.a Commercial refrigeration

Supermarkets and small shops: The refrigeration systems of supermarkets and small shops are maintained by specialised service companies. Most of them install and service the systems, some are specialised on service activities. Stock and refilling data was collected from a national database of F-gas equipment set up according to Regulation (EU) 517/2014 (named 'FOKA' database). The 2023 stock data (59.26 t of HFC) had to be completed by the estimation of the stock by supplementary 2.91 t which makes a total sum of 62.17 t of HFC. This estimated amount should also cover small shops, whose HFC stock is under-represented in databases. The estimation is conservative and low with the aim not to overestimate the stock.

The total amount of HFC refrigerants was 662.17 t for the 2023 stock of supermarkets and small shops (reported and estimated) and includes non-HFC components of refrigerant blends, e.g., R-448A, R-449A. R-404A equipment in ca 30 supermarkets has been decommissioned and CO_2 based equipment installed instead. Refrigerant from decommissioned equipment is mostly re-used for servicing the remaining equipment or sometimes sent for destruction.

Restaurants, etc.: The stock of HFC refrigerants in restaurants, canteens and similar institutions was estimated based on some of 4583 possible clients (with on average three devices with a refrigerant charge of 350 g/device), resulting in about 4.62 t of HFC- and HC-refrigerants. Estonian experts estimated that R-404A constituted 30% (1.38 t) and R-134a 33% (1.50 t) in this subcategory. The share of other HFC refrigerants (R-422A, R-422D, R-452A) is ca 4%. The rest of the stock (1.55 t) consists of HC-refrigerants.

The number of vending machines in Estonia (ca 13 000 at 250 g refrigerant) was extrapolated based on the data from the three biggest Estonian manufacturers and importers of beer and other beverages delivering such machines to Estonian shops. A large percentage of them are already HFC free with R-290. The HFC-charge in vending machines amounted to 2.36 t of R-134a and 0.26 t of R-404A, respectively.

According to the above experts, the lifetime of refrigeration systems in supermarkets and small shops, including kitchen systems in Estonia is on average about 15 years (in case of vending machines 5–10 years).

2.F.1.b Domestic refrigeration (CRT 2.F.1.b)

According to Statistics Estonia, there were about 643 500 households in Estonia in 2023. The number of domestic refrigerators was estimated at 627 341 and the number of newly imported fridges/freezers at 49 331 (data from the Register of Products of Concern (abbreviation: PROTO) and the Estonian Association for Recycling of Electrical and Electronic Equipment (EES Ringlus) by the Estonian Environment Agency).

The stock of HFC-134a containing fridges/freezers is based on the estimation of HFC-134a containing fridges/freezers decommissioned in 2023 which in turn is estimated via lifetime. The average lifetime of fridges/freezers was estimated to be 9 years in 2023. The stock of domestic refrigerators consists of equipment with isobutane (R-600A), HFC-134A, and even CFC-s (e.g., R-12).

Wholesalers and EES Ringlus estimated the lifetime of domestic refrigeration equipment as follows: isobutane – 5-8 years, HFC-134A – up to 15 years, HCFC – up to 25–30 years. In the waste refrigerant removed from the fridges in 2019-2023 there was no more HCFC. The proportion of HFC-134A containing refrigerators brought to market was maximally 1% each year in 2006-2009. Since the lifetime of HFC-134a containing fridges is 15 years, new equipment of the years 2006-2009 is accounted in the stock. Since only 1% of new fridges brought to market in 2006-2009 were with HFC-134a, it could be concluded that the stock of HFC-134A is nearing to zero.

2.F.1.c Industrial refrigeration (CRT 2.F.1.c)

Information on potential HFC users in the food and other industries was compiled in cooperation with experts from refrigeration service providers/companies specialised in industrial application. Activity data was collected from FOKA database and also previous years' data from questionnaires was used. Basic data about the Estonian food industry can be found in the statistics of the Agriculture and Food Board (PTA[101]) as companies handling foodstuff shall be approved by the PTA and the data is available online.

[101] https://jvis.agri.ee/jvis/avalik.html#/toitKaitlemisettevotedparing (22.12.2024)

As the refrigerant stock based on the data from service companies and the national PTA database covers the total stock to only a certain part, the remaining stock had to be estimated by the inventory compilers in cooperation with national sectoral experts. Thus, the estimated percentage of HFC stock in industrial refrigeration was estimated to constitute 17.2% or 13.36 t of the total HFC stock of 77.60 t (reported and estimated, including non-HFC ingredients of some refrigerant blends, e.g., R-448A, R-422D, etc.).

According to the national sectoral experts, the average lifetime of industrial refrigeration systems in Estonia is about 15 years or more. Therefore, calculating 15 years back, the amount of R-404A, R-134a, R-407C filled in new equipment in 2008 was decommissioned in 2023.

Calculating refrigerants in pure forms and in blends

Table 4.26 shows as an example how the amounts of refrigerants are calculated in pure forms and in blends that sum up in the table 2(II)B-Hs2 in case of R-134a (Industrial refrigeration). Information about these calculations of certain F-gases in pure forms and in blends was asked additionally by 2022 UNFCC review team and added thereafter as a table to clarify more in detail the recalculations of 2019 data that was reported in 2022 submission.

Table 4.26. R-134a amounts calculated in pure forms and in blends.

HFC	Filled in new manufactured products	In operating systems (average annual stocks)
HFC-134a (in pure form)	**1.2**	**4.98**
HFC-404A (blend)	0.16	66.02
HFC-143a	0.08	34.33
HFC-125	0.07	29.05
HFC-134a	**0.01**	**2.64**
HFC-407C (blend)	0	3.54
HFC-134a	**0**	**1.84**
HFC-32	0	0.81
HFC-125	0	0.89
HFC-407F (blend)	0.16	1.96
HFC-134a	**0.06**	**0.78**
HFC-32	0.05	0.59
HFC-125	0.05	0.59
HFC-422A (blend)	NO	0.59
HFC-125	NO	0.5
HFC-134a	**NO**	**0.07**
HFC-422D (blend)	NO	0.46
HFC-125	NO	0.3
HFC-134a	**NO**	**0.14**
HFC-417A (blend)	NO	0.3
HFC-125	NO	0.14
HFC-134a	**NO**	**0.15**
HFC-448A (blend)	0.2	0.22
HFC-32	0.05	0.06
HFC-125	0.05	0.06
HFC-134a (blend)	**0.04**	**0.05**
HFC-134a (In pure form and in blend)	**1.31** (1.20+0.01+0.06+ 0.04)	**10.66** (4.98+2.64+1.84+0.78+0.76+0.07+ 0.14+0.15+0.05)

2.F.1.d Transport refrigeration (CRT 2.F.1.d)

Refrigerated vehicles

The Estonian Transport Administration provided a list of all vehicles registered at the end of 2023, subdivided into weight classes (N_1, N_2, and N_3 according to Regulation 2001/16/EC), makes, models and production years dating back to 1995 and beyond.

Information on the types of refrigeration units of the Estonian vehicles, the HFC-types they are charged with, the refrigerant charges, the emissions and the frequency of refilling is based on information provided by three biggest service companies for refrigerated vehicles, all linked to the leading international manufacturers of refrigeration units for trucks and trailers. The service companies provide the amount of refrigerants filled into the equipment of first registered vehicles and estimates on average refrigerant charges and refilling rates.

Vans and smaller trucks (class N_1 and half of class N_2 according to 2001/16/EC) run R-134A and R-452A systems (average charge 2.0 kg/unit), bigger trucks (half of class N_2 and class N_3) run equipment with R-404A and new lower-GWP refrigerant R-452A (average charge 5.8 kg/unit). For trailers, an average charge of 8.0 kg of R-404A and R-452A is supposed. The proportion of different refrigerants in stock is estimated by service companies. Over 70% of vehicles still have R-404A based refrigeration systems and a lower proportion have R-452A and R-134A.

Reefer containers

The starting point of the estimation is not country-specific but worldwide data. As this data was already available in the German F-gas inventory, our research into the worldwide HFC stock and emissions was not necessary. Only the share of Estonia in the world trade had to be identified.

The worldwide HFC stock was estimated in three steps:

1. Annual number of 20 feet units (new manufactured, decommissioned, total stock) from World Cargo News online[102];
2. Refrigerant charge per set (6 kg of R-134A or 4 kg of R-404A; from German F-gas inventory);
3. HFC-split between R-134A and R-404A (80% to 20%; from German F-gas inventory).

The lifetime for reefer containers is according to experts about 14 years.

2.F.1.e Mobile air-conditioning

Passenger cars

The Estonian Transport Administration provided a list of all passenger cars registered at the end of 2023, subdivided into production years (dating back to 1994 and beyond). In 2023 no cars with HFC-134a were registered in accordance with the EU directive 2006/40/EC (MAC Directive).

In 2023, there were 660 718 passenger cars in the traffic register kept by Estonian Transport Administration.

From 2006 onward Estonia has used country-specific number of new makes and models of cars for cross-checking of congruence with German new car fleet. In addition, incomplete data on HFO-1234yf for mobile air conditioning in passenger cars in 2014 was used for the validation

[102] https://www.worldcargonews.com/container-industry/2021/02/lessors-maintain-a-positive-mood/ (22.12.2024)

of German data. There was congruence between new car makes and models of Estonian and German car fleets. For this reason, German quota and charges for HFC-134a were used before 2016. The Estonian MAC charges were considered 2% smaller than the analogous German charges.

Detailed German data on new cars using HFC-134a (charged amounts and share of use) could not be shared with the Estonian inventory compiler for 2016 and subsequent years owing to confidentiality reasons. Using German data without validation was out of question because it would have caused an inaccuracy in estimation. In consequence of lack of German data, Estonian country-specific data was collected for the years 2016-2018. Data was collected from all car brands importers in Estonia.

Significant differences were identified in the share of HFC-134a in German and Estonian new cars in 2016 (e.g., for 2016 the Estonian HFC-134a share was 54 per cent while in Germany the share was 43.7 per cent). Collecting country-specific data for 2016–2017 from Estonia's car sellers enabled it to use more accurate data compared to using German data without validation. This also enabled to avoid errors at the end of the time series regarding the share of cars with HFC-134a, which could have been purchased according to article 27 of the EU directive 2007/46/EC.

The Association of Estonian Car Dealers (AMTEL) gave an expert opinion that both validated German data and Estonian-specific data in 2016-2018 have minimal error and therefore guarantee best consistency of time series that is possible.

In 2017-2018, only end of series vehicles with HFC-134A were placed on the Estonian market according to article 27 of the Directive 2007/46/EC. In 2019 no cars with HFC-134a were brought onto market according to the Association of Estonian car Dealers (AMTEL).

Trucks

The Estonian Transport Administration provided a list of all trucks registered at the end of 2023, subdivided into weight classes (N_1, N_2, and N_3), makes, models and production years dating back to 1995 and beyond. No official data about air conditioning was available.

In 2023, there were about 147 378 trucks of the weight classes (according to 2002/16/EC) N_1, N_2, and N_3 in the national vehicles' registry of Estonia (including vehicles with suspended registry entry).

As the 2006 investigation results had shown congruence between Estonian and German passenger car fleets and their MAC data (based on the high share of imported used vehicles from Germany) the following approach was applied to establish necessary truck MAC data. The German F-gas inventory treats the MAC quotas and charges of certain truck models as representatives of their respective weight classes and extrapolates their specific figures to the total N_1, N_2, and N_3 trucks in the country. The same truck models as in Germany were identified in the Estonian truck park for each weight category (N_1, N_2, N_3). The German MAC quotas and refrigerant charges of these representative models were applied to the same models in the Estonian truck fleet. The total values of N_1, N_2 and N_3 trucks in Estonia result from the extrapolation of model values according to the share that these models have in the total Estonian fleet, by the three different weight classes N_1, N_2 and N_3.

In 2020 and onwards, Estonian specific data on A/C charges and quota of N_2 and N_3 category vehicles was collected from Estonian truck sellers and used in calculation. None of the N_1 category vehicles had HFC-134a in their air conditioners because of the ban of such new registrations according to the Directive 2006/40/EC.

The relevant MAC properties (equipment quota, refrigerant charge, leakage rate) depend on truck makes and models. The refrigerant charge of truck MAC systems ranges from 0.77 kg to 1.2 kg, the emission rate is 10–15% depending on the weight class.

Buses

The Estonian Transport Administration provided a list of all buses registered at the end of 2023 (M_3 category), subdivided into makes, models and production years dating back to 1992 and beyond. Data on the city-intercity-tourist bus split were not included, nor is there official data available about air conditioning.

In 2023, 5 175 buses were in the national vehicles register of Estonia (including vehicles with suspended registry entry). A large part of the Estonian bus fleet consists of second-hand vehicles from Western Europe.

Several big national and local bus operators were interviewed in 2020 about the MAC data of their fleet and the countrywide bus fleet. The data they provided on average quota on intercity and tourist buses largely match the data of Western Europe (Schwarz, 2007)[79] in consequence of the extensive importation of second-hand vehicles from there.

Ships

Ships under the Estonian flag with GT 100 or more and fishing vessels >18 m is listed in the Estonian Ship Register (Estonian Transport Administration). Data on AC and provision cooling systems of these ships and additionally data on all ferries of the two relevant Estonian ferryboat companies were collected from the operating companies via reporting forms. The data on the type of refrigerant, charge and refilling in 2023 were provided directly by the ship owners. The estimation of the stock emissions is based on the average refilling rate.

According to the Estonian Transport Administration, tugboats >100 GT have no air-conditioning devices.

Railcars

The Estonian Technical Regulatory Authority was contacted to establish the size of the countrywide railcar fleet.

In 2023, there were 171 railcars and engines in the Estonian fleet equipped with a working air conditioner. The number of railcars is the same as in 2022.

For obtaining MAC data in Estonian railcars local rail operators involved in passenger transport were interviewed in 2020. Dining cars, sleeping cars and coaches of international trains (historically) had much higher refrigerant charges (30 kg) than standard cars (average 11.09 kg). The average charge in engines MAC is 0.68 kg.

Wheel tractors and mobile machinery

The Estonian Transport Administration provided a list of all wheel tractors and mobile machinery registered at the end of 2023. Official data about air-conditioning of the vehicles was not available.

In 2023, there were 30 356wheel-tractors and 9501 mobile types of machinery in the national vehicles register of Estonia (including vehicles with suspended registry entry), over half of which were older than 10 years.

The data on average charges and quotas were collected from the wholesalers of the new machines registered in 2021. The average charges and quotas of Estonian agricultural machines match the respective values of Western Europe. The authors of this report, taking into account the particularities of the Estonian vehicle fleet, estimated the number of leakages and refills.

2.F.1.f Stationary air-conditioning

Heat pumps

Estonian Heat Pump Association provided expert report on heat pumps in Estonia in 2023. The report is based on data from member companies of the association (most of heat pump suppliers and service companies with larger market share). In order to avoid double-counting, the classification of heat pumps on the one hand, and stationary respective room air-conditioning systems, on the other hand, is discussed together with experts from the Estonian Refrigeration Association.

In 2023, the stock of installed heat pumps in Estonia amounted to approximately 210 849 systems (22 649 ground, 21 957 water, 165 117 air and 1126 other heat pumps) out of which 19 909 were installed in 2023. Air heat pumps have become a very popular substitution for stove heating. It is assumed that heat pumps which reach the end of lifetime (15 years) are decommissioned each year. The average charge in a heat pump (HP) was estimated at 2.0 kg for ground, air to water and other HP. For air-to-air HP-s the average charge was estimated at 1.0 kg refrigerant.

Stationary and room air-conditioning

2023 year´s data was used which was supplied by the Estonian Refrigeration Association and companies (manufacturers, traders, service companies) belonging to this association. The data included newly installed systems, the total 2023 equipment stock, refrigerant charges by weight and HFC types and EF for domestic manufacturing and operating stock.

The numbers of operating systems are the following: 2 356 chillers, 6 845 ventilation systems and 34 605 split systems.

Foam blowing agents (CRT 2.F.2)

2.F.2.a Closed cells

PU insulation panels

The present bank of HFC-134a as an insulating gas in imported sandwich elements was assessed by a model (because the import/export data from the Estonian customs only indicate origin and total weight of sandwich elements without information on the insulating gases). The model is based on information from Statistics Estonia (annual import of sandwich elements minus export), Estonian experts/importers (average quota of imported sandwich elements with PU-core in 1998–2001: 15%, 2002–2006: 40%), and foreign manufacturers of sandwich elements (average quota of PU-foam with HFC-134a: 1998/99: 100%, 2000: 50%, 2001: 10%, 2002: 5%; PU core: 30% of the sandwich elements weight). As a result, the bank of HFC containing PU panels (about 760 t) in 2006 was estimated to contain approximately 230 tons PU with HFC-134a with the HFC-134a content in the foam-stock of 6.75%[103].

Spray and injection PU foam

In the EU, for on-site applied foam the blowing agent HCFC-141b (ozone depleting substance) was no longer permitted as of 2004 at the latest. Difficulties with alternative blowing agents arose from two sides. On the one hand, the application of HFC-365mfc was not trivial from a technical point of view. On the other hand, the manufacturer of this fluid could not satisfy the demand for HFC-365mfc in 2004 due to problems in his production plant. Consequently, in the

[103] The panels are manufactured according to experts with 7.5% HFC-134a; after a first-year loss (FYL) of 10% during and after manufacturing 6.75% of the blowing agent remain within the foam.

EU the HCFC-141b was still in use after 2004 and according to PU system suppliers also in Estonia.

In 2006–2008, one company in Estonia used HFC-365mfc/HFC-227ea (in addition to a small amount of HFC-134a) as blowing agent for on-site applied PU foam. HFC quota in this mixture: HFC-365mfc = 93%, HFC-227ea = 7%.

According to chemical suppliers, the HFC content in the spray foam system before application was 7.5% in the years 2006-2008. In 2017-2019 another company has sold HFC-containing closed-cell polyurethane spray foam blend in Estonia. The HFC content in this foam was 8.7% (93% HFC-365mfc and 7% HFC-227ea) according to the producer.

XPS insulation foam

Seven international chemical companies gave data on the XPS foam market in Estonia. Based on this information, both the year-on-year growth in the domestic XPS-foam bank and the HFC content in the annual sales quantities were assessed for the 2001–2005 period. From 12.5% (2001) a gradual decrease in the HFC-134a content to 0% (2006) was established, resulting in 5% HFC content of the final 2006 XPS stock (72 000 m^3 XPS, thereof 3 600 m^3 HFC-containing XPS). As the HFC quantity used to produce one m^3 XPS foam is known (3.3 kg), the HFC bank was calculated from the volume of XPS sold in Estonia. A use-phase emission factor (EF_{op}) of 0.66% was applied to this long-term bank of enclosed HFC-134a. Country-specific EF_{op} is lower than the value given in the IPCC 2006 Guidelines, 0.75%.

Open cells (CRT 2.F.2.b)

One component PU foam

The following data was collected for emission estimation from manufacturing and use of OCF:

1. Number of cans (in terms of 750 ml volume) with HFC as blowing agent manufactured in Estonia, average amount of HFC per can, emissions on filling.
2. Number of OCF cans (in terms of 750 ml content) with HFC as blowing agent sold to the Estonian market, average amount of HFC propellant per can.

Information sources:

- The two Estonian companies manufacturing OCF within the country and selling OCF to the Estonian market.
- Wholesalers selling HFC-152a containing OCF to the Estonian market.

PU integral skin foam

Information on the consumption of HFC-365mfc was provided by the manufacturer of integral skin products in Estonia.

Fire protection (2.F.3)

Data on the amount of the three mentioned HFC-based fluids for fire protection in the 2023 stock was acquired from the database set up according to article 6 of the Regulation No 517/2014The first HFC installation dates to 2000.

2.F.4 Aerosols

2.F.4.a Metered dose inhalers

The domestic manufacturer provided the data on manufacturing, domestic consumption and export of MDIs for natural drug products including the emissions rate from manufacturing (EF_{manu} = 3% in 2023). Use-phase emissions: The number of MDIs for both anti-asthma and natural medicines sold to the domestic market in 2023 (production + import - export) is the stock of the year 2023. As the consumption of the products follows the purchase immediately, annual stock and the annual emissions are the same. HFC-134a and HFC-227ea are completely exhaled after inhalation so that 100% is the appropriate value for the use-phase emission factor, which is likewise in accordance with the IPCC 2006 Guidelines and IPCC Good Practice Guidance.

The 2023 year's sales figures and HFC content of the MDIs (asthma/COPD) and other pharmaceutical products were provided by the Estonian Medical Board and information on HFC content per device was provided by respective companies.

Emission factors

Refrigeration and air-conditioning (CRT 2.F.1)

2.F.1.a Commercial refrigeration

The actual refilling rate 11.7% is used as operating emission factor in 2021-2023. This is lower than in years before that (15%). The refilling rates of all service companies were significantly lower than in previous years and the service companies substantiate it that the most leaking equipment was replaced with CO_2 equipment first and the remaining equipment is leaking less. Another reason could be that according to Regulation (EU) no 517/2014 article 13 larger equipment must not be serviced with virgin R-404A since 1th January 2020 and that is why only minimal amounts of (recycled) R-404A were refilled.

The amount of R-134a, R-404A and R-407C filled in new equipment in 2008 was decommissioned according to 15 years lifetime in 2023.

2.F.1.b Domestic refrigeration (CRT 2.F.1.b)

Emission factors: EES Ringlus estimated that about 6% of the original charge has already emitted by the time when fridges/freezers are collected for recycling. The annual operating emission rate is, following this information, 0.4%/year (EF_{op}). This country-specific emission factor is within the value range 0.1–0.5% given in the IPCC 2006 Guidelines[104].

2.F.1.c Industrial refrigeration (CRT 2.F.1.c)

The results of the surveys in 2021 showed that the refilling ratios of the individual companies range from 2 to 38%. The average refilling rate was 9.1% which is lower than the prior value of 15%. In 2023 refilling rate of 9.1% was used as in 2021-2022. The service companies explained that the low refilling ratio has two reasons: 1) because of service ban with virgin R-404A recycled refrigerant is used very sparingly; 2) the most leaking equipment has been exchanged with R-134A, R-448A and R-452A containing equipment. The latter substantiation cannot be extrapolated to the whole stock because only 3% of the old equipment with R-404A has been replaced with R-448A and R-452A.

The emission factor 9.1% is in the range of the IPCC 2006 Guidelines and the IPCC Good Practice Guidance (7–25% of the stock).

[104] IPCC 2006 Guidelines, Volume 3, Chapter 7, table 7.9, page 7.52.

The EF_{manu} (filling of new equipment) is estimated at a low value of 0.5%, which is likewise in accordance with the IPCC 2006 Guidelines and IPCC Good Practice Guidance. The EF_{disp} (disposal loss factor) is estimated at a value of 50%. The disposal emission factor is based on the IPCC 2006 Guidelines[105] estimates of recovery efficiency and estimates from service companies. 50% of HFC containing refrigerants are recovered.

- Country-specific EF_{manu} (filling): 0.5%;
- Country-specific operating emission factor EF_{op}: 9.1%;
- Country-specific disposal emission factor EF_{disp}: 50%.

2.F.1.d Transport refrigeration (CRT 2.F.1.d)

Refrigerated vehicles

The Estonian experts estimate the emissions at first domestic filling (empty units of imported new and second-hand vehicles) at 1%, which is in accordance with the IPCC 2006 Guidelines[106]. These emissions are equated to the CRT emission category 'emissions from manufacturing'. The annual losses from the operating systems (emissions from stocks) including service emissions on refilling amount to an average of 30% (EF_{op} – operating emission factor) of the refrigerant stock in the refrigerated vehicles. This country-specific emission factor is within the value range given by the IPCC 2006 Guidelines. The disposal emission factor is based on estimates from service companies and is at the high end of the IPCC 2006 Guidelines estimates.

- Country-specific average refrigerant charges per unit (for estimating the stock): weight classes N_1 and half N_2: 2.0 kg; N_3 and half weight class N_2: 5.8 kg; trailers: 8.0 kg;
- Country-specific manufacturing emission factor: 1%;
- Country-specific operating emission factor: 30%;
- Country-specific disposal emission factor: 30%.

Reefer containers

The emissions of R-134A and R-404A are calculated by means of emission factors. The operating emission factor is 10%[107]. The disposal emission factor is 30%, which lies at the upper boundary of the range given by the *Tier2a* method in the IPCC Good Practice Guidance[108]. Manufacturing emissions are not distributed by world trade shares but are estimated in the (few) countries of container manufacturing. Method was also validated by the German Öko-Recherche experts in 2006.

2.F.1.e Mobile air-conditioning

Passenger cars

The emissions from the refrigerant stock in the Estonian car fleet are estimated applying the leakage rate established in the 2003 EU study (Schwarz & Harnisch, 2003)[109], where the authors claim the data published in it to be representative of all EU countries.

[105] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.
[106] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.
[107] 2002 report of the refrigeration, air conditioning and heat pump technical options committee (RTOC) https://wedocs.unep.org/handle/20.500.11822/7796, (22.12.2024)
[108] IPCC 2006 Guidelines, Volume 3, Chapter 7.5.2.2 "Choice of emission factors" and 7.5.2.3 "Choice of activity data"
[109] Schwarz, W. and J. Harnisch, 2003: Establishing the Leakage Rates of Mobile Air Conditioners. Report prepared for DG Environment of the European Commission, Ecofys, Öko-Recherche and Ecofys, Frankfurt, Germany.

Different types of vehicles have different product life factors (PLF). PLF for different types of vehicles (passenger cars, trucks, buses, ships, railcars, wheel tractors and mobile machinery) that have mobile air-conditioning were calculated as follows:

emissions from stocks ÷ average annual stocks × 100.

Total PLF for mobile air-conditioning category is calculated as follows:

total actual emissions from stocks ÷ average annual stocks × 100.[110]

- Country-specific average refrigerant charge;
- Emission factor: 10%, which is in accordance with the IPCC 2006 Guidelines;
- MAC quotas: In the total fleet, the MAC quotas vary by the production years;
- Disposal emission factor 50% is based on the IPCC 2006 Guidelines estimates of recovery efficiency and estimates from service companies.

Trucks

- Country-specific average refrigerant charges: weight class N_1: 0.77 kg; weight class N_2: 0.91 kg; and weight class N_3: 0.91 kg.
- Emission factors (Schwarz, 2007)[111]: weight class N_1: 10%; weight classes N_2 and N_3: 15%, which are likewise in accordance with the IPCC 2006 Guidelines and the IPCC Good Practice Guidance[112].
- MAC quotas: In the total fleet, the MAC quotas vary by the production years.
- Disposal emission factor 50% is based on the IPCC 2006 Guidelines[113] estimates of recovery efficiency and estimates from service companies.

Buses

Method according to the IPCC 2006 Guidelines[114]: *Tier 2a* with country-specific determination of EF.

- Country-specific average refrigerant charges: City and tourist (single) buses: 10 kg, intercity buses: 4 kg; articulated buses and double-deckers: 18 kg.
- Country-specific emission factors: city, tourist single buses 1.5 kg/year; intercity buses 0.6 kg/year; articulated buses and double-deckers: 3 kg/year, which are likewise in accordance with the IPCC 2006 Guidelines and the IPCC Good Practice Guidance.
- MAC quotas: In the total fleet, the MAC quotas vary by the production years. For all types of buses Estonian quota was used which was obtained from interviews with bus sellers.
- The disposal emission factor of 50% is based on the IPCC 2006 Guidelines estimates of recovery efficiency and estimates from service companies.

Ships

- Country-specific HFC refrigerant blend stock
- EF of 30% (average of previous years) is used for emission calculation, which is in accordance with the IPCC Good Practice Guidance.

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[110] Information about the development of the PLF for different types of vehicles that have mobile air conditioning was included as the recommendation of the UNFCCC review team.
[111] Schwarz, W. (2007). Establishing the Leakage Rates of Mobile Air Conditioners in Heavy Duty Vehicles (070501/2005/422963/MAR/C1). Part I trucks, and part II buses. Prepared for the European Commission (DG Environment).
[112] IPCC 2006 Good Practice Guidance and Uncertainty Management, Chapter 3, table 3.23, page 3.110.
[113] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.
[114] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

- Country-specific decommissioning emissions factor: 50%. Disposal emission factor 50% is estimated based on data from waste collecting companies.

Railcars

The refrigerant charges and emission factors used:

- Country-specific average refrigerant charges: 30 kg of R-134a for cars of international trains, 11.09 kg for standard cars and 0.68 kg of R-134a (engines).
- Country-specific emission factors: calculation based on annual losses of R-134a and the amount of refrigerant stock leads to the implied emission factor of 0.2% for all railcars in 2023, which is in accordance with the IPCC Good Practice Guidance[115].

Wheel tractors and mobile machinery

The refrigerant charges and emission factors used:

- Country-specific average refrigerant charges of new vehicles: excavators, loaders: 1.5 kg, roadwork machines 1.0 kg, wheel tractors 1.25 kg, forestry machines 2.3 kg and combine harvesters: 2.2 kg.
- Country-specific emission factors: wheel tractors 20% (EF is in the range of the IPCC 2006 Guidelines and the IPCC Good Practice Guidance); combine harvesters, construction machines, forestry, and roadwork machines 25%, which is likewise in accordance with the IPCC Good Practice Guidance.
- MAC quotas: In the total fleet, MAC quotas vary by production years.

2.F.1.f Stationary air-conditioning

Heat pumps

The discussion with Estonian experts resulted in emission factors for manufacturing (EF_{manu}) of 2.0%, which lies above the value range proposed in the IPCC 2006 Guidelines and the IPCC Good Practice Guidance (0.2–1%); for operating systems (EF_{op}) of 2.5%, which is in accordance with the IPCC 2006 Guidelines[116] and the IPCC Good Practice Guidance[117]. The disposal emission factor is 30.0%, which lies in the lower part of the range proposed in the IPCC 2006 Guidelines. The disposal emission factor considers estimates from service companies. It is estimated that 70% of the refrigerant is recovered.

- Country-specific EF_{manu}: 2%;
- Country-specific EF_{op}: 2.5%;
- Country-specific EF_{disp}: 30%.

Stationary and room air-conditioning

The EF_{manu} (first filling loss) was established at 20 g/system for chillers (0.019%) and 40 g/system (factor: 0.24%) for ventilation systems, the EF_{op} (Product Life Factor) at 1% (chillers), 10.5% (ventilation systems) and 2% (split systems). Chillers and split systems are industrially manufactured and tighter than ventilation systems that are assembled on site. Although the emission factor of chillers, estimated by the national experts, is deemed too low compared with the values presented by other countries, there is currently no more reliable data available. Emissions factors of ventilation systems and split systems are in the range of the IPCC 2006

[115] IPCC 2006 Good Practice Guidance, Chapter 3, page 3.110, table 3.23.
[116] IPCC 2006 Guidelines, Volume 3, chapter 7, page 7.52, table 7.9.
[117] IPCC Good Practice Guidance 2000, Chapter 3, page 3.106, table 3.22.

Guidelines[118]. The country-specific emission factor used for disposal (EF_{disp}=30%) is at the low end of the range proposed in the IPCC 2006 Guidelines. The disposal emission factor is based on the IPCC 2006 Guidelines estimates of recovery efficiency and estimates from service companies.

- Country-specific EF_{manu}: 0.019% (chillers) and 0.24% (ventilation);
- Country-specific EF_{op}: 1% (chillers), 10.5% (ventilation) and 2% (split);
- Country-specific EF_{disp}: 30%;
- Country-specific recovery percentage: 70%.

Foam blowing agents (CRT 2.F.2)

2.F.2.a Closed cells

PU insulation panels

The annual use-phase HFC-134a emissions from the bank (EF_{op}) are estimated according to experts from manufacturing companies at 0.5%, which is likewise in accordance with the IPCC 2006 Guidelines[119] and the IPCC Good Practice Guidance.

- Country-specific EF_{op}: 0.5%.

Spray and injection PU foam

On application (manufacturing), a blowing agent loss (EF_{manu}) must be considered which includes two HFC fractions: one released directly upon application, and another being released within one year after application. Both fractions together are called first-year loss (FYL). The FYL amounts to 20%; 80% of the original blowing agent remains in the foam cells during the use-phase[120]. The product life factor (EF_{op}) is according to chemical suppliers 1%.

- Country-specific EF_{manu}: 20%;
- Country-specific EF_{op}: 1%.

XPS insulation foam

A use-phase emission factor (EF_{op}) of 0.66% was applied to this long-term bank of enclosed HFC-134a. Country-specific EF_{op} is lower than the value given in the IPCC 2006 Guidelines, 0.75%.

- Country-specific EF_{op}: 0.66%;

Open cells (CRT 2.F.2.b)

One component PU foam

The EF_{manu} (0.52%) is based on information from the two domestic manufacturers. As to the application of OCF, it is assumed that all HFC is emitted from the cans in the year of the OCF use. In contrast to the method of the IPCC 2006 Guidelines but in accordance with other submissions under the UNFCCC, it is assumed that all use-phase emissions occur in the year of sale (use and disposal occurring promptly after the sale). The row 'stock' in CRT Reporter is equated to the HFC content of OFC cans sold to the Estonian market and used in the relevant year. Hence only emissions from manufacturing and use (= stock) are entered in the CRT table,

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[118] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.
[119] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.37, table 7.7.
[120] In contrast to the IPCC 2006 Guidelines (p. 7.35: FYL 10%), in this report an FYL of 20% is used (Krähling/Solvay 2002: 15% loss on manufacturing, 5% additional loss within the first year).

no emissions from disposal. EF_{op} is 100%, which is higher than the value given in the IPCC Good Practice Guidance and IPCC 2006 Guidelines (95%).

- Country-specific EF_{manu}: 0.52% (HFC-152a);
- Country-specific EF_{op}: 100%;

PU integral skin foam

For manufacturing of PU integral skin foam, small quantities (1–2%) of HFC are added as an auxiliary blowing agent to improve product quality. As integral skin is open-cell foam, upon foaming the blowing agent is released almost completely within one year (according to the industrial foam system supplier). The EF_{manu} (First Year Loss) is 100%. This means methodologically that there is no need for estimating an HFC bank and operating emissions from this bank. Information on the consumption of HFC-365mfc was provided by the manufacturer of integral skin products in Estonia.

Method according to IPCC 2006 Guidelines: *Tier 2a* with country-specific determination of EF.

- Country-specific EF_{manu}: 100%.

2.F.3 Fire protection

According to the IPCC 2006 Guidelines, the annual emissions from installed flooding systems are in the range of 2 ± 1 per cent of the installed base. As there are no detailed indications on operating emissions from flooding systems in Estonia for a longer period, an EF_{op} of 2% is applied to the bank. Emissions upon filling/refilling (EF_{manu}) are not calculated. Based on interviews done in 2020 with fire protection systems service companies it has been concluded that they use the decommissioned/removed F-gas cylinders in another object, if possible, return to the manufacturers or send to the F-gas recycling/destruction facilities. Therefor due to the long lifetime of flooding systems (15–20 years) and the possibilities of recovery, no end-of-life emissions are assumed.

Method *Tier 2a* according to IPCC 2006 Guidelines, using IPCC default EF_{op}.

- Operating emission factor EF_{op}: 2%.

2.F.4 Aerosols (2.F.4)

2.F.4.a Metered dose inhalers

Method according to IPCC 2006 Guidelines: *Tier 2a* with country-specific EF.

- Country-specific EF_{manu}: 3%;
- Country-specific EF_{op}: 100%;

2.F.4.b Technical aerosols

As in case of MDIs, the HFC-consumption for freezing spray in a year is equated to the emission in the same year (EF_{op} 100%), which is in accordance with the IPCC 2006 Guidelines and IPCC Good Practice Guidance.

4.6.3. Uncertainty assessment and time-series consistency

For uncertainty assessment please see Annex A.II.2 IPPU, 2.F Product uses as substitutes for ODS chapter.

4.6.4. Category-specific QA/QC and verification, if applicable

The data for this report was collected by the expert of the Estonian Environmental Research Centre. A complete Quality Assurance (QA) and Quality Control (QC) was carried out for Industrial processes and product use sector according to the IPCC *Tier 1* method.

4.6.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

No category-specific recalculations were done.

4.6.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

There are no planned category-specific improvements.

4.7. Other product manufacture and use (CRT 2.G)

4.7.1. Category description

This category includes:

- SF_6 emissions from Electrical equipment (CRT 2.G.1);
- SF_6 emissions from Accelerators (CRT 2.G.2b), historical SF_6 and PFC emissions from Sport shoes and Car tires (CRT 2.G.2.d);
- N_2O emissions from Medical applications (CRT 2.G.3.a) and from Propellant for pressure and aerosol products (CRT 2.G.3.b).

Emissions from category Other product manufacture and use are shown in Figure 4.8.

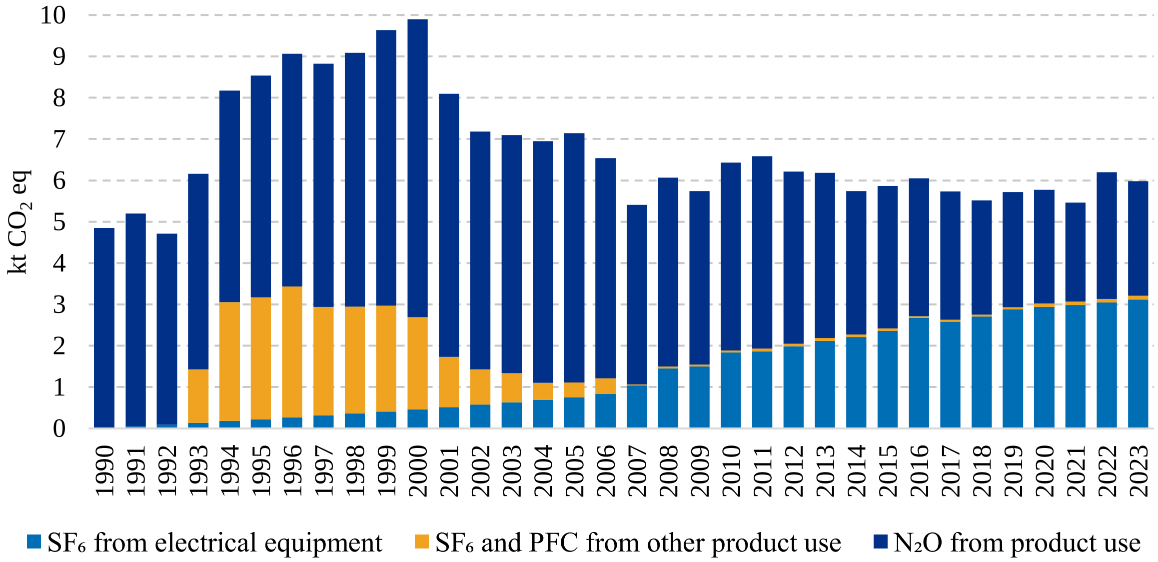

Figure 4.8. Emissions from Other product manufacture and use in Estonia in 1990–2023, kt CO_2 eq.

2.G.1 Electrical equipment

SF_6 is used as an arc quenching and insulating gas in high-voltage (110–380 kV) and medium-voltage (6–35 kV) switchgear (GIS) and control gear. In Estonia the use of SF_6 in this sector started in 1991 (high-voltage) and 1999 (medium-voltage), respectively. The equipment is not manufactured within the country. Medium-voltage GIS (distribution equipment) operates with low over-pressure and little gas quantities of only some kg/system. They are already SF_6 charged when imported and are hermetically closed ('sealed for life'). High-voltage GIS (transmission equipment) with a higher operating pressure (up to 7 bar) and bigger gas quantities ('closed for life') must be replenished in their lifetime. They are imported with a transport filling and are filled up in site (on site erection).

Although vacuum switchgear gain popularity in medium-voltage networks, the operator of the biggest distribution network in Estonia is still preferring SF_6 insulated switchgear, mainly because of its lower price.

In 2023, total stock in operating systems amounted to 34.26 t of SF_6. Manufacturing emissions amounted to 0.98 kg. Total emissions from stock were 0.13 t. 44.8 kg of SF_6 was disposed and emissions from it were 0.90 kg in 2023.

Total emissions from switchgear in 2023 were 0.13 t of SF_6 which is 3.12 kt CO_2 equivalent.

2.G.2 SF_6 and PFCs from Other product use

2.G.2.b Accelerators

Under this source category, Estonia reports emissions of SF_6 from radiotherapy devices. Two hospitals in Estonia use SF_6 insulated radiotherapy equipment for oncology purposes. One hospital operates four devices, which are of the same size. Two smaller devices are used in another hospital. Other applications, e.g., SF_6 insulated particle accelerators or gas impregnation of power capacitors, do not occur in Estonia.

The 2023 stock of SF_6 totaled 39.8 kg, with 2023 operating emissions of 3.77 kg. There were no emissions from disposal, as no equipment was decommissioned in 2023.

Emissions from accelerators totaled 3.77 kg (or 0.089 kt CO_2 equivalent) in 2023.

2.G.2.d Adiabatic properties: Shoes and Tires

Under this category aggregated SF_6 from both Shoe soles and Car tires are reported. PFC emissions occurred only from Shoe soles in Estonia in the past.

Sport shoes

Sports shoes using soles with SF_6-gas cushions were introduced to the European market in the early 1990s. From 2003 to 2005 SF_6 was replaced by PFC-218 (perfluoro propane). Footwear with SF_6/PFC-cushions has not been manufactured in Estonia but were imported. 100% of the F-gases in the soles are emitted at the end-of-life of the shoes. The lifetime of such shoes is calculated at three years. 100% of the F-gases in these soles are considered to have emitted to the atmosphere at the end-of-life of the shoes.

Car tires

In Estonia, SF_6 has never been filled into car tires. This was, however, to some extent practice in Germany in the 1990s. As a considerable part of the Estonian passenger cars are imported second-hand vehicles from Germany, SF_6 in tires transferred to Estonia via imported vehicles. The gas is assumed to have completely released to the atmosphere on disposal three years after the filling[121] or one year after importation.

2.G.3 N_2O from product uses (CRT 2.G.3)

2.G.3.a Medical applications

Under this source category, Estonia reports N_2O emissions from the use of N_2O in medical and other applications. N_2O emissions from aerosol cans are reported under category Propellant for pressure and aerosol products.

The amount of medical N_2O sold and emitted in Estonia in 2023 was 7.85 t (2.08 kt CO_2 eq.). The amount of N_2O sold and emitted was 13% lower than in 2023.

2.G.3.b Propellant for pressure and aerosol products

Under this source category, Estonia reports N_2O emissions from aerosol cans.

The amount of N_2O used as propellant in aerosol cans in Estonia in 2023 was 0.0026 kt (0.69 kt CO_2 eq).

4.7.2. Methodological issues

Choice of methods

2.G.1 Electrical equipment

The method used for calculations is *Tier 3*, as described in the IPCC 2006 Guidelines.

2.G.2 SF_6 and PFCs from Other product use

Method according to IPCC 2006 Guidelines: *Tier 2a* with country-specific EF.

2.G.3 N_2O from product uses

Method according to IPCC 2006 Guidelines: *Tier 2a* with country-specific EF.

Estonia has reported N_2O emissions from aerosol cans starting from 2019 submission using country-specific data as during the EU internal annual review of national greenhouse gas inventory data pursuant to Article 19(2) of Regulation (EU) No 525/2013 (for period 2013-2020) (ESD review) the TERT recommended to estimate the emissions either from country-specific data or average t N_2O/capita factor from Member States that report country-specific data using amount of gas as activity data.

[121] IPCC 2006 Guidelines, Volume 3, Chapter 8, page 8.31.

Activity data

2.G.1 Electrical equipment

Estonian companies of electrical power distribution provided data on their equipment, on their SF_6 consumption in total and on refilling every year.

2.G.2 SF_6 and PFCs from Other product use

2.G.2.b Accelerators

Data on charge and use-phase losses were directly submitted from the medical operators.

2.G.2.d Adiabatic properties: Shoes and Tires

Sport shoes

Data on the Estonian market of sports shoes with PFC gas cushion was provided by the manufacturer. New footwear on the Estonian market has been clear of SF_6 from July 2003 onwards. Final disposal emissions occurred in 2006. PFC-stock, PFC quantity for disposal/PFC disposal emissions have been calculated for 2003–2007 and 2006–2008, respectively.

New footwear on the Estonian market has been clear of SF_6 from July 2003 onwards. Final disposal emissions occurred in 2006. PFC-stock, PFC quantity for disposal/PFC disposal emissions have been calculated for 2003–2007 and 2006–2008, respectively.

The method follows the IPCC 2006 Guidelines (Emissions in year t = Sales in year t-3).

Car tires

The Öko-Recherche archives include the time series from 1990 for the annual number of German cars whose tires were filled with SF_6 (one car = four tires = 1 kg), in comparison to the total number of cars registered in Germany in the same year. This quota was some 0.3% in 1992–1995, 0.17% to 0.08% (1996–1998), and negligible from 1999.

Applying these quotas to the annual number of Estonian cars imported from Germany, 1992–1998, the disposal emissions of SF_6 from the tires of these cars rose (1 kg per car). The simplified assumption is that in a particular year the imported cars show the same SF_6 quota as the cars in Germany in the same year. The disposal emissions from tire dismantling are assumed to arise one year after importation (two years are assumed to be the running time in Germany).

The annual number of used cars imported from Germany varied about 20 000 in the 1992–1998 period. Assuming this yearly number constant, a rough estimation of the SF_6 emissions in Estonia can be given.

2.G.3 N_2O from product uses

2.G.3.a Medical applications

Activity data was collected directly from the companies importing N_2O for medical use and other applications to Estonia from 1992 to 2023. Activity data for 1990–1991 was estimated based on the surrogate data method. It is assumed that all N_2O sold to the Estonian market in a year is used in the same year.

2.G.3.b Propellant for pressure and aerosol products

N_2O containing whipped cream cans were not produced in Estonia and were imported since 1992 when Estonia started international trade of consumer goods. Data on international trade of all kinds of whipped cream were collected from Eurostat database. Data was available for 2005-2023. For 1992-2004 surrogate data was created using average consumption of whipped cream in 2005-2019 per capita and multiplying this number with population in 1992-2004.

N_2O containing technical aerosol cans are not produced in Estonia but were imported and sold to the Estonian market from 2007 until 2023. The total quantity of N_2O supplied to the Estonian market was asked from the distributors of N_2O products. In 2023, 369 aerosol cans containing N_2O were sold to the Estonian market.

Emission factors

2.G.1 Electrical equipment

Estonian companies of electrical power distribution provided data on their equipment, on their SF_6 consumption in total and on refilling every year. The refilling data of the HV equipment reported from different power suppliers ranged from 0.1% to 0.7%/year. In the case of MV-GIS no losses occurred according to the companies. The main operator of HV-GIS estimated the EF_{manu} (topping up of imported HV-GIS within the country) to 0.1%. The EF_{op} of HV- and MV-GIS used in this report is based on the default emission factors of the IPCC 2006 Guidelines with 0.7% (high voltage) and 0.1% (medium voltage) per year, respectively.

- Country-specific EF_{manu} (manufacturing emission factor, on site erection): 0.1%;
- EF_{op} (according to IPCC GL): 0.7% (HV), 0.1% (MV).
- Disposal emission is estimated to be 2% of initial quantity[122].

2.G.2 SF_6 and PFCs from Other product use

2.G.2.b Accelerators

Method according to IPCC 2006 Guidelines: *Tier 2a* with country-specific EF.

- Country-specific EF_{op}: 4.9%.
- Disposal emissions are estimated to be ca 5%, which is in the same magnitude as in the case of switchgear.

2.G.2.d Adiabatic properties: Shoes and Tires

The method follows the IPCC 2006 Guidelines (Emissions in year t = Sales in year t-3).

- EF_{disp}: 100% (IPCC GL).

2.G.3 N_2O from product uses

N_2O emissions from N_2O used in medical and other applications are estimated considering the amount of N_2O sold to the Estonian market.

[122] Wartmann, S; Harnisch, J. (2005). Reduction of SF_6 emissions from high and medium voltage electrical equipment in Europe. Report to CAPIEL. https://www.tandfonline.com/doi/pdf/10.1080/15693430500402234 (22.12.2024)

2.G.3.a Medical applications

According to the IPCC 2006 Guidelines[123], it is assumed that none of the administered N_2O is chemically changed by the body and therefore the emission factor of 1.0 was applied.

2.G.3.b Propellant for pressure and aerosol products

From interviews with supermarket chains in 2020, it was learned that only 2% of all kinds of whipped cream sold in supermarkets were cans with propellant.

From ingredient lists of whipped cream cans it was found out that percentage of N_2O is maximally 5% and this was used for calculation.

According to the IPCC 2006 Guidelines, none of the N_2O is reacted during the process and all the N_2O is emitted to the atmosphere resulting in the emissions factor of 1.0 for this source.

4.7.3. Uncertainty assessment and time-series consistency

For uncertainty assessment please see Annex A.II.2 IPPU, 2.G Other product manufacture and use chapter.

4.7.4. Category-specific QA/QC and verification, if applicable

2.G.1 Electrical equipment

The data for 2.G, 2.G.2.b and 2.G.3 for this report was collected by the expert of the Estonian Environmental Research Centre. The data for 2.G.2.d was collected within the framework of the Twinning Project EE2005/IB/EN/01.

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the Industrial processes and product use sector according to the IPCC *Tier 1* method.

4.7.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

No category-specific recalculations have been done.

4.7.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

There are no planned category-specific improvements.

4.8. Other production (CRT 2.H)

4.8.1. Category description

2.H.1 Pulp and paper

This source category includes the NMVOC emissions from the Pulp and paper (CRT 2.H.1) and Food industries (CRT 2.H.2). In addition, NO_x, CO and SO_2 emissions from the Pulp and

[123] IPCC 2006 Guidelines, Volume 3, Chapter 8, page 8.36.

paper industry are reported under 2.H Other production. The non-fuel-based CO_2 emissions from pulp and paper industry are estimated to be negligible in Estonia. All N_2O emissions from the pulp and paper and food industry are reported as fuel-based emissions under CRT 1 – 1.A.2.d Pulp, paper and print and 1.A.2.e Food processing, beverages and tobacco.

4.8.2. Methodological issues

Choice of methods

Emissions are based on the data reported in NEC/CLRTAP inventories by the Estonian Environment Agency (EstEA). The emissions from pulp and paper industry are calculated by using actual emissions data reported by the production plants. The incomplete time series before the year 2006 is complemented with interpolated data (calculated on production volumes).

Activity data

Activity data for the years 1990–1994 is obtained from the annual proceeding of Statistics Estonia 'Industry' and for the years 1995–2023 from the electronic database on the website of Statistics Estonia.

Emission factors

The NMVOC emissions from food industry are calculated as diffuse sources based on statistical data and using the EMEP/EEA Guidebook 2023.[124]

4.8.3. Uncertainty assessment and time-series consistency

For uncertainty assessment please see Annex A.II.2 IPPU, 2.H Other production chapter.

4.8.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for Industrial processes and product use sector according to the IPCC *Tier 1* method.

The activity data from Estonian Environmental Decisions Information database KOTKAS was compared with the data from Statistics Estonia. The number of pulp and paper plants was checked from the Estonian database of environmental permits of enterprises and from newspapers and the internet.

4.8.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

No category-specific recalculations have been done.

4.8.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

There are no planned category-specific improvements.

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[124] EMEP/EEA air pollutant emission inventory guidebook 2023. [www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2023 (22.12.2024)

5. AGRICULTURE (CRT SECTOR 3)

5.1. Overview of the sector (e.g. quantitative overview and description, including trends and methodological tiers by category) and background information

The total GHG emissions reported in the Agricultural sector for Estonia were 1534.73 kt CO_2 eq. in 2023. The sector contributed about 14.1% to the total CO_2 eq. emissions in Estonia. In 2023, the emissions from Enteric fermentation decreased by 0.96% compared to the previous year and the emissions from Manure management decreased by 0.72%. This is mostly caused by lower livestock population for cattle, sheep and goats. The emissions from Agricultural soils category accounted for 43.9% of total emissions from agriculture sector in 2023 (Figure 5.1).

Agricultural GHG emissions in Estonia consist of:

- CH_4 emissions from enteric fermentation of domestic livestock (for 16 subcategories of livestock);
- CH_4, direct and indirect N_2O emissions from manure management systems;
- direct and indirect N_2O emissions from agricultural soils (direct N_2O emissions include emissions from synthetic fertilizers, animal waste, compost, and sludge applied to agricultural soils, crop residues, mineralization associated with the gain or loss of soil organic matter; cultivation of organic soils and emissions from urine and dung deposited by grazing animals. Indirect N_2O emissions include emissions due to atmospheric deposition and leaching and run-off.);
- liming;
- urea application.

Direct emissions from agricultural soils and enteric fermentation of livestock were the highest contributors to the total emissions from the Agricultural sector (Figure 5.1).

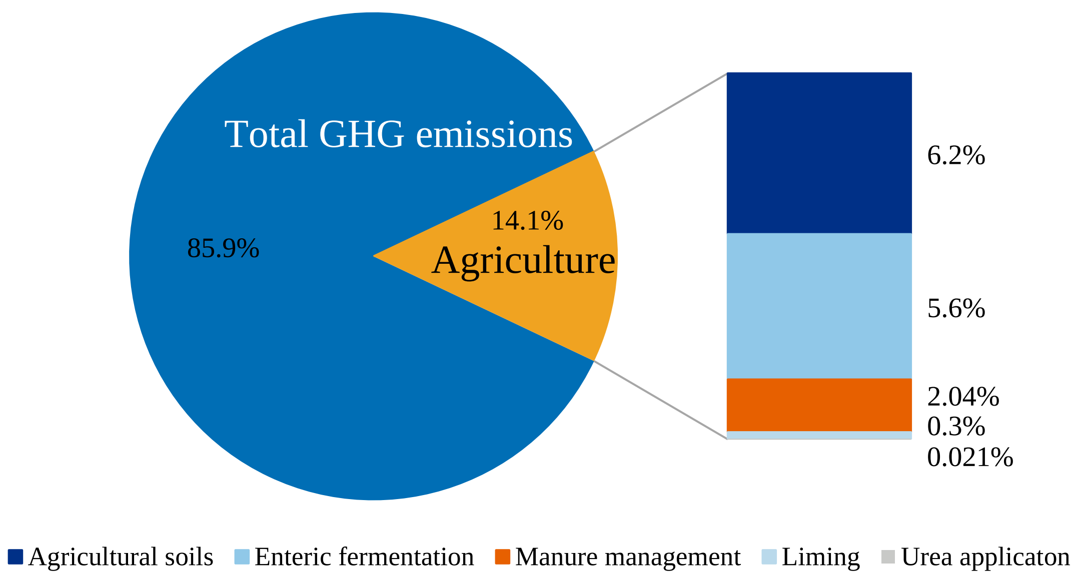

Figure 5.1. Emissions from the Agriculture sector compared to the total CO_2 eq. emissions in 2023, %

As a result of the Soviet Union markets collapsing, Estonia was left with a large excess supply of agricultural production. Western markets remained closed to Estonian agricultural products, mostly for two reasons – high customs barriers and non-compliance with the requirements and practices abroad. Prices for agricultural products in Estonia fell up to 50% lower than prices on world markets and became insufficient to cover production costs.[5] This led to a rapid decline of agricultural production in Estonia. The OECD review of agricultural policies in Estonia in 1986–1996 stated: 'Farmers were lacking in both working capital and investment capital. Agriculture was a high-risk sector with a low rate of return on capital. Furthermore, borrowing was complicated due to an underdeveloped banking system. The period of 1992–1993, which was a period of major macro-economic reforms and dramatic, sometimes even chaotic reorganization, ended with the agricultural sector being subjected to hidden taxes of 50% on average. In 1996–2001 because of low producer prices and small subsidies, investments in Estonian agriculture amounted to 11% in respect of the value added, which is 2.5 to 3 times less than in most European countries (25–30%). According to international monitoring (Situatsionsbericht 2002, DVB, Bonn), in Central and Eastern European countries, the total agricultural production decreased the most in Bulgaria with a 55% decline during the years of 1990–2000, followed by Estonia with 54%.[9]

Between 2002 and 2008 the essential driving force for Estonian agriculture was the EU accession and the application of supporting the EU's common agricultural policy.[10] The positive impact on agricultural production manifested itself in the years preceding the EU accession and is reflected in the falling GHG emissions trend that began in the 1990s.

Consequently, CO_2 eq. emissions from the Agricultural sector (Table 5.1) declined by 43.88% in 2023 compared with the base year (i.e. 1990), mostly due to a decrease in the livestock population and thus animal manure applied to agricultural fields. The trend in emissions in CO_2 eq. by category is presented in Figure 5.2.

The agricultural production is in a declining trend in Estonia as the population of cattle, sheep and goats decreased in 2023 compared to the previous year. This is mostly caused by the current difficulties in the agriculture sector that started in 2021, as production costs exceed the profit. This is in turn caused by the energy crisis in EU, leading to higher prices for fertilizers, energy, and feed.[11] The dairy industry has suffered a decline in production due to economic sanctions imposed by Russia on the EU starting from August 2014, when Russia announced import restrictions for food supply coming from the EU. According to the restrictions, it is prohibited to import beef, pork, poultry, fish, milk and dairy, cheese, sausages, fruits, and nuts etc. from EU countries to Russia.[12] Consequently, the number of dairy cattle in 2023 fell by 12.9% in comparison with 2014. The number of dairy cattle was record low in 2023 – being only 83,300 heads.[13] The number of swine has fallen by 23.2% in 2023 compared to 2014 in Estonia because of the outbreak of African swine fever in the region in 2015. Regarding the spread of the disease, Baltic countries and Poland are a buffer zone for the whole EU, meaning it was necessary to apply measures to prevent the spreading of the African swine fever to other European countries. Prevention measures included population control that led to lower number of swine population in the country.[10] Then, starting from 2017, the number of swine started steadily growing again. This was mainly caused by the improved economic situation in the country. Also, a high demand for pork in both inland and foreign markets as pork being the most popular meat in Estonia helped, to some extent, to recover the number of swine after the low point that started after the African swine fever in 2015. Then, after 2020, the number of swine started decreasing again. This was caused by more outbreaks of African swine fever occurred in 2021.[11] [12] [13] What is more, as pork meat's free market purchase prices have been at least 1/3 lower than the actual production costs, several pork producers have been forced to close down their production.[7]

Furthermore, imported pork is cheaper for the buyer, so people have started to prefer it to domestic pork.[14] However, compared to last year, swine numbers have risen by 2.1% in 2023.

Emissions from Agricultural soils and Liming sub-categories also decreased in 2023 compared to the previous year. This is caused by the decreased usage of lime, mineral and organic fertilizers on the fields, and a lower production of agricultural crops. Emissions from Urea application, however, increased from 0.02 kt CO_2 in 2022 to 2.28 kt CO_2 in 2023. This is in correlation with the prices of other mineral fertilizers on the market – in 2023, the prices for N-containing mineral fertilizers were higher than usual and therefore agricultural producers preferred cheaper urea fertilizers instead.

Table 5.1. Estonia's agricultural GHG emissions by sources in 1990–2023, kt

Year	Enteric fermentation	Manure management		Agricultural soils	Liming	Urea application	Total CO_2 eq. emissions
	CH_4	CH_4	N_2O[125]	N_2O[126]	CO_2	CO_2	CO_2 eq.
1990	50.74	6.64	0.38	3.83	12.11	1.00	2734.62
2005	21.22	3.44	0.18	1.79	7.22	1.41	1221.38
2019	22.45	6.14	0.22	2.58	15.46	0.56	1560.59
2020	21.94	6.12	0.22	2.58	15.73	0.53	1544.83
2021	21.99	6.04	0.22	2.63	28.48	0.23	1568.26
2022	21.99	5.87	0.22	2.67	36.04	0.02	1583.00
2023	21.77	5.88	0.21	2.54	27.49	2.28	1534.73

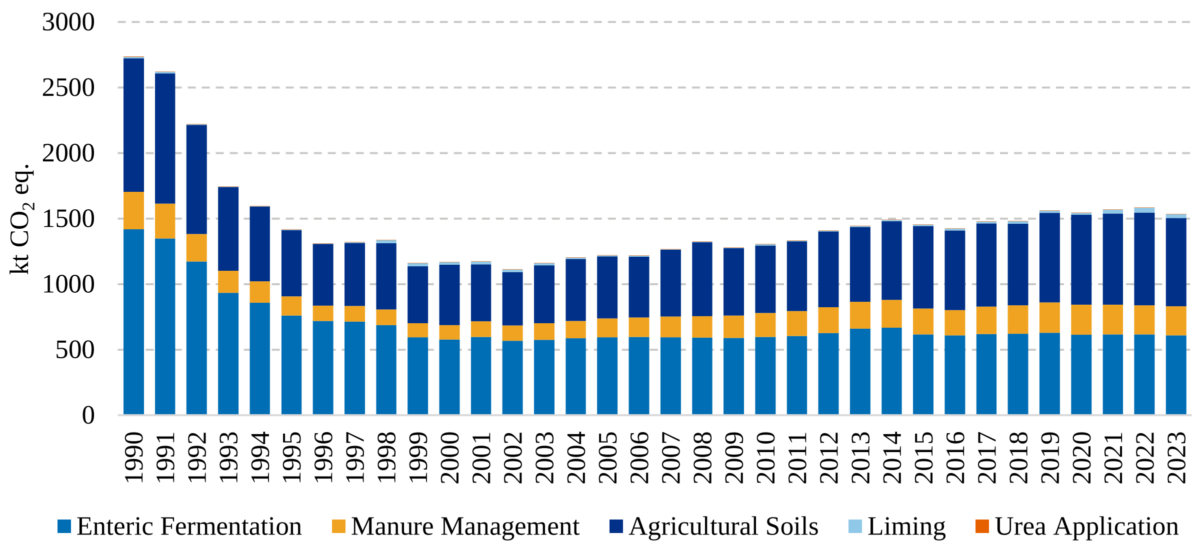

Figure 5.2. Trends in emissions by categories in Estonia in 1990–2023, kt CO_2 eq.

The following is a short overview of the results in the nitrogen balance in Estonia in 2023.

The total amount of nitrogen excreted with manure was 23 214 tons in 2023. The total nitrogen that volatilized from manure management as NH_3 and NO_3 was 3 881 tons. The total nitrogen from nitrogen leaching and run-off from manure management was 38 tons. Liquid storage manure management system (MMS) was the main source of N_2O emissions from manure management. Nitrogen that contained synthetic fertilizers applied to agricultural soils made up for 38 404 kilotons and from crop residues 31 113 kilotons of the total amount. Nitrogen in other sources, which were accounted for in the Agriculture sector, was noticeably lower than

[125] N_2O emissions include Indirect N_2O emissions from the Manure management category.
[126] N_2O emissions include Indirect N_2O emissions from the Agricultural soils category.

nitrogen excreted with manure and contained in fertilizers and crop residues. The total amount of nitrogen that volatilized from agricultural soils as NH_3, NO_3, and N_2 was 8 455 kilotons. The total nitrogen from nitrogen leaching and run-off from agricultural soils was 28 831 kilotons in Estonia.

Category description and methodology

The *Tier 1* and *Tier 2* approaches were implemented to estimate GHG emissions from the Agriculture sector in Estonia. A list of methods and emission factors employed in the estimates for each subcategory of the Agriculture sector is presented in Table 5.2. Rice is not cultivated in Estonia. Savannah areas do not exist in Estonia.

Some recalculations were carried out to improve the quality of the inventory in the following sub-sectors of the Agriculture sector:

- CH_4 emissions from enteric fermentation of mature male and female cattle, bovine animals aged 1-2 years for the years 2020-2022;
- CH_4 emissions from manure management of mature female cattle, poultry and rabbit;
- N_2O emissions from manure management of mature female cattle, poultry and rabbit;
- N_2O emissions from sewage sludge and compost applied to soils for the years 1990-1998;
- N_2O emissions from organic soils cultivation;
- N_2O emissions from mineralization;
- Indirect N_2O emissions from agricultural soils.

Table 5.2. Methods and emission factors used for estimating GHG emissions of the Agriculture sector

	Method applied / EF used		
GHG SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**
3. AGRICULTURE			
3.A.1 Cattle		T2/ CS, D	
3.A.2 Sheep		T1/D	
3.A.3 Swine		T2/CS, D	
3.A.4 Other livestock		T1/D, OTH	
3.B Cattle		T2/CS, D	T2/CS, D
3.B Sheep		T1/D	T1/D
3.B Swine		T2/CS, D	T2/CS, D
3.B Other livestock		T1/D	T1/D
3.B.5 Indirect N_2O emissions			T2/CS
3.D.1.a Inorganic N fertilizers			T1/D
3.D.1.b Organic N fertilizers			T1/D
3.D.1.c Urine and dung deposited by grazing animals			T1/D
3.D.1.d Crop residues			T1/D
3.D.1.e Mineralization/immobilization associated with loss/gain of soil organic matter			T1/D
3.D.1.f Cultivation of organic soils			T1/D
3.D.2 Indirect N_2O emissions from managed soils			T1/D
3.G Liming	T1/D		
3.H Urea application	T1/D		

T1 – *Tier 1*; T2 – *Tier 2*; D – IPCC default; CS – Country-specific; NA – Not applicable; OTH – Other

References – source information

The estimations were carried out based on approaches presented in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Activity data was obtained from Estonian national statistics, default emission factors (EFs) were taken from the 2006 IPCC Guidelines and country-specific EFs were calculated based on country-specific data. The list of institutions directly and indirectly involved in the inventory process is presented in Table 5.3.

Table 5.3. List of institutions (datasets) involved in the emission inventory for the Agricultural sector

References	Link	Data, activity
Estonian Environmental Research Centre (EERC)	http://www.klab.ee/	- activity data handling; - estimation of emissions; - reporting (CRT, NID).
Statistics Estonia – Agricultural Statistics (SE)	www.stat.ee	- collection and reporting of data on livestock population; - location of animal waste management systems; - milk production per cow; - quantities of crop produced; - amounts of fertilizers, compost, urea, and carbonate lime applied to fields.
Estonian Animal Recording Centre (EARC)	https://www.epj.ee/	- collection and reporting of data on milk production, fat and protein content in milk; - collection of data on dairy cattle population by dairy-cattle breed; - percentage of cows that give birth in a year.
Estonian Environment Agency (EstEA)	https://www.keskkonnaagentuur.ee/en	- providing data on areas of organic soils under cultivation; - data on mineralization associated with loss of soil organic matter; - data on NH_3, NO_x and N_2 emissions from manure management; - data on sewage sludge applied to agricultural soils; - average air temperature during winter months; - collection and reporting of data on composted organic waste and amounts of sewage sludge used in agricultural fields.
Agricultural Registres and Information Board (ARIB)	https://www.pria.ee/en	- data on horse population since 2019 - data about manure distribution from grazing for mature female cattle
Agriculture and Food Board	https://pta.agri.ee/	- sales records of urea and lime fertilizers
Nitrofert Ltd.	-	- plant-specific activity data on urea fertilizers produced in Estonia in 2004-2009 and 2013
Environmental Decisions Information System KOTKAS	https://kotkas.envir.ee/	- manure management system splits since 2021
Mineral fertilizer producers and resellers	-	- urea fertilizers sold to Estonian markets, since 2016

NMVOC and NO_x emissions

NMVOC emission from Manure management and NO_x emission originating from Agricultural soils have been reported in the CRT (Table 5.4). The emissions are in compliance with the data submitted under the Convention on Long-Range Transboundary Air Pollution in the Estonian Informative Inventory Report 1990–2023 compiled by the EstEA. In the Agriculture sector, NO_x emission from Agricultural soils and NMVOC emissions from Manure management decreased by 49.4% and 65.6%, respectively, compared to the base year (1990). The decrease in air pollution is mainly the result of the rapid economic changes in the 1990s. Emission calculations from Manure management and Agricultural soils are based mainly on the *Tier 1* method from the renewed EMEP/EEA Guidebook 2023. The *Tier 2* method was used to calculate NMVOC and NO_x emissions from cattle and NO_x emissions from swine and poultry. For further insight regarding the trends and activity data and methodology applied for NMVOC and NO_x emission estimations, see Estonian Informative Inventory Report 1990–2023 submitted under the Convention on Long-Range Transboundary Air Pollution[127].

Table 5.4. NMVOC and NO_x emissions originating from the Agriculture sector in 1990–2023, kt

Gas	1990	2005	2019	2020	2021	2022	2023
NO_x	4.77	1.63	2.58	2.57	2.78	2.57	2.41
NMVOC	12.57	4.92	4.41	4.36	4.32	4.37	4.33

5.2. Enteric fermentation (CRT 3.A)

5.2.1. Category description (e.g. characteristics of sources)

Methane is emitted as a by-product of livestock digestive process, in which microbes resident in the animal's digestive system ferment the feed consumed by the animal. This fermentation process is also known as enteric fermentation. The methane is then eructated or exhaled by the animal. Within livestock, ruminant livestock (cattle, buffalo, sheep, and goats) are the primary source of emissions. Pigs are non-ruminant animals and convert a smaller proportion of feed intake into methane than ruminants.

Around 95% of the CH_4 emissions arising from animal husbandry in Estonia are caused by cattle. Dairy cattle livestock was the main contributor to CH_4 emissions from cattle enteric fermentation in Estonia in 2023 (Table 5.6). The number of dairy cows, which has been decreasing in Estonia over the last 20 years, was around 95.6–97.9 thousand in 2009–2014. The decrease in the dairy cattle population in 2015–2023 compared to 2014 is the result of Russia's economic sanctions against the EU. In fact, the population of dairy cows was record low in 2023, being only 83.3 thousand heads. In turn, the emissions from enteric fermentation have been in a decreasing trend for the past few years and decreased by 0.96% in 2023 compared to the previous year. The CO_2 eq. emissions from enteric fermentation of Estonian livestock made up 39.7% of the total CO_2 eq. emissions from the Agricultural sector in 2023. CH_4 emissions from enteric fermentation in 2023 were 57.1% lower than the emissions of the base year due to the decrease in the number of the livestock population (Table 5.5, Figure 5.3).

[127] Estonian Environment Agency. Estonian Informative Inventory Report 1990–2023, Ch. 5 Agriculture (NFR 3).

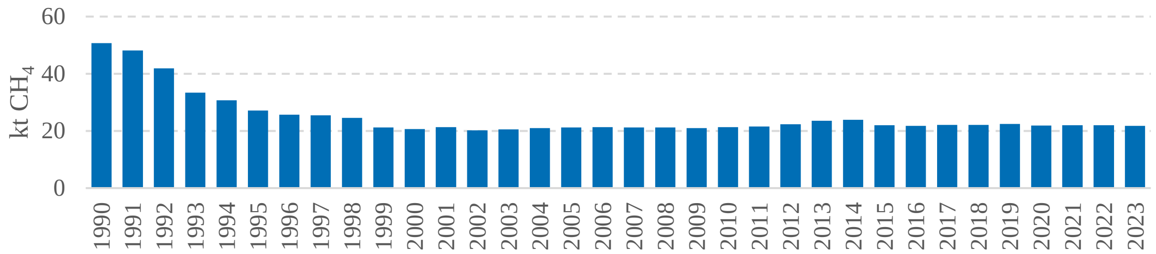

Figure 5.3. Enteric fermentation CH_4 emissions from Estonian livestock in 1990–2023, kt

Table 5.5. CH_4 emissions from Enteric fermentation by animal type in 1990–2023 in Estonia, kt

Livestock category	1990	2005	2019	2020	2021	2022	2023
Cattle	48.39	20.30	21.36	20.85	20.93	21.01	20.82
Swine	0.89	0.37	0.32	0.36	0.34	0.30	0.31
Sheep	1.27	0.44	0.65	0.60	0.60	0.56	0.53
Goats	0.01	0.02	0.03	0.02	0.02	0.02	0.02
Horses	0.15	0.09	0.10	0.10	0.09	0.09	0.09
Poultry	NE	NE	NE	NE	NE	NE	NE
Rabbits	NE	NE	NE	NE	NE	NE	NE
Fur animals	0.02	0.01	0.0004	0.0003	0.00004	0.00002	NO
Total CH_4, kt	50.74	21.22	22.45	21.94	21.99	21.99	21.77

3.A.1 Enteric fermentation of cattle

Total CH_4 emissions from cattle enteric fermentation were 20.82 kt in 2023. Dairy cattle livestock was the main contributor to CH_4 emissions from cattle enteric fermentation in Estonia in 2023 (Table 5.6). The number of dairy cows, which has been decreasing in Estonia over the last 20 years, was 95.6-97.9 thousand heads during 2009–2014. In 2015, the dairy industry faced a decline in production due to the economic sanctions imposed by Russia on the EU starting from August 2014, when Russia announced import restrictions for food supply coming from the EU. According to the restrictions, it is prohibited to import meat, pork, poultry, fish, milk and dairy, cheese, sausages, fruits, and nuts etc. from EU countries to Russia. The influence was apparent also in 2023, so the number of dairy cattle in 2023 fell by 12.9% in comparison with 2014, consequently. In fact, the number of dairy cattle was record low in 2023– being only 83,300 heads. However, milk yield per cow set a record in 2023, being the highest in the last 31 years.[128]

The continuous growth of CH_4 emissions per dairy cow has been contributed by the yearly increase in milk production per cow. The growth of milk yield is a result of investments made into advanced housing and milking technologies, successful breeding, and the use of more qualitative feeding strategies. The milk yield per cow in Estonia is in the 1st place in Europe.[128] CH_4 emissions from cattle enteric fermentation decreased by 56.1% in 2023 compared with the base year.

[128] Statistikaamet. Piimatoodang lööb rekordeid. [www] https://www.stat.ee/et/uudised/piimatoodang-loob-rekordeid (03.03.2025).

Table 5.6. CH_4 emissions from Enteric fermentation of cattle in 1990–2023 in Estonia, kt

Year	Cattle[129]			Total, CH_4, kt
	Dairy cattle	Other mature cattle	Growing cattle	
1990	29.32	4.88	14.18	48.39
2005	14.43	1.60	4.26	20.30
2019	13.34	4.25	3.76	21.36
2020	13.17	4.10	3.58	20.85
2021	13.11	4.15	3.68	20.93
2022	13.30	4.16	3.55	21.01
2023	13.57	3.85	3.41	20.82

3.A.3 Enteric fermentation of swine

The total CH_4 emissions from swine enteric fermentation were 0.31 kt in 2023. The emissions have decreased by 65.5% since the base year (Figure 5.4). The main reason for this is the decline in pork production in Estonia compared to the base year due to the decreasing population of swine after the collapse of Soviet Union and, thus, collective farms. During 2002–2010, the Estonian swine population started to slowly recover and grew 0.8–0.9% per year. The number of swine fell by 23.2% in 2023 compared to 2014 in Estonia because of the outbreak of African swine fever in the region in 2015. Regarding the spread of African swine fever, Baltic countries and Poland are a buffer zone for the whole EU, meaning it was necessary to apply measures for preventing the spreading of the African swine fever to other European countries. Prevention measures included population control that led to lower number of swine population in the country. Then, starting from 2017, the number of swine started steadily growing again. This was mainly caused by the improved economic situation in the country. Also, a high demand for pork in both inland and foreign markets as pork being the most popular meat in Estonia helped, to some extent, to recover the number of swine after the low point that started after the African swine fever in 2015. Then, after 2020, the number of swine started decreasing again. This was caused by more outbreaks of African swine fever occurred in 2021. What is more, pork meat's free market purchase prices have been at least 1/3 lower than the actual production costs, several pork producers have been forced to close their production. What is more, imported pork is cheaper for the buyer, so people have started to prefer it to domestic pork. However, compared to last year, swine numbers have risen by 2.1% in 2023.

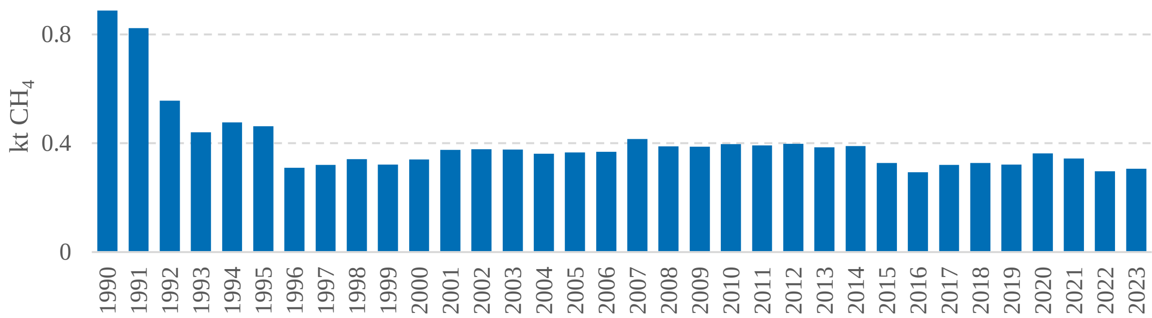

Figure 5.4. CH_4 emissions from Enteric fermentation of swine in 1990–2023 in Estonia, kt

[129] CH_4 emissions are reported according to the classification of the CRF Reporter since Option B was implemented to report emissions from enteric fermentation of cattle.

3.A.2 and 3.A.4 Enteric fermentation of sheep and other livestock

The total CH_4 emissions from Enteric fermentation of sheep and other livestock were 0.65 kt in 2023. CH_4 emissions have declined by 55.5% in 2023 compared with the base year due to a decrease in the number of other livestock population (Figure 5.5).

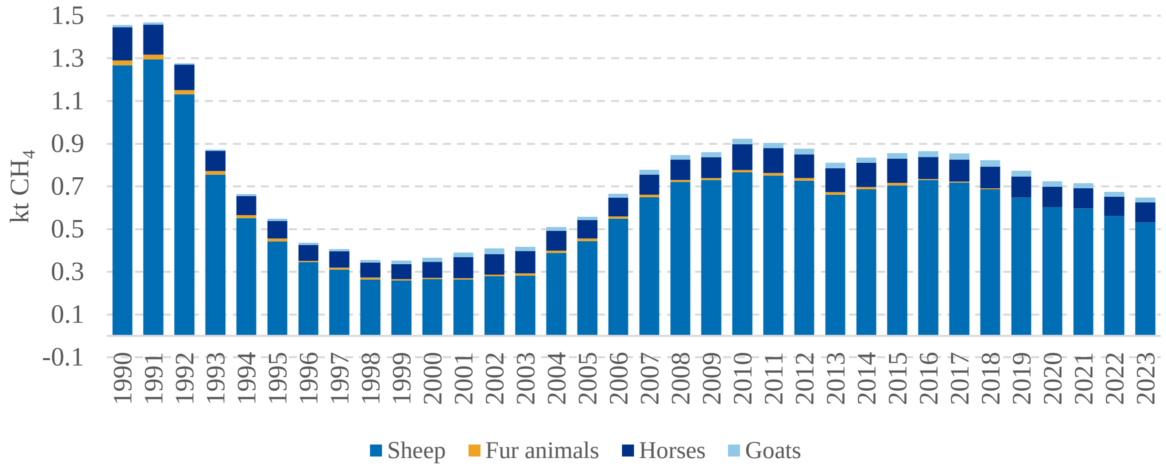

Figure 5.5. CH_4 emissions from Enteric fermentation of other livestock categories in 1990–2023, kt

5.2.2. Methodological issues

Choice of methods

3.A.1 Enteric fermentation of cattle

The *Tier 2* method of IPCC 2006 (Equation 5.1-Equation 5.10) was used to estimate CH_4 emissions from enteric fermentation of dairy cattle and mature non-dairy and growing cattle (bovine cattle, calves aged 0–6 months and 6–12 months). Since the 2013 submission, two key recalculations have been performed: namely, the population of calves (less than 1 year old) has been split into two groups: calves aged 0–6 months and calves aged 6–12 months. Methane emissions from enteric fermentation have been estimated separately for these two groups of calves (a recommendation of ERT, see ARR2011, para 70). In addition, the way of reporting emissions in the ETF Reporting Tool has changed: CH_4 emissions from enteric fermentation of bovine animals have been excluded from the category 'Mature cattle' and included in and reported under the 'Growing cattle' category. Starting from the 2019 submission, the number of calves less than 6 months and 6–12 months old are distributed according to the recommended methodology of the European Commission 2018 Effort Sharing Decision (ESD) review team. Since the 2019 submission, the calculations for finding the share of 0–6 and 7–12-month-old calves are based on the number of calves which are slaughtered (based on national statistics and considering that the number of births is similar for males and females and that males are much more frequently slaughtered in their first year than females) and on the number of calves raised for breeding.

Net energy for maintenance – Net energy required to keep the animals in energy equilibrium (Equation 5.1)

Equation 5.1[130]

$$NE_{mj} = C_{f\ j} \times (weight_j)^{0.75}$$

Where:

NE_{mji} = net energy for maintenance by *j* category of cattle; MJ/head/day;
Weight = live weight of *j* category of cattle, kg.

Equation 5.2[131]

$$Cf\ (in\ cold)\ = Cf_i +\ 0.0048 \times (20 - ℃)$$

Where:

Cf = coefficient for calculating NE_m (Table 5.8);
℃ = mean daily temperature during the winter season.

Net energy for activity for animals (Equation 5.3)

Equation 5.3[132]

$$NE_{aj} = C_a \times NE_{mj}$$

Where:

NE_{aj} = net energy intake by *j* category of cattle, MJ/head/day;
C_a = coefficient corresponding to animals' feeding situation (Table 5.9);
NE_m = net energy required for maintenance by *j* category of cattle (Equation 5.1).

Net energy for growing – net energy needed for growth (live weight gain) (Equation 5.4). According to the 2006 IPCC Guidelines, mature animals are generally assumed to have no net weight gain or loss over an entire year. Thus, data on weight gain are used only in calculations of growing cattle.

Equation 5.4[133]

$$NE_g = 22.02 \times (\frac{BW}{C \times MW})^{0.75} \times WG^{1.097}$$

Where:

NE_{gji}= net energy for growing by *j* category of cattle, MJ/head/day;
BW= average live body weight of the animals in the population, kg;
WG= weight gain by *j* category of cattle, kg per day;

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[130] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.15, equation 10.3.
[131] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.13, equation 10.2.
[132] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.16, equation 10.4.
[133] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.17, equation 10.6.

C= a coefficient with a value of 0.8 for females, 1.0 for castrates and 1.2 for bulls;
MW = the mature live body weight of an adult female in moderate body condition, kg.

Net energy for lactation – energy for lactation

Equation 5.5[134]

$$Ne_{li} = kg\_of\_milk/day_i \times (1.47 + 0.40 \times Fat_i)$$

Where:

NE_{li} = net energy for lactation by dairy cattle, MJ/head/day;
Fat = fat content of milk, %.

Net energy for pregnancy

Equation 5.6[135]

$$NE_{pregnancy} = C_{pregnancy} \times NE_m$$

Where:

$NE_{pregnancy}$ = net energy required for pregnancy, MJ/head/day;
$C_{pregnancy}$= pregnancy coefficient = 0.1[(136)];
NE_m= net energy required by the animal for maintenance, MJ/head/day.

Ratio of net energy available in a diet for maintenance to digestible energy consumed

Equation 5.7[137]

$$REM = 1.123 - \left(4.092 \times 10^{-3} \times DE_{ji}\%\right) + (1.126 \times 10^{-5} \times \left(DE_{ji}\%)^2\right) - 25.4/DE_{ji}\%$$

Where:

REM = ratio of net energy available in a diet for maintenance to digestible energy consumed for *j* category of cattle;
DE_{ji} = digestible energy expressed as a percentage of gross energy for *j* category of cattle.

Ratio of net energy available for growth in a diet to digestible energy consumed

Equation 5.8[138]

$$REG = 1.164 - \left(5.160 \times 10^{-3} \times DE_{ji}\%\right) + (1.308 \times 10^{-5} \times \left(DE_{ji}\%)^2\right) - 37.4/DE_{ji}\%$$

Where:
REG = ratio of net energy available for growth in a diet to digestible energy consumed for *j* category of cattle;

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[134] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.18, equation 10.8.
[135] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, equation 10.13.
[136] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, table 10.7.
[137] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, equation 10.14.
[138] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.21, equation 10.15.

$DE_{ji}\%$= digestible energy expressed as a percentage of gross energy for j category of cattle.

Gross energy for cattle

Equation 5.9[139]

$$GE = \frac{(NE_{mji} + NE_{feedji} + NE_l + NE_{workji} + NE_{pregnancyj}) \times (\frac{100}{DE_{ji}\%})}{(NE/DE)_{ji} + (NE_{gji}/\{NE_g/DE\}_{ji})}$$

Where:

GE = gross energy intake by *j* category of cattle, MJ/head/day;
NE_m = net energy required by the animal for maintenance by *j* category of cattle, MJ/head/day;
NE_a or N_{feed} = net energy for animal activity by *j* category of cattle, MJ/day;
NE_l = net energy for lactation by dairy cattle, MJ/head/day;
NE_{work} = net energy for work by *j* category of cattle[140], MJ/head/day;
NE_p or $NE_{pregnancy}$= net energy required for pregnancy by dairy cattle, MJ/head/day;
NE = net energy for cattle, MJ/head/day;
NE_g = net energy needed for growth by *j* category of cattle, MJ/head/day;
$DE\%$ = digestible energy as a percentage of gross energy of *j* category of cattle, %.

Methane emission factor from the livestock category

Equation 5.10[141]

$$EF = [GE \times Y_m \times (365 days/yr)]/[55.65 MJ/CH_4 kg]$$

Where:

EF = methane emissions from enteric fermentation of *j* category of cattle, kg CH_4/year;
GE = gross energy intake by *j* category of cattle, MJ/head/day;
Y_m = methane conversion rate, which is the factor of gross energy in feed converted to methane.

Main data sources used in the estimations of CH_4 EF for Enteric fermentation by subcategories of cattle are the following:

Weight, kg – data on the weight of dairy-cattle were calculated based on the data of EARC, an expert judgment on the weight of the main categories of dairy-cattle and from scientific literature (Table 5.11, Annex A.V.3_III.1);

Milk production per day, kg/day – a source of data is SE (Annexes A.V.3_II.1-2);

Fat content of milk, % – data was obtained from EARC (Annexes A.V.3_II.3.);

[139] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.21, equation 10.16.
[140] Net energy for work was not calculated.
[141] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.31, equation 10.21.

Percentage of cows that give birth in a year, % – data were employed from EARC (Annex A.V.3_II.5);

Feed digestibility, % – data were obtained from Kaasik, A. report, 2020;

Methane conversion rate, Y_m % (Table 5.10) – the values of Ym of mature dairy and non-dairy cattle and bovine animals were obtained from the 2006 IPCC Guidelines.

3.A.3 Enteric fermentation of swine

The *Tier 2* method (Equation 5.11–Equation 5.14) was used to estimate CH_4 emissions from Enteric fermentation of swine. The estimation was carried out for the main subcategories of pigs broken down by the weight of animals.

Gross energy intake by swine

Equation 5.11[142]

$$GE_j = ME_j/(DE_j - Ym - UE)$$

Where:

GE = gross energy intake by *j* swine category, MJ/head/day;
DE = digestible energy as a percentage of gross energy of *j* category of swine, %;
Y_m = methane conversion rate, which is the factor of gross energy in feed converted to methane, 0.6% for swine[143];
UE = urinary energy excretion, 2% for swine[144].

Equation 5.12[145]

$$ME_j = 2.0 \times w_j^{0.63}$$

Where:

ME_j = energy intake for maintenance and growth of *j* swine category, MJ/head/day;
w_j = live weight of *j* category, kg.

Methane emission factor from the livestock category

Equation 5.13[146]

$$CH_4Emission = EF_j \times population_j/(10^6 kg/Gg)$$

[142] Oll, Ü., Nigul, L. (1991). Sigade söötmine. Tallinn: Valgus, lk 267; Turnpenny J. R., Parsons, D. J., Armstrong, A. C., Clark, J. A., Cooper, K., Matthews, A. M. (2001). Integrated models of livestock systems for climate change studies. 2. Intensive systems. Global Change Biology no. 7, p. 163–170. ; Ym and UE in this calculation were added due to the recommendation of ESD review in 2018.
[143] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.35, table A-4.
[144] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, p 10.42.
[145] Oll, Ü., Nigul, L. (1991). Sigade söötmine. Tallinn: Valgus, lk 267; Turnpenny J. R., Parsons, D. J., Armstrong, A. C., Clark, J. A., Cooper, K., Matthews, A. M. (2001). Integrated models of livestock systems for climate change studies. 2. Intensive systems. Global Change Biology no. 7, p. 163–170..
[146] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, p 10.28, equation 10.19.

Where:

CH_4 Emission$_j$ = methane emissions from Enteric fermentation from *j* category of swine, kt CH_4/year.

Equation 5.14[147]

$$EF = [GE \times Y_m \times (365 days/yr)]/[55.65 MJ/CH_4 kg]$$

Where:

GE = gross energy intake, MJ/head/day;
Y_m = methane conversion rate, which is the factor of gross energy in feed converted to methane.

3.A.2 and 3.A.4 Enteric fermentation of sheep and other livestock

Tier 1 of IPCC 2006 (Equation 5.15) was used to estimate CH_4 emissions from Enteric fermentation of other livestock.

Equation 5.15[148]

$$CH_4 Emission = EF_j \times population_j/(10^6 kg/Gg)$$

Where:

CH_4 Emission$_j$ = methane emissions from Enteric fermentation from *j* category of animals, kt CH_4/year;
EF_j = methane emission factor for *j* category of animals, CH_4 kg/head/year;
Population$_j$ = number of *j* category of animals, head.

Activity data

For most animal categories, activity data is obtained from Statistics Estonia (SE) database, only for horses the Agricultural Registers and Information board (ARIB) Equine database is used, since SE does not collect activity data on horse population in Estonia since 2019.

Livestock population decreased in 2023 in comparison with the base year (Figure 5.6): the number of dairy cattle decreased by 70.3%, i.e., from 280.7 thousand heads to 83.3 thousand heads (Figure 5.6, Figure 5.7), the number of non-dairy cattle decreased from 475.2 thousand heads in 1990 to 158.0 thousand heads in 2023 (Figure 5.6, Figure 5.7). The total number of swine decreased by 68.0%, i.e., from 859.9 thousand heads in 1990 to 275 thousand heads in 2023 (Figure 5.6, Figure 5.9). The number of horses decreased from 8.6 thousand heads in 1990 to 5.3 thousand heads in 2023 – by 38.9%. The number of sheep decreased by 58.1% – from 158.5 thousand heads in 1990 to 66.4 thousand heads in 2023 (Figure 5.6). However, the population of goats increased from 2.1 thousand heads to 4.5 thousand from 1990 to 2023 (Figure 5.6).

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[147] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.31, equation 10.21.
[148] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, equation 10.19.

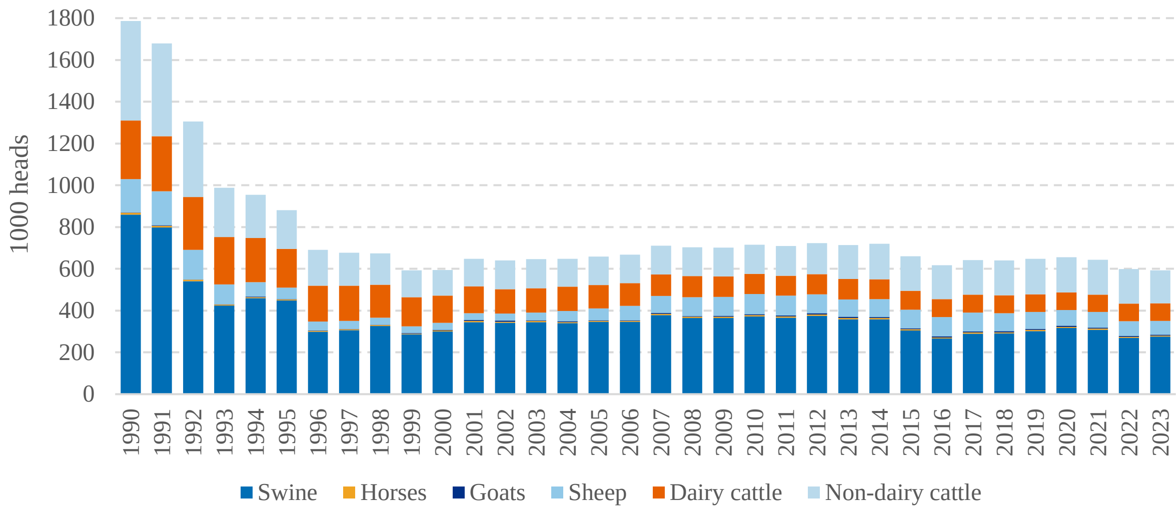

Figure 5.6. Population of livestock in Estonia in 1990–2023 (December 31st), 1000 heads

Table 5.7. The number of livestock population in Estonia in 1992–2023, in accordance with SE (as of 31 December) and FAO datasets, 1000 heads[149]

Category	Source	1992	2005	2019	2020	2021	2022	2023
Cattle	SE	614.6	249.5	254	253.3	250.8	249.6	241.3
	FAO	708.3	249.8	254.0	253.3	250.8	249.6	241.4
Pigs	SE	541.1	346.5	301.6	316.8	308	269.4	275
	FAO	798.6	340.1	301.6	316.8	308	269.4	275
Sheep	SE	123.1	49.6	70.8	68.1	65.6	63.1	55.1
	FAO	141.9	38.8	70.8	68.1	65.6	63.1	55.1
Goats	SE	1.1	2.8	4.7	4.5	4.3	4	3.7
	FAO	NR	2.9	4.7	4.5	4.3	4	3.7
Horses	SE/ARIB	6.6	4.8	5.5	5.4	5.2	5.0	5.3
	FAO	7.8	5.1	NA	NA	NA	NA	NA
Poultry	SE	3 418.1	1 878.7	2 150.9	2 148.8	2 105.1	2151	2211.8
	FAO	5 704	2 183	2 080	2 055	2 032	2 092	2 132

NR – data is not reported by the FAO, NA – data was not available during the inventory compilation.

The activity data used in the estimations differed from those reported in the FAO statistic dataset due to different methods of data reporting until 2015 (Table 5.7). In the framework of the FAO datasets, the data on the livestock population are reported according to the following methodology: the total number of live animals is given for the year ending with 30 September (e.g., the number of live animals enumerated in a given country any time between 1 October and 30 September of the following year should be considered for the later year). According to the methodology established in SE, the total number of live animals is presented for the year ending on 31 December. The data of SE were used in the estimates of the 2023 submission, except for data on horse population that was taken from the ARIB database starting from 2019; data from ARIB Equine database on horse population is also fixed each year on the 31st of December to ensure consistency in the methodology.

[149] Statistics Estonia. Livestock and poltry by county (quarters) [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__loomakasvatussaaduste-tootmine/PM09 (12.11.2024); FAO. FAOSTAT data. Crops and livestock products. [www] https://www.fao.org/faostat/en/#data/QCL (03.03.2025).

Seasonal births or slaughter may cause the population size to expand or contract at different times of the year, which will require the population numbers to be adjusted accordingly. Annual average populations are estimated in various ways, depending on the available data and the nature of the animal population. In the case of static animal populations (e.g., dairy cows, breeding swine, layers), estimating the annual average population may be as simple as obtaining data related to one-time animal inventory data.

However, estimating annual average populations for a growing population (e.g., meat animals, such as broilers, turkeys, beef cattle, and market swine) requires more evaluation. Most animals in these growing populations are alive for only a part of a complete year. Animals should be included in the populations regardless of if they are slaughtered for human consumption or die of natural causes[150]. In the Estonian GHG inventory, the annual average population Equation 5.16 has been used in estimates of the annual average of livestock population for broiler chickens, fur animals killed for fur and broiler rabbits.

Equation 5.16

$$AAP = Days\_alive \times \frac{NAPA}{365}$$

Where:

AAP = annual average population;

NAPA= number of animals produced annually.

3.A.1 Enteric fermentation of cattle

The data on mature non-dairy cattle population were collected and reported by SE according to two methodologies: for 1990–1998 – livestock population data were reported for two subcategories (bovine animals and mature males) and since 1999 the population of three subcategories of non-dairy mature cattle were reported by SE (bovine animals, mature males, and mature females). To guarantee consistency in activity data used, the data for 1990–1998 were updated based on the assumptions made in the 2010 submission; the results are illustrated in Figure 5.8. The number of non-dairy cattle reported in the CRT tables (Figure 5.8, Annex A.V.3_I.1) consists of calves, bovine animals, mature males and mature females, of which calves and bovine animals belong to the subcategory of Growing cattle, while mature males and mature females fall in the subcategory of Other mature cattle.

Currently, Statistics Estonia does not collect separate data on calves aged 0–6 months and 6–12 months, they collect and report aggregated data on the population of calves less than 1-year-old. Starting from the 2019 submission, the numbers of calves less than 6 months and 6–12 months old are distributed according to the recommended methodology of the European Commission 2018 Effort Sharing Decision (ESD) review team. The calculations for the share of 0–6 and 6–12-month-old calves are based on the number of calves slaughtered (based on national statistics and considering that the number of births is similar for males and females and that males are much more frequently slaughtered in their first year than females) and on the number of calves raised for breeding. GHG emissions from enteric fermentation and manure management were estimated for calves 0–6 months and calves 6–12 months old.

[150] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, p 10.8.

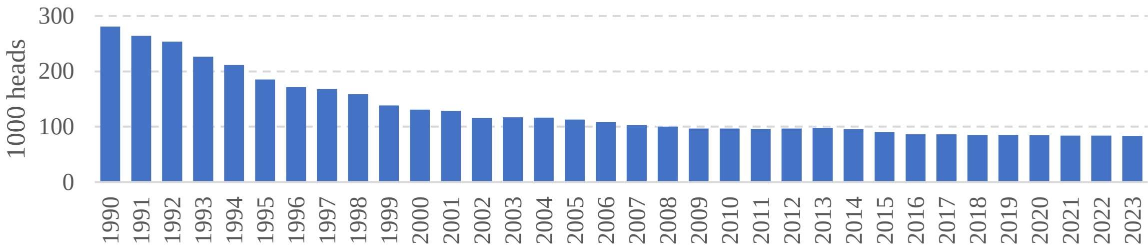

Figure 5.7. Population of dairy cattle in Estonia in 1990–2023 (December 31st), 1000 heads

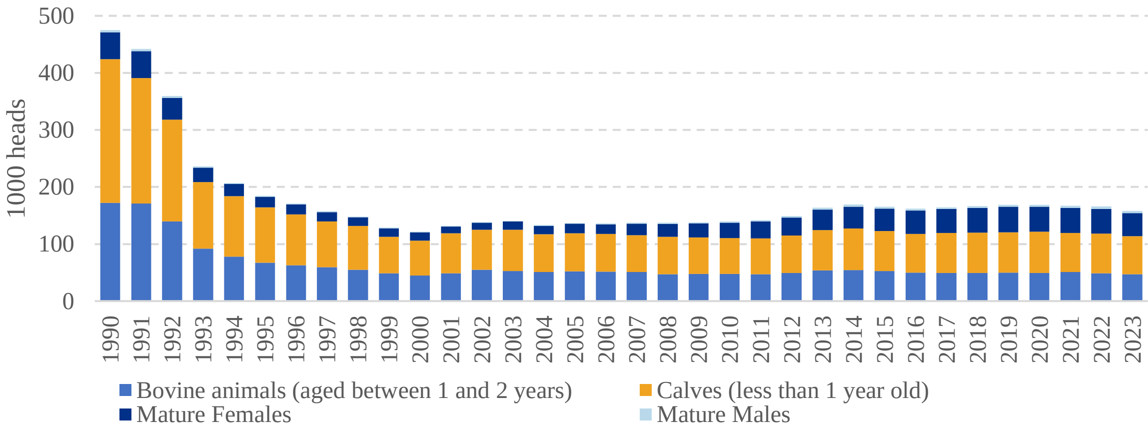

Figure 5.8. Population of non-dairy cattle in Estonia in 1990–2023 (December 31st), 1000

3.A.3 Enteric fermentation of swine

Activity data on the swine population in 1990–1998 were updated in the 2009 submission. Since then, the number of the swine population for 1990–1998 has been reported for three subcategories of swine (breeding sows, fattening pigs and young swine); however, the number of the swine population for 1999–2008 has been reported for six subcategories of swine (piglets, with live weight less than 20 kg; young pigs, with live weight 20–<50kg; pigs, with live weight 50–<80kg, 80–<110kg and 110 kg and more; and breeding sows). Therefore, based on the average structure of the swine population (by categories) of 1999–2008, activity data on the swine population in 1990–1998 were recalculated for six subcategories instead of three reported earlier (Figure 5.9, Annex A.V.3_I.2).

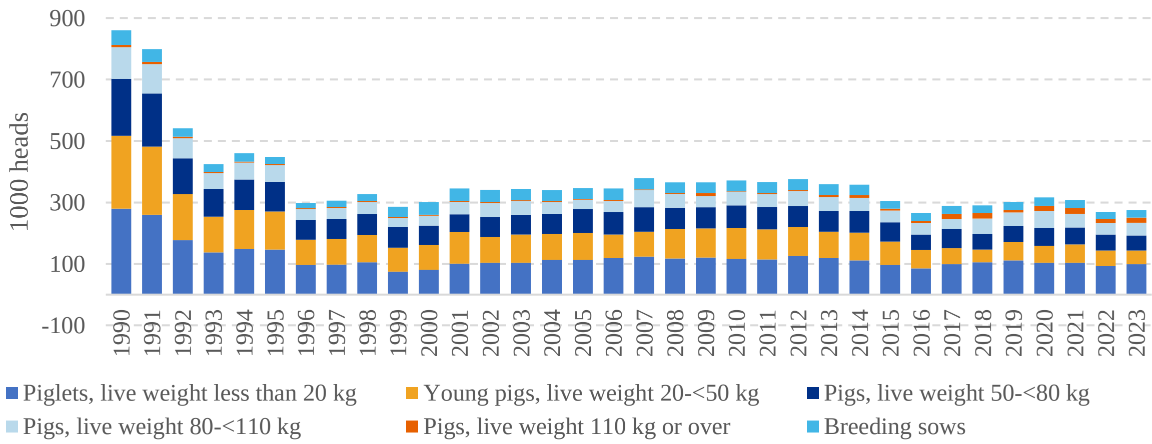

Figure 5.9. Population of swine in Estonia in 1990–2023 (December 31st), 1000 heads

3.A.2 and 3.A.4 Enteric fermentation of sheep and other livestock

Sheep and goats

The SE has been producing four censuses of aggregated sheep and goat numbers per year since 2007. The censuses are conducted in March, June, September, and December. The quarterly mean total is adjusted according to the ratio of sheep and goats for the separately collected sheep and goat data of December. Preceding years' population numbers were gathered in the framework of a once-a-year census; therefore, the annual average population was adjusted according to the calculated annual average population of 2007–2022 The data used in the calculations of the average yearly population of sheep and goats are presented in Annex A.V.3_I.5.

The annual average population for a year t was calculated with Equation 5.17 by using the chronological mean of censuses, as follows:

Equation 5.17

$$NoA = (NoA_{March} + NoA_{June} + NoA_{Sep} + NoA_{Dec})/4$$

Where:

NoA = chronological mean of the annual population of a livestock category in a year [1000 heads];

NoA_{March} = population of a livestock category in March [1000 heads];

NoA_{June} = population of a livestock category in June [1000 heads];

NoA_{Sep} = population of a livestock category in September [1000 heads];

NoA_{Dec} = population of a livestock category in December [1000 heads].

Horses

The number for horse population was updated in 2023 submission for the years 2019-2020 as Statistics Estonia stopped collecting horse population data in 2019. From 2023 submission, Estonia has switched to the Agricultural Registers and Information Board (ARIB) Equine database. The database provides the current numbers of horse population and does not provide historical overviews. Horse population number is fixed as of 31st December every year (for keeping the consistency with other animal groups). For the years 2019-2021, an interpolation was made for keeping the time series consistency with the SA database.

Fur animals

In Estonia, the population of fur animals decreased remarkably by 1999 compared to 1990 due to the absence of markets. In 1998, Estonian fur farmers established a relationship with colleagues from the Nordic countries. These new partners provided Estonian farmers with valuable assistance regarding breeding programmers, improving basic herds etc.[151]. During 2000–2015, the number of fur animals increased steadily. However, in 2016, the population of fur animals fell as much as 57% compared to 2015 due to the diminished areas of living space, as cages were being renovated. The extensive renovating process was driven by the Regulation of the Minister of Rural Affairs (now Ministry of Regional Affairs and Agriculture) no. 88 of

[151] Saveli, O. (2004). Fur farming of Estonia. Animal Breeding in Estonia. Tartu: Paar OÜ.

6/09/2010, according to which the cages of fur animals had to be increased in size by 2017[152]. Fur animal population has been in a strong decreasing trend the past years as since fur farming will be banned in Estonia by 2026.

For the estimation of the average annual population of fur animals the statistical data on seasonal births and the number of animals killed for fur were used.

December–March is the time of year that farmers focus on bringing mink (both male and female) into good breeding condition. In preparation for breeding, minks are positioned within the barns depending on the breeding system practiced in the farm. Most farms breed a ratio of 4–5 females for every male[153]. Gestation varies from 40–70 days (due to delayed implantation). Major birthing of minks usually takes place at the end of April. A litter of mink ranges from 2 to 10 kits, but five or six is typical. Most minks are graded in November or early December, depending on the color-type and sex.

Foxes are bred once a year and the breeding season of the silver fox is from January to March. Their pregnancy lasts for 54 days and a litter of 1 to 9 youngsters (average of 3/litter) is born during March–May[154]. The average fertility rate for Ltd. Balti Karusnahk in 2005 was 3.8/litter[155]. The vixen nurses her youngsters for about 6 weeks, and they are weaned in May and June. Winter fur development begins in August and the fur is prime for pelting in November and December. Foxes are polygamous, so farms breed a ratio of 8–10 females for every male. The data used in the calculations of the average yearly fur animals' population are presented in Annex A.V.3_I.8.

Since 2023, there are no fur animal breeders in Estonia (e-mail with the expert from Statistics Estonia documented in the archive (in Estonian)). Fur farms will be banned in Estonia from 2026.[156]

Emission factors

3.A.1 Enteric fermentation of cattle

Default coefficients used to calculate Net energy for maintenance for cattle are presented in Table 5.8.

Table 5.8. C_{fi} coefficients used[157]

Animal category	C_{fi}
Cattle (non-lactating)	0.322
Cattle (lactating)	0.386
Cattle (bulls)	0.370

Default coefficients corresponding to animals' feeding situation for cattle are presented in Table 5.9.

152 Riigi Teataja. Nõuded karuslooma pidamise ja selleks ettenähtud ruumi või ehitise kohta. [www] https://www.riigiteataja.ee/akt/13356899?leiaKehtiv (12.11.2024).
153 Piirsalu, P. Minkide värvusmutandid ja nende kasvatamine. [www] http://www.eau.ee/~alo/karusloomad/mingid/?Minkide_sigimine/Poegimine (12.11.2024).
154 Fur Institute of Canada. Fox farming. [www] https://fur.ca/fur-farming/fox-farming/ (12.11.2024).
155 Piirsalu, P. Hõbe- ja sinirebaste värvusmutandid ja nende kasvatamine. [www] http://www.eau.ee/~alo/karusloomad/rebased/?Rebased (12.11.2024).
156 ERR. Riigikogu keelustas karusloomafarmid. [www] available: https://www.err.ee/1608232770/riigikogu-keelustas-karusloomafarmid (11.11.2024).
157 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.16, table 10.4.

Table 5.9. Activity coefficients corresponding to animals' feeding situation[158]

Feeding situation	Definition	C_a
Stall	Animals are confined to a small area with the result that they expend very little or no energy to acquire feed.	0
Pasture	Animals are confined in areas with sufficient means to forage, requiring a modest energy expense to acquire feed.	0.17

Default values for Methane conversion rates for cattle are presented in Table 5.10.

Table 5.10. Methane conversion rate, %[159]

Cattle category	Ym, %
Mature dairy cattle	6.5
Mature non-dairy cattle	
Mature males (2 years and over)	6.5
Mature females (2 years and over)	6.5
Young cattle	
Bovine animals (aged between 1 and 2 years)	6.5
Calves (6–12 months)	6.5
Calves (0–6 months)	3.25

The value of Y_m for calves (0–6 months) was estimated considering feed intake, the diet of animals and development conditions of rumen: namely, the development of rumen of calves is complete between the 7th and 9th week of life, but may take several additional weeks[160], which stipulate markedly lower methane emissions. Additionally, the consumption of milk (only) assumes zero methane emissions from the rumen[161]. In Estonia, it was investigated that calves get milk and milk substitute until the age of 3 months, which assume zero emissions from enteric fermentation: at the age of 3–6 months, calves feed on mineral fodder[162]. Hence, it was assumed that the methane conversion rate of calves (0–6 months) is 3.25%, the rate was estimated as an arithmetic mean based on the rate of calves between 0 and 3 months (which is zero) and from 3 to 6 months (Y_m is 6.5%). Since the 2019 submission, Y_m of young cattle (reported in CRT Table 3.A.1) is calculated as a weighted average Y_ms of bovine cattle, calves aged 0–6 months and 6–12 months.

The values of CH_4 EFs for Enteric fermentation of non-dairy cattle (mature and young) are presented in Table 5.11.

Table 5.11. CH_4 EF of Enteric fermentation of non-dairy cattle in 2023, kg CH_4/head/year

Livestock category of non-dairy cattle	Emission factor, kg CH_4/head/year
Mature males (2 years and over)	73.3

158 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.17, table 10.5.
159 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.30, table 10.12.
160 Federal Environment Agency. National Inventory Report for the German Greenhouse Gas Inventory 1990–2010. [www] https://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories/submissions-of-annual-greenhouse-gas-inventories-for-2017/submissions-of-annual-ghg-inventories-2012 (12.11.2024).
161 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.30.
162 Lehtsalu, S., Kaart, T., Kiiman, H. (2010). Lehmvasikate kasvatamine sündimisest seemendamiseni. Agraarteadus, 21 (1), lk 14–23.

Livestock category of non-dairy cattle	Emission factor, kg CH_4/head/year
Mature females (2 years and over)	88.0
Bovine animals (aged between 1 and 2 years)	57.4
Calves (6–12 months)	18.8
Calves (0–6 months)	3.3

The values of CH_4 EF have increased in the period of 1990–2023, mainly due to the increased milk production per cow (Figure 5.10). Figure 5.10 illustrates the trend of annual changes in CH_4 EFs for dairy cattle, milk yield per cow and the number of dairy cattle populations in relation to the base year (1990 = 1). The values of CH_4 EFs estimated for Enteric fermentation of dairy cattle are presented in Table 5.12.

Table 5.12. Weight, milk yield per cow and fat content of milk, gross energy intake and enteric fermentation CH_4 EFs for dairy cattle in 1990–2023 (Annexes A.V.2_II.1–4, A.V.3_III.1)

Year	Weight of dairy-cattle, kg/head	Fat content of milk, %	Milk yield per cow, kg/head/yr	Gross energy intake, MJ/head/day	Emission factor, kg CH_4/head/yr
1990	544.9	4.09	4 164	245	105
2005	588.7	4.21	5 886	300	128
2019	632.6	3.89	9 633	368	157
2020	635.9	3.89	9 943	367	156
2021	636.3	3.90	9 966	367	157
2022	636.5	3.95	10 144	373	159
2023	636.6	3.91	10 608	382	163
IPCC default					
EE[163]	550[164]		2 555[163]		99[165]
WE	600		5 986		117

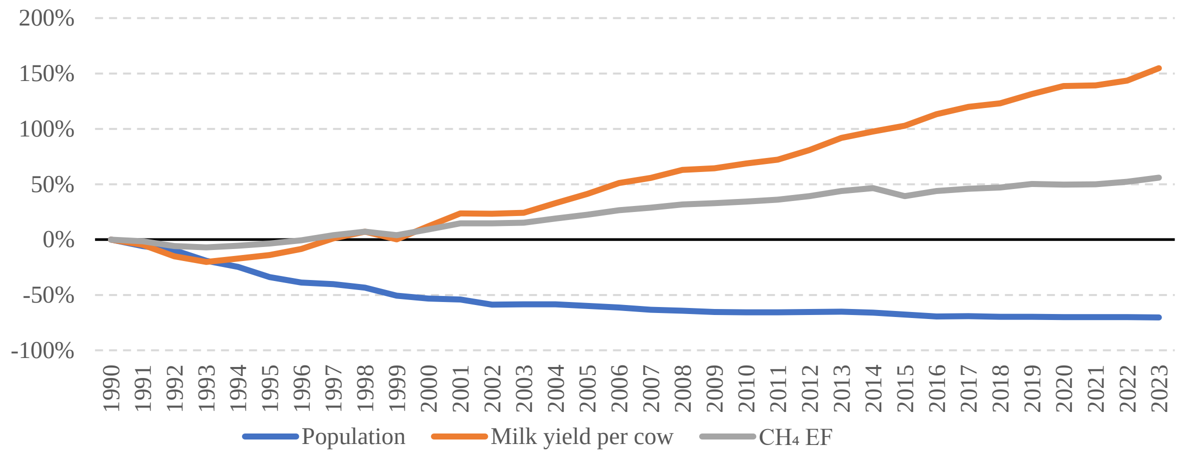

Figure 5.10. Changes in dairy cattle population, milk yield per cow and CH_4 EF in the period of 1990–2023 in relation to the base year (1990), %

3.A.3 Enteric fermentation of swine

Table 5.13 demonstrates CH_4 emission factors for each category of swine and the IPCC default EF for swine recommended for developed countries. Methane conversion factors are taken from the 2006 IPCC Guidelines.

[163] EE – Eastern Europe, WE – Western Europe.
[164] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.72, table 10A.1.
[165] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.29, table 10.11.

Methane emission factors in Table 5.13 were taken from the 2006 IPCC Guidelines; ratios of feed digestibility were obtained from a study by A. Kaasik[166].

Table 5.13. Methane emission factors for swine enteric fermentation, kg CH_4/head/year

Swine category	Emission factor, kg CH_4/head/year	
	Calculated	**IPCC default[167]**
Total		1.5
Piglets, live weight less than 20 kg	0.42	
Young pigs, live weight 20–<50 kg	0.92	
Fattening pigs		
live weight 50–<80 kg	1.41	
live weight 80–<110 kg	1.79	
live weight 110 kg or more	1.96	
Breeding pigs, live weight 50 kg or more	1.96	

3.A.2 and 3.A.4 Enteric fermentation of sheep and other livestock

CH_4 emission factors, recommended by the 2006 IPCC Guidelines for developed countries, were used to estimate CH_4 emissions from Enteric fermentation of sheep, goats, and horses (Table 5.14). The emission factors for fur animals were provided by a Finnish expert in the Agriculture sector (Sanna Pitkänen, personal communication).

Table 5.14. Enteric fermentation methane emission factors, kg CH_4/head/year[168]

Livestock category	Emission factor, kg CH_4/head/year
Sheep	8
Goats	5
Horses	18
Poultry	Not estimated
Fur animals	0.1[169]
Rabbits	Not estimated

5.2.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Enteric fermentation subcategory, please see Annex A.II.3 Agriculture, 3.A Enteric fermentation chapter.

[166] Kaasik, A. Report of the projekt „Kariloomade söödaplaanide uuring 1990–2020“. [www] https://kliimaministeerium.ee/media/1415/download (12.11.2024).
[167] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, table 10.10.
[168] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, table 10.10 (developed countries).
[169] For fur animals, the Norwegian emission factor was used (0.1 kg/animal/year). The emission factor was derived by scaling the emission factor of swine based on a comparison between the average weights of swine and fur animals. Swine emission factors were assumed to be similar to fur animals’ with regard to their digestive system and feeding. The emission factor of Norwegian fur animals has been developed for the reporting purposes of fur animals similar to those in Estonia. The species of the reported Norwegian fur animals include foxes and minks as in Estonia.

5.2.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.5.

The QC/QA plan for the Enteric fermentation subsector includes the QC activities described in the IPCC 2006 Guidelines Volume 1, Chapter 6 and the activities listed in Volume 4, Chapter 10[170]. The activities are carried out every year during the inventory. The QC check list is used during the inventory.

5.2.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

Correcting the average winter temperature for Mature males for 2022

Average winter temperature was corrected for emission calculations for the year 2022 due to a copying error in previous submission.

Correcting the Cfi (energy needed for maintenance) parameter for Bovine animals (aged 1-2 years) for the years 2020-2022

Energy needed for maintenance was corrected for emission calculations for the years 2020-2022 due to a copying error in the previous submission.

Correcting the fat content in milk for Mature females for the years 2021-2022

Fat content in milk for mature female cattle was corrected for emission calculations for the years 2021-2022 due to a copying error in the previous submission.

A comparison of the changed values of CH_4 emissions due to the recalculations between 2025 and 2024 submissions is shown in Table 5.15.

Table 5.15. Reported CH_4 emissions in the 2024 and 2025 submissions from enteric fermentation, kt

Enteric fermentation	2020	2021	2022
2024 submission	22.19	22.25	22.23
2025 submission	21.94	21.99	21.99

5.2.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

Estonia is conducting an inventory development project in the period of 2024-2027 to measure CH_4 emissions for the most represented ruminants in Estonia and thus develop county-specific emission factors.

[170] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.33-10.34.

5.3. Manure management (CRT 3.B)

5.3.1. Category description (e.g. characteristics of sources)

CH_4 emissions from Manure management

CH_4 is produced from the decomposition of the organic matter remaining in the manure under anaerobic conditions. CH_4 emission rates from Manure management directly depend on the manure management system (MMS) and temperature[171].

CH_4 emissions from Manure management formed 14.4% of the total agricultural emissions in Estonia in 2023.

The largest contributor to the CH_4 emissions in manure management in 2023 was the cattle subcategory. The total CH_4 emissions from livestock manure management were 5.88 kt in Estonia in 2023, the emissions have decreased by 22.7% in comparison with the base year (Table 5.16, Figure 5.11). The main reason for this decline is the decrease in livestock population numbers for all animal categories and amounts of animal manure applied to soils. Another reason for decreased emissions compared to the base year is biogas production that started in Estonia in 2006 and the production volumes have increased since then. Biogas is produced from animal manure and waste-based co-substrates. The emission factor for manure that is anaerobically digested is lower than for liquid manure that is the dominant manure management system in Estonia for most animal categories.

In the 2024 submission, biogas production was considered for the first time in the national inventory and emission calculations. This is a result of a project (2020-2023) during what Estonia developed a methodology to estimate GHG emissions from the production of biogas from agricultural (and waste) sources. Considering biogas production under Agriculture sector reduces CH_4 emissions from manure management as the emission factor for anaerobic digester is lower than for the liquid manure that is mostly used in biogas reactors. Manure from cattle, pigs and poultry is used to produce biogas. Country-specific emission factors for biogas production were calculated according to IPCC 2019 Refinement, equation 10.23 (Equation 5.20). For methane conversion factor, IPCC 2019 Refinement default factor was used, and a country-specific methane conversion factor for anaerobic digester is being developed. Emissions from biogas use are reported under the Energy sector and emissions from biogas production from waste sources are reported under the Waste sector. Biogas production also includes adding waste-based co-substrates to the manure into the biogas reactor. This waste-based digestate is after applied to agricultural soils as a fertilizer – that increases the N_2O emissions from Agricultural Soils category.

Table 5.16. CH_4 emissions from Manure management in 1990–2023 in Estonia, kt

Livestock category	1990	2005	2019	2020	2021	2022	2023
Cattle	2.14	1.71	4.40	4.17	4.21	4.28	4.17
Swine	4.14	1.57	1.65	1.86	1.75	1.50	1.62
Sheep	0.03	0.01	0.02	0.01	0.01	0.01	0.01
Goats	0.0003	0.0004	0.0007	0.0006	0.0006	0.0006	0.0006
Horses	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Poultry	0.15	0.05	0.06	0.06	0.06	0.06	0.07
Fur animals	0.16	0.09	0.003	0.002	0.0002	0.0001	NO
Rabbits	0.01	0.01	0.002	0.002	0.001	0.0008	0.0004
Total	6.64	3.44	6.14	6.12	6.04	5.87	5.88

[171] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.35.

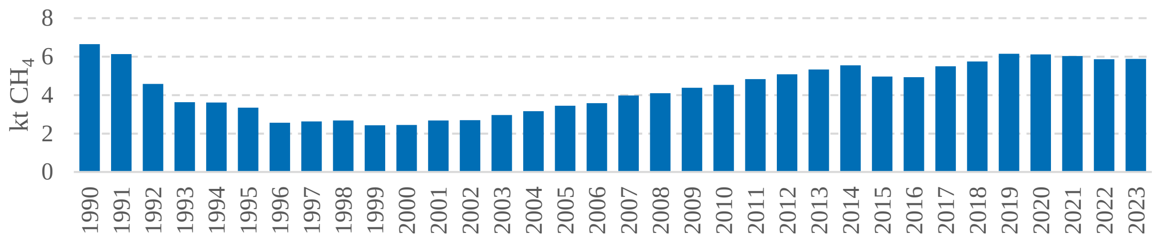

Figure 5.11. CH_4 emissions from Estonian livestock manure management in 1990–2023, kt

3.B.1 Manure management of cattle

The total CH_4 emissions from cattle manure management were 4.17 kt in Estonia in 2023, the emissions increased by 94.6% by 2023 in comparison with the base year (Table 5.17). This is mostly due to the decreased proportion of solid manure and the more widespread use of liquid manure and deep litter systems for growing cattle, which IEFs are higher.

Table 5.17. CH_4 emissions from cattle manure management in 1990–2023 in Estonia, kt

Livestock category	1990	2005	2019	2020	2021	2022	2023
Dairy cattle	1.43	1.31	2.81	2.71	2.74	2.82	2.86
Other mature cattle	0.18	0.06	0.77	0.69	0.67	0.69	0.60
Growing cattle	0.54	0.34	0.83	0.77	0.79	0.77	0.71
Total emissions	2.14	1.71	4.40	4.17	4.21	4.28	4.17

3.B.3 Manure management of swine

The total CH_4 emissions from swine manure management were 1.62 kt in Estonia in 2023 (Figure 5.12). Emissions decreased by 60.9% in 2023 compared with the base year due to the decrease in the number of the swine population.

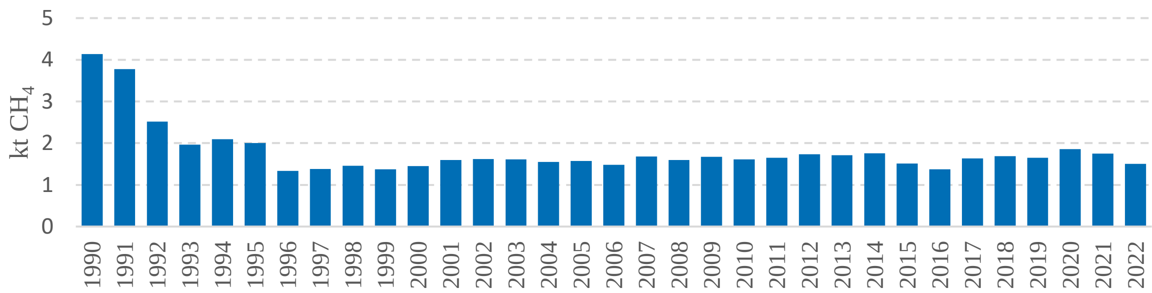

Figure 5.12. CH_4 emissions from swine MMSs in 1990–2023 in Estonia, kt

3.B.2 and 3.B.4 Manure management of sheep and other livestock

The total CH_4 emission from the MMS of other livestock categories was 0.09 kt in Estonia in 2023 (Figure 5.13). The emission declined by 74.8% in 2023 compared with the base year due to the decrease in the number of other livestock population. The emissions in 2023 increased compared to the previous year, this is mostly caused by a small increase horse and poultry population.

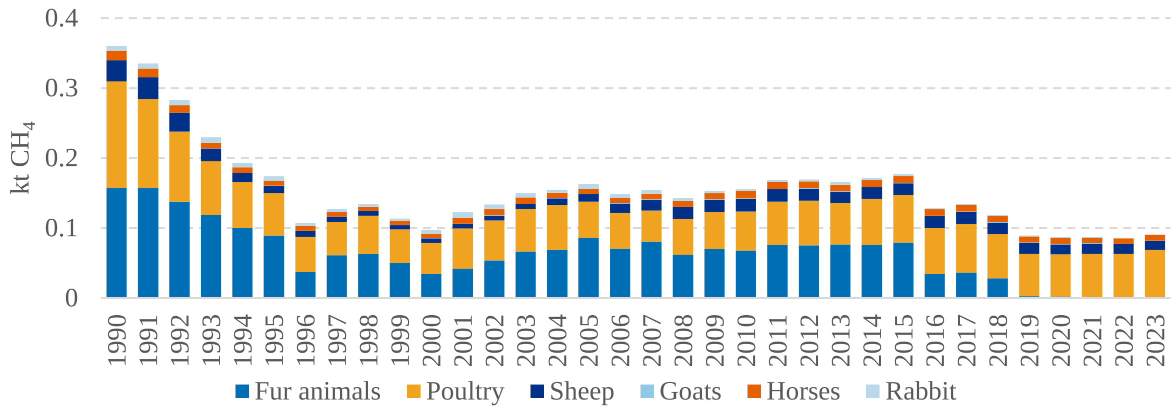

Figure 5.13. CH_4 emissions from other livestock MMSs in 1990–2023 in Estonia, kt

Direct N_2O emissions from Manure management

Production of N_2O during the storage and treatment of animal wastes can occur via combined nitrification-denitrification of nitrogen contained in the wastes[172].

The total quantity of nitrogen generated by livestock and stored in solid, liquid, and deep litter types, as well as in anaerobic digester, of MMSs was 20 909 tons in 2023 (Table 5.19) and 0.14 kt of direct N_2O emissions (Table 5.18) occurred from the stored manure. The fall in N_2O emissions from Manure management is associated with changes in the MMS structure and the shrinking of animal husbandry compared to the 1990 emissions.

Table 5.18. Total direct N_2O emissions from MMSs in Estonia during 1990–2023, kt

MMS system	1990	2005	2019	2020	2021	2022	2023
Liquid/slurry	NO	0.02	0.09	0.09	0.09	0.09	0.09
Solid storage	0.21	0.08	0.01	0.01	0.01	0.01	0.01
Deep litter	NO	0.01	0.05	0.04	0.05	0.05	0.04
Anaerobic digester	NO	NO	0.002	0.002	0.002	0.002	0.002
Total [173]	0.21	0.10	0.14	0.14	0.14	0.14	0.14

Table 5.19. Total nitrogen (in manure) excreted by livestock in Estonia during 1990–2023, kg

MMS system	1990	2005	2019	2020	2021	2022	2023
Liquid/slurry	6 622 353	4 829 865	13 605 705	13 959 054	13 875 771	13 759 011	14 030 733
Solid storage	33 333 672	12 763 411	3 118 182	2 716 801	2 745 787	2 535 020	2 416 772
Deep litter	NO	391 544	3 025 463	2 848 123	2 927 270	2 943 365	2 471 110
Anaerobic digester	NO	NO	1 756 639	2 089 742	1 803 575	1 866 903	1 990 072
Total[174]	39 956 025	17 984 820	21 505 989	21 613 720	21 352 404	21 104 299	20 908 688

3.B.1 Manure management of cattle

The total quantity of nitrogen generated by cattle was 18 230 tons in Estonia in 2023. The allocation of nitrogen excreted among different types of MMSs is presented in Table 5.20.

[172] Background Papers – IPCC Expert Meetings on Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2003). CH_4 and N_2O emissions from livestock manure, page 322.
[173] N_2O emissions from 'Pasture/range and paddock' were considered under Direct soil emissions.
[174] N_2O emissions from 'Pasture/range and paddock' were considered under Direct soil emissions.

Table 5.20. The allocation of the quantity of nitrogen (in manure) excreted by cattle, kg

MMS system	1990	2005	2019	2020	2021	2022	2023
Liquid system	NO	2 219 634	11 039 588	11 211 314	11 300 591	11 526 552	11 645 686
Solid storage	25 894 721	9 025 257	1 040 875	757 053	740 545	633 029	559 899
Deep litter	NO	391 544	2 936 205	2 746 930	2 820 906	2 846 004	2 336 958
Pasture, range and paddock	7 302 122	3 319 052	2 027 593	1 853 350	2 017 127	1 868 622	1 733 437
Anaerobic digester	NO	NO	1 626 872	1 909 690	1 671 410	1 723 489	1 953 970
Total nitrogen	33 196 843	14 955 488	18 671 133	18 478 337	18 550 580	18 597 696	18 229 949

3.B.3 Manure management of swine

The total quantity of nitrogen generated by pigs was 2 576 tons in Estonia in 2023. The allocation of nitrogen excreted among different types of MMSs is presented in Table 5.21. As the formation of a natural crust cover for uncovered pig slurry is highly unlikely, Estonia has applied a value of 0 kg N_2O–N (kg N ex)$^{-1}$ since the 2016 submission to estimate N_2O emissions from pig slurry management.

Table 5.21. The allocation of the amount of nitrogen (contained in manure) excreted by pigs and stored in different types of MMSs, kg N/year

MMS system	1990	2005	2019	2020	2021	2022	2023
Liquid system	6 622 353	2 610 231	2 566 117	2 747 740	2 575 180	2 232 460	2 385 048
Solid storage	1 009 930	718 517	41 075	50 388	136 393	109 567	56 858
Deep litter	NO	NO	89 258	101 194	106 365	97 362	134 153
Pasture, range and paddock	NO	NO	NO	NO	NO	NO	NO
Anaerobic digester	NO	NO	101 234	130 580	86 557	91 378	NO
Total nitrogen	7 632 283	3 328 747	2 797 685	3 029 902	2 904 496	2 530 766	2 576 058

3.B.2 and 3.B.4 manure management of sheep and other livestock

The total amount of nitrogen generated by sheep and other livestock was 2 490 tons in 2023. The breakdown of the quantity of nitrogen excreted by other livestock categories is reported in Table 5.22.

Table 5.22. Nitrogen (in manure) excreted by other livestock categories, kg N/year

Year	Livestock category						Total nitrogen
	Sheep	Goats	Horses	Poultry	Fur animals	Rabbits	
1990	2 424 573	39 133	517 935	2 480 870	1 698 262	696 219	7 856 992
2005	848 211	58 493	289 080	843 713	869 845	676 293	3 585 636
2019	1 237 842	100 373	332 743	1 005 425	21 209	163 936	2 861 528
2020	1 152 310	93 010	322 204	959 654	16 685	161 587	2 705 450
2021	1 142 473	91 478	311 664	981 918	2 004	121 597	2 651 134
2022	1 076 446	83 367	301 065	996 710	1 022	81 608	2 540 218
2023	1 015 972	83 348	316 302	1 051 071	NO	41 610	2 508 303

Indirect N_2O emissions from Manure management

Indirect N_2O emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO_x and N_2. Nitrogen is also lost through run-off and leaching into soils from the solid storage of manure in outdoor areas, feedlots, and pastures where animals are grazing. Pasture losses are considered separately in the Agricultural soils category.

The total amount of 0.07 kt of indirect N_2O occurred from the stored manure (Table 5.23).

Table 5.23. Indirect N_2O emissions from Manure management in 1990–2022, kt

Category	1990	2005	2019	2020	2021	2022	2023
N losses due to volatilization from manure management	0.10	0.05	0.06	0.06	0.06	0.06	0.06
N losses due to leaching from MMSs	0.01	0.004	0.001	0.001	0.001	0.0005	0.0005
Total Indirect N_2O emissions from manure management	0.11	0.05	0.06	0.06	0.06	0.07	0.07

5.3.2. Methodological issues

Choice of methods

CH_4 emissions from Manure management

3.B.1 Manure management of cattle

CH_4 production from the manure of dairy cattle and non-dairy cattle was estimated based on the algorithm presented in the IPCC 2006 using country-specific data and IPCC default factors (Equation 5.18-Equation 5.20).

Equation 5.18[175]

$$CH_4\_Emission_j = EF_j \times Population_j / (10^6 kg/Gg)$$

Where:

CH_4 Emissions$_j$ = methane emissions from Manure management of *j* category of cattle, kt CH_4/year;

EF_j = methane emission factor for *j* category of cattle, kg CH_4/head/year;

Population$_j$ = the number of head in *j* category of cattle, heads.

Equation 5.19[176]

$$EF_j = VS_j \times {}^{365\ days}/_{yr} \times B_{oj} \times 0.67\ {}^{kg}/_{m^3} \times \sum_{nK} MCF_{nK} \times MS\%_{jK}$$

[175] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.37, equation 10.22.

[176] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.41, equation 10.23.

Where:

EF(T) = annual methane emission factor for *T* category of cattle, kg CH_4 animal^{-1} yr^{-1};
VS(T) = daily volatile solid excreted for *T* category of cattle, kg dry matter animal^{-1} day^{-1};
Bo(T) = maximum CH_4 producing capacity for manure produced by *T* category of cattle, m^3 CH_4 kg^{-1} of VS excreted (Table 5.28);
MCF$_{nk}$ = CH_4 conversion factors for each MMS *n* by climate region k;
MS$_{njk}$ = fraction of animal species/category *j*'s manure handled using manure system *n* in climate region *k*.

Equation 5.20[177]

$$EF_{(T)} = (VS_T \times 365)[B_{o(T)} \times 0.67 \times \sum_{s,k} MCF_{s,k} \times AWMS_{(T,S,k)}$$

Where:

EF(T) = annual methane emission factor for livestock category of cattle, kg CH_4 animal^{-1} yr^{-1};
VS$_T$ = volatile solid excreted for *j* category of cattle, kg dry matter animal^{-1} day^{-1};
Bo(T) = maximum CH_4 producing capacity for manure produced by *j* category of cattle, m^3 CH_4 kg^{-1} of VS excreted[178];
MCF(s,k) = CH_4 conversion factors for each MMS *S* by climate region k, percent;
AWMS(T,s,k) = fraction of livestock category *T*'s manure handled using animal waste management system *S* in climate region *k*.

Equation 5.21[179]

$$VS = [GE \times (1 - (DE\%)/100) + (UE \times GE)][((1 - ASH)/18.45)]$$

Where:

VS$_j$ = volatile solid excretion per day on a dry-matter weight basis of *j* category of cattle, kg DM/day;
GE$_j$ = daily gross energy intake per head of *j* category of cattle, MJ/day; 1 dm kg – 18.45 MJ;
DE$_i$ = digestible energy of the feed for *j* category of cattle, %;
ASH = ash content of the manure as a percentage, % (8%);
(UE x GE) = urinary energy expressed as fraction of GE. Typically, 0.04 GE can be considered urinary energy excretion by most ruminants.

[177] IPCC 2019 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.64, equation 10.23.
[178] IPCC 2019 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.67, Table 10.16a.
[179]IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.42, equation 10.24.

3.B.3 Manure management of swine

Methane production from the manure management of swine by subcategories was estimated based on the algorithm described under 3.B.1.1 Manure management of cattle.

3.B.2 and 3.B.4 Manure management of sheep and other livestock

CH_4 emissions from manure management of other livestock were calculated in accordance with the Equation 5.18 using activity data on the population of livestock and the default IPCC emission factors.

Direct N_2O emissions from Manure management

3.B.1 Manure management of cattle

The key methodology used for the estimation of N_2O emissions from Manure management was the *Tier 2* method (Equation 5.21-Equation 5.22).

Equation 5.22[180]

$$N_2O_{D(mm)} = \sum\nolimits_{(S)} \{[\sum\nolimits_{(T)} N_{(T)} \times Nex_{(T)} \times MS_{(T,S)}] \times EF_{3(S)}\} \times \frac{44}{28}$$

Where:

$N_2O_{D\ (mm)}$ =	direct N_2O emissions from Manure management in the country, kg N_2O/year;
$N_{(T)}$ =	number of head of livestock species *j* in the country;
$Nex_{(T)}$ =	annual average N excretion per head of livestock species *j* in the country, kg N/head/year;
$MS_{(T,\ S)}$ =	fraction of total annual excretion for each livestock species *T* that is managed in the MMS *S* in the country;
$EF_{3(S)}$ =	N_2O emission factor for the MSS *S* in the country, kg N_2O–N/kg N in the MMS *S*;
S=	MMS;
T =	species of livestock.

Nitrogen excretion factors for all categories of cattle were calculated based on the nitrogen balance described in Equation 5.22[181]:

Equation 5.23

$$N_{excreta_j} = N_{feed_j} - (N_{milk} + N_{weight\_gain} + N_{embryo})_j$$

Where:

$N_{excreta\_j}$ =	nitrogen excreted per *j* category of cattle, kg/head/year;
N_{feed_j} =	nitrogen consumption with feed by *j* category of cattle, kg/head/year;

[180] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.54, equation 10.25.

[181] The amount of nitrogen excreted by cattle can be estimated as the difference between the total nitrogen taken in by the animal and the total nitrogen retained for growth and milk production, according to IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.58.

N_{milk_j}= nitrogen absorbed in milk, kg/head/year;
$N_{weight\ gain\_j}$= nitrogen retained for growth per *j* category of cattle, kg/head/year;
N_{embryo_j} = nitrogen required to support embryo development, kg/head/year.

Nitrogen contained in feed consumed by different categories of cattle was calculated considering the values of gross intake (kg/head/yr); the algorithm is described in 5.3.2. Methodological issues as well as the average rates of nitrogen content in animal feed (Annex A.V.3_V.1). N_{milk}, N_{gain} and N_{embryo} were estimated as follows[182]:

N_{milk} = kg milk protein per cow per year / 6.38
N_{gain} = kg weight gain per head per year * nitrogen content in body weight
N_{embryo} = kg calf * nitrogen content in embryo.

The values of nitrogen content in milk, body weight and embryo are reported in Annex A.V.3_V.2. Values of the average milk protein content in Estonia in 1990–2023 were obtained from EARC.

3.B.3 Manure management of swine

The key methodology used for the estimation of N_2O emissions from Manure management was the *Tier 2* method (Equation 5.21-Equation 5.22).

3.B.2 and 3.B.4 Manure management of sheep and other livestock

The *Tier 1* method was used to estimate direct N_2O emissions from other livestock (Equation 5.21, using IPCC 2006 Default parameters).

Indirect N_2O emissions from Manure management

N losses due to volatilization from manure management

The *Tier 2* method (Equation 5.23) of the IPCC 2006 Guidelines[183] was applied to estimate indirect N_2O emissions from manure management due to volatilization:

Equation 5.24

$$N_2O_{G(mm)} = (N_{volatilization-MMS} \times EF_4) \times 44/28$$

Where:

$N_2O_{G(mm)}$= indirect N_2O emissions due to volatilization of N from Manure management in the country, kg N_2O yr^{-1};

EF_4 = emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O–N (kg NH_3–N + NO_x–N volatilized)$^{-1}$; default value is 0.01 kg N_2O–N (kg NH_3–N +NO_x–N volatilized)$^{-1}$;

$$N_{volatilization-MMS} = \mathrm{NO_X - N + NH_3 - N};$$

[182] DIAS. Standard Values for Farm Manure. [www] https://dcapub.au.dk/djfpublikation/djfpdf/djfhd7.pdf (12.11.2024).

[183] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.54–10.56.

Where:

$N_{volatilization\text{-}MMS}$ = amount of manure nitrogen that is lost due to volatilization of NH_3 and NO_x, kg N yr^{-1}. Estimates of NO_x and NH_3 are received from EstEA and are in line with the respective estimates reported in the Estonian Informative Inventory Report. The emission estimates have been calculated with the methodology provided by the EMEP/EEA guidebook 2023.

N losses due to leaching from manure management

The *Tier 2* methodology for the estimation of N losses due to leaching from MMSs is applied and the respective IPCC 2006[184] equations are used:

Equation 5.25

$$N_2O_{L(mm)} = \left(N_{leaching-MMS} \times EF_5\right) \times \frac{44}{28}$$

Where:

$N_2O_{L(mm)}$ = indirect N_2O emissions due to leaching and run-off from Manure management in the country, kg N_2O yr^{-1};

EF_5 = emission factor for N_2O emissions from nitrogen leaching and run-off, kg N_2O–N/kg N leached and run-off (default value 0.0075 kg N_2O–N (kg N leaching/run-off)$^{-1}$.

Equation 5.26

$$N_{leaching-MMS} = \sum_S \left[\sum_T \left[\left(N_T \times Nex_T \times MS_{T,S}\right) \times \left(\frac{Frac_{leachMS}}{100}\right)_{T,S}\right]\right]$$

Where:

$Frac_{leachMS}$ = percent of managed manure nitrogen losses for livestock category *T* due to run-off and leaching during solid and liquid storage of manure (typical range 1–20%).

Activity data

CH_4 emissions from Manure management

3.B.1 Manure management of cattle

For livestock numbers and characteristics for cattle, please see info under Chapter 5.2.2. Methodological issues Activity Data 3.A.1 Enteric fermentation of cattle.

[184] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.56–10.57.

The complete information about manure management system distributions for the years 1990-2023 for cattle is presented Annex A.V.3_IV, a module on MMS distributions is presented in Table 5.24.

Table 5.24. Manure management system distributions for dairy cattle in 1990-2023, %

MMS	1990	2005	2019	2020	2021	2022	2023
Liquid/slurry	NO	20.12	78.46	77.91	79.73	80.99	80.20
Solid storage	82.73	63.01	6.40	4.45	4.05	2.40	1.99
Pasture/range	17.27	16.87	1.83	1.34	1.23	1.34	0.81
Deep litter	NO	NO	2.06	2.89	3.14	3.21	3.03
Anaerobic digester	NO	NO	11.25	13.41	11.85	12.06	13.97

In Estonia, the types of housing used for dairy cows are tie-stall housing and loose-housing. In tie-stall housing systems, solid manure forms. In loose-housing systems 1) the formation of liquid manure is dominant, and it forms when litter is not used or a very small amount of litter is used, and 2) less frequently solid manure forms when litter is used. The share of loose housing, which has become a dominant means of housing, has been increasing since 2003. In a loose-housing system animals can move freely in feeding or resting areas. The slurry from loose-housing systems is mostly removed by tractors or screepers. Screepers are the only means of removing manure from the barns where robotic milking systems are used. In Estonia, according to the Estonian Environmental Decisions Information System KOTKAS[185], the share of slurry stored in pit storage below dairy cows is zero. In addition, the Estonian document on best available techniques (BAT)[186] for the intensive rearing of cows and its annex claim that 1) tie-stall housing where liquid manure is produced is not BAT and 2) pit storage (fully slatted floor – a prerequisite for a pit storage) below the cows in loose-housing systems is not BAT. In Estonia, using BATs is obligatory for operators owning Air or Integrated Pollution Prevention and Control (IPPC) permit according to the Ambient air protection act[187].

The transition from tie-stall housing technology to loose-housing technology launched in Estonian farms in the beginning of the 2000s saw a switch from solid storage MMS to liquid/slurry MMS in dairy cattle farms (see Annex A.V.3_IV). Since 2021 submission, MMS distributions for most cattle groups are obtained from KOTKAS database.[182] However, for mature female cattle, the share of Pasture/Range and Paddock (PRP) manure was calculated based on the data received from ARIB that is a national statistics that are constantly updated. Data on the movements of mature female cattle and their grazing days were used to calculate the more reliable share of grazing for this animal group. That is because in the KOTKAS database there are only agricultural producers (threshold capacity 400 and more adult cattle), and among them the are only a few beef cattle breeders in the country – so the actual share of grazing for mature female cattle is higher than presented in the database.

Amounts of manure from cattle delivered to biogas plants were calculated based on animal numbers in the agricultural facilities who sent their manure to biogas plants. Estonia started producing biogas from cattle manure from 2012. In biogas plants, liquid manure from dairy cattle is mostly used for biogas production.

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[185] KOTKAS, [www] https://kotkas.envir.ee/ (12.11.2024).
[186] Estonian University of Life Sciences. Saastuse kompleksne vältimine ja kontroll. Parim võimalik tehnika veiste intensiivkasvatuses. [www] http://vl.emu.ee/userfiles/instituudid/vl/VLI/tervisjakeskk/PVT_tooversioon_28_03_2014.pdf (02.01.2025).
[187] Riigi Teataja. Atmosfääriõhu kaitse seadus. [www] https://www.riigiteataja.ee/akt/A%C3%95KS (14.11.2024).

In 1990–2000, a share of mature non-dairy cattle manure stored in solid storage MMS constituted about 68% and manure from pasture about 32%. Since 2001, the MMSs of mature non-dairy cattle have made a shift from solid MMS towards liquid MMS and deep litter MMS. Hence, in 2023, the share of mature non-dairy cattle manure was the following: 39.54% manure from pasture, 28.52% liquid, 26.68% deep litter, 4.85% solid storage, and 0.41% anaerobic digester MMS fraction.

Table 5.25. Manure management system distributions for growing cattle in Estonia in 2023, %[182]

MMS	Bovine animals (1-2 years old)	Calves (6–12 months old)	Calves (0–6 months old)
Liquid/slurry	45.06	10.98	10.98
Solid storage	6.77	NO	NO
Pasture/range	10.37	12.79	12.79
Deep litter	28.31	68.23	68.23
Anaerobic digester	9.49	8.0	8.0

3.B.3 Manure management of swine

For livestock numbers and characteristics for swine, please see info under Chapter 5.2.2. Methodological issues Activity Data 3.A.3 Enteric fermentation of swine.

The dataset used to develop the country-specific module on MMS in Estonia is described in Annex A.V.3_IV and the results are presented in Table 5.26.

Amounts of manure from swine delivered to biogas plants were calculated based on animal numbers in the agricultural facilities who sent their manure to biogas plants. Estonia started producing biogas from swine manure from 2006. In fact, the first biogas production plant in Estonia started operating in 2006 and only used pig slurry for biogas production.

Table 5.26. Manure management system distributions for swine in Estonia in 2023, %[182]

MMS	Young pigs	Fattening pigs	Breeding pigs
Liquid/slurry	100	88.11	9.32
Solid storage	NO	NO	90.68
Pasture/range	NO	NO	NO
Deep litter	NO	11.89	NO
Anaerobic digester	NO	NO	NO

3.B.2 and 3.B.4 Manure management of sheep and other livestock

The module on MMS for sheep, goats and horse livestock categories was developed based on the animals’ grazing period (Annex A.V.3_IV). Animal waste generated by livestock categories are mostly stored in 'solid MMS' (Table 5.27).

Amounts of manure from poultry delivered to biogas plants were calculated based on animal numbers in the agricultural facilities who sent their manure to biogas plants. Estonia started using poultry manure in biogas production in 2019.

Table 5.27. MMS distributions from Manure management of other livestock categories in Estonia in 2023

Livestock category	MMS, %		
	Solid storage	Pasture/range/yards	Anaerobic digester
Sheep	50.68	49.32	NO
Goats	50.68	49.32	NO
Horses	58.9	41.1	NO
Poultry			
Layers	85.6	0.6	13.8
Broilers	99.4	0.6	NO
Other hens and roosters	92.4	0.6	NO
Other Poultry	99.4	0.6	NO
Rabbits	100	NO	NO

Poultry

The annual average poultry population decreased 46% by 2023 compared to the base year – from 4 337.7 thousand heads in 1990 to 2 345.8 thousand heads in 2023.

The average population of poultry is based on the statistical data of layers, number of poultry for slaughter, dead and perished birds, other hens and roosters, and other poultry. For the years that the number of layers was not available, the total production of eggs and production per layer was used in the calculations. The average rearing period of the Estonian broiler is 42 days[188] which was also used in the estimation of the average annual population using the Equation 5.16. The data used in the calculations of the average yearly poultry population are presented in Annex A.V.3_I.6.

Poultry population by all sub-categories of poultry are presented in Figure 5.14.

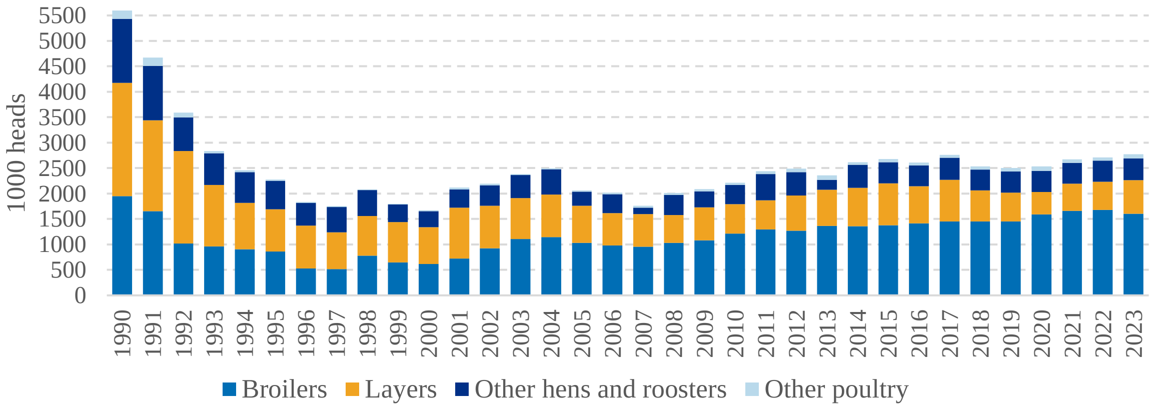

Figure 5.14. Population of poultry by animal group in Estonia in 1990–2023, 1000 heads

Rabbits

For the years 1990–2000 the number of rabbits originates from the records of agricultural production statistics according to the leading expert of Statistics Estonia. This data primarily represents rabbits kept in private households. There was practically no industrial level farming of rabbits in collective farms, later rabbits in homesteads accrued.

In the period of 2001–2019, only one census for the total number of rabbits was conducted (July 2001); in 2020 and 2023, two other censuses were carried out. The mentioned surveys covered

[188] Tikk, H., Tikk, V., Piirsalu, M., Hämmal, J. (2007). Linnukasvatus I. Tartu: OÜ Tartumaa Trükikoda, lk 32.

only the number of breeding females in compliance with the EU regulation 2018/1091[189] or the respective earlier regulations, and only the census conducted in 2001 covered both female rabbit numbers and the total population of rabbits.

Breeding females without young and breeding males are usually kept on their own in separate cages. Each female will have around five to eight litters of eight to ten youngsters per year[190]. Breeding rabbits are usually kept until around 18 to 36 months of age. For every male, farms usually breed 8–10 females. These characteristics were taken as presumptions upon which the annual average population of rabbits was estimated.

Direct N_2O emissions from Manure management

The data on the livestock population by categories were obtained from the database of SE (Annex A.V.3_I). Activity data on other livestock population were obtained from national statistics, the module on MMS was used from Table 5.27.

Indirect N_2O emissions from Manure management

Amounts of NO_x, NH_3 and N_2 emissions were obtained from the compiler of the agricultural expert from Environment Agency. The emissions are in compliance with the data submitted under the Convention on Long-Range Transboundary Air Pollution in the Estonian Informative Inventory Report 1990–2023, compiled by the EstEA.

Emission factors

3.B.1 Manure management of cattle

Parameters used in the estimates are presented in Table 5.28.

Table 5.28. Parameters used in the estimates

Cattle category	**Digestibility of feed, %**[191]	**Bo** [192] **m^3 CH_4/kg VS**
Mature cattle[193]		
Dairy	70.2	0.24
Non-dairy cattle:		
Mature females	63	0.17
Mature males	63	0.17
Bovine animals (aged between 1 and 2 years)	65.1	0.17
Calves (6–12 months old)	65.1	0.17
Calves (0–6 months old)	63	0.17

[189] EUR-Lex. Regulation (EU) 2018/1091 of the European Parliament and of the Council of 18 July 2018 on integrated farm statistics and repealing Regulations (EC) No 1166/2008 and (EU) No 1337/2011 (Text with EEA relevance.). [www] https://eur-lex.europa.eu/eli/reg/2018/1091/oj (12.11.2024).

[190] Home page of Härma Küülikud. Küülikute hooldamisest ja pidamisest. [www] http://www.rabbitfarm.planet.ee/kasulikinfo.html (05.11.2024).

[191] Kaasik, A. (2020) Report of the project ”Kariloomade söödaplaanide uuring 1990–2020”, pages 18–19.

[192] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.77–10.78, table 10A-4.

[193] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.72 and 10.77, tables 10A.1 and 10A.4 (dairy cows); pages 10.73 and 10.7, tables 10A.2 and 10 A.5 (other cattle for Eastern European countries).

CH_4 EFs employed in the estimations are presented in Table 5.29. The country specific CH_4 EFs are higher than IPCC default CH_4 EFs, because the amount of manure stored in the liquid/slurry system is higher than IPCC default share (for Eastern Europe).

Table 5.29. Methane conversion factors (MCFs) and manure management emission factors for dairy cattle in 2023 in Estonia

Parameter	Liquid/slurry	Solid storage	Pasture/range	Anaerobic digester	Deep litter
Emission factor, kg CH_4/head/yr	30.31	0.15	0.03	1.87	1.95
MCFs, % [194]	10	2	1	3.55	17

Estonia uses MCF of 10% for the liquid/slurry MMS in the inventory as crust is the main coverage for the dairy cattle and non-cattle storages. Although no official national statistics are consistently gathered about the covering of manure storage facilities, this statement is confirmed by a study of the Estonian University of Life Sciences[195].

In 2023, CH_4 EFs applied in the estimations of mature non-dairy cattle were the following: mature males – 15.08 kg CH_4/head/year and mature females – 13.43 kg CH_4 per head/year. MMSs used to store animal waste generated by growing cattle (bovine animals and calves) and average CH_4 EFs in Estonia are presented in Table 5.30. (See also Annex A.V.3_IV).

Table 5.30. Methane conversion factors and manure management emission factors for growing cattle in 2023 in Estonia

Parameter	Animal group	Liquid/slurry	Solid storage	Pasture/range	Anaerobic digester	Deep litter
Emission factor, kg CH_4/head/yr	Bovine animals (1-2 years old)	4.89	0.15	0.11	0.37	5.23
	Calves (6-12 months old)	0.39	0	0.05	0.10	4.13
	Calves (0-6 months old)	0.15	0	0.02	0.04	1.55
MCFs, % [196]	Growing cattle	10	2	1	3.55[197]	17

3.B.3 Manure management of swine

Methane conversion factors and the use of different systems of manure management for swine manure storage are presented in Table 5.31.

MCFs related to each type of MMS and CH_4 EFs are reported in Table 5.32.

[194] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.45, table 10.17.
[195] Kaasik, A., Möls, M. Loomakasvatusest eralduvate saasteainete heitkoguste inventuurimetoodikate täiendamine ja heite vähendamistehnoloogiate kaardistamine. [www] https://envir.ee/media/5276/download (12.11.2024).
[196] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.45, table 10.17.
[197] 2019 Refinement to the 2006 IPCC Guidelines, Chapter 10: Emissions from Livestock and Manure Management.

Since the 2016 submission, the liquid manure management MCF value of 17% for pigs has been used in calculations instead of 10% used in the previous submissions, as the formation of a natural crust cover for uncovered pig slurry is highly unlikely.

Estonia uses six sub-categories of swine (piglets, with live weight less than 20 kg; young pigs, with live weight 20–<50kg; pigs, with live weight 50–<80kg, 80–<110kg and 110 kg and more; and breeding sows) in calculations. CH_4 EFs increase from the least weighing category to the most weighing category. For example, in 1999 there was a sharp decrease in the number of swine compared to 1998 as buying-in prices of pork had fallen. As a result, compared to 1998, in 1999 the number of swine in the youngest age groups fell, whereas the number of swine in the three most weighing swine groups increased remarkably.

Table 5.31. Parameters used in the estimates

Swine category	Feed digestibility, %[165]	VS, kg/h/d	Bo, m^3 CH_4/kg VS[198]	MCF, %[199]
Piglets, live weight less than 20 kg	83	0.11	0.45	0.6
Young pigs, live weight 20–<50 kg		0.24		
Fattening pigs				
…live weight 50–<80 kg	80	0.42		
…live weight 80–<110 kg		0.53		
…live weight 110 kg or more		0.58		
Breeding pigs, live weight 50 kg or more		0.32		

Table 5.32. Manure management emission factors for swine manure management systems, %

MMS	MCFs[200], %
Liquid/ slurry	17
Solid storage	2
Deep litter	17
Anaerobic digester	3.55[197]

3.B.2 and 3.B.4 Manure management of sheep and other livestock

Emission factors used in the estimates for other livestock are presented in Table 5.33.

Table 5.33. Manure management emission factors of other livestock categories[201]

Livestock category	Emission factor[202], kg CH_4/head/year
Sheep	0.19
Goats	0.13
Horses	1.56
Poultry	
Broilers	0.02

[198] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.80-10.81, tables 10A-7 and 10A-8.
[199] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.35, table A-4.
[200] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.45, table 10.17.
[201] The module was applied only in the estimation of N_2O emissions from manure management of other livestock, since CH_4 emission from manure management was estimated based on *Tier 1* of the IPCC Guidelines.
[202] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.40-10.41, tables 10.15-10.16 (developed countries, cool climate region).

Livestock category	Emission factor[202], kg CH_4/head/year
Layers and other chickens	0.03
Other Poultry	0.055
Fur animals	
Foxes and raccoons	0.68
Minks	0.68
Rabbits	0.08

Direct N_2O emissions from Manure management

The breakdown of the emission factors used to estimate N_2O emissions released from different types of MMSs is reported in Table 5.34.

Table 5.34. Applied emission factors of manure management, kg N_2O–N/kg Nitrogen excreted[203]

MMS	EF_3 (kg N_2O–N/kg Nitrogen excreted)
Liquid system (with natural crust cover)	0.005
Liquid system (without natural crust cover)	0
Solid storage	0.005
Deep bedding (no mixing)	0.01

3.B.1 Manure management of cattle

The trends in average weight of dairy cattle, milk yield per cow and protein content in milk and (implied) nitrogen excretion rates reported in the CRT are presented in Table 5.35.

Table 5.35. Weight, milk yield per cow and protein content of milk in 1990–2023 (Annexes A.V.3_III.1, A.V.3_II.1–2, A.V.3_V.3-4)

Year	Weight of dairy cattle, kg	Milk yield per cow, kg/head/yr	Protein content of milk, g/kg	Nitrogen excretion rate, kg N/head/yr
1990	544.9	4 164	3.22	74.28
2005	588.7	5 886	3.34	93.22
2019	632.6	9 633	3.41	141.27
2020	635.9	9 943	3.39	140.05
2021	636.3	9 966	3.40	140.22
2022	636.5	10 144	3.41	142.04
2023	636.6	10 608	3.49	143.09
IPCC default				
EE[204]	550	2 555[201]	-	96.4[205]
WE	600	5 986	-	105.1

The N excretion rates are reported in Table 5.36.

[203] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.62, table 10.21.

[204] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.72, table 10A.1.

[205] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.59, table 10.19.

Table 5.36. Country-specific nitrogen excretion rates of non-dairy cattle in 2023, kg N/head/year

Livestock category of non-dairy cattle	Nitrogen excretion rate, kg N/head/yr
Mature males (2 years and over)	73.2
Mature females (2 years and over)	74.9
Bovine animals (aged between 1 and 2 years)	51.0
Calves (6–12 months)[206]	16.0
Calves (0–6 months)	2.9

3.B.3 Manure management of swine

Nitrogen excretion rates were taken from the Regulation of the Minister of the Environment no 66, 14/12/2016[207] (Table 5.37). Applied emission factors are indicated in Table 5.34. Nitrogen (implied) excretion rates reported in the CRT are demonstrated in Figure 5.15. The rate has slightly changed over the entire time series due to changes in the structure of the swine population.

Table 5.37. Average N excretion factors used in the estimates, kg N/head/year

Swine category	Nitrogen excretion rate, kg N/head/year	IPCC default, kg N/head/year
Piglets, live weight less than 20 kg	4.5	–
Young pigs, live weight 20–<50 kg	8.7	–
Fattening pigs		
live weight 50–<80 kg	10.6	–
live weight 80–<110 kg	10.6	–
live weight 110 kg or more	10.6	–
Breeding pigs, live weight 50 kg or more	25.1	–
Swine[208]	–	–
Market (average 50 kg)	–	10
Breeding (average 180 kg)	–	30

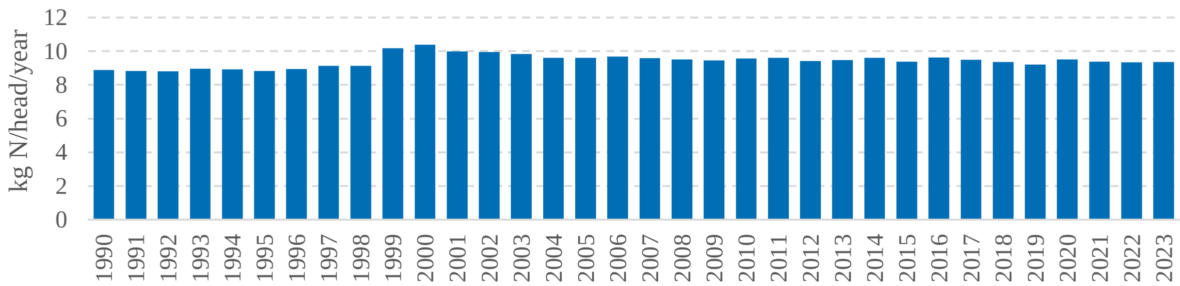

Figure 5.15. Implied swine nitrogen excretion rates reported in the CRT for 1990–2023, kg N/head/year

3.B.2 and 3.B.4 Manure management of sheep and other livestock

Nitrogen excretion rates (Table 5.38) were obtained from the IPCC 2006 Guidelines.

[206] 2-round production cycle was applied for calves (0–6 months and 6–12 months).
[207] Riigi Teataja. Keskkonnaministri 14.12.2016. a määrus nr 66 „Looma- ja linnukasvatusest välisõhku väljutatavate saasteainete heidete mõõtmise ja arvutusliku määramise meetodid Lisa." [www] https://www.riigiteataja.ee/aktilisa/1221/2201/6004/KKM_m66_Lisa.pdf# (12.11.2024).
[208] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.59, table 10.19.

Table 5.38. Nitrogen excretion rates per head of animal, kg N/head/year

Livestock category[209]	**Nitrogen excretion rate, kg N/head/year**
Poultry	
Layers (1.8 kg)	0.39
Broilers (0.9 kg)	0.36
Other chickens (1.8 kg)	0.54
Other poultry (4.75 kg)	1.36
Sheep (65 kg)	21
Goats (40 kg)	19
Horses (550 kg)	60
Fur farming	
Foxes and raccoons	12.09
Minks	4.59
Rabbits	8.1

Indirect N_2O emissions from Manure management

Leaching and run-off of manure nutrients is prevented when the manure storage facility is compacted and sealed. According to an expert opinion by A. Kaasik, a docent of the Chair of Animal Nutrition in Estonian University of Life Sciences, leakage may be presumed for 70% of solid manure storage in 1990s, as most of the manure was kept in manure stacks.[210]

The leak-tightness of manure storage facilities was studied in a 2010 survey[211] conducted by Ltd. Estonian, Latvian & Lithuanian Environment. The survey was carried out in Pandivere and Adavere-Põltsamaa nitrate vulnerable zones in farms with over 10 livestock units. 44 farms that were entities to an environmental permit were visited during the inventory.

The results of the inventory showed that leakage was notable in the case of solid manure storage. Leaching and run-off appeared to be a problem for 23% of solid storage facilities. In the case of liquid manure storage, no leaking facilities were detected. It should be noted that the leakage was determined by visual inspection and on the grounds of records. The latter was used for the assessment of leakage probability. This kind of approach does not ensure 100% accurate results but does provide a basis for making assumptions. Therefore, the existence of more leaking manure storage facilities than detected by the inventory compilers was likely. The majority of liquid manure storage facilities are newer than 10 years and have been constructed according to the respective project requirements (circular drainage, manholes, etc). Hence, leak-tightness of liquid manure storage facilities should be provided.

Leaching and run-off were calculated for 32% of solid manure in 2010 and it is assumed to be the same for the following years. The leakage percentages for the years of 2000–2009 have been found via interpolation.

[209] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.59 and 10.82, tables 10.19 and 10A-9 (average weight).

[210] A. Kaasik, M. Möls. Loomakasvatusest eralduvate saasteainete heitkoguste inventuurimetoodikate täiendamine ja heite vähendamistehnoloogiate kaardistamine [www] https://kliimaministeerium.ee/sites/default/files/documents/2021-12/Loomakasvatusest%20eralduvate%20saasteainete%20heitkoguste%20inventuurimetoodikate%20t%C3%A4iendamine%20ja%20heite%20v%C3%A4hendamistehnoloogiate%20kaardistamine.pdf (13.01.2025)

[211] Kliimaministeerium. Algab sõnnikukäitluse inventuur. [www] https://kliimaministeerium.ee/uudised/algab-sonnikukaitluse-inventuur (06.01.2024).

The value of $Frac_{leachMS}$ = 5% is taken from the *Best Available Technique manual for intensive cattle farming*[212] for Estonian farmers.

5.3.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Manure management subcategory, please see Annex A.II.3 Agriculture, 3.B Manure management chapter.

5.3.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

The QC/QA plan for the Manure management subsector includes the QC activities described in the IPCC 2006 Guidelines Volume 1, Chapter 6 and the activities listed in Volume 4, Chapters 10.4.5 and 10.5.6. The activities are carried out every year during the inventory. The QC check list is used during the inventory.

5.3.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

CH_4 emissions from Manure management

Correcting the number of rabbits for the years 2017-2019; 2021-2022

Rabbit population numbers were corrected for emission calculations for the years 2017-2019 and 2021-2022 due to an interpolation error in the previous submissions.

Correcting the annual average poultry population for the whole timeseries

Average annual poultry population numbers were corrected for emission calculations for the years 1990-2022 due to an overestimation of the total annual average population in the previous submissions.

The population of Poultry in the previous inventories was overestimated by adding "Other Hens and Roosters" population numbers to the annual average Poultry population while in fact "Other Hens and Roosters" category is already included in the total Poultry numbers in Statistics Estonia database.

Correcting the mature female cattle manure management system distributions for 2001-2022

Values for MMS splits for mature female cattle for the years 2001-2022 were updated due to correcting the share of Pasture, Range and Paddock (PRP) manure in manure management system distribution for mature female cattle.

Since 2023 submission, MMS distributions are obtained from KOTKAS database. For the 2025 submission, however, the share of Pasture, Range and Paddock (PRP) manure for mature female cattle was recalculated based on the data received from ARIB database for the years 2005-2022,

[212] Estonian University of Life Sciences. Saastuse kompleksne vältimine ja kontroll. Parim võimalik tehnika veiste intensiivkasvatuses. [www] http://vl.emu.ee/userfiles/instituudid/vl/VLI/tervisjakeskk/PVT_tooversioon_28_03_2014.pdf (08.01.2025).

which were the years ARIB database could provide the data on grazing. The data on the grazing days was used to calculate the more reliable share of PRP manure for this animal group. That is because in the KOTKAS database there are only large-scale agricultural producers (threshold capacity 400 and more adult cattle) – among them there are only a few beef cattle breeders – so the actual share of grazing for mature female cattle is higher than presented in the KOTKAS database. Therefore, the whole time series was corrected using the data from ARIB, which is a national agricultural statistics database that is quarterly updated. For the years 2001-2004 the share of PRP for MMS was interpolated. For the years 1990-2000, the share of PRP for mature female cattle was obtained from a study by A.Kaasik.[213] The values for liquid and solid manure were also revised in the framework of updating the values for PRP for the years 2001-2022.

The updated values and comparison of the changed values for distribution of mature female cattle manure management systems in the 2025 submission compared to the 2024 submission are shown in Table 5.39.

Table 5.39. Previously reported and updated country-specific MMS distributions of mature female cattle in 1990–2022, %

	Mature non-dairy females, %							
Year	**Liquid/ Slurry 2024 submission**	**Liquid/ Slurry 2025 submission**	**Solid Storage 2024 submission**	**Solid Storage 2025 submission**	**Deep litter**	**Pasture/ Range 2024 submission**	**Pasture/ Range 2025 submission**	**An-aerobic digester**
1990	0	0	67.8	67.8	0	32.2	32.2	0
1991	0	0	67.8	67.8	0	32.2	32.2	0
1992	0	0	67.8	67.8	0	32.2	32.2	0
1993	0	0	67.8	67.8	0	32.2	32.2	0
1994	0	0	67.8	67.8	0	32.2	32.2	0
1995	0	0	67.8	67.8	0	32.2	32.2	0
1996	0	0	67.8	67.8	0	32.2	32.2	0
1997	0	0	67.8	67.8	0	32.2	32.2	0
1998	0	0	67.8	67.8	0	32.2	32.2	0
1999	0	0	67.8	67.8	0	32.2	32.2	0
2000	0	0	67.8	67.8	0	32.2	32.2	0
2001	0.5	0.5	66.7	63	0	32.8	36.5	0
2002	1	1	65.7	58.1	0	33.4	40.9	0
2003	1.5	1.5	64.6	53.3	0	34	45.3	0
2004	2	2	63.5	48.4	0	34.6	49.7	0
2005	2.5	2.5	62.4	43.5	0	35.1	54	0
2006	7.8	3.8	59.2	53.9	0	33	42.3	0
2007	13.2	5	56	49	0	30.9	45.9	0
2008	18.6	6.3	52.7	43.8	0	28.7	49.9	0
2009	23.9	7.6	49.5	48.2	0	26.6	44.1	0
2010	29.3	8.9	46.3	46.3	0	24.4	44.8	0
2011	29.2	15.2	44	44	1.4	25.4	39.3	0
2012	27.6	9.7	41.7	41.7	2.9	26.3	44.1	1.6
2013	29.3	12.9	39.4	39.4	4.3	27.2	41.6	1.8
2014	27.8	13.3	37.2	37.2	5.7	28.2	42.7	1.1
2015	28.1	22.7	34.9	34.9	7.1	29.1	34.5	0.8
2016	31.4	16.6	28.8	28.8	13.3	26.1	40.8	0.4
2017	34.2	17.5	22.8	22.8	19.5	23.0	39.6	0.5
2018	36.7	17.6	16.8	16.8	25.7	20.0	39.1	0.9
2019	42.8	16.5	4.7	4.7	38.1	13.8	40.1	0.6
2020	58.6	27.6	3.5	3.5	28.9	8.4	39.5	0.5

[213] Kaasik, A. (2020). Eesti lauda- ja sõnnikukäitlustehnoloogiate ning sõnniku laotamise tehnoloogia uuring, [www] https://www.klab.ee/wp-content/uploads/2021/09/Laudatehnoloogiad_final.pdf (12.11.2024).

	Mature non-dairy females, %							
Year	**Liquid/ Slurry 2024 submission**	**Liquid/ Slurry 2025 submission**	**Solid Storage 2024 submission**	**Solid Storage 2025 submission**	**Deep litter**	**Pasture/ Range 2024 submission**	**Pasture/ Range 2025 submission**	**An-aerobic digester**
2021	58.6	23.9	3.9	3.9	28.4	8.8	43.4	0.3
2022	58.0	25.9	5.2	5.2	28.8	7.6	39.7	0.5

A comparison of the changed values of CH_4 emissions due to the recalculations between 2025 and 2024 submissions is shown in Table 5.40.

Table 5.40. Reported CH_4 emissions in the 2024 and 2025 submissions from manure management, kt

Manure management	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
2024 submission	2.68	2.70	2.96	3.16	3.45	3.59	4.01	4.15	4.45	4.63	4.89
2025 submission	2.68	2.70	2.96	3.16	3.44	3.58	3.98	4.10	4.38	4.54	4.82

Table 5.41. Reported CH_4 emissions in the 2024 and 2025 submissions from manure management, kt (continued)

Manure management	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2024 submission	5.18	5.42	5.65	5.00	5.03	5.61	5.89	6.33	6.38	6.33	6.14
2025 submission	5.09	5.33	5.56	4.96	4.93	5.50	5.75	6.14	6.12	6.04	5.87

Direct N_2O emissions from Manure management

Due to the changes in data used for calculating CH_4 emissions from manure management, direct N_2O emissions were also recalculated for the years 1990-2022 in the inventory.

A comparison of the changed values of direct N_2O emissions due to the recalculations between 2025 and 2024 submissions is shown in Table 5.42.

Table 5.42 Reported direct N_2O emissions in the 2024 and 2025 submissions from manure management, kt

Manure management	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
2024 submission	0.17	0.17	0.17	0.17	0.18	0.19	0.19	0.19	0.19	0.21	0.21	0.21
2025 submission	0.17	0.16	0.16	0.17	0.18	0.18	0.18	0.18	0.19	0.21	0.21	0.21

Table 5.43 Reported direct N_2O emissions in the 2024 and 2025 submissions from manure management, kt (continued)

Manure management	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2024 submission	0.22	0.21	0.22	0.22	0.22	0.23	0.23	0.23	0.24	0.24
2025 submission	0.21	0.21	0.22	0.21	0.22	0.22	0.22	0.22	0.22	0.22

5.3.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

Estonia is working on developing country-specific methane conversion factors for animal manure sent to biogas digesters.

What is more, Estonia is conducting an inventory development project in the period of 2024-2027 to measure CH4 emissions for the most represented ruminants in Estonia and thus develop county-specific emission factors.

5.4. Agricultural soils (CRT 3.D)

5.4.1. Category description (e.g. characteristics of sources)

Direct N_2O emissions from managed soils (CRT 3.D.1)

N_2O is produced naturally in soils through the microbial processes of nitrification and denitrification. Several agricultural activities add nitrogen to soils, increasing the amount of nitrogen available for nitrification and the amount of N_2O[214].

The following agricultural activities influence N flows in agricultural soils:

- synthetic fertilizers;
- animal excreta nitrogen used as fertilizer (including manure digestates);
- sewage sludge application on agricultural soils;
- application of other organic waste on agricultural soils (compost, and waste digestates);
- crop residues;
- mineralization associated with the loss/gain of soil organic matter;
- cultivation of high organic content soils; and
- urine and dung deposited by grazing animals.

Even though the cereal production in Estonia has revived following the EU accession to 1990 levels, the volume of the production of livestock products has not achieved the level of 30 years ago. Accordingly, direct N_2O emissions from managed soils decreased by 32.2% in 2023 compared with the base year due to the decrease in the number of the livestock population (i.e., amount of animal manure applied on agricultural soils and emissions from grazing animals) and due to the decline in the quantity of fertilizers applied on agricultural land (Figure 5.16). In 2023, the main contributor to the direct N_2O emissions from agricultural soils was the use of synthetic fertilizers (29%), followed by emissions originating from the cultivation of organic soils (26%), crop residues left on the fields (24%), animal manure applied to soils (including manure digestates) (12%), mineralization associated with the loss/gain of soil organic matter, the use of other organic fertilizers (including digestates from co-substrates) and animals grazing (all 3%) and sludge application on agricultural fields (0.3%) (Figure 5.17). The total direct N_2O emissions from Agricultural soils were 2.1 kt in Estonia in 2023 (Figure 5.16).

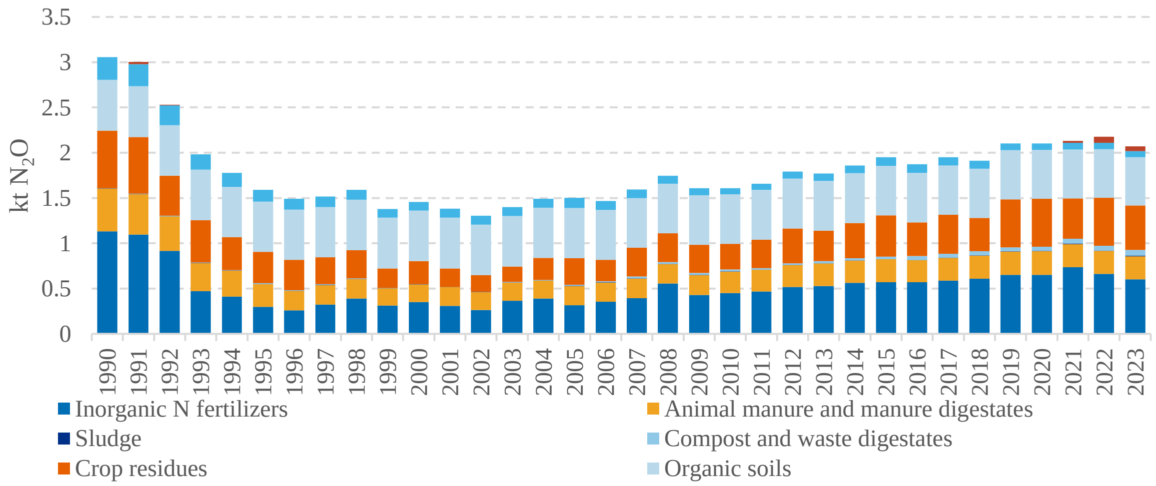

Figure 5.16. Direct N_2O emissions from Agricultural soils in Estonia in 1990–2023, kt

[214] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.53.

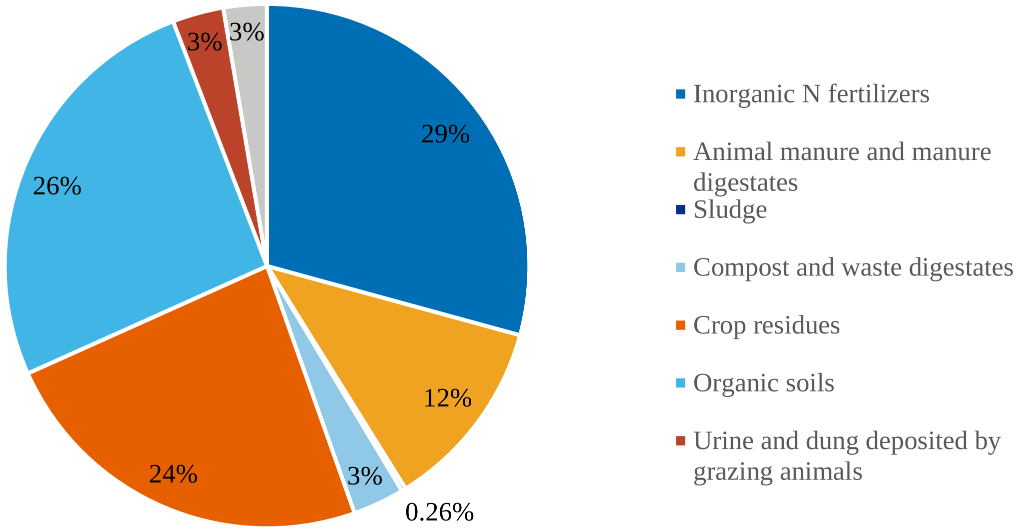

Figure 5.17. Direct N_2O emissions from Agricultural soils in Estonia in 2023, %

3.D.1.a N_2O emissions from Inorganic nitrogen fertilizers applied to soils

The total N_2O emissions from synthetic fertilizers applied onto agricultural soils were 0.60 kt in Estonia in 2023 (Figure 5.18). The emissions declined by 46.7% in 2023 compared with the base year due to the decrease in the amounts of synthetic fertilizers applied to agricultural fields (Figure 5.18, Annex A.V.3_VI). Emissions from mineral fertilizers have been increasing with a few fluctuations since 2009. This is due to the increase of agricultural crop production area, and it's been in correlation with the economic situation in the country. What is more, the structure of agricultural households has been changing – the number of larger households that use more fertilizer and have a larger area for crop production, is rising. However, mineral fertilizer prices have been in a growing trend as well over the past few years – that is why mineral fertilizers' usage decreased in 2023 compared to 2022.[215] Compared to 2022, emissions from mineral fertilizers decreased by 8.7% in 2023.

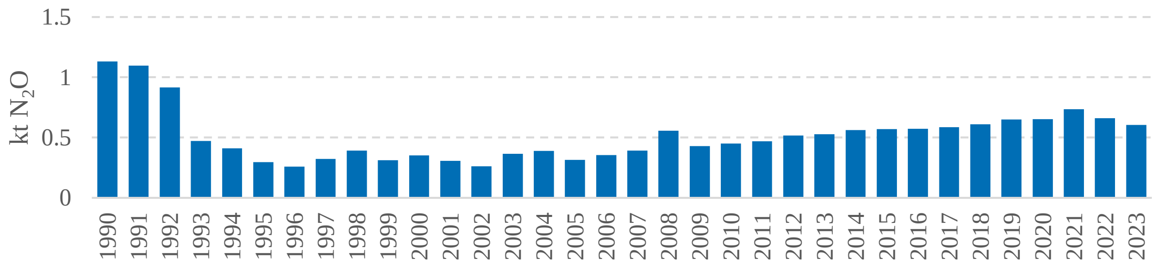

Figure 5.18. Emissions from synthetic fertilizers applied to agricultural soils in 1990–2023 in Estonia, kt N_2O

3.D.1.b.i N_2O emissions from Animal manure applied to soils (including manure digestates)

N_2O emits from agricultural soil through manure application to fields as organic fertilizer. That includes manure digestates that are applied to soils after going through the biogas reactor.

[215] Eesti Põllumajandus-Kaubanduskoda. Mööduv aasta suurendas sektori ebakindlust, millest kiiret pääsu ei paista. [www] https://epkk.ee/sormus-mooduv-aasta-suurendas-sektori-ebakindlust-millest-kiiret-paasu-ei-paista/ (12.11.2024).

Direct N_2O emissions from animal manure applied on agricultural soils were 0.25 kt in Estonia in 2023 (Figure 5.19). The emissions decreased by 46.3% in 2023 compared to the base year, due to the decline in the number of the livestock population.

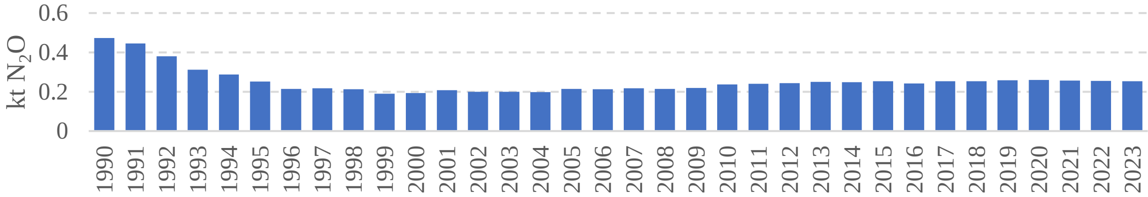

Figure 5.19. N_2O emissions from animal manure applied to soils in Estonia in 1990–2023, kt

3.D.1.b.ii N_2O emissions from Sewage sludge applied to soils

Sludge from domestic wastewater treatment plants is used on agricultural land.

The total N_2O emissions from sewage sludge applied on agricultural land were 0.005 kt in Estonia in 2023 (Figure 5.20).

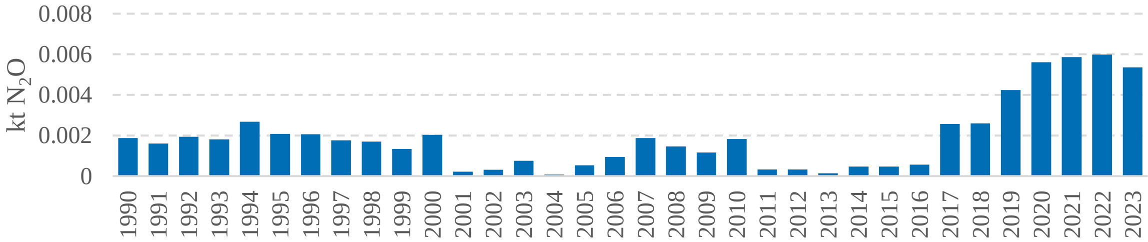

Figure 5.20. N_2O emissions from sewage sludge applied on agricultural land in Estonia in 1990–2023, kt

3.D.1.b.iii N_2O emissions from Other organic fertilizers applied to soils (compost and waste digestates)

The total N_2O emissions from compost and waste digestates applied on agricultural land were 0.07 kt in Estonia in 2023, that is the highest throughout the whole timeseries (Figure 5.21). This can be explained by the amounts of waste digestates applied to soils that have been growing in time – biogas producers have been adding more co-digestates into the biogas reactor besides animal manure – the amounts have reached its peak in 2023.

Additional information on the fluctuations of composted waste can be found in Chapter 7.3 Biological treatment of solid waste (CRT 5.B). In addition to the amounts of compost, amounts of waste-source digestates that are applied to agricultural land are also accounted there.

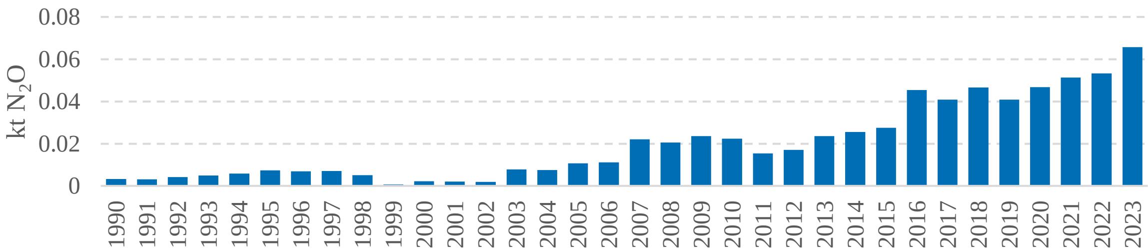

Figure 5.21. N_2O emissions from compost and waste digestates applied on agricultural land in Estonia in 1990–2023, kt

3.D.1.c N_2O emissions from Urine and dung deposited by grazing animals

The total N_2O emissions from pasture, range and paddock made up 0.07 kt in 2023. The emission decreased by 74.2% compared to the base year due to the decline in the number of the livestock population and due to the decline in animal grazing. (Figure 5.22).

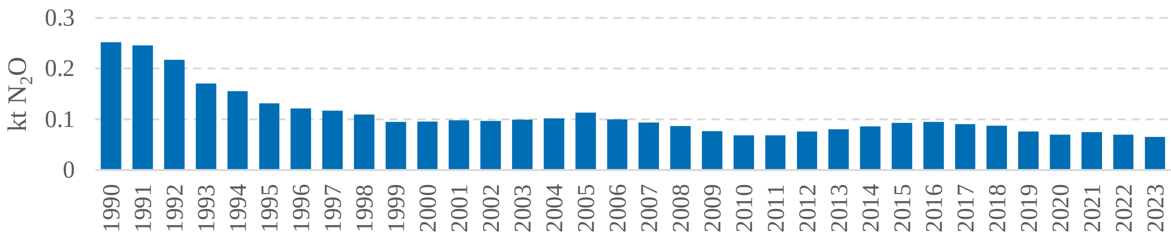

Figure 5.22. N_2O emissions from urine and dung deposited by grazing animals in 1990–2023, kt

3.D.1.d N_2O emissions from nitrogen input from Crop residues

The amount of nitrogen returned to soils annually through the incorporation of crop residues.

The total N_2O emissions from crop residues left on agricultural land was 0.49 kt in 2023 (Figure 5.23). The respective emissions have declined by 23.0% compared with the base year. The recuperation of crop production following the transition to market economy has been more prominent compared to animal husbandry. Increased crop production has been favoured by the steady growth of cereals export in recent years.

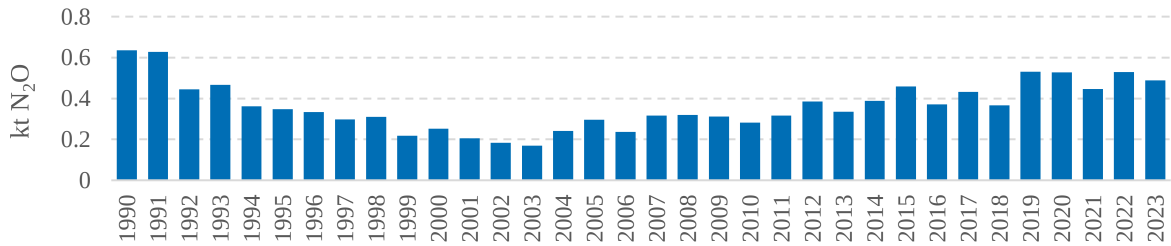

Figure 5.23. N_2O emissions from crop residues left on agricultural fields in 1990–2023 in Estonia, kt

3.D.1.e N_2O emissions from Mineralization/immobilization associated with the loss/gain of soil organic matter

N mineralization associated with the loss of soil organic matter resulting from changes in land use is one of the N_2O emission sources. When soil C is lost through oxidation because of land-use change, the loss of C is accompanied by simultaneous mineralization of N. This mineralized N is an additional resource of N available for conversion to N_2O. Consequently, N_2O emissions are being reported only about the years when carbon stock in mineral soils has decreased compared to the previous year.

In 2023, N_2O emissions from mineralization of the loss of soil organic matter were 0.055 kt, that is 15.0% less than a year before. Since 1990, the emissions have occurred only in 1991, 1992, 2021, 2022 and 2023. The respective amounts of N_2O were 0.022, 0.009, 0.022, 0.065 and 0.055 kt. In other years, since 1990, the carbon stock in mineral soils has increased compared to the previous year and thus the N_2O emissions have not occurred.

3.D.1.f N_2O emissions from Cultivation of organic soils

N_2O emissions occur as a result of cultivation of organic soils due to enhanced mineralization of old, N-rich organic matter. The rate of N-mineralization is determined by N-quality of histosols, management practice and climatic conditions.[216]

N_2O emissions from cultivation of organic soils were 0.53 kt in 2023 in Estonia (Figure 5.24). The estimation was carried out based on the data received in the framework of the National Forest Inventory (see Chapter 6 Land use, land-use change and forestry (CRT sector 4)).

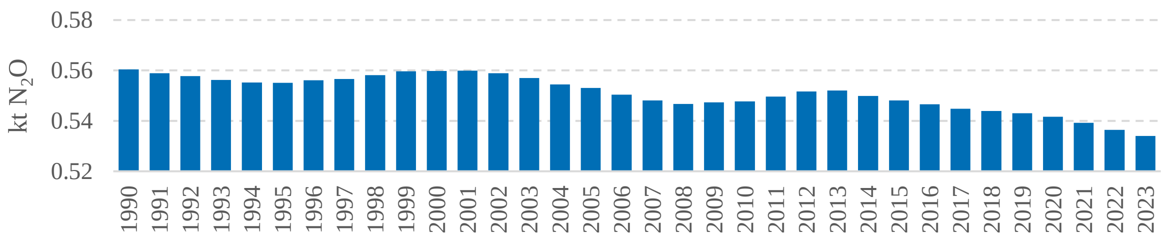

Figure 5.24. N_2O emissions from cultivation of organic soils in Estonia in 1990–2023, kt

Indirect N_2O emissions from managed soils (CRT 3.D.2)

Nitrous oxide is produced naturally in soils and aquatic systems through the microbial processes of nitrification and denitrification. Several agricultural and other anthropogenic activities add nitrogen (N) to soils and aquatic systems, increasing the amount of N available for nitrification and denitrification, and ultimately the amount of N_2O emitted[217].

The total indirect N_2O emissions from agricultural soils were 0.47 kt in 2023 (Figure 5.25). The emissions declined compared to the base year (1990) by 38.79% in 2023 due to the decrease in the number of the livestock population and synthetic and organic fertilizer application onto agricultural land.

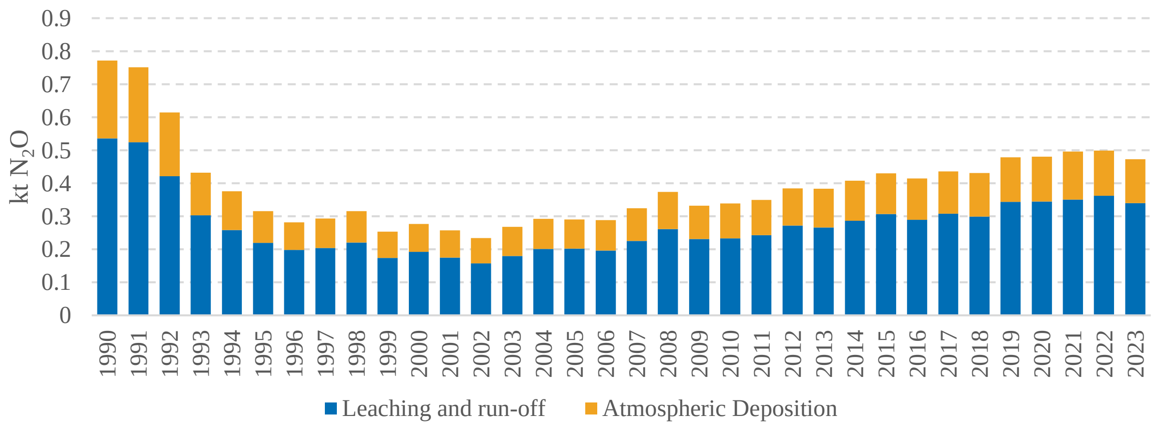

Figure 5.25. Indirect N_2O emissions from Agricultural soils in Estonia in 1990–2023, kt

[216] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.91.
[217] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.53.

3.D.2.a Atmospheric deposition of NO_X and NH_3

Atmospheric deposition of nitrogen compounds such as nitrogen oxides (NO_x) and ammonium (NH_3) fertilize soils and surface waters, which results in enhanced biogenic N_2O formation[221]. Total N_2O emissions from atmospheric deposition were 0.13 kt in 2023 in Estonia.

3.D.2.b Leaching/run-off of applied or deposited nitrogen

A large proportion of nitrogen is lost from agricultural soils through leaching and run-off. This nitrogen enters the groundwater, riparian areas and wetlands, rivers, and eventually the ocean, where it enhances the biogenic production of N_2O[218]. The total N_2O emissions from leaching and run-off were 0.34 kt in 2023 in Estonia.

5.4.2. Methodological issues

Choice of methods

Direct N_2O emissions from managed soils (CRT 3.D.1)

3.D.1.a N_2O emissions from Inorganic nitrogen fertilizers applied to soils

N_2O emissions are estimated from the annual synthetic nitrogen applied to soils. The algorithm reported in IPCC 2006 was used to estimate the nitrogen input into agricultural soils adjusted for volatilization.

$Frac_{GASF}$ = Fraction of the total synthetic fertilizer nitrogen that is emitted as NO_x+NH_3, kg N/kg N (Table 5.50);

N_2O emissions into the atmosphere from the use of synthetic nitrogen were calculated based on the Equation 5.26:

Equation 5.27

$$N_2O_{direct} = F_{SN} \times EF \times \frac{44}{28}$$

Where:

F_{SN} = total use of synthetic fertilizers in a country, kg N/year;

EF = emission factor (Table 5.50).

3.D.1.b.i N_2O emissions from Animal manure applied to soils (including manure digestates)

N_2O emissions into the atmosphere from animal waste applied to agricultural fields as organic fertilizer was estimated according to the algorithm proposed by the IPCC 2006 (Equation 5.27-Equation 5.29):

Equation 5.28[219]

$$N_2O_{direct} - N = F_{AM} \times EF_l$$

[218] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.70.

[219] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.7, equation 11.1.

Equation 5.29[220]

$$F_{AM} = N_{MMS\ Avb} \times [1 - (Frac_{FEED} + Frac_{FUEL} + Frac_{CNST})]$$

Where:

EF_1 = emission factor (Table 5.50);
F_{AM} = annual amount of animal manure N applied to soils, kg N yr^{-1};
$N_{MMS\ Avb}$ = amount of managed manure N available for soil application, feed, fuel or construction, kg N yr^{-1};
$Frac_{FEED}$ = fraction of managed manure used for feed;
$Frac_{FUEL}$ = fraction of managed manure used for fuel;
$Frac_{CNST}$ = fraction of managed manure used for construction.

Equation 5.30[221]

$$N_{MMS\ Avb} = \sum_{S}\left\{\sum_{(T)}\left[\left[\langle N_{(T)} \times Nex_{(T)} \times MS_{(T,S)}\rangle \times \langle 1 - \frac{Frac_{LossMS}}{100}\rangle\right] + \left[N_{(T)} \times MS_{(T,S)} \times N_{beddingMS}\right]\right]\right\}$$

Where:

$N_{MMS\ Avb}$ = amount of managed manure nitrogen available for application to managed soils or for feed, fuel, or construction purposes, kg N yr^{-1};
$N_{(T)}$ = number of head of livestock species/category *T* in the country;
$Nex_{(T)}$ = annual average N excretion per animal of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1};
$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in MMS *S* in the country, dimensionless;
$Frac_{LossMS}$ = amount of managed manure nitrogen for livestock category *T* that is lost in the MMS *S*, %;
$N_{beddingMS}$ = amount of nitrogen from bedding (to be applied for solid storage and deep bedding MMS if organic bedding usage is known), kg N $animal^{-1}$ yr^{-1};
S = MMS;
T = species/category of livestock.

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.

3.D.1.b.ii N_2O emissions from Sewage sludge applied to soils

The IPCC 2006 *Tier 1* (Equation 5.30) approach was employed to estimate N_2O emissions from sludge applied on agricultural land:

Equation 5.31[214]

$$N_2O_{direct} = F_{SL} \times EF_1 \times \frac{44}{28}$$

[220] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.13, equation 11.4.
[221] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.65, equation 10.34.

Where:

F_{SL}= annual amount of sewage sludge N applied to soils, kg N yr^{-1};
EF_1= emission factor (Table 5.50).

3.D.1.b.iii N_2O emissions from Other organic fertilizers applied to soils (compost, and waste digestates)

The IPCC 2006 *Tier 1* (Equation 5.31) approach was employed to estimate N_2O emissions from organic fertilizers applied to agricultural land:

Equation 5.32[214]

$$N_2O_{direct} = F_{ON} \times EF_1 \times \frac{44}{28}$$

Where:

F_{ON} = annual amount of organic fertilizer N applied to soils, kg N yr^{-1};
EF_1 = emission factor.

Since 2021 submission, the emission calculations from compost are based on dry weight of compost instead of formerly used wet weight. Since 2024 submission, N_2O emissions from waste digestates applied to soils are also considered in this subcategory. The emissions are calculated using the same equation (Equation 5.31).

3.D.1.c N_2O emissions from Urine and dung deposited by grazing animals

The method reported in Chapter 5.3.2. Methodological issues, Choice of methods, Direct N2O emissions from Manure management was used to estimate N_2O emissions from animal pasture, range, and paddock.

3.D.1.d N_2O emissions from nitrogen input from Crop residues

The IPCC *Tier 1* (Equation 5.32) method was used to estimate emissions from crop residues returned to the soil.

Equation 5.33[222]

$$F_{CR} = \sum_T \{Crop_T \times Frac_{Renew(T)} \times [(Area_{(T)} - Area\ burnt_{(T)} \times C_f) \times R_{AG(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)}) + Area_{(T)} \times R_{BG(T)} \times N_{BG(T)}]\}$$

Where:

Data for $Frac_{Remove}$ are not available in Estonia, therefore no removal was assumed. Also, as no agricultural burning practices have been carried out in Estonia, Area burnt $_{(T)}$ is zero. IPCC default values have been used for factors $R_{AG(T)}$, $N_{AG(T)}$, $R_{BG(T)}$ and $N_{BG(T)}$ available in Table 11.2 in the IPCC 2006 Guidelines[223].

F_{CR} = annual amount of N in crop residues (above and below ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually, kg N yr^{-1};

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[222] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.14, equation 11.6.
[223] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, pages 11.17–11.18, table 11.2.

$Crop_{(T)}$ = harvested annual dry matter yield for crop *T*, kg d.m. ha^{-1};
$Area_{(T)}$ = total annual area harvested of crop *T*, ha yr^{-1};
Area burnt $_{(T)}$ = annual area of crop *T* burnt, ha yr^{-1};
C_f = combustion factor, dimensionless
$Frac_{Renew\ (T)}$ = fraction of total area under crop *T* that is renewed annually. For countries where pastures are renewed on average every X years;
$Frac_{Renew}$ = 1 /X. For annual crops $Frac_{Renew}$ = 1;
$R_{AG(T)}$ = ratio of dry matter of above-ground residues ($AG_{DM\ (T)}$) to harvested yield for crop *T* ($Crop_{(T)}$), kg d.m. (kg d.m.)$^{-1}$, = $AG_{DM(T)}$ ×1000 / $Crop_{(T)}$;
$N_{AG(T)}$ = N content of above-ground residues for crop *T*, kg N (kg d.m.) $^{-1}$;
$Frac_{Remove(T)}$ = fraction of above-ground residues of crop *T* removed annually for purposes such as feed, bedding and construction, kg N (kg crop-N)$^{-1}$;
$R_{BG(T)}$ = ratio of below-ground residues to harvested yield for crop *T*, kg d.m. (kg d.m.)$^{-1}$. If alternative data are not available, $R_{BG(T)}$ may be calculated by multiplying R_{BG-BIO} by the ratio of total above-ground biomass to crop yield (= [($AG_{DM(T)}$ • 1000 + $Crop_{(T)}$) / $Crop_{(T)}$];
$N_{BG(T)}$ = N content of below-ground residues for crop *T*, kg N (kg d.m.)$^{-1}$;
T = crop or forage type.

Annual N_2O emissions from crop residues were calculated using the Equation 5.33.

Equation 5.34[214]

$$N_2O_{direct} = F_{CR} \times EF_1 \times \frac{44}{28}$$

Where:

F_{CR} = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr-1;
EF_1 = emission factor (Table 5.50).

3.D.1.e N_2O emissions from Mineralization/immobilization associated with the loss/gain of soil organic matter

For calculating N_2O emissions from mineralization/immobilization associated with the loss/gain of soil organic matter, the data on land-use change of Cropland remaining Cropland were used. Annual N mineralized in mineral soils because of the loss of soil C through change in land use was calculated using the Equation 5.34 from the *Tier 1* method.

Equation 5.35[224]

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,\ LU} \times \frac{1}{R} \right) \times 1000 \right]$$

Where:

$N_2O - N = F_{SOM} \times EF_1$

F_{SOM} = the net annual amount of N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management, kg N;

[224] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.16, equation 11.8.

$\Delta C_{Mineral, LU}$ = average annual loss of soil carbon for each land-use type (LU), tons C;
R = C:N ratio of the soil organic matter;
LU = land-use and/or management system type.

3.D.1.f N_2O emissions from Cultivation of organic soils

The 2006 IPCC *Tier 1* method was applied to estimate N_2O emissions from organic soils cultivation (Equation 5.35). Since the 2019 submission, in addition to croplands, areas of drained grasslands have been included in emission estimates of cultivated organic soils.

Equation 5.36[225]

$$N_2O_{direct} = F_{OS} \times EF_2 \times \frac{44}{28}$$

Where:

F_{OS} = area of cultivated organic soils, ha;
EF_2 = emission factor for organic soil mineralization due to cultivation, kg N_2O–N ha/year (Table 5.50).

Indirect N_2O emissions from managed soils (CRT 3.D.2)

3.D.2.a Atmospheric deposition of NO_X and NH_4

The *Tier 1* (Equation 5.36) method was used to estimate emissions from the Atmospheric deposition.

Equation 5.37[226]

$$N_2O_{(ATD)} - N = \left[(F_{SN} \times Frac_{GASF}) + \left((F_{ON} + F_{PRP}) \times Frac_{GASM}\right)\right] \times EF_4$$

Where:

$N_2O_{(ATD)}$–N = annual amount of N_2O–N produced from atmospheric deposition of N volatilized from managed soils, kg N_2O–N yr^{-1};
F_{SN} = annual amount of synthetic fertilizer N applied to soils, kg N yr^{-1};
$Frac_{GASF}$ = fraction of synthetic fertilizer N that volatilizes as NH_3 and NO_x, kg N volatilized (kg of N applied)$^{-1}$ (Table 5.50);
F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr^{-1};
F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1};
$Frac_{GASM}$ = fraction of applied organic N fertilizer materials (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilizes as NH_3 and NO_x, kg N volatilized (kg of N applied or deposited)$^{-1}$ (Table 5.50);
EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, [kg N–N_2O (kg NH_3–N + NO_x–N volatilized)$^{-1}$] (Table 5.50).

225 IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.16.
226 IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.21, equation 11.9.

3.D.2.b Leaching/run-off of applied or deposited nitrogen

The *Tier 1* method from the IPCC 2006 Guidelines was used to estimate emissions from Leaching/run-off (Equation 5.37).

Equation 5.38[227]

$$N_2O_{(L)} - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH-(H)} \times EF_5$$

Where:

$N_2O_{(L)–N}$ = annual amount of N_2O–N produced from leaching and run-off of N additions to managed soils in regions where leaching/run-off occurs, kg N_2O–N yr^{-1};

F_{SN} = annual amount of synthetic fertilizer N applied to soils in regions where leaching/run-off occurs, kg N yr^{-1};

F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils in regions where leaching/run-off occurs, kg N yr^{-1};

F_{PRP} = annual amount of urine and dung N deposited by grazing animals in regions where leaching/run-off occurs, kg N yr^{-1};

F_{CR} = amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/run-off occurs, kg N yr^{-1};

F_{SOM} = annual amount of N mineralized in mineral soils associated with the loss of soil C from soil organic matter as a result of changes in land use or management in regions where leaching/run-off occurs, kg N yr^{-1};

$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralized in managed soils in regions where leaching/run-off occurs that is lost through leaching and run-off, kg N (kg of N additions)$^{-1}$ (Table 5.50);

EF_5 = emission factor for N_2O emissions from N leaching and run-off, kg N_2O–N (kg N leached and run-off)$^{-1}$ (Table 5.50).

Activity data

Direct N_2O emissions from managed soils (CRT 3.D.1)

3.D.1.a N_2O emissions from Inorganic nitrogen fertilizers applied to soils

Activity data on the amounts of synthetic fertilizers used on agricultural lands in Estonia was obtained from the datasets of Statistics Estonia from the table PM065.[228] Before 2015, the data about the usage of mineral fertilizers were gathered by statistical enquiry. Since 2015, SE has used indices calculated by using the data on the amounts of mineral fertilizers gathered by the Centre of Estonian Rural Research and Knowledge (former Agricultural Research Centre) in the framework of the Farm Accountancy Data Network (FADN). FADN data were also reported to the European Commission by SE.

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[227] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.21, equation 11.10.

[228] Statistics Estonia. PM065: USE OF MINERAL FERTILIZERS FOR THE PRODUCTION IN THE ACCOUNTING YEAR. [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__taimekasvatussaaduste-tootmine/PM065 (12.11.2024).

3.D.1.b.i N_2O emissions from Animal manure applied to soils (including manure digestates)

Amounts of managed manure Nitrogen available for soil application, kg N yr-1, is calculated based on Equation 5.29 from IPCC 2006 Guidelines.

3.D.1.b.ii N_2O emissions from Sewage sludge applied to soils

The data on the amounts of sludge used on agricultural lands was received from the EstEA.

Table 5.49 illustrates the amounts of sewage sludge used for improving the environmental situation (R10).

The methodology of sewage sludge treated according to the R10 category in 1990-1998 was formerly developed and given by the Tallinn University of Technology (TalTech) compiling the GHG inventory until 2012. During that period, limited waste related data was gathered by the predecessor of Estonian Environment Agency (EstEA) – Estonian Environment Information Centre – and therefore an assumption was made that 50% of the total amount of generated sewage sludge was used for improving the environmental situation. In accordance with the 2022 ERT review's recommendation ARR2022/A.7, Estonia has received an expert judgement for the evaluation made by TalTech in 2012. The expert, an authorized engineer in water supply and sewerage, Dr. Kuusik used all available preserved materials to compile an expert opinion on the usage of sewage sludge in the years 1990-1998 and conducted an evaluation on the amounts of sludge being used on agricultural lands and the amounts composted during these years. The complete expert judgement, including the references to supporting documents, are stored in the Inventory archive (in Estonian).

Data for the years 1999–2019 were obtained from datasets of EstEA and national online waste reporting system, JATS. EstEA started to collect data in accordance with the Estonian waste classification in 1992, but in 1999 the adapted classification system changed, and the European Waste Catalogue was adopted. Starting from 2020, companies submit their waste data through Environmental Decisions Information System KOTKAS, managed by Environmental Board. Reports are stored in Data Warehouse, managed by Ministry of Climate and published in EstEA's Tableau.[229]

EstEA is doing data processing and validating its accuracy. Estonian Environmental Research Centre waste expert is validating the data by asking companies and EstEA to clarify the amounts of R10 sewage, if there are significant fluctuations occurring. The time series is fluctuating, but this is in correlation with the official sewage sludge data as sewage sludge is also composted (and reported under Waste sector, 5.B). During the years when the sewage application is lower in the Agriculture sector, the percentage of sewage sludge in compost is higher, so the fluctuations are in correlation (see Chapter 7.3 Biological treatment of solid waste (CRT 5.B), Table 7.12). Please note that "sludge" in Table 7.12 includes sludge from composting activities (R3o and R12o) and does not include sludge reported under R10).

In the second half of the 1990's, developments in the sewage sludge treatment technologies made it possible to purify the sewage water to a higher degree, therefore more sludge was generated. However, sludge management in Estonian wastewater treatment plants consisted mainly of making sludge transportable (solidification) and transporting sludge to landfills, less

[229] The Information Technology Centre of the Ministry of the Environment Waste data visualizing system (Tableau). [www] https://tableau.envir.ee/views/Avalikud_pringud_Jtmed/Riigitasand?%3Aembed=y&%3Aiid=1&%3AisGuestRedirectFromVizportal=y (02.01.2025).

frequently to agricultural fields, for use in landscaping, and the recultivation of quarries, industrial sites and old military camps. Sludge collected and deposited on the sites of sewage treatment plants and landfills was also used for the closure of old landfills, landfill cover and landscaping.[230] Since 2001, the amount of sewage sludge treated biologically started to increase. Therefore, the amounts of sewage sludge directly used for improving the environmental situation, i.e applying it to soils, decreased. This was due to a rising trend in recycling, i.e composting, sludge in waste-water treatment plants.[231]

Since 2017, especially large amounts of R10 are reported by two companies due to the construction works of an industrial park and larger landscaping activities.

The revised usage of sludge on agricultural fields in Estonia can be seen in Table 5.44.

Table 5.44. Amounts of municipal sludge application on agricultural land, tons[232]

Year	R10
1990	24 287
1991	20 860
1992	25 227
1993	23 509
1994	34 890
1995	27 000
1996	26 800
1997	23 000
1998	22 000
2000	26 489
2005	6 992
2010	23 663
2011	4 317
2012	4 193
2013	1 825
2014	6 114
2015	6 131
2016	7 361
2017	33 437
2018	33 733
2019	54 971
2020	72 795
2021	76 140
2022	77 694
2023	69 536

3.D.1.b.iii N_2O emissions from Other organic fertilizers applied to soils (compost, and waste digestates)

For the years 1990-1998, the amounts of compost applied on agricultural fields were revised based on the expert opinion[228] by Dr. Aare Kuusik.

From 1999, data on the amounts of compost and waste digestates applied on agricultural fields was obtained from the datasets of EstEA.

[230] A. Kuusik, (PhD). Expert judgement, stored in the Inventory archive (in Estonian).
[231] Information obtained from an email exchange between M. Leevik, former Chief specialist of the Data Management Department of EstEA and M. Möls, former Agriculture sector specialist in EERC.
[232] R10 of the European Waste Catalogue (2002) – Land treatment resulting in benefit to agriculture or improvement.

Waste handling companies are obligated to report the amount of waste biologically treated to EstEA which checks the accuracy of the data. Starting from 2020, companies submit their waste data through Environmental Decisions Information System KOTKAS, managed by Environmental Board. Reports are stored in Data Warehouse, managed by Ministry of Climate and published in EstEA's Tableau[224]. Tableau provides information about the entire waste stream, including quantities of compost (recovery code R3o and R12o) and waste digestates applied to agricultural soils (see Waste sector, Chapter 7).

The practice of adding co-digestates to biogas reactors besides animal manure has been increasing over the years and has reached its peak in 2023, therefore the amounts of waste-based digestates applied on agricultural land are also increasing. This is because of the continuously increasing production volumes of biogas and the lack of animal manure near the production plant; therefore, biogas producers are obligated to add more co-digestates into the reactor. Additionally, a continuous increase in obligation to recycle waste is contributing to the increasing usage of co-digestates in biogas production. Typical co-digestates added to manure are silo, garden waste, waste from food industry, etc.

3.D.1.c N_2O emissions from Urine and dung deposited by grazing animals

Nitrogen Excretion by pasture, range and paddock by animal category, kg N yr-1, is calculated based on Equation 5.29.

3.D.1.d N_2O emissions from nitrogen input from Crop residues

Activity data on crop production, yield and production area in Estonia was obtained from the datasets of SE.

Crop production decreased for most crop types in 2023 compared to last year, due to harsh weather conditions: cold spring, droughty summer and excessively wet autumn.[233] According to Statistics Estonia, the total production of cereals was 1 200 666 tons, which is 21% less than a year before. The total production of cereals in 2023 included 694 120 tons of wheat, 331 690 tons of barley and 61 814 tons of rye. Cereal yield per hectare was 3.4 tons – that is the lowest outcome in the last five years. Both yield and sown area decreased for most crop types in 2023 compared to 2022. Winter crops accounted for almost 70% both for sown area and production of cereals. The importance of winter crops has been in a rising trend because of the higher production amounts over spring crops. Total production of dry pulses was 118 558 tons, which is 3.8% less than last year. Production of winter rape and turnip rape seeds also decreased – being 127 783 tons. That is as much as 37.3% less than a year before. The sown area of winter rape and winter turnip rape decreased to 70 201 hectares; the yield of winter rape seeds and turnip rape seeds decreased to 1.8 tons per hectare, which is 28.7% lower than a year before. The sown area of dry pulses was 48 833 hectares, which is only 0.3% lower than last year. The yield per hectare of dry pulses was 2.2 tons, which is 12.0% less than a year before. The total production of potatoes, however, grew – being 84 860 tons, which is 9% more than last year. The production of open–field vegetables decreased slightly – from 39 599 in 2022 to 38 051 in 2023. The sown area of potatoes and open-field vegetables was 3 457 and 1 570 hectares, respectively, in 2023. In 2023, the average yield per hectare for potatoes was 24.5 tons per

[233] Statistikaamet. Mullune saagiaasta oli kehv. [www] https://www.stat.ee/et/uudised/mullune-saagiaasta-oli-kehv (07.12.2024).

hectare, which is 6.4% more than last year. The yield per hectare of open-field vegetables was of 24.2 tons, which is only 1.2% more than a year before.[234] [235]

The production of different crops throughout the time-series is illustrated in Figure 5.26 and Figure 5.27 and in the tables of Annexes A.V.3_VII. The inter-annual changes in crop production are explained by changes in the total sown area (Annex A.V.3_VII.2) and by weather conditions (Annex A.V.3_X).

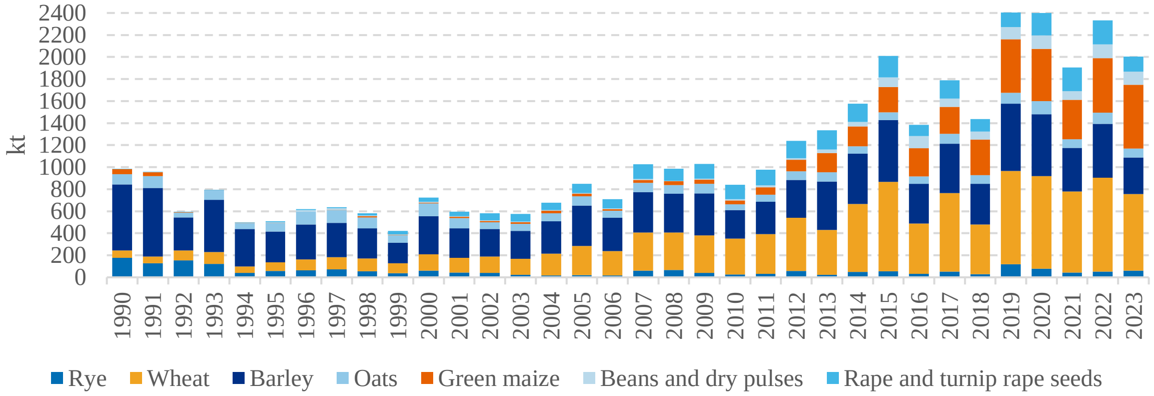

Figure 5.26. Cereals, maize, dry pulses and rape seed production in 1990–2023 in Estonia, kt

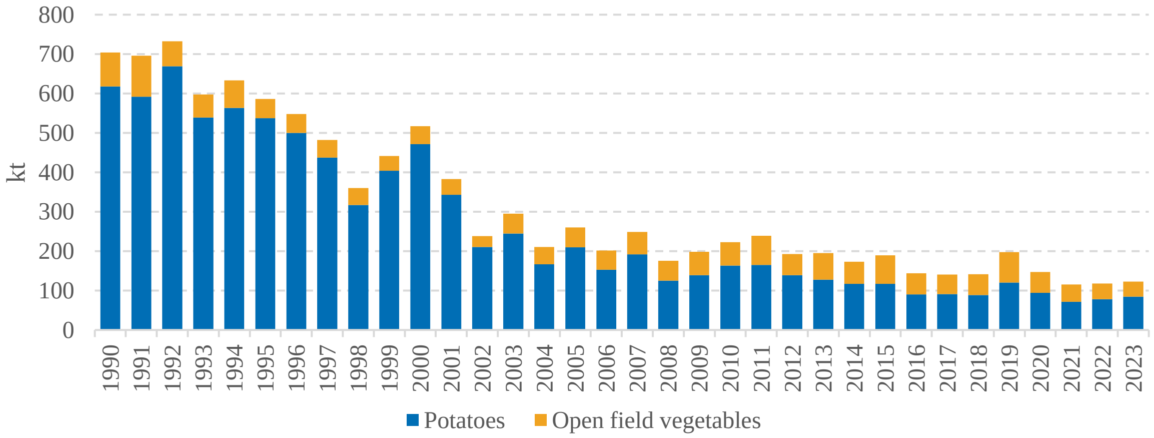

Figure 5.27. Potato and open-field vegetables production in 1990–2023, kt

3.D.1.e N_2O emissions from Mineralization/immobilization associated with the loss/gain of soil organic matter

The activity data of carbon stock change in mineral soils on the area of cropland remaining cropland were received from the EstEA.

[234] Statistics Estonia. Agricultural land and crops by county. [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__taimekasvatussaaduste-tootmine/PM0281 (07.08.2024).
[235] Statistics Estonia. Agriculture. [www] https://www.stat.ee/en/find-statistics/statistics-theme/agriculture-fisheries-and-hunting/agriculture (07.08.2024).

3.D.1.f N_2O emissions from Cultivation of organic soils

The data on areas of histosols under cultivation in Estonia were obtained in the framework of the National Forest Inventory (see Chapter 6 LULUCF).

Indirect N_2O emissions from managed soils (CRT 3.D.2)

3.D.2.a Atmospheric deposition of NO_X and NH_4

The amounts of volatilized N from agricultural inputs of N NH_3 and NO_x are calculated based on the activity data on 3.D.1.1 Inorganic N fertilizers applied to soils, 3.D.1.2 Organic N fertilizers applied to soils and 3.D.1.3 Urine and Dung deposited by grazing animals.

3.D.2.b Leaching/run-off of applied or deposited nitrogen

The amounts of N from fertilizers and other agricultural inputs that is lost through leaching and run-off are calculated based on the activity data on 3.D.1.a Inorganic N fertilizers applied to soils, 3.D.1.b Organic N fertilizers applied to soils, 3.D.1.c Urine and Dung deposited by grazing animals, 3.D.1.d Crop residues and 3.D.1.e Mineralization.

Emission factors

Table 5.45. N_2O emission factors for Agricultural soils used in Estonian GHG Inventory

Category	Emission factor			Source
3.D.1 Direct N_2O emissions				
N additions from mineral fertilizers, organic amendments and crop residues, and N mineralized from mineral soil as a result of loss of soil carbon	EF_1	0.01	kg N_2O–N (kg N)$^{-1}$	IPCC (2006), table 11.1
Temperate organic crop and grassland soils	EF_2 CG, Temp	8	kg N_2O–N ha^{-1}	IPCC (2006), table 11.1
Cattle (dairy, non-dairy and buffalo), poultry and pigs	EF_3PRP, CPP	0.02	kg N_2O–N (kg N)$^{-1}$	IPCC (2006), table 11.1
Sheep and 'other animals'	EF_3PRP	0.01	kg N_2O–N (kg N)$^{-1}$	IPCC (2006), table 11.1
3.D.2 Indirect N_2O emissions				
N volatilization and re-deposition	EF_4	0.01	kg N_2O–N (kg NH_3–N + NO_x–N volatilized)$^{-1}$	IPCC (2006), Table 11.3
Leaching/run-off	EF_5	0.0075	kg N_2O–N (kg N leaching/run-off)	IPCC (2006), Table 11.3
Volatilization from synthetic fertilizers	$Frac_{GASF}$	0.1	(kg NH_3–N + NO_x–N) (kg N applied) $^{-1}$	IPCC (2006), Table 11.3
Volatilization from all organic N fertilizers applied,	$Frac_{GASM}$	0.2	(kg NH_3–N + NO_x–N) (kg N	IPCC (2006), Table 11.3

Category	Emission factor			Source
and dung and urine deposited by grazing animals			applied or deposited) $^{-1}$	
N losses by leaching/run-off	$Frac_{LEACH(H)}$	0.3	kg N (kg N additions or deposition by grazing animals)$^{-1}$	IPCC (2006), Table 11.3

Direct N_2O emissions from managed soils (CRT 3.D.1)

3.D.1.a N_2O emissions from Inorganic nitrogen fertilizers applied to soils

Default emission factor was used to estimate emissions from mineral fertilizers applied to soils (see Table 5.46).

3.D.1.b.i N_2O emissions from Animal manure applied to soils (including manure digestates)

Nitrogen excreted per head of different categories of animals and per waste management systems was estimated in N_2O emissions from the 3.B Manure management chapter. IPCC default factors were used to estimate nitrogen input to Agricultural soils (see Table 5.46).

Table 5.46. IPCC default factors used in the estimation of N_2O emissions from animal waste applied to soils

Factor	Value
$Frac_{FUEL}$	0.0 kg N/kg nitrogen excreted
$Frac_{FEED}$	0.0 kg N/kg nitrogen excreted
$Frac_{CONST}$	0.0 kg N/kg nitrogen excreted

3.D.1.b.ii N_2O emissions from Sewage sludge applied to soils

Parameters and factors used in the estimates are presented in Table 5.45 and Table 5.47.

Table 5.47. Parameters used in the estimates

Factor	Value	Unit
N content of sewage sludge[236]	4.9	% dry matter

3.D.1.b.iii N_2O emissions from Other organic fertilizers applied to soils (compost, and waste digestates)

The factors used in the estimates are presented in Table 5.457 and Table 5.48.

Table 5.48. Parameters used in the estimates

Factor	Value	Unit
N content of compost[237]	1.83	% dry matter
N content of waste digestates[238]	2	% dry matter

[236] Milieu Ltd, WRc and RPA. Environmental, economic and social impacts of the use of sewage sludge on land. [www] https://rpaltd.co.uk/wp-content/uploads/2023/03/j661-sewagesludge-finalreport-pubd.pdf (04.01.2024).

[237] Linnasmägi, M.-L. (2012). Ülevaade Eestis toodetud jäätmekompostidest. Bachelor thesis, page 53.

[238] Riigi Teataja, Eri tüüpi sõnniku toitainesisalduse arvutuslikud väärtused, põllumajandusloomade loomühikuteks ümberarvutamise koefitsiendid ja sõnnikuhoidla mahu arvutamise meetoodika. [www] https://www.riigiteataja.ee/akt/101102019011 (12.11.2024).

3.D.1.c N_2O emissions from Urine and dung deposited by grazing animals

Default emission factor was used to estimate emissions from Urine and dung deposited by grazing animals (see Table 5.45).

3.D.1.d N_2O emissions from nitrogen input from Crop residues

The selected crop residue statistics and factors used in the algorithm to estimate emissions from crop residues are presented in Table 5.49.

Table 5.49. Factors used in the algorithm to estimate N_2O emissions from crop residues, kg N/kg crop-N [239]

Factor	Value
$Frac_{REMOVE}$	0 [240]
$Frac_{RENEW\ annual}$	1
$Frac_{RENEW\ herbacous}$	8
$Frac_{RENEW\ legumes}$	4

3.D.1.e N_2O emissions from Mineralization/immobilization associated with the loss/gain of soil organic matter

The *Tier 1* method and the same emission factor (EF_1=0.01 kg N_2O-N/kg N) that is used for direct emissions from agricultural land and the default C:N ratio [10 kg C (kg N)$^{-1}$] were applied from IPCC 2006 to estimate N_2O emissions from mineralization/immobilization associated with the loss/gain of soil organic matter (see Table 5.45 above).

3.D.1.f N_2O emissions from Cultivation of organic soils

Default emission factors from IPCC 2006 are used to estimate N_2O emissions from cultivation of organic soils (see Table 5.45 above).

Indirect N_2O emissions from managed soils (CRT 3.D.2)

3.D.2.a Atmospheric deposition of NO_X and NH_4

Default emission factors from IPCC 2006 are used to estimate indirect N_2O emissions from atmospheric deposition of NO_X and NH_4 (see Table 5.45 above).

3.D.2.b Leaching/run-off of applied or deposited nitrogen

Default emission factors from IPCC 2006 are used to estimate indirect N_2O emissions from Leaching/run-off of applied or deposited nitrogen (see Table 5.45 above).

5.4.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Agricultural soils subcategory, please see Annex A.II.3 Agriculture, 3.D Agricultural soils chapter.

5.4.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

[239] Expert opinion of the Estonian Agricultural Research Centre.
[240] $Frac_{REMOVE}$ at a value of 0 was applied because of a recommendation of the TERT (conducted in 2012).

The QC/QA plan for the Agricultural soils subsector includes the QC activities described in the IPCC 2006 Guidelines Volume 1, Chapter 6 and the activities listed in Volume 4, Chapter 11.2.3. The activities are carried out every year during the inventory. The QC checklist is used during the inventory.

5.4.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

Direct N_2O emissions from managed soils (CRT 3.D.1)

- Emissions from Animal manure applied to soils (CRT 3.D.1.b.i) and from Urine and Dung deposited by grazing animals (CRT 3.D.1.c) were recalculated for the whole time-series due to recalculations and corrections made in 3.B Manure management category. Emissions from Sewage sludge applied to Soils (CRT 3.D.1.b.ii) and Other organic fertilizers applied to soils (CRT 3.D.1.b.iii) were recalculated due to the revised amount of sewage sludge and compost applied to soils in 1990-1998.
- The N_2O emissions from Mineralization/Immobilization Associated with the Loss/Gain of Soil Organic Matter (CRT 3.D.1.e) for the years 1991-1992 and 2021-2022, and from Cultivation of organic soils (CRT 3.D.1.g) for the whole timeseries were updated in the framework of updating the land area activity data in the NFI (see Chapter 6 LULUCF). This impacts also the direct N_2O emissions from managed soils for the mentioned years.

A comparison of the recalculated direct N_2O emissions from manure management between 2024 and 2025 submissions is shown in Table 5.50.

Table 5.50. Reported direct N_2O emissions in 2024 and 2025 submissions from Agricultural soils, kt

Direct N_2O emissions from Agricultural soils	**1990**	**1991**	**1992**		**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
2024 submission	3.02	2.96	2.49		1.94	1.74	1.55	1.45	1.48	1.55	1.34	1.42
2025 submission	3.06	3.00	2.53		1.98	1.78	1.59	1.49	1.52	1.59	1.38	1.46

Table 5.51. Reported direct N_2O emissions in 2024 and 2025 submissions from Agricultural soils, kt (continued)

Direct N_2O emissions from Agricultural soils	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
2024 submission	1.35	1.27	1.36	1.46	1.46	1.43	1.55	1.70	1.57	1.57	1.62
2025 submission	1.38	1.30	1.40	1.49	1.50	1.47	1.59	1.75	1.61	1.61	1.66

Table 5.52. Reported direct N_2O emissions in 2024 and 2025 submissions from Agricultural soils, kt (continued)

Direct N_2O emissions from Agricultural soils	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
2024 submission	1.75	1.73	182	1.91	1.83	1.91	1.87	2.06	2.06	2.09	2.14
2025 submission	1.79	1.77	1.86	1.95	1.87	1.95	1.91	2.10	2.10	2.13	2.18

5.4.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

Estonia is planning an inventory development project to develop county-specific emission factors for emission calculations from Crop residues and Grazing.

What is more, Estonia is planning an inventory development project to develop country-specific emission factors for emission calculations from Cultivation of organic soils.

5.5. Field burning of agricultural residues (CRT 3.F)

In 2007, the burning of crop residues was prohibited by Estonian law[241]. Until the 2015 submission, the default value of the fraction of the crop residues burned had been used in the estimates of emissions, since to date there was no reliable quantitative data developed. The IPCC good practice guidance suggests that an estimate of 10% of residues burned may be appropriate for developed countries, but also suggests that the default values: 'are very speculative and should be used with caution. The actual percentage of crop residues burned varies substantially by country and crop type. This is an area where locally developed, country-specific data is highly desirable'[242].

As no other official records of agricultural burning of crop residues exist in Estonia, then for the reporting period of 1990–2007, an inquiry to the Estonian Ministry of Regional Affairs and Agriculture (documented in an archive in accordance with the 2006 IPCC Guidelines (Volume 1, Chapter 2, Annex 2A.1)) was made and according to their best knowledge, no widespread practice of agricultural residues burning has taken place during the reporting period or has been marginal, as the generation of agricultural residues in the form of litter is scant and often insufficient to cover the demand for it. For 2023 submission, the expert opinion was renewed by the Estonian Ministry of Regional Affairs and Agriculture (MoRAA) in accordance with the ERT 2022 review's recommendation. MoRAA confirms that no widespread practice of agricultural residue burning has taken place during the reporting period. It is a common practice in Estonia for a farmer to plough crop residues into the soil to enrich it with nitrogen if the farmer has no animals or no straw buyers located in the vicinity. Using straw for litter or as a fertilizer has been economically more feasible than burning it. Estonia uses straw also for heat production, and CH_4 and N_2O emissions from this process are reported under the Energy sector (Chapter 3 and CRT 1.A.4).

Since 2021 submission, notation key 'NO' was applied for the whole time series.

5.6. CO_2 emissions from liming (CRT 3.G)

5.6.1. Category description (e.g. characteristics of sources)

In Estonia, annual precipitation exceeds evapotranspiration, causing calcium and magnesium carbonates to leach out from the surface levels of the soil by percolating water. As a result of the leaching carbonates, soil becomes deprived of calcium and magnesium. Acidificated soils (pH <6.5) cover 54.5% of arable land in Estonia. Though, not all this area needs liming due to the different calcium contents.[243]. Total CO_2 emissions from lime applied on agricultural land were 27.5 kt in Estonia in 2023, from which CO_2 emissions from dolomite were 2.84 kt and 24.65 kt from limestone (Figure 5.28). The emissions have decreased by 23.7% compared to the previous year.

[241] Riigi Teataja. Maa heas põllumajandus- ja keskkonnaseisundis hoidmise nõuded. [www] https://www.riigiteataja.ee/akt/129122022006?leiaKehtiv (14.11.2024).
[242] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.89.
[243] Loide, V. (2019). Põllumuldade kaltsiumisisaldusest ja lupjamisest. Presentation, 10th World Soil Day, Tartu, Estonia.

Overall, liming emissions are in correlation with the Estonian economic situation during the entire time series. During 1992–1997, CO_2 emissions caused by liming were considerably lower due to the economic transition and agricultural production decline. In 1998, investments in Estonian agriculture increased and agricultural land area and applied amount of lime also increased. The lowest point of emissions in 2009 can be explained by the economic recession in Estonia during 2008–2010. After the economic recession, the emissions had been growing steadily until 2018, then, after a small decrease in the amounts used in 2019-2020, emissions from liming started growing again and reached its peak in 2022, being record high in the whole timeseries. However, in 2023 they dropped back to about 2021 level.

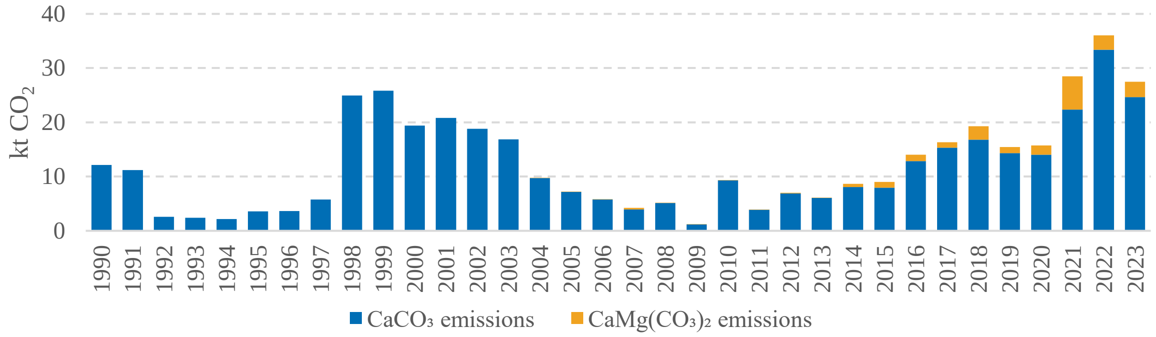

Figure 5.28. CO_2 emission from $CaMg(CO_3)_2$ and $CaCO_3$ in 1990–2023, kt

5.6.2. Methodological issues

Choice of methods

The *Tier 1* (Equation 5.38) method was used to estimate CO_2 emissions from the liming of croplands.

Equation 5.39[244]

$$\Delta C_{CC\ Lime} = M_{Limestone} \times EF_{Limestone} + M_{Dolomite} \times EF_{Dolomite}$$

Where:

$\Delta C_{CC\ Lime}$ = annual C emissions from agricultural lime application, tons C yr^{-1};

M = annual amount of calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), tonnes yr^{-1};

EF = emission factor, tons C (ton limestone or dolomite)$^{-1}$; these are equivalent to carbonate carbon contents of the materials (12% for $CaCO_3$, 13% for $CaMg(CO_3)_2$).

Activity data

Activity data on agricultural land areas on which lime was applied were obtained from the Estonian Ministry of Regional Affairs and Agriculture for the period of 1990–2003. Data about liming was then not implicit, as it was based on applied agricultural subsidies only and liming performed at a landowner's own expense was left out of the statistics. However, the scope of

[244] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.27, equation 11.12.

liming carried out at a landowner's own expense was marginal according to the Estonian Ministry of Regional Affairs and Agriculture[245]. Data about the average quantity of lime applied per one hectare (5 t/ha) were taken from a report published by the Agricultural Research Centre[246]. Since 2005, Statistics Estonia has been collecting detailed data about the area and applied amount of liming. Data for 2004 has been interpolated from the data of MoRAA in 2003 and from the data of SE in 2005. The area of liming has fluctuated widely over the years, depending significantly on government subsidies and on the economic situation.

To estimate the fractions of different fertilizer types used for neutralization of acidic soils resulting in CO_2 emissions, data reported by E. Turbas[247] for the period of 1990–2001 and the sales records obtained from the Agriculture and Food Board for the years of 2002–2014 were applied, as until 2014 Statistics Estonia collected only aggregated data for lime used on Estonian agricultural lands. Since 2015, Statistics Estonia collects data about different lime fertilizer types. The amounts of lime fertilizers applied on agricultural soils are reported in Annex A.V.3_VIII.

The emissions resulting from limestone application were calculated using data on clinker dust, powdered limestone, other meliorate and dolomite.

Yearly differences in the use of specific fertilizer types used for liming contribute to the CO_2 emission fluctuations in the time series (Table 5.53). No CO_2 emissions occur from the use of some lime fertilizers (oil shale ashes, ash) as they do not contain inorganic carbon.

Table 5.53. Amounts of lime fertilizers applied on the fields 1990–2023, kt/yr

Fertilizer	1990	2005	2019	2020	2021	2022	2023
Clinker dust	68	22.9	0	0	0	0	0
Other lime fertilizer	NO	NO	10.4	4.4	2.2	1.6	2.4
Powder limestone	NO	7	22.1	27.5	48.7	74.2	53.6
Oil shale ash	68	NO	19.9	25.0	17.6	29.8	23.4
Ash	NO	NO	14.4	8.6	9.4	15.4	15.3
Powder dolomite	NO	0.1	2.4	3.6	12.8	5.6	6.0
Total	136	30	69.2	69.1	90.7	126.6	100.7

Emission factors

The default emission factor from IPCC 2006 Guidelines was used to estimate emissions from liming: 12% for $CaCO_3$, 13% for $CaMg(CO_3)_2$.

The fraction of $CaCO_3$ in the cement clinker dust (40.48%) was received by a personal inquiry as a result of an analysis and is validated by an expert judgement (documented in archive according to the instruction of the 2006 IPCC Guidelines (Volume 1, chapter 2, Annex 2A.1)) from the Estonian Kunda Cement factory (as requested by the 2022 ERT review's recommendation).

5.6.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Liming subcategory, please see Annex A.II.3 Agriculture, 3.G Liming chapter.

[245] Eesti maaelu arengukava 2014-2020. [www] https://energiatalgud.ee/sites/default/files/images_sala/a/ac/P%C3%B5llumajandusministeerium._Eesti_maaelu_arengukava_%28MAK%29_2014-2020_eeln%C3%B5u._2014.pdf (13.11.2024).

[246] Järvan, M. (2005). Põldude lupjamine. Saku: Maalehe Kirjastus, lk 6.

[247] Turbas, E. (2000). Muldade lupjamise mõtte ja lupjamistööde arengust Eestis. Agraarteadus, nr 11 (2), lk 117–131.

5.6.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

The QC/QA plan for the Liming subsector includes the QC activities described in the IPCC 2006 Guidelines Volume 1, Chapter 6 and the activities listed in Volume 4, Chapter 11.3.5. The activities are carried out every year during the inventory. The QC checklist is used during the inventory.

5.6.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

There were no category-specific recalculations.

5.6.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

There are no category-specific planned improvements.

5.7. Urea application (CRT 3.H)

5.7.1. Category description (e.g. characteristics of sources)

Adding urea to soils during fertilization leads to a loss of CO_2 that was fixed in the industrial production process. Urea ($CO(NH_2)_2$) is converted into ammonium (NH_4+), hydroxyl ion (OH-), and bicarbonate (HCO_3-), in the presence of water and urease enzymes. Emissions ranged from 0.01 to 1.55 kt CO_2 per year for the period 1990-2023 (Figure 5.29). In 2023, however, the emissions from urea application were record high – 2.28 kt CO_2. That can be explained by higher prices for mineral fertilizers in 2023 and lower for urea fertilizers – the two are in correlation.

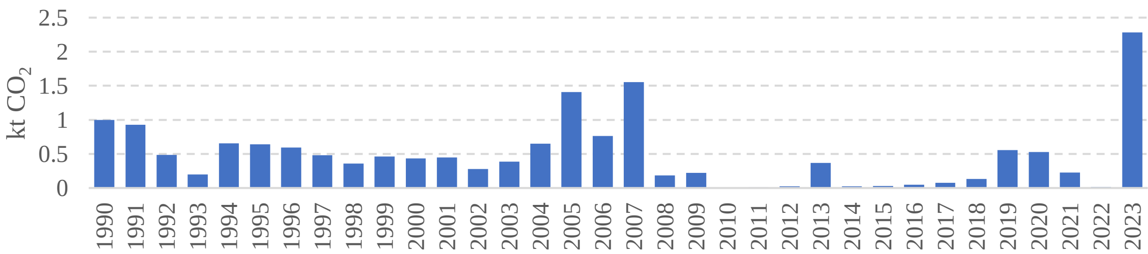

Figure 5.29. CO_2 emissions from urea fertilizer application 1990–2023, kt

5.7.2. Methodological issues

Choice of methods

The *Tier 1* (Equation 5.40) method was used to estimate CO_2 emissions from urea application to croplands.

Equation 5.40[248]

$$CO_2\ Emission = M \times EF \times \frac{44}{12}$$

Where:

CO_2–C Emission =	annual C emissions from urea application, tons C yr^{-1};
M =	annual amount of urea fertilization, tons urea yr^{-1};
EF =	emission factor, tons of C (tons of urea)$^{-1}$

Activity data

For the years 1990-2003, urea fertilizers' production data was obtained from Statistics Estonia database. For the years 2004-2009 and for 2013, data was obtained from the only urea fertilizer producer in Estonia – LLC Nitrofert. LLC Nitrofert shut down their production in 2014. An approximate estimate of the amount of urea applied to soils on an annual basis was obtained using domestic production records, import/export data and Equation 5.39 (see also Annex A.V.3_IX.1). In compliance with the IPCC 2006 Guidelines, it was assumed that all urea fertilizers produced annually minus annual exports are applied to soils[249]. The emission estimation was compiled based on LLC Nitrofert production data and import-export statistical data provided by SE. In 2011, 2012 and 2014–2018, there was no production of urea fertilizers in Estonia, nor did the records of SE show urea-based fertilizer import activity, therefore emission estimations for the years with absent data was developed using urea fertilizer marketing data provided by the Agriculture and Food Board. Until the 2018 submission, it was assumed that all imported urea fertilizers were applied to soils in Estonia. A part of imported fertilizers is exported again, but its proportion or amounts are not known. Due to the lack of valid data and suggestions made by the ERT review team (2018) to homogenize urea fertilizer time series, a surrogate method was used to find more realistic values for the emissions from urea fertilizer application since the 2019 submission. Therefore, since the 2019 submission, data series were homogenized by correcting the values of the emissions from urea fertilizers from the year 2010, when only marketing data was available, except the year 2013, when data from LLC Nitrofert was used.

As the Agriculture and Food Board does not collect data of the amounts of marketed urea fertilizers since 2019, the amounts of urea used in 2018 were temporarily extended until 2021. In accordance with the 2022 ERT review's recommendation ARR2022/A.10, urea resellers and manufacturers have been contacted and their sales data have been validated. Additionally, Estonian inventory team had capacity building consultations with external experts facilitated by Umweltbundesamt (UBA) within the Effort Sharing Regulation sectors capacity-building support, on the proposed approach to use the manufacturers' sales data in Estonia's emission estimates. The external experts concluded that emissions between using the approach used before and the new beforementioned approach do not differ significantly so that there is no need to apply any model for this shift of databases. Data on urea fertilizers sold to Estonian markets can be used from 2016 (the year that the data is available) and assumed that all urea sold on Estonian markets is used on Estonian agricultural lands. Therefore, since 2024 submission, the emissions from urea application starting from the year 2016 have been calculated using the manufacturers' and resellers' data on sold fertilizers to Estonian markets. The new approach,

[248] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.32, equation 11.13.
[249] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.34, equation 11.1.

validated by an expert judgement, is documented in archive according to the instruction of the 2006 IPCC Guidelines (Volume 1, chapter 2, Annex 2A.1).

Emission factors

For emission factor, IPCC 2006 GL default value of 0.20 is applied.

5.7.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Urea application subcategory, please see Annex A.II.3 Agriculture, 3.H Urea application chapter.

5.7.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5

The QC/QA plan for the Urea application subsector includes the QC activities described in the IPCC 2006 Guidelines Volume 1, Chapter 6 and the activities listed in Volume 4, Chapter 11.4.5. The activities are carried out every year during the inventory. The QC checklist is used during the inventory.

5.6.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

There are no category-specific recalculations.

5.6.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including tracking of those identified in the review process

There are no category-specific planned improvements.

6. LAND USE, LAND-USE CHANGE AND FORESTRY (CRT SECTOR 4)

6.1. Overview of the sector (e.g. quantitative overview and description, including trends and methodological tiers by category, and coverage of pools) and background information

The methodology used for calculating emissions and removals from the Land use, land-use change, and forestry (LULUCF) sector follows the 2006 IPCC Guidelines. Emissions and removals from the LULUCF sector are divided into the following categories: Forest land, Cropland, Grassland, Wetlands, Settlements, Other land and Harvested wood products (HWP). Each category, except HWP, is further divided into 'land remaining' and 'land converted to' subcategories.

In 2023, LULUCF sector acted as a net CO_2 source, resulting in net GHG emissions of 2 130.79 kt CO_2 equivalent, meaning that total emissions arising from the sector exceeded total removals (Table 6.1, Figure 6.1). The LULUCF sector sink is mainly affected by the age structure of forests, management practices in forestry and agriculture, area of drained organic soils, production of horticultural peat, and C sequestration in HWP. Forest land covers more than half of the Estonian land area and generally has the greatest impact on the LULUCF sector GHG balance. The age structure of managed forests in Estonia is dominated by mature stands as approximately 39.2% of forest stands are more than 60 years old[250], also the proportion of forest area belonging to the first development classes (treeless area, area under regeneration and young stands) has increased (mostly due to fellings). Therefore, the capacity of carbon sequestration in living biomass has decreased in recent decade, i.e the ratio of mortality to increment has increased. In addition, the annual conversion areas from other land categories to Forest land (afforestation and reforestation) has been decreasing, and the total forest land area has stabilized. The fluctuation in annual carbon stock changes in Forest land living biomass is mainly caused by the felling rates. In 2023, only categories sequestering CO_2 were HWP and Grassland, but it did not compensate emissions from the other LULUCF categories. The highest net emitter was Wetlands category with emissions from peat extraction areas and horticultural use of peat.

Table 6.1. Net emissions from the LULUCF sector by categories in 1990–2023, kt CO_2 eq.

Year	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	HWP	Total LULUCF
1990	-5 622.52	646.36	-119.56	281.95	NO	NO	-156.27	-4 970.05
2005	-2 965.12	198.06	-236.55	921.84	214.28	33.55	-608.41	-2 442.34
2020	175.50	619.83	-189.29	916.01	490.81	63.53	-934.58	1 140.78
2021	-413.60	768.93	-181.12	1 139.53	441.60	30.71	-937.58	848.48
2022	-1 594.76	869.95	-181.64	1 322.37	406.44	38.73	-662.89	198.20
2023	497.06	847.79	-175.41	1 084.29	340.04	39.11	-502.07	2 130.79

[250] Estonian Environment Agency (2024). NFI 2023. Distribution of stands by age classes and dominant tree species, 10-year age classes. [www] https://keskkonnaportaal.ee/sites/default/files/Teemad/Mets/SMI%20tulemused%202023/SMI2023_tulemused_graafikud.xlsx (27.12.2024).

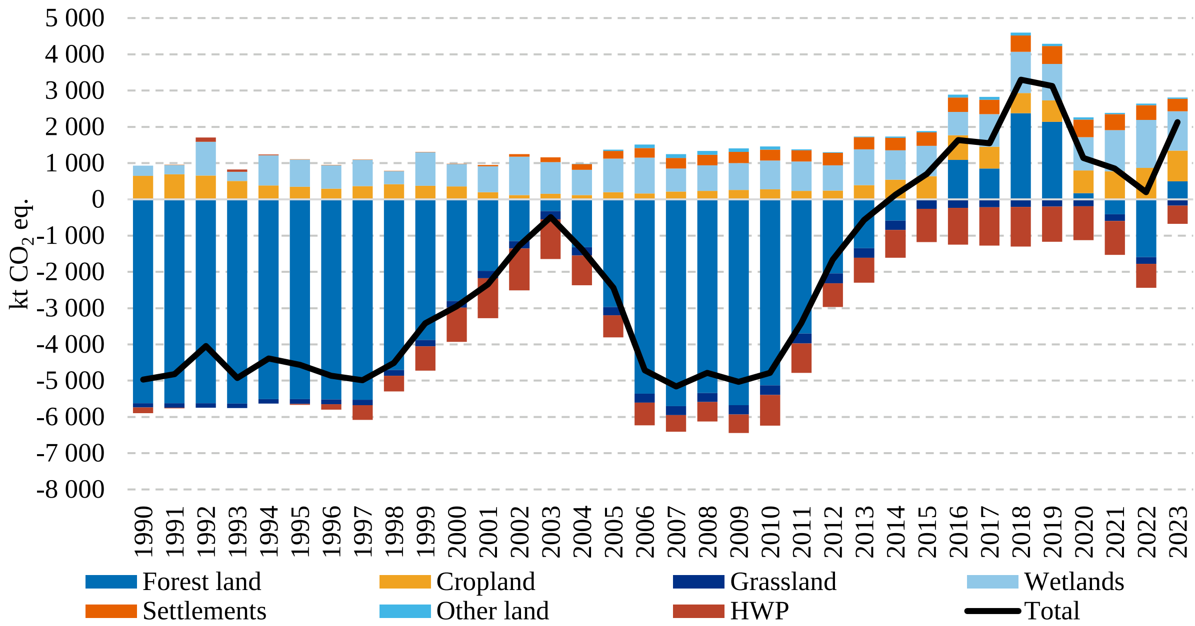

Figure 6.1. Trend in GHG emissions (+) and removals (-) from land use, land-use change and forestry sector 1990–2023, kt CO_2 eq.

The net CO_2 emissions/removals of the Estonian LULUCF sector are presented in Figure 6.2. Forest is the prevailing land-use category in Estonia and carbon flows derived from the forest category have the largest influence on the LULUCF sector's total carbon balance trends. Emissions and uptake of Forest land are predominantly determined by changes in forest growing stock. Further explanations are provided in Chapter 6.4.

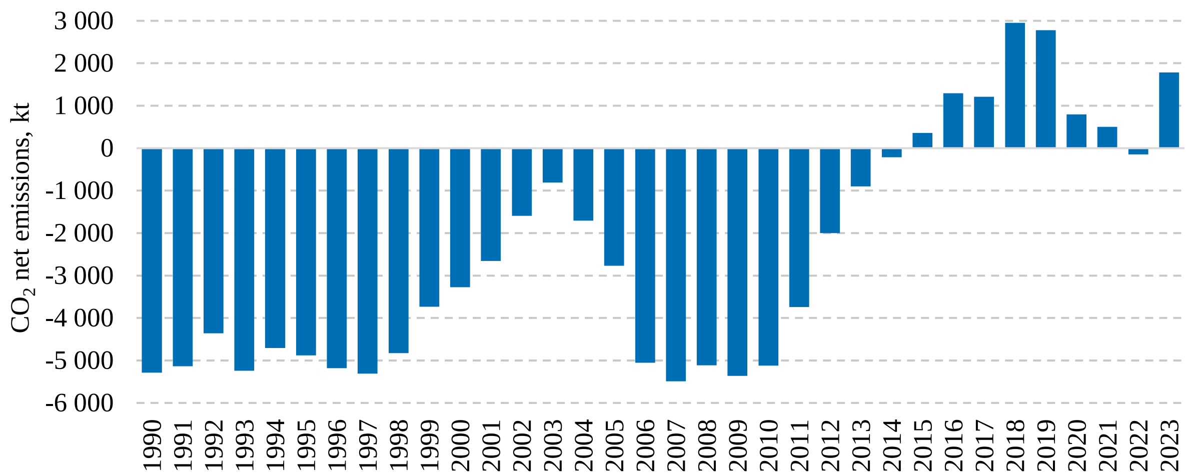

Figure 6.2. Annual change in emissions/removals of CO_2 from the Estonian LULUCF sector in 1990−2023

Figure 6.3 and Figure 6.4 show total emitted quantities of CH_4 and N_2O during the period 1990–2023. CH_4 emissions originate from forest, grassland and wetland wildfires, and drained organic soils (Forest land and peat extraction areas). N_2O emissions comprise emissions from wildfires, peat extraction, drainage of organic forest soils, and direct and indirect N_2O emissions resulting from land-use change on mineral soil. In 1992, 2002, 2006 and 2018, extensive wildfires spread, having an impact on the annual GHG emissions of these years.

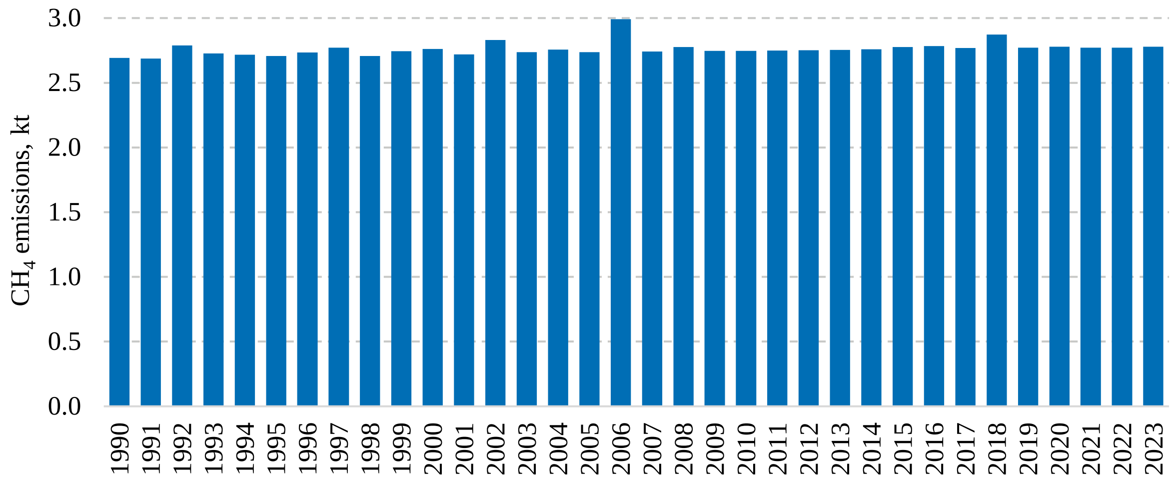

Figure 6.3. Emissions of CH_4 from the LULUCF sector in Estonia in 1990–2023, kt CH_4

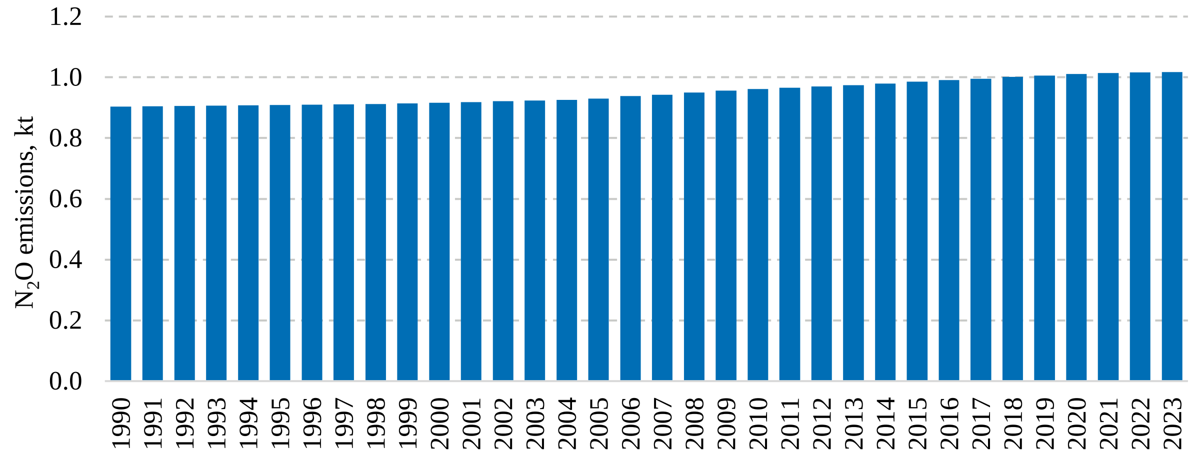

Figure 6.4. Emissions of N_2O from the LULUCF sector in Estonia in 1990–2023, kt N_2O

In the 2025 annual submission, Estonia reports following emissions and removals:

- Forest land (FL; CRT 4.A): C stock changes in living biomass, deadwood, litter (only on Land converted to FL), mineral and drained organic soils, CH_4 and N_2O emissions from drained organic soils, N_2O emissions from N mineralization due to land conversion to Forest land, and non-CO_2 emissions from wildfires;
- Cropland (CL; CRT 4.B): C stock changes in living biomass, dead organic matter (only on Land converted to CL), mineral and organic soils, and N_2O emissions related to land conversion to cropland. N_2O emissions from cultivated organic soils and from N mineralization in the Cropland remaining cropland category are reported under the Agriculture sector (CRT 3.D);
- Grassland (GL; CRT 4.C): C stock changes in living biomass, dead organic matter, mineral soils (only on Land converted to GL), drained organic soils, and non-CO_2 emissions from wildfires;
- Wetlands (WL; CRT 4.D): CO_2, N_2O and CH_4 emissions related to peat extraction and horticultural use of peat, and loss of living biomass and dead organic matter due to land conversion to peat extraction areas or other wetlands. Emissions from wildfires are reported under the Grassland category;

- Settlements (SL; CRT 4.E): CO_2 emissions related to Forest land, Cropland, Grassland and Other land conversion to Settlements in living biomass, dead organic matter and soil carbon pools, N_2O emissions related to land conversion to Settlements;
- Other land (OL; CRT 4.F): CO_2 and N_2O emissions from Forest land, Cropland, Grassland and Wetlands conversion to Other land; and
- Harvested wood products (HWP; CRT 4.G): C stock changes in Solid wood (sawnwood and wood panels), Paper and paperboard and Bleached semi-chemical wood pulp.

Since the 2024 submission, *Tier 3* methods have been applied to estimate carbon stock changes in living biomass and deadwood (Table 6.2). Currently, Estonia does not have country-specific emission factors (EF-s) for litter and forest mineral soils. As an interim approach, C stock change estimates of these pools are based on EF-s from the Swedish National Inventory Submission 2024[251] (considered as a *Tier 2* method). Estonia has launched several projects aimed at elaborating on country-specific data regarding litter and soil pools for future submissions (see Chapters 6.4.6, 6.5.6, and 6.6.6, Category-specific planned improvements). Also, studies by Kõlli et al. (2009[252], 2010[253]) were used to develop country-specific factors for estimating C stock changes in mineral soils during land-use changes between Forest land, Cropland and Grassland, and country-specific EF-s by Salm et al. (2012[254]) have been implemented for peat extraction sites (*Tier 2*).

Table 6.2. Methods and emission factors used for estimating the emissions/removals of GHG from the LULUCF sector in Estonia

	Method applied / EF used		
GHG SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**
4.LULUCF	T1,T2,T3/ CS,D,OTH		
4.A.1 Forest land remaining forest land	T1,T2,T3/ CS,D,OTH		
4.A.2 Land converted to forest land	T1,T2,T3/ CS,D,OTH		
4.B.1 Cropland remaining cropland	T1,T2/ CS,D		
4.B.2 Land converted to cropland	T1,T2,T3/ CS,D,OTH		
4.C.1 Grassland remaining grassland	T1,T2,T3/ CS,D		
4.C.2 Land converted to grassland	T1,T2,T3/ CS,D,OTH		
4.D.1 Wetlands remaining wetlands[255]	T2/ CS		
4.D.2 Land converted to wetlands	T2,T3/ CS,D,OTH		
4.E.1 Settlements remaining settlements[256]	NA/NA		
4.E.2 Land converted to settlements	T1,T2,T3/ CS,D,OTH		
4.F.2 Land converted to other land	T2,T3/ CS,D,OTH		
4.G. HWP	T2/ CS,D		
4(II) Emissions from drainage	NA/NA	T1,T2/ CS,D	T1,T2/CS,D
4(III) Direct and indirect N_2O emissions from N mineralization			T1/D

[251] This approach is approved by ERT (FCCC/ARR/2012/EST para.94, 104; FCCC/ARR/2013/EST para. 63).
[252] Kõlli, R., Ellermäe, O., Köster, T., Lemetti, I. Asi, E., Kauer, K. (2009). Stocks of organic carbon in Estonian soils. Estonian Journal of Earth Sciences, 58, 95–108.
[253] Kõlli, R., Köster, T., Kauer, K., Lemetti, I. (2010). Pedoecological regularities of organic carbon retention in Estonian mineral soils. International Journal of Geosciences, 1, 139–148.
[254] Salm, J-O., Maddison, M., Tammik, S., Soosaar, K., Truu, J., Mander, Ü. (2012). Emissions of CO_2, CH_4 and N_2O from undisturbed, drained and mined peatlands in Estonia. Hydrobiologia, 692, 41–55
[255] Wetlands are divided into managed and unmanaged wetlands. Emissions from unmanaged wetlands are not reported, since it is not mandatory according to the IPCC 2006 Guidelines.
[256] Settlements remaining settlements reporting is not mandatory.

	Method applied / EF used		
GHG SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**
4(IV) Biomass burning	NA[257]/NA	T2/D	T2/D

EF – Emission Factor, NA – not applicable, T1 – *Tier 1* method, T2 – *Tier 2* method, T3 – *Tier 3* method, CS – country-specific, D – IPCC default, OTH – other, in the case of missing country-specific data, EFs from Sweden were applied.

The inventory in the LULUCF sector is carried out by the Estonian Environment Agency (EstEA), Forest Department. Annual reports published by different institutions (EstEA, Statistics Estonia (SE), etc.; see Table 6.3) have been used in the estimation of greenhouse gas fluxes related to the LULUCF sector.

Table 6.3. List of institutions (datasets) involved in the inventory of the LULUCF sector

References	Link	Abbreviation	Activity
Estonian Environment Agency	keskkonnaagentuur.ee/en	EstEA	- EstEA carries out National Forest Inventory - collecting and providing data on areas of land-use categories (Forest land, Cropland, Grassland, Wetlands, Settlements, Other land) - areas of land-use changes - areas of peat extraction - Forest land, Grassland and Cropland woody biomass and deadwood stocks - felling volumes - field inventories of wildfires (started in 2012)
Estonian Rescue Board	rescue.ee/en	ERB	- collecting and publishing data on forest fires (location, type, cause, etc.)
Statistics Estonia	stat.ee/en	SE	- providing data for calculating Cropland mineral soil emissions (areas with different land use and input regimes within the Cropland category; share of areas with different tillage practices) - data on peat extraction - foreign trade and production data for HWP calculations
Agricultural Registers and Information Board	pria.ee/en	ARIB	- providing data for calculating Cropland mineral soil emissions (operates Land Parcel Identification System in Estonia)
Centre of Estonian Rural Research and Knowledge	metk.agri.ee/en	METK	providing know-how for calculating Cropland mineral soil emissions (C input of different cropping systems, share of areas with different tillage practices)
Estonian Land and Spatial Development Board	maaruum.ee/	ELSDB	- collecting and providing additional data on land areas - providing data on peat extraction

[257] Biomass C stock change estimates include CO_2 loss from burning.

References	Link	Abbreviation	Activity
Estonian Forest and Wood Industries Association	empl.ee		- expert assessment of sawnwood production data for HWP calculations

The LULUCF sector key categories in 1990 and 2023 by level and trend (*Tier 1*) are presented in Table 1.2.

6.2. Land-use definitions and the land representation approach(es) used and their correspondence to the land use, land-use change and forestry categories (e.g. land use and land-use change matrix)

LULUCF land categories presented in the inventory report are consistent with the land-use categories given in the 2006 IPCC Guidelines. Area estimates for land-use categories are obtained from the National Forest Inventory (NFI) that is carried out by the Forest Department of the Estonian Environment Agency. The NFI is a systematic collection of forest information on randomly based sample plots that cover the whole country (Figure 6.5) and all land-use categories. The NFI also provides information on soils, distribution of mineral and organic soils as well as into drained and undrained land. The nationally classified NFI sample plots are reclassified into IPCC land-use categories (Table 6.7). All area estimates are being re-estimated annually in the GHG inventory due to the method used by the NFI. Land use changes are calculated backwards from the latest year i.e. if the previous land use is obviously known on the permanent plots, then on the temporary plots the change of land use is indicated if it has occurred in the last five years. The sampling design of the Estonian NFI and the method of estimation of land-use changes are described in Chapter 6.3.1.

6.2.1. Definitions of land categories

Forest land

Forest area is estimated according to the FRA (UNFAO – Forest Resources Assessment) definition [258] (Table 6.4). All temporarily unstocked forest areas and regeneration areas which have yet to reach a crown density of 10 per cent and a tree height of 5 meters are also included as forest, as are areas which are temporarily unstocked because of human intervention such as harvesting, or natural causes (fires, etc.) but which are expected to revert to the forest. Forest land also includes abandoned shifting cultivation land with a regeneration of trees that have, or are expected to reach, a canopy cover of 10 percent and tree height of 5 meters. It does not include land that is predominantly under agricultural or urban land use.

Table 6.4. Parameters for forest definition

Minimum tree crown cover	10%
Minimum land area	0.5 ha
Minimum tree height	5 m

[258] FAO (2023). Terms and definitions FRA 2025. Forest resources assessment working paper 194. [www] https://openknowledge.fao.org/server/api/core/bitstreams/a6e225da-4a31-4e06-818d-ca3aeadfd635/content (27.12.2024)

Estonian Forest Act stipulates forest land as land which meets at least one of the following requirements:

- forest land use has been registered in the Land Cadastre; and
- has an area of 0.1 hectares of land, growing woody plants with a minimum height of 1.3 meters and the tree crown cover of at least 30 percent.

To meet the requirements of UNFCCC reporting, the NFI is compiling statistical analyses based on both the national and the UNFCCC definition of a forest regarding the minimum area of a forest.

All forest land is considered managed in Estonia – the total forest land in Estonia is or has been covered with forest management plans. In addition, protected forests are covered with a protection scheme.

Cropland

According to the definition used by the NFI, Cropland is 'arable land, area where annual or perennial crops are growing (incl. fallows, orchards, short-term and long-term cultural grasslands and temporary greenhouses)'. It does not include built garden land under 0.3 ha (that is included in Settlements).

Abandoned cropland is classified as Cropland until it has not lost arable land features – changes in soil and vegetation have not taken place and the land is still usable as cropland without the implementation of specific treatments.

Grassland

According to the national definition, this category includes rangelands and pastureland that is not considered Cropland nor Forest land: land with perennial grasses that is proper for mow and pasture, smaller fallows and former cultural grasslands that have lost arable land features and Grassland from wild lands ('natural grassland').

Wetlands

Wetland's category includes mires, inland water bodies, including larger bog holes, and peat extraction sites. Mires are defined as land that is permanently saturated by water and/or areas where the peat layer is at least 30 cm thick and that does not fall into the Forest land, Cropland, Grassland or Settlements categories. Also, smaller bog holes are considered under mires area.

Wetlands are divided into unmanaged and managed wetlands. Natural lakes, rivers and undrained mires are considered unmanaged land whereas peat extraction sites and flooded areas are reported under managed wetlands. Also, all land areas that have been converted to wetlands are considered managed.

Settlements

Built-up areas, wide roads, streets and squares, traffic and power lines, urban parks, industrial and manufacturing land, sports facilities, airports, legal waste down points, construction sites and buildings with up to 0.3 ha of garden yard (including permanent greenhouses), and open cast areas (except for peat extraction areas) are reported under the Settlements land-use category.

Other land

Land areas that do not fall into any of the other five land-use categories. For example, areas with a closed regime for which the land category cannot be determined. Other land also includes unusable mineral land, i.e., land that is not economically usable without the application of special measures and that has soil organic layer thickness less than 30 cm. Consistent with the IPCC Guidelines, this land-use category is used to allow the total of identified land areas to match the national area.

6.2.2. Land use trends

The areas of land-use categories in the 2025 inventory submission are reported in Table 6.5. Areas of managed wetlands include peat extraction sites, flooded lands and lands that have been converted to wetlands.

Table 6.5. The area of different land-use categories in 1990–2023[259] (NFI), kha

Year	Forest land	Cropland	Grassland	Unmanaged wetlands	Managed wetlands	Settlements	Other land
1990	2 368.69	1 059.21	300.31	397.34	33.99	314.34	60.21
2005	2 437.86	994.42	312.96	393.65	32.03	312.79	50.39
2020	2 452.02	989.66	276.77	387.76	37.50	340.53	49.85
2021	2 453.01	989.80	274.29	387.38	37.74	342.50	49.38
2022	2 453.93	989.94	271.99	387.06	38.00	344.10	49.07
2023	2 454.15	990.15	270.78	386.84	38.23	345.03	48.91

Table 6.6 gives an overview of land-use transitions between 31.12.1989 and 31.12.2023. The largest decrease in area has occurred in the Cropland category (-69.60 kha) as due to the lack of active management, many croplands have turned into grasslands. The area of the Grassland category has decreased by 10.0% since 1990. At the same time, Forest Land area has increased by 3.7%. These changes result mostly from the reallocation of grasslands to the Forest land category when their tree crown cover begins to meet the Forest land definition in the course of natural succession.

Table 6.6. The land-use change matrix for IPCC land-use categories from 31.12.1989 to 31.12.2023 (kha)

	Initial						Final area
Final	**FL**	**CL**	**GL**	**WL**	**SL**	**OL**	
Forest land	2 326.22	38.97	56.47	11.37	7.98	13.15	2 454.15
Cropland	2.40	960.78	26.56	0.21	0.20	0.00	990.15
Grassland	9.47	49.16	207.86	0.95	1.84	1.51	270.78
Wetlands	4.07	0.19	0.60	418.53	1.68	0.00	425.07
Settlements	21.44	10.07	9.13	0.18	303.08	1.14	345.03
Other land	3.36	0.57	0.26	0.12	0.00	44.61	48.91
Initial area	2 366.96	1 059.74	300.86	431.34	314.78	60.40	4 534.09
Change since 1990, kha	87.19	-69.60	-30.08	-6.28	30.25	-11.49	
Change since 1990, %	3.7	-6.6	-10.0	-1.5	9.6	-19.0	

[259] The correspondence between national and IPCC land-use categories is shown in Table 6.7

6.3. Country-specific approaches

6.3.1. Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

Estonia uses *Approach 3* - geographically-explicit land-use conversion data for representing land-use areas (in accordance with the 2006 IPCC Guidelines). Information on current land use and its changes are collected during the NFI and stored in the NFI database. Estonian NFI network of sample plots cover the whole country and consists of both permanent plots that are revisited after every 5 years, and temporary plots (Figure 6.5). In 2023, one inventory plot represents ca 156 ha of land. Data on the Estonian total land area comes from the geoportal of the Estonian Land and Spatial Development Board[260]. The area of Estonia, 4 534.088 kha, includes land divided between counties and the undivided area of the Narva River, Lake Peipsi, Lake Lämmi, Lake Pskov, Lake Võrtsjärv and Kulje Bay.

Time series for different land use and land use change are calculated backwards from the latest available year (in NID 2025 from 2023 to 1990). Plots from five fieldwork years have been used to evaluate the change in the reporting year. The change in land use is estimated as a five-year average on plots where land use has taken place during the last five years before the measurement.

National Forest Inventory

Until the end of the 1990s, the national estimation of forest resources was based on stand-wise forest inventories. Regular inventories were carried out every 10 years on most of the forest land: state forest districts as well as the forests of collective and state farms. After independence was regained in Estonia in 1991, the ownership reform program was started. Part of the program was the land reform. Land, which had been unlawfully expropriated, was to be returned to its initial owners or to their descendants. Borders of the state forests were restored according to the situation in 1940, and the remaining land was left for privatisation. Changes were also carried out in forest survey. The planned economy, which had existed for 50 years, was replaced by a market economy resulting in intensive cutting of forests. As the land reform was not quick enough (it took almost 25 years and is now in final stages), a situation occurred where valid, current information was available only about one-third of Estonian forests. Changed ownership structure and stopping of the former centralised forest management planning system created a need for new inventory methods. Long lasting land reform is partly also the reason why forests in Estonia have unbalanced age structure.

The first National Forest Inventory covering the whole country commenced in 1999. With rather modest means, the NFI can give quite a precise assessment of forest area, resources and cutting volume. The main objective of the NFI is to provide estimates about major characteristics of forests, but nowadays the NFI also gives information about topics such as the distribution of land by land-use categories and the afforestation and growing stock of non-forest land, etc.

Methodologically, the NFI is designed as an annual research effort, which, using optimal methods, must ensure continuous updating of information and the forest database. An increased frequency network (starting from 2014)[261] of sample plots (Figure 6.5), covering the whole country, has been planned for five years with 20% or approximately 370 clusters (ca 5 500

[260] Administrative and Settlement Division. Geoportal. Estonian Land Board [www] https://geoportaal.maaamet.ee/eng/spatial-data/administrative-and-settlement-division-p312.html (27.12.2024).
[261] In FCCC/ARR/2014/EST, paragraph 68, the ERT recommended increasing the sampling frequency.

sample plots) measured each year, so that permanent plots will be re-measured in every 5 years. Point estimates of parameters are calculated using data from the sample plots and form the basis for inferences to the entire population.

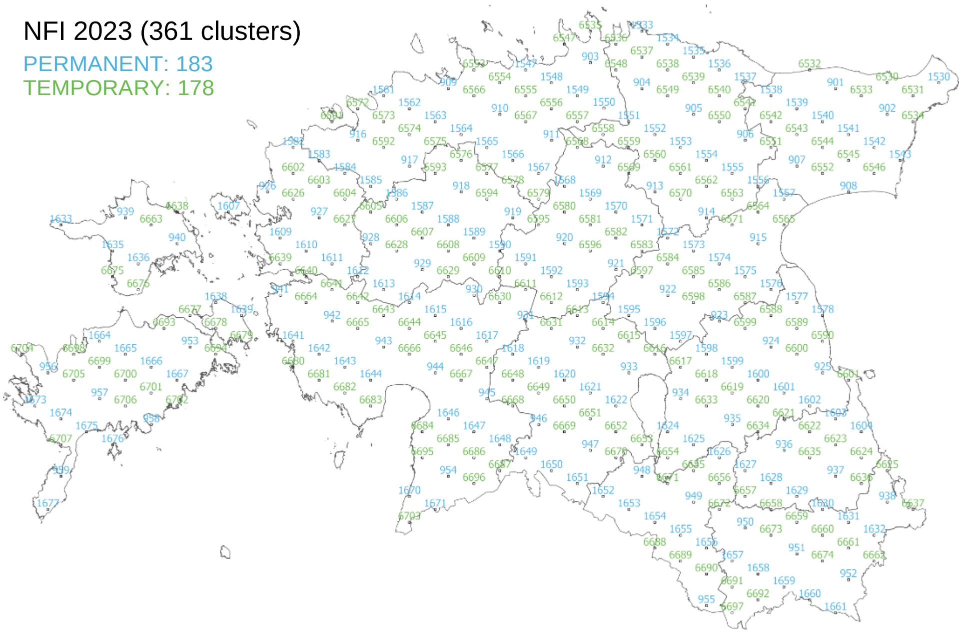

Figure 6.5. Cluster network of the Estonian National Forest Inventory

NFI has an important role in decision-making on the effective management of forests and future projections – in large-area forest management planning such as estimating the optimum cutting level. The Estonian NFI covers all land-use categories, including all forests and other wooded lands in all ownership groups, including protected areas. Assessments of the forest resource by the NFI have become the basis for national and international statistical reporting in Estonia, such as the United Nations/FAO Forest Resources Assessment procedure, the Ministerial Conference on the Protection of Forests in Europe (Forest Europe MCPFE). The NFI also produces information on forest carbon pools and changes for the LULUCF sector in the GHG inventory.

Design of the Estonian NFI is a systematic sample without pre-stratification. The network of sample plots covers the whole country and is planned as a five-year cycle. The sampling grid is designed to meet the accuracy requirements at the national level. The sampling intensity is the same throughout the whole country. The sample (cluster) distribution is based on a national 5-km x 5-km quadrangle grid, determined by the L-EST co-ordinates system.

Sample plots are concentrated into clusters (Figure 6.6) to increase the efficiency of the survey. An observation unit is an individual field plot that is the centre of sample circles with defined radii. The method of sampling with partial replacement is used. Plots are divided into permanent clusters and temporary clusters that form 800 x 800 metre squares. All the permanent clusters (sample plots) are re-measured after 5 years. The sample plot radius depends on the assessed variables, as well as their values (e.g., tree diameter). In addition to plots with the main radii of 10 m and 7 m, where the land-use category is determined, plots of other radii are also used.

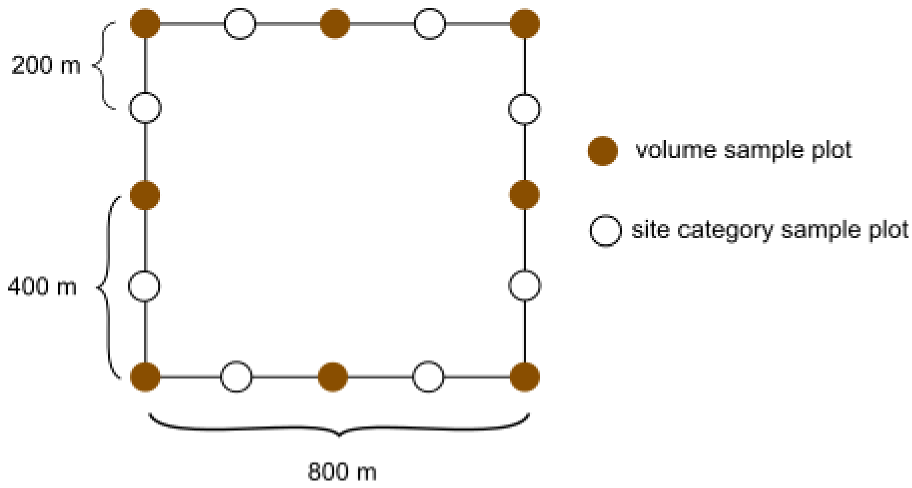

Figure 6.6. Estonian NFI cluster design

All population units have an equal probability of being selected into the sample. The result is point estimates of multiple population parameters based on the measurement data. Although all NFI estimates are based on sampling, they are not absolute. Therefore, each estimate of a general parameter is always accompanied with a sampling error.

The sampling scheme and design are described in more detail by Adermann (2010)[262].

The present status and change of land use is assessed during the NFI fieldworks. The recalculation of historical land use time-series is based on the combination of both indicators.

To collect data about land-use transitions, additional field studies were started in 2009 in the framework of NFI. Collected data provides information on different land-use categories (on 20 years, retrospectively), the year of changes, and soil types. During land category registration, "LULUCF former land category" is registered on every sample plot to see if the land category has changed after the base point (31.12.1989). The year of change is being estimated first directly in the field. Older maps and aerial photographs are used afterwards as supporting material to determine the exact year more accurately.

An illustrative example of how land-use changes are verified with maps and relevant materials are presented as follows. In the cluster in Figure 6.7, Figure 6.8 and Figure 6.9, there are 6 identified land-use changes on the NFI sample plots since 1990:

- N02 – Grassland to forest land, LUC in 1995
- E06 – Cropland to forest land, LUC in 1999
- S02 – Cropland to forest land, LUC in 2009
- W04 – Cropland to forest land, LUC in 2005
- W06 and W08 – Cropland to forest land, LUC in 2008.

[262] Adermann, V. (2010). Estonia. In: Tomppo, E., Gschwantner, T., Lawrence, M., McRoberts, R. (eds). National forest inventories: Pathways for common reporting. Dordrecht: Springer, pp. 171–184.

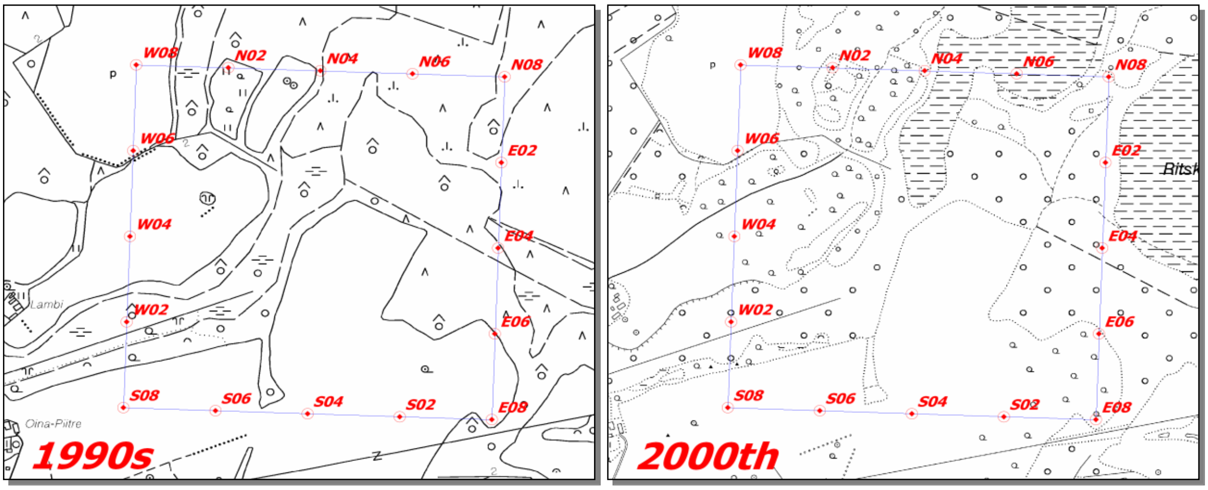

Figure 6.7. Base maps of the 1990s and the year 2000

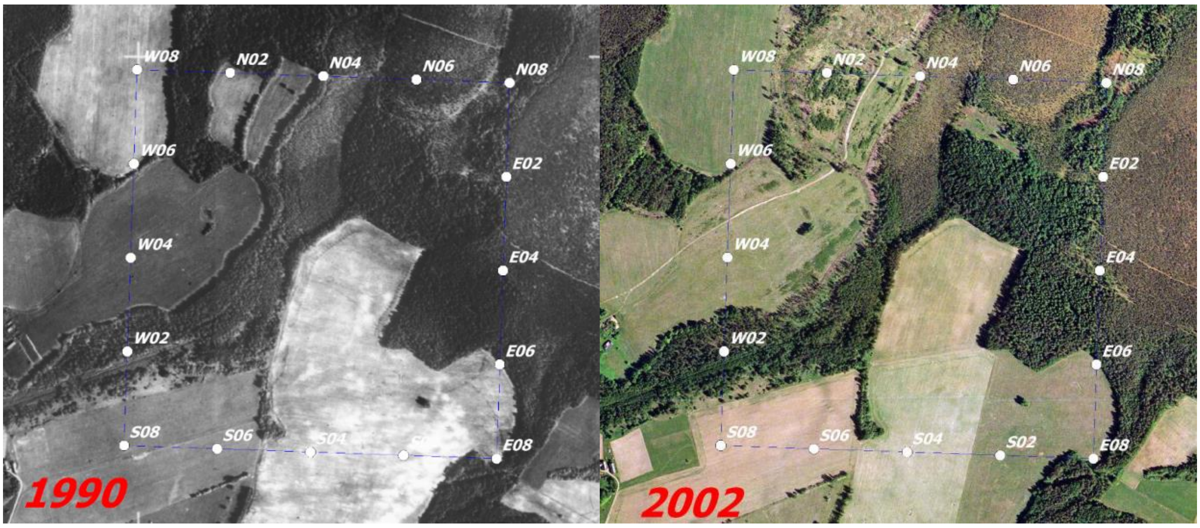

Figure 6.8. Orthophotos of 1990 and 2002

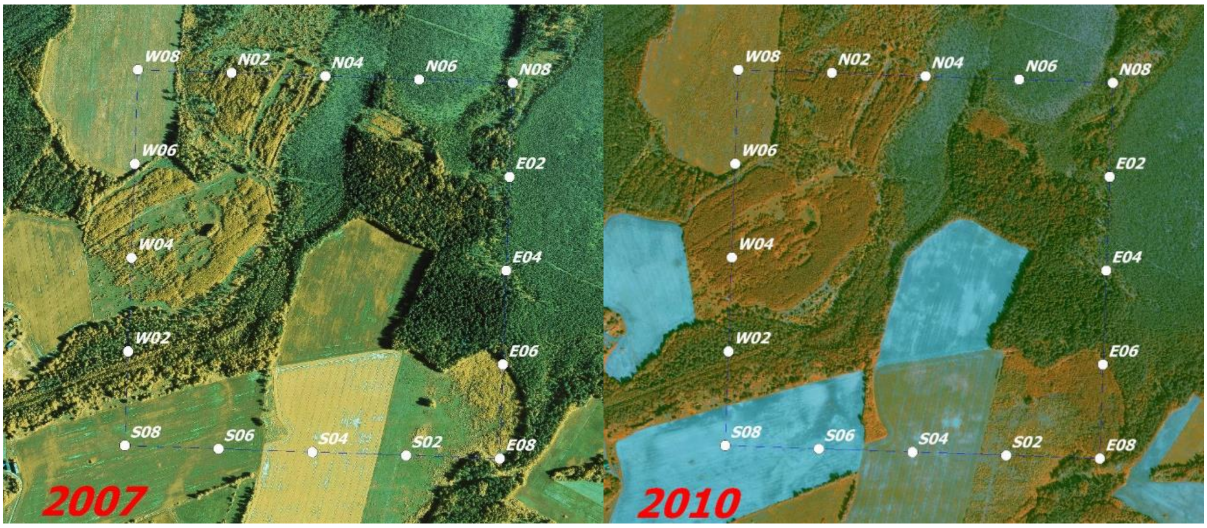

Figure 6.9. Orthophotos of 2007 and 2010

Since 1999, information on permanent sample plots has been available. The resulting data set is a matrix with previous and the current land-use categories in the timeline.

During a field study, soil types (mineral/organic) are also estimated, and all sample plots are assigned with the soil type ‘mineral’ or ‘organic’. In case the former land category type differs from the current one, the soil type is estimated by the current land category. For undrained soils the ‘organic’ soil type is defined with an organic layer of more than 30 cm in depth and for drained soils more than 25 cm in depth. The soil is drained when the distance from the functioning drainage ditch is up to 100 m.

The NFI determines more land categories than in the IPCC 2006 Guidelines, therefore an aggregation has been made, which is shown in Table 6.7. Not all national and IPCC land-use categories have an exact match, few national land-use categories can be forest land or grassland, which is specified in the field.

Table 6.7. National definitions for land-use categories and relevant land-use categories defined by IPCC 2006 in 2023 (kha)

	Forest land	**Cropland**	**Grassland**	**Wetlands**	**Settlements**	**Other land**
Forest land (M)	2 122.09					
Unstocked forest land (MM)	212.08					
Arable land (excluding PK, PR) (PM)		683.10				
Permanent crops (PK)		4.05				
Long-term cultural grassland (PR)		303.00				
Bushes (P)	17.35		39.66			
Natural grassland (RM)	34.00		201.72			
Mire (S)	64.39		25.82	134.89		
Inland water bodies (SV)				263.02		
Peat quarry (KT)				27.17		
Opencast pit (excl. KT) (K)					8.49	
Settlements (excl. T, TR) (A)					188.75	
Roads and railways (T)					67.84	
Lines, power lines, etc. (TR)					77.54	
Wooded settlements area (PA)					2.40	
Solar park (PP)			0.78			
Unusable mineral land (KK)	4.23		2.81			36.86
Other land (Y)						12.05
Total	**2 454.15**	**990.15**	**270.78**	**425.07**	**345.03**	**48.91**

6.3.2. Information on approaches used for natural disturbances, if applicable

Estonia is estimating emissions from biomass burning and these emissions are included in the national total. More information is available in Chapter 6.11.

6.3.3. Information on approaches used for reporting harvested wood products

Estonia applies the production approach for reporting emissions and removals from harvested wood products. More information is available in Chapter 6.12.

6.4. Forest land (CRT 4.A)

6.4.1. Category description

Forest land category covered 2454.15 kha in 2023, which is more than half of Estonia's territory. In total the Forest land area has increased by 85.47 kha compared to 1990 (Figure 6.10). After Estonia regained its independence in 1991, the soviet agricultural system fell apart, and a significant part of the agricultural land was abandoned. When the tree crown cover of grasslands satisfies criteria for Forest land, the land is reallocated, which has been the main reason for the increase in Forest land area. Afforestation of wetlands, settlements and other land categories has been less important. In the last decade, however, the forest land area has stabilized as a result of reduced afforestation and increased deforestation.

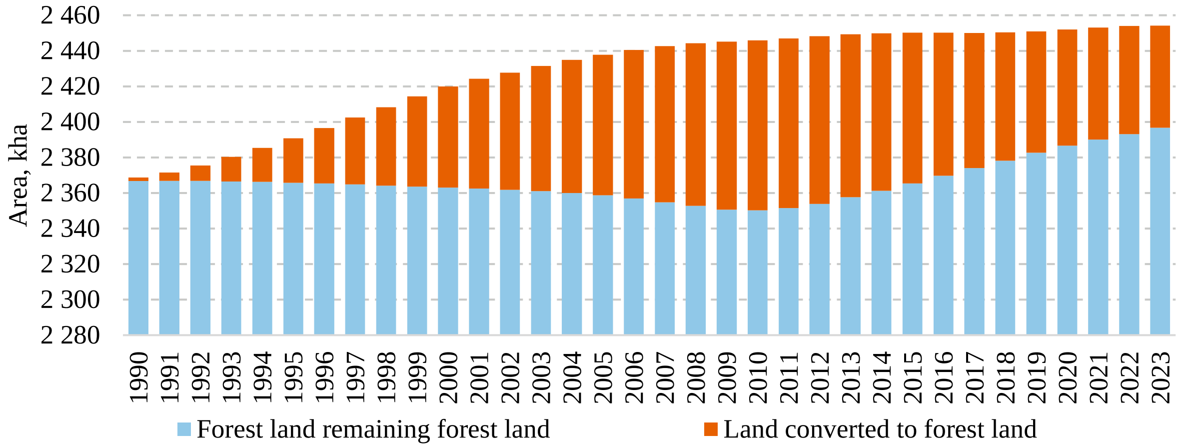

Figure 6.10. Forest land area in Estonia in 1990–2023, kha

The net emissions from Forest land were 497.06 kt CO_2 eq. (Figure 6.11) in 2023. Estimations include CO_2 emissions and removals from living biomass, dead organic matter, mineral and organic soils, non-CO_2 emissions from drained organic forest soils, direct and indirect N_2O emissions from N mineralization and emissions from wildfires.

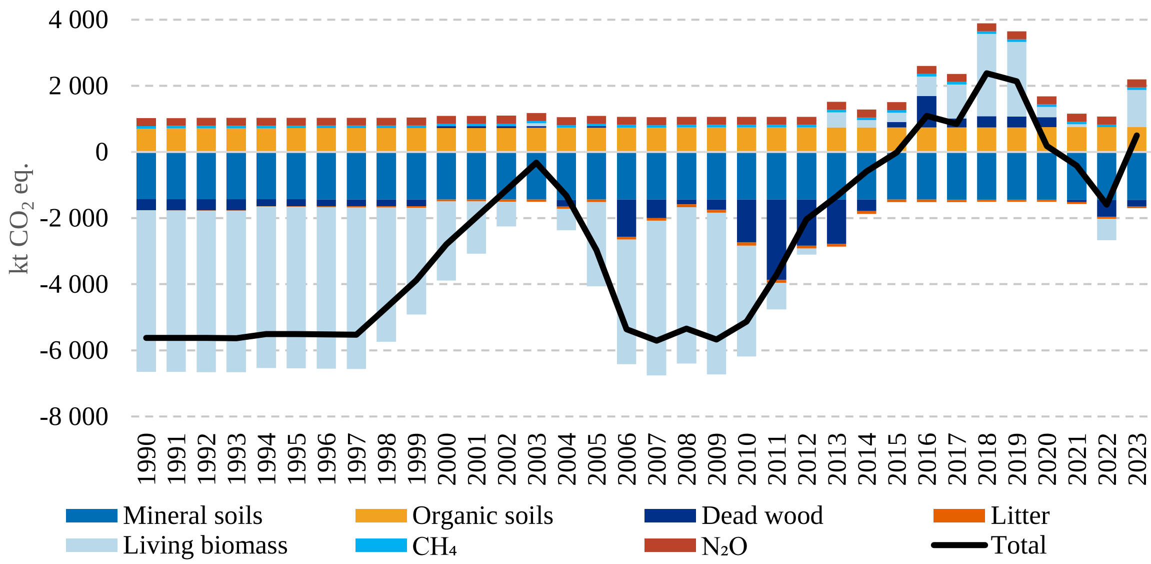

Figure 6.11. Annual net change in GHG emissions (+) and removals (-) from the Forest land category in 1990–2023, kt CO_2 eq.

Forest land is the most important category that affects LULUCF sector trends and keeping generally LULUCF sector GHG emissions and removals balance on a sink side. The age structure of managed forests in Estonia is dominated by mature stands as approximately 39.2% of forest stands are more than 60 years old[263], also the proportion of forest area belonging to the first development classes (treeless area, area under regeneration and young stands) has increased. Therefore, the capacity of carbon sequestration in living biomass has decreased in recent decade, i.e the ratio of mortality to increment has increased. In addition, the annual conversion areas from other land categories to Forest land (afforestation and reforestation) has been decreasing, and the total forest land area has stabilized.

6.4.2. Methodological issues

The carbon stock change in the category 4.A.1 Forest land remaining forest land is given by the sum of changes in above- and below-ground biomass, deadwood, litter, and soils. The algorithm employed to estimate carbon flows related to the category Forest land remaining forest land is presented below:

Equation 6.1[264]

$$\Delta C_{LU} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO}$$

Where:

ΔC_{LUi} = carbon stock change for a stratum of land-use category;
AB = above-ground biomass;
BB = below-ground biomass;
DW = dead wood;
LI = litter; and
SO = soils.

Equation 6.1 is also used for calculations on the subcategory of land converted to Forest land.

Carbon stock change in living biomass

Living biomass on Forest land includes the biomass of perennial woody plants. Starting from this year's submission, Estonia uses a new approach, the *Gain-Loss Method,* for estimating carbon stock changes in living biomass (Equation 6.2, *Tier 3*):

Equation 6.2[265]

$$\Delta C_{LU=}\Delta C_G - \Delta C_L$$

Where:

ΔC_{LUi} = carbon stock change for a stratum of land-use category;
ΔC_G = annual gain of carbon; t C yr^{-1}.
ΔC_L= annual loss of carbon; t C yr^{-1}.

[263] Estonian Environment Agency (2024). NFI 2023. Distribution of stands by age classes and dominant tree species, 10-year age classes. [www] https://keskkonnaportaal.ee/sites/default/files/Teemad/Mets/SMI%20tulemused%202023/SMI2023_tulemused_graafikud.xlsx (27.12.2024).
[264] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.7, Equation 2.3.
[265] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.23, Equation 2.12.

The methodology is described in detail in Annex A.V.4. In short, C stock changes in Forest land living biomass are estimated as follows.

1) The current growing stock (stem volume) per hectare of FL is estimated based on the distribution of stand age and site quality index of the forest stands assessed by NFI during the last five years' field measurements. Growing stock is calculated using model that predicts plot-level growing stock (tree stem volume) per hectare given the average age of the dominant tree species and the site quality index.
   It should be noted that this essentially estimates the average difference between the increment (tree growth) and growing stock reductions due to intermediate loggings (thinnings, cleanings, selection fellings) and natural mortality – i.e., reductions, where the age of the dominant species is not altered – since the volumes used to fit model include the impacts of these.
2) From the plot measurement time the stock is projected to the reporting year using the same model and assuming that the site quality index remains the same. Years of growth were adjusted by the coefficient of real change in average age (usually, the forest becomes five years older in five years, but due to natural disturbances or intermediate fellings, the age change may be different).
3) The annual average gains (in stem volume) per hectare of FL are obtained as the annual average change between the projected and original stocks.
4) Annual losses of stem volume are reported as an average over the last three harvest seasons. Thus, the new methodology reflects short-term changes in harvest levels, as recommended by ERT[266]. Mean volume lost per hectare of clear-felled FL is estimated by projecting the pre-harvest volumes of the clear-felled plots with the same model that is used for gains, and subtracting from this projected value the average share of volume remaining in clear-felling areas (seed trees, retention trees etc). Other fellings due to which the age drops to zero were also added to clear fellings.
5) Stem volume is converted to whole tree biomass using nationally developed factors of growing stock volume to above-ground biomass (BCEF) and ratios of below-ground to above-ground biomass, and further to carbon stocks by applying default carbon fractions from the 2006 IPCC Guidelines.
6) Based on Estonian NFI data, the average annual increase of stem volume in young stands is estimated to be 3.04 m^3 ha^{-1}. Growing stock was converted to C by applying average woody biomass C stock/growing stock ratio from FL remaining FL (0.324 t C m^{-3}). C gains on Land converted to FL, based on this estimate and the area converted to FL, are subtracted from C change on total FL to obtain C change on FL remaining FL.
7) As the first NFI cycle ended in 2003, NFI growing stock data is available from that year onwards. For the period 1990–1997, C stock change in FL living biomass was estimated using standwise inventory based growing stock data from Statistics Estonia and felling volumes from felling documentation. Growing stocks change were smoothed using linear trend; exponential trend was applied for felling data. For the period 1998–2002, C stock change in FL living biomass was interpolated.

Total net emissions from Forest land living biomass sub-category were 1 129.91 kt CO_2 in 2023 (Figure 6.12). The fluctuation in annual carbon stock changes in Forest land living biomass is mainly caused by the felling rates (losses). Total and regeneration felling rates for years 1991–2022 are presented in Figure 6.13. Estimates for fellings in 1991–2001 are based on the felling documentary data, NFI data is available from 2002 onwards. Growing stock and fellings based on

[266] FCCC/ARR/2022/EST L.16.

standvise forest are systematically underestimated (e.g., Arumäe & Lang 2016[267]; Kulješis et al. 2016[268]), but trends can be considered correct, thus, they can be used to assess the change. The one-year number from NFI comes from the measurements in three felling seasons based on the May to April (e.g. 2022 estimate is the average form felling seasons 2020/2021, 2021/2022, and 2022/2023).

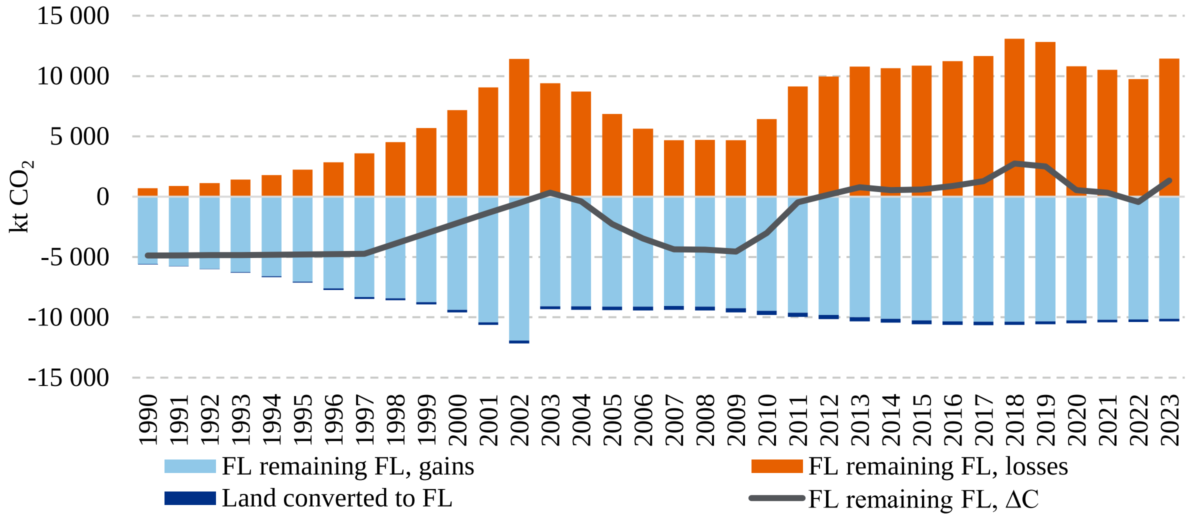

Figure 6.12. Annual carbon stock changes in Forest land living biomass in 1990–2023, kt CO_2

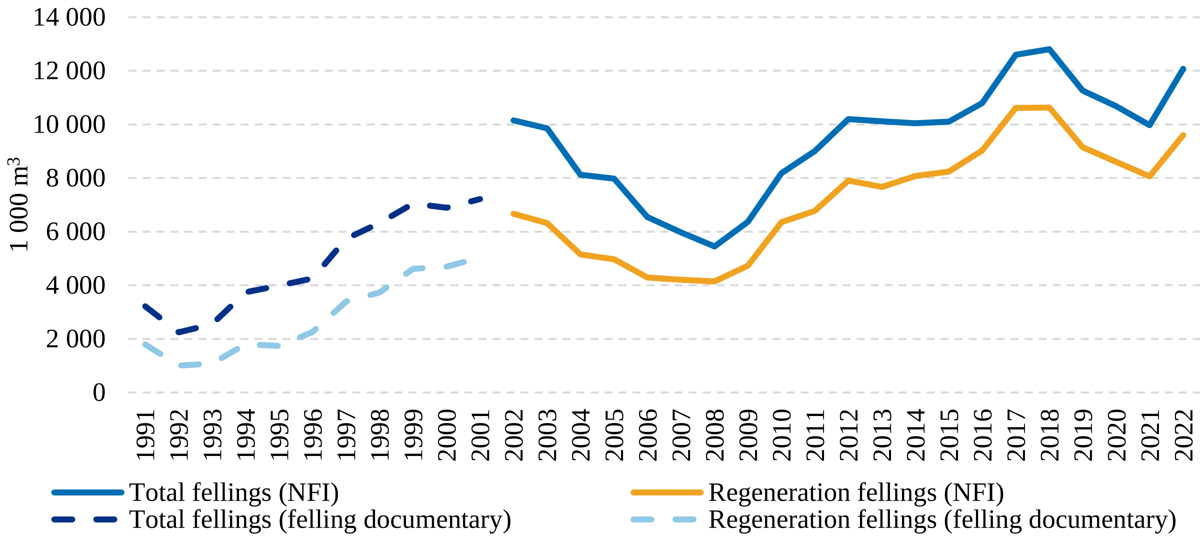

Figure 6.13. Total and regeneration fellings in 1990–2022, 1000 m^3

Carbon stock change in dead wood

Dead wood includes wood lying on the surface, standing deadwood, dead roots and stumps and dead branches. For estimating carbon stock changes in the dead wood pool, the *Tier 3* and stock difference method was applied. The NFI annually provides data about the volume of dead wood

[267] Arumäe, T., Lang, M. (2016). Aerolidarilt puistu tüvemahu hindamise mudelid ning võrdlus takseeritud tagavaraga. [ALS-based wood volume models of forest stands and comparison with forest inventory data.] Forestry Studies, 64, 5–16.
[268] Kuliešis, A., Tomter, S.M., Vidal, C. & Lanz, A. (2016). Estimates of stem wood increments in forest resources: comparison of different approaches in forest inventory: consequences for international reporting: case study of European forests. Annals of Forest Science, 73, 857–869.

for the entire forest area (land remaining FL and conversion to FL). Dead wood stems are measured if their diameter is over 8 cm (stemwood has utilization value) or over 15 cm (stemwood has no utilization value). Stem biomass was expanded to the above-ground biomass assuming that branch biomass accounts for 16% of that of the stems[269]. Below-ground biomass was estimated using species-specific root to shoot ratios[270]. Dead wood volumes were converted to C stocks by using the dead wood densities and C contents by decay classes from Köster *et al*. 2015[271]. For dead wood with utilization value, the averages of decay classes 1–2 and for dead wood without utilization value the averages of decay classes 3–5 were applied (Table 6.8 and Table 6.9).

Table 6.8. Dead wood (DW) density by tree species and existence of utilization value, t m^{-3}

DW class	Pine	Spruce	Birch	Aspen	Grey Alder	Black Alder	Others
DW with utilization value	0.359	0.382	0.397	0.361	0.386	0.356	0.374
DW without utilization value	0.211	0.199	0.173	0.151	0.186	0.156	0.179

Table 6.9. Dead wood (DW) carbon fraction by tree species and existence of utilization value

DW class	Pine	Spruce	Birch	Aspen	Grey Alder	Black Alder	Others
DW with utilization value	0.491	0.483	0.474	0.473	0.480	0.481	0.481
DW without utilization value	0.498	0.496	0.488	0.468	0.482	0.482	0.486

Carbon stock change in the deadwood pool was calculated following Equation 6.3. The annual stock is first converted to stock per area, after which the equation can be applied in order not to confound the estimates of carbon stocks and stock changes due to differences in area.

Equation 6.3[272]

$$\Delta C_{DW} = A \times \frac{(DW_{t_2} - DW_{t_1})}{T}$$

Where:

ΔC_{DW} = annual change in carbon stocks in deadwood (DW), t C yr^{-1};
A = area of Forest land remaining forest land, ha;
DW_{t_1} = average dead wood C stock at t_1 for Forest land remaining forest land, t C ha^{-1};
DW_{t_2} = average dead wood C stock at t_2 (the previous time) for Forest land remaining forest land, t C ha^{-1}; and
T = (t_2-t_1) = time period between time of the second stock estimate and the first stock estimate, yr.

[269] Based on Estonian Wood Balance 2022, Table 3. [www] https://keskkonnaportaal.ee/sites/default/files/Teemad/Mets/Puidubilanss%202022.pdf (27.12.2024)
[270] Table A.V.4_9 in the Annex.
[271] Köster, K., Metslaid, M., Engelhart, J., Köster E. (2015). Deadwood basic density, and concentration of carbon and nitrogen for main tree species in managed hemiboreal forests. Forest Ecology and Management, 354, 35–42.
[272] After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.23, Equation 2.19.

According to the NFI on Land converted to forest land areas, dead wood stock was assumed to increase at rate of 0.045 m^3 ha^{-1} yr^{-1}. Dead wood volume was converted to C by applying average dead wood C stock/volume ratio from FL-FL (0.251 t C m^{-3}).

Figure 6.14 illustrates annual dead wood stock changes on Land remaining forest land and Land converted to forest land. Average dead wood volume for Forest land remaining forest land was calculated based on five-year measurements. For earlier years , for which the NFI measurements were not available, dead wood stocks were extrapolated using linear trends. The current NFI system assesses four types of dead wood: 1. standing dead wood with utilization value, 2. lying dead wood with utilization value, 3. standing dead wood without utilization value, 4. lying dead wood without utilization value. A comparable and consistent time series of these types of dead wood began in different years: type 1 in 2003, type 2 in 2013, type 3 in 2009 and type 4 in 2009. The dead wood carbon stock decreased in 2016–2020 due the increase in felling volume and thus increasing proportion of forest area belonging to the first development classes (treeless area, area under regeneration and young stands). In addition, dead wood is also removed from the forest during harvesting. The stumps and roots of harvested trees are immediately included in the emissions, as the pre-harvesting growing stocks on NFI plots that have been clear-felled have been converted to the whole-tree biomass, although the extraction of stumps with roots is not practiced in Estonia. Since 2021, C sequestration in dead wood pool has increased due to the higher mortality, as forest age structure is shifting toward mature forests, and the intensity of natural disturbances (like spruce bark beetle) is increasing.

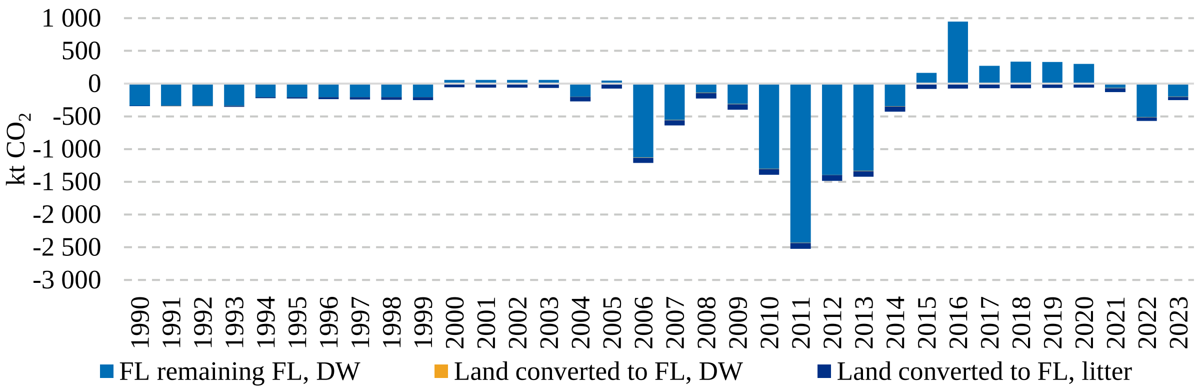

Figure 6.14. Net carbon stock change in forest dead wood and litter pools in 1990–2023, kt CO_2

Carbon stock change in litter

Estonia does not have sufficient data regarding litter stocks, thus under Forest land remaining forest land, the *Tier 1* method was implemented, assuming that carbon stocks are in equilibrium. Under Land converted to forest land, the emission factor from Sweden NIR[273] (0.25 t C ha^{-1} yr^{-1}) was used for litter. It was also possible to apply the Swedish EF for litter on Land remaining forest land, but it would have resulted in C sequestration in the pool. Therefore, Estonia decided to implement a more conservative approach, *i.e.*, *Tier 1*, assuming no change in the pool.

Carbon stock change in mineral soils

In Table 6.10, the cumulative areas and proportions of Land-use changes to Forest land in 2023 are shown, as well as applied emission factors for mineral and organic soils. In case of missing

[273] National Inventory Report Sweden 2024: Annexes, page 146, Table A3:2.14

or insufficient country-specific data, emission factors from the Sweden 2024 annual submission were implemented with the agreement of ERT[274].

Table 6.10. Cumulative Land-use changes to Forest land in 2023 and implemented soil emission factors

Land-use change	kha	%	EF mineral soil t C ha^{-1}	EF organic soil t C ha^{-1}
Cropland→ Forest land	9.85	17.2	0.18	-
Grassland→ Forest land	34.21	59.6	-0.12	-0.68
Wetlands→ Forest land	6.92	12.1	-	-0.68
Settlements→ Forest land	2.08	3.6	0.22	-0.68
Other land→ Forest land	4.31	7.5	0.22	-
Total	57.37	100.0		

Due to insufficient country-specific data regarding carbon stock changes in forest mineral soil, the emission factor from Sweden NIR[275] (0.22 t C ha^{-1} yr^{-1}) was implemented for Land remaining forest land and for Settlements and Other land converted to forest land subcategories (Table 6.10). Country-specific EFs were applied for Cropland and Grassland converted to Forest land. Changes in mineral soil SOC stocks due to land-use conversions were obtained from the literature (Kõlli et al. 2010) and divided by 20 years to find the annual C stock change. Emission factors were estimated separately for different soil types and the weighted average EF was calculated based on the distribution of soil types in previous land use (Kõlli et al. 2009). Implementation of emission factors from a neighbouring country is a temporary solution suggested by the ERT (FCCC/ARR/2012/EST para.94). Currently Estonia is working on developing *Tier 3* methods for reporting on Forest land litter and soil carbon stock changes (Chapter 6.4.6).

In 2023, there was a C uptake in forest mineral soils by -1 447.19 kt CO_2, of which -1 449.66 kt CO_2 was contributed by Forest land remaining forest land. Under the Land converted to forest land subcategory, net emissions were 2.47 kt CO_2. Overall, the annual carbon sequestration by forest mineral soils has remained at the same level compared to 1990 (Figure 6.15).

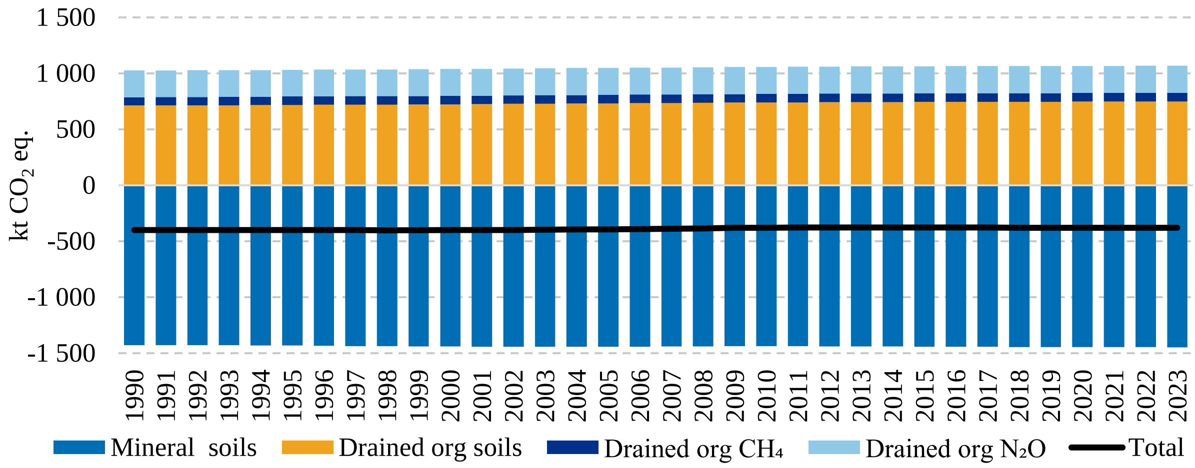

Figure 6.15. Annual stock change in Forest land mineral and drained organic soil pools including non-CO_2 emissions from drained soils in 1990–2023, kt CO_2 eq.

[274] FCCC/ARR/2012, para 94.
[275] The average implied emission factor of 1990–2022 in Sweden CRT 4.A tables, Sweden 2024 Submission.

Carbon stock change in drained organic soils

For undrained soils the 'organic' soil type is defined with an organic layer of more than 30 cm in depth and for drained soils more than 25 cm in depth. The soil is drained when the distance from the functioning drainage ditch is up to 100 m. Equation 6.4 was applied for estimating carbon loss from drained organic forest soils.

Equation 6.4[276]

$$L_{Organic} = A \times EF$$

Where:

$L_{Organic}$ =	annual carbon loss from drained organic soils, tonnes C yr^{1};
A =	area of drained organic soils, ha;
EF =	emission factor for CO_2 from drained organic soils, tonnes C ha^{-1} yr^{-1}

Equation 6.4 is also used for calculating emissions from organic forest soils after Land is converted to forest land.

The default emission factor for drained organic forest soils from the 2006 IPCC Guidelines[277] was applied according to the 2022 ERT recommendation[278].

Approximately 24.6% of all Estonian forest soils are organic soils, of which about 48.7% are drained according to the NFI. Emissions from drained organic forest soils have increased only by 0.01% since 1990 (Figure 6.15).

Non-CO_2 emissions from drained organic soils

Non-CO_2 emissions from drained organic soils depend on soil nutrient status. Forest land was divided into nutrient-rich and nutrient-poor areas based on site quality class (SQC). SQC I and II are categorized as nutrient-rich and III–V are categorized as nutrient-poor. Respective areas in 1990 and 2023 are presented in Table 6.11.

Equation 6.5 with factors from the IPCC 2013 Wetlands Supplement[279] (*Tier 1)* was applied for estimating CH_4 emissions from drained organic forest land and drainage ditches.

Equation 6.5[280]

$$CH_{4\_OS} = \sum_{n} A_n \times \left((1 - Frac_{ditch}) \times EF_{CH_4\_land_n} + Frac_{ditch} \times EF_{CH_4\_ditch} \right)$$

Where:

CH_{4_OS} =	annual CH_4 loss from drained organic forest soils, kg CH_4 yr^{-1};
A_n =	area of drained organic forest soils in nutrient status n, ha;
$EF_{CH_4\_land_n}$ =	emission factors for direct CH_4 emissions from drained organic forest soils by nutrient status n, kg CH_4 ha^{-1} yr^{-1} (Table 6.11);
$EF_{CH_4\ ditch}$ =	emission factor for CH_4 emissions from drainage ditches, kg CH_4 ha^{-1} yr^{-1} (Table 6.11);

[276] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.35, Equation 2.26.
[277] IPCC 2006 Guidelines, Volume 4, Chapter 4: Forest Land, page 4.53, Table 4.6 (Temperate).
[278] FCCC/ARR/2022/EST L.13.
[279] IPCC (2014b). 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (*IPCC 2013 Wetlands Supplement*).
[280] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.22, Equation 2.6.

$Frac_{ditch}$ = fraction of the total area of drained organic soils which is occupied by ditches (where "ditches" are any area of manmade channel cut into the peatland) (Table 6.11).

Equation 6.6 with default emission factors from the IPCC 2013 Wetlands supplement (*Tier 1*) was used for estimating N_2O emissions from drained organic forest land.

Equation 6.6[281]

$$N_2O_{OS} = \left[\left(A_{NR} \times EF_{N_2O-N,NR}\right) + \left(A_{NP} \times EF_{N_2O-N,NP}\right)\right] \times \frac{44}{28}$$

Where:

N_2O_{OS} = annual direct N_2O-N emissions from drained organic forest soils, kg N_2O yr^{-1};

A = area of drained organic forest soils, ha (the subscripts NR and NP refer to Nutrient-Rich and Nutrient-Poor, respectively);

EF_{N_2O-N} = emission factor for N_2O emissions from drained organic forest soils, kg N_2O-N ha^{-1} yr^{-1} (the subscripts NR and NP refer to Nutrient-Rich and Nutrient-Poor, respectively) (Table 6.11).

In 2023, non-CO_2 emissions from drained organic forest soils were equal to 319.72 kt CO_2 eq., which is 2.4% higher compared to the base year (Figure 6.15). Land converted to forest land emissions are included in Forest land remaining category (CRT Table 4(II).A.1).

Table 6.11. Areas of drained organic forest soils with different nutrient status and associated emission factors for non-CO_2 emissions

Nutrient status	Area 1990, kha	Area 2023, kha	Emission factors			$Frac_{ditch}$ [282]
			N_2O-N[283], kg N ha^{-1} yr^{-1}	CH_4 land[284], kg CH_4 ha^{-1} yr^{-1}	CH_4 ditch[296], kg CH_4 ha^{-1} yr^{-1}	
Nutrient-rich	170.08	173.41	3.2	2.0	217	0.025
Nutrient-poor	116.16	121.57	0.22	7.0		

6.4.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Forest land subcategory, please see Annex A.II.4 LULUCF, Forest land (4.A) chapter.

6.4.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the LULUCF sector according to the IPCC Tier 1 method. The activities are carried out every year during the inventory and the QC check list is used.

The new methodology for Forest land living biomass compared to the 2023 submission was evaluated by an external expert before the 2024 submission, when the gain-loss method was first applied. The assessment was made by Juha Heikkinen, Research Professor in statistical methods in Natural Resources Institute Finland (Luke). The assessment has been published[285]

[281] After IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.31, Equation 2.7.
[282] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.30, Table 2.4 (boreal).
[283] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.33, Table 2.5 (boreal).
[284] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.25, Table 2.3 (boreal).
[285] Heikkinen, J. (2023). Report for the 2023 Estonian national greenhouse gas inventory LULUCF (Land-use, land use change and forestry) sector forest land remaining forest land subcategory biomass pool. [www]

and stored in the archive. The methodology applied in the inventory has been supplemented with recommendations suggested in the report.

Country-specific emission factors for mineral soil under Land converted to forest land were compared to the values found in published studies. A large part of abandoned agricultural land in Estonia has been naturally afforested with silver birch. A study by Varik et al. (2015) found that in a 13-year-old silver birch stand growing on fertile former arable land, soil C exchange was in equilibrium, thus the soil C pool remained stable. However, in a young grey alder stand, which are also common on abandoned fields, the average C accumulation in the soil was 0.32 t C ha^{-1} $year^{-1}$ (Aosaar et al. 2013). Our emission factor for the CL to FL category falls between these values (Table 6.10) There is a lack of studies on grassland afforestation in Estonia, but Lutter et al. (2016) found a small decrease in the total SOC stock on grasslands converted to hybrid aspen plantations, which agrees with our emission factor for the GL to FL category.

6.4.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

The entire time series of activity data is annually recalculated for all areas of land categories and land-use conversions since new data about land-use transitions is collected every year and new estimates will be integrated into overall activity data. All area estimates are being re-estimated annually in the GHG inventory due to the method used by the NFI. Land use changes are calculated backwards from the latest year i.e. if the previous land use is obviously known on the permanent plots, then on the temporary plots the change of land use is indicated if it has occurred in the last five years. In addition, annual average C stock gains and losses in living biomass and average dead wood stocks in Forest land remaining forest land category were also updated.

Emissions from DOM have changed compared to the previous submission also because of changes methodology for estimating C stock changes in dead wood on Forest land remaining forest land (concerns the period 1990–2012) and updated EF for litter on Land converted to forest land areas (Table 6.12). In addition, EF for Forest land remaining forest land mineral soils has been updated, which has resulted in somewhat higher C sequestration.

Table 6.12. Quantitative overview of recalculations compared to the 31.12.2024 submission

		Forest land remaining forest land C stock change, kt				**Land converted to forest land** C stock change, kt				**Total net CO_2, kt**
		Living biomass	Dead organic matter	Mineral soils	Organic soils	Living biomass	Dead organic matter	Mineral soils	Organic soils	
1990	Previous submission	1 329.73	190.35	342.13	-189.16	1.74	0.55	0.10	NO	-6 142.94
	Current submission	1 329.67	92.49	388.87	-194.57	1.74	0.46	0.10	NO	-6 253.56
	Difference %	**-0.005**	**-51.4**	**13.6**	**2.9**	**NO**	**-16.0**	**-0.4**	**NO**	**1.8**
2005	Previous submission	600.05	158.16	340.71	-188.93	77.96	24.61	6.17	NO	-3 715.68
	Current submission	616.22	-13.07	387.26	-194.35	77.95	20.67	6.16	NO	-4 870.82

https://keskkonnaportaal.ee/et/kasvuhoonegaaside-lulucf-sektori-biomassi-tekke-kao-metoodika-analuus-2023-eng (27.12.2024).

		Forest land remaining forest land C stock change, kt				Land converted to forest land C stock change, kt				Total net CO_2, kt
		Living biomass	Dead organic matter	Mineral soils	Organic soils	Living biomass	Dead organic matter	Mineral soils	Organic soils	
	Difference %	**2.7**	**108.27**	**13.7**	**2.9**	**-0.005**	**-16.0**	**-0.2**	**NO**	**-31.1**
2020	Previous submission	-167.34	-81.08	346.13	-190.68	62.89	19.85	0.80	-7.80	63.17
	Current submission	-149.61	-82.58	393.45	-195.88	64.40	17.08	0.71	-7.89	-145.49
	Difference %	**-10.6**	**1.8**	**13.7**	**2.7**	**2.4**	**-14.0**	**-11.8**	**1.1**	**-330.3**
2021	Previous submission	-103.89	60.97	346.74	-190.9	59.78	18.87	0.29	-7.52	-675.74
	Current submission	-87.25	18.56	394.07	-196.11	62.11	16.47	0.16	7.67	-734.56
	Difference %	**-16.0**	**-69.6**	**13.7**	**2.7**	**3.9**	**-12.7**	**-45.2**	**2.0**	**8.7**
2022	Previous submission	101.49	132.23	347.33	-191.30	56.92	17.97	-0.14	-7.28	-1676.50
	Current submission	116.54	139.59	394.64	-196.44	60.03	15.92	-0.31	-7.49	-1915.76
	Difference %	**14.8**	**5.6**	**13.6**	**2.7**	**5.5**	**-11.4**	**121.1**	**2.9**	**14.3**

6.4.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

Estonia is working on specifying the estimates of land categories, which affects the whole LULUCF sector. First, the project by the University of Tartu aims to develop a new methodology for compiling annual land use change matrices (considering soil types and the presence of drainage). The methodology includes both land use change information of the NFI plots as well as their current land use status, i.e., land use change estimates are calibrated with information on the current situation. Second, as the transition period for conversions between land categories is 20 years, Estonia seeks to assess land use changes in the period 1970–1990 to refine the area estimates for 1990–2009.

Various remote sensing projects for forest resources have been launched with the purpose of annually calculating country-wide tree cover maps (tree species, growing stock, etc.). These maps will help to monitor annual tree cover gain and identify areas converted to other wooded land (grassland) or to forestland. Areas with tree cover loss can be identified and, in combination with our forest notice system, clear-cut and deforestation can be distinguished. Tree cover change will be monitored also in other wooded land where usually tree cover loss means land use changes to cropland.

Several completed, ongoing and planned NFI developments support more accurate estimates of annual biomass C stock changes, such as „Analysis of National Forest Inventory tract network and study related to calculation methods“ by the Institute of Mathematics and Statistic from University of Tartu, which ended in 2023. Follow-up project addresses the use of models and specification of error estimates. EstEA has also a consulting contract with the Estonian University of Life Sciences to develop different aspects of NFI (including NFI design and models used).

In 2024, a project for developing a governance system for land and soil management[286] was launched. The project aims to update and consolidate land use-related datasets and to develop higher tier methodologies for estimating SOC changes in all land-use categories. The project has already initiated the updating of the Estonian soil map (2024–2026). In 2025, a project was initiated with the goal of implementing Tier 3 methodology to assess GHG fluxes from mineral and organic forest soils.

Estonia has recently concluded a research project (conducted by University of Tartu) to specify the activity data and emissions from drainage diches in all land use categories: "Creation of a map layer of operational ditches and development of GHG emission factors for ditches (2021-2023)". The map layer of ditches is based mainly on the Estonian Topographic Database (ETAK) and supplemented on the basis of other public spatial data and digital elevation model. In addition, the actual condition and type of ditches will be assessed for a sample of diches during the fieldworks in order to refine the map layer through GIS analysis. Results will be evaluated and implemented in the GHG inventory.

Project "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland" (LIFE OrgBalt, LIFE18 CCM/LV/001158)[287] aims to improve the GHG accounting methods and activity data for nutrient-rich organic soils in the temperate cool & moist climate region. GHG emissions from nutrient-poor drained organic forest soils are specified during the project "Assessment of emissions and carbon stock dynamics in Estonian drained organic forest soils in the national greenhouse gas inventory" led by the University of Tartu.

6.5. Cropland (CRT 4.B)

6.5.1. Category description

Total net emissions from croplands were 847.79 kt CO_2 eq. in 2023 (Figure 6.16). The Cropland category includes carbon stock changes in living biomass, dead organic matter, mineral and organic soils and N_2O emissions related to the land conversion to croplands (see Chapter 6.10). The highest CO_2 emissions result from the cultivation of organic soils, which has remained relatively stable since 1990. Inter-annual emission fluctuations in the Cropland category are mainly caused by the changes in the mineral soil C stocks.

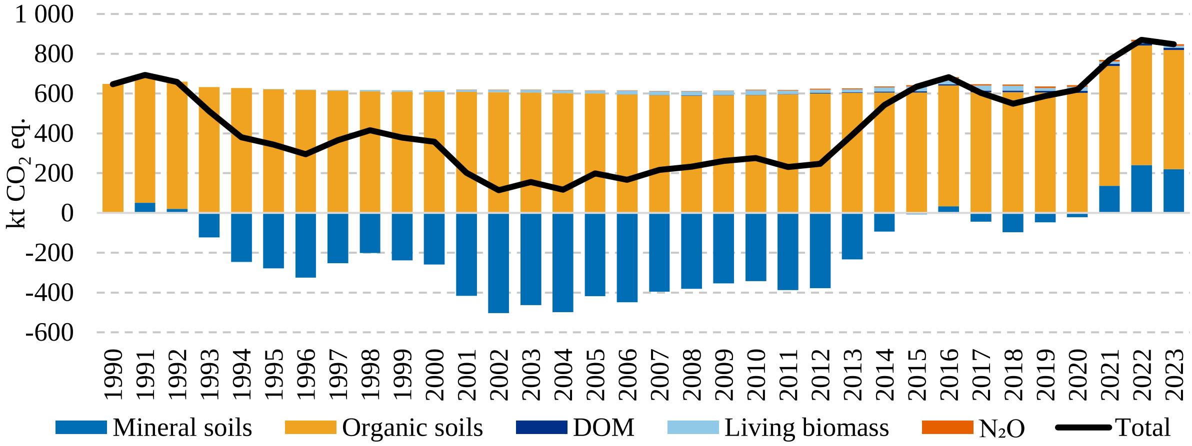

Figure 6.16. Annual GHG emissions (+) and removals (-) from the Cropland category in 1990–2023, kt CO_2 eq.

[286]Maa- ja mullakasutuse teadus-arendusprojekt. [www] https://keskkonnaportaal.ee/et/teemad/muld-ja-maahoive/maa-ja-mullakasutuse-teadus-arendusprojekt (29.11.2024).
[287] LIFE OrgBalt project. [www] https://www.orgbalt.eu/ (27.12.2024).

The area of Cropland category was 990.15 kha in 2023. From 1991, when Estonia regained its independence, until 2005, an overall decline characterised Estonia's agriculture, causing the decrease in the area of croplands (Figure 6.17). Arable lands were abandoned due to the reduced demand for local food products, which was caused by the availability of cheap import goods because of opened markets. Abandoned croplands are still classified as Cropland (as set-aside areas) until they have not lost arable land features, but significant part of cropland area has also been converted to grasslands due to the reduced need for arable land (Table 6.6). As from 2005, managing croplands has been on the rise again due to increased investments and subsidiaries from the European Union to Estonia's agricultural sector, expansion of export opportunities and popularization of organic farming. Despite that, the area of Land converted to cropland is very small compared to the total Cropland area (Table 6.18). Conversions to cropland occur mainly from the Grassland category.

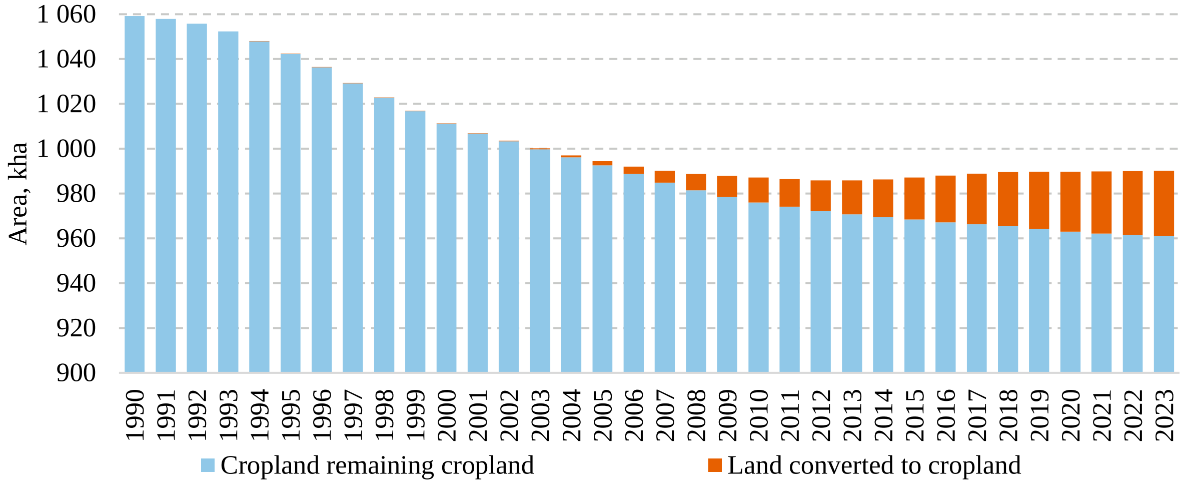

Figure 6.17. Cropland area in Estonia in 1990–2023, kha

6.5.2. Methodological issues

Carbon stock change in living biomass

The biomass of perennial woody crops was estimated based on measurements conducted in main market gardens and privately owned orchards in Estonia. Fieldwork included determining tree species, age, density per area and measuring individual tree components: tree height, diameter at different heights, height up to the crown and crown length. The measured variables were used as input data in the biomass function for birch (Repola et al. 2007[288]), which was implemented to estimate the average above-ground, below-ground and total biomass of orchards. The results are shown in Table 6.13.

Table 6.13. Average biomass stock in cropland orchards[289]

Biomass C pool	**Living biomass stock, t d.m. ha^{-1}**	
	Average	**Uncertainty range**
Total biomass	20.68	17.4….32.7
Above-ground	16.60	13.6…28.5
Below-ground	4.07	2.9…6.1

[288] Repola. J, Ojansuu, R., Kukkola, M. (2007). Biomass functions for Scots pine, Norway spruce and birch in Finland. Working Papers of the Finnish Forest Research Institute, 53.
[289] Metsaruum OÜ (2012). Põllumajandusmaadel kasvava puitse biomassi määramine. Report, unpublished.

The annual change in the biomass of perennial woody crops was calculated based on the inter-annual changes in the area of orchards (Equation 6.7, *Tier 2*).

Equation 6.7

$$\Delta C_{LB} = B_{total} \times \left(A_{t_2} - A_{t_1}\right) \times CF$$

Where:

ΔC_{LB} = annual change in living biomass (LB) carbon stock under the Cropland remaining cropland subcategory, tonnes C yr^{-1};
B_{total} = total average biomass stock of orchards, t d.m ha^{-1} (Table 6.13)
A_{t_1} = orchards area in the previous year, ha;
A_{t_2} = orchards area in the current year, ha; and
CF = carbon fraction of dry matter (default = 0.47), tonnes C (tonne d.m.)$^{-1}$.

The area of orchards was obtained from Statistics Estonia. Data were smoothed due to high variability. The area of orchards has declined from 9 198 ha in 1990 to 1 380 ha in 2023 (Figure 6.18), thus the carbon stocks have generally also decreased. In 2022, there was no change in the orchards' biomass C stock as their area remained the same as in 2021. In 2023, however, there was a slight increase the orchards' area and biomass C stock.

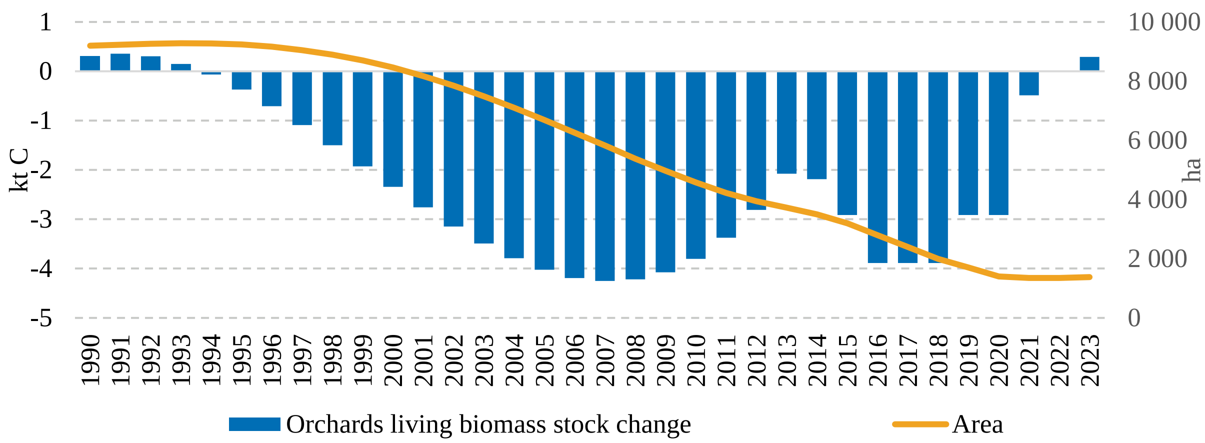

Figure 6.18. Area (ha) and annual change in the C stocks of cropland perennial woody crops (orchards)

When Forest land and Grassland are converted to cropland, biomass losses occur in the year of transition. These carbon losses were estimated according to Equation 6.8.

Equation 6.8[290]

$$\Delta C_{CONVERSION} = \sum_i \left(C_{AFTER_i} - C_{BEFORE_i}\right) \times \Delta A_{TO\_OTHERS_i}$$

Where:

$\Delta C_{CONVERSION}$ = initial change in biomass carbon stocks on land converted to another land category;
C_{AFTER_i} = C stocks on land type *i* immediately after the conversion, t C ha^{-1};

[290] After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.20, Equation 2.16.

C_{BEFORE_i} = biomass stocks on land type *i* before the conversion, t C ha^{-1};
$\Delta A_{TO\_OTHERS_i}$= area of land use *i* converted to another land-use category in a certain year, ha; and
i = type of land use converted to another land-use category.

C_{AFTER} - C_{BEFORE} values were estimated for Forest land and Grassland converted to cropland categories as average initial C stocks in NFI plots, where such conversions have occurred (Table 6.14). Calculation of living biomass C stocks on NFI plots is described in Chapter 6.4.2. Conversions from other categories to croplands were expected to increase living biomass C pool from zero to the average C stock of crops. Annual average C stocks for each crop were calculated based on average yields using the same yield-to- biomass ratios, and humidity and C contents as in Kauer et al. (2022)[291]. For each year, a weighted average biomass C stock was calculated on the basis of crop areas. Overall average for the period 2004–2023 was applied in calculations (Table 6.14). Crop yield and area data were obtained from Statistics Estonia [292].

Table 6.14. Average living biomass and dead wood C stock changes after conversion to croplands, t C ha^{-1}

C pool	Forest land converted to cropland	Grassland converted to cropland	Wetlands and settlements converted to cropland
Living biomass	-16.08	-0.13	3.29
Dead wood	-1.25	0	0

Carbon stock change in dead organic matter

Dead organic matter (DOM) C pool comprises deadwood and litter pools. C stock change in DOM under the Cropland remaining cropland subcategory was not estimated and reported as "NE". Small changes in DOM pool occur due to removal or establishment of orchards, but these emissions or removals would be insignificant in terms of the overall level and trend in national emissions (as are changes in orchards' living biomass).

Under the Land converted to cropland subcategory, the loss of dead wood was estimated for Forest land and Grassland converted to cropland using the *Tier 3* method and Equation 6.8, where C_{BEFORE_i} is the average dead wood C stock before and C_{AFTER_i} after the conversion (equal to zero in Cropland). C_{BEFORE} values were estimated for Forest land and Grassland converted to cropland categories as average C stocks in NFI plots, where such conversions have occurred (Table 6.14). Calculation of dead wood C stocks on NFI plots is described in Chapter 6.4.2.

C stock reductions in litter pool were estimated only for conversion from Forest land to cropland. Since Estonia does not have sufficient country-specific data regarding forest litter stocks, the emission factor from Sweden (Table 6.18) was used. The average litter C stock in Sweden (25 t C ha^{-1}) was estimated based on the samples taken from the O or H horizons[293] and

[291] Kauer, K. et al. (2022). Mineraalmuldadel asuvatel põllumajandusmaade mulla orgaanilise süsiniku varu muutuse hindamine simulatsioonimudeliga. Lõpparuanne. [Assessment of SOC change in agricultural mineral soils using a simulation model.] Final report. [www] https://klab.ee/wp-content/uploads/2023/03/Lopparunne_EMU_loplik.pdf (20.12.2024).
[292] PM0281: Agricultural land and crops by county. Statistical database, Statistics Estonia. [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__taimekasvatussaaduste-tootmine/PM0281 (20.12.2024).
[293] National Inventory Report Sweden 2024. Annex 3:2: Land Use, Land-Use Change and Forestry (CRF sector 4)

is similar to the Estonian value (Kõlli et al. 2004)[294]. It was assumed, that the litter layer will decompose during 20 years after forest land conversion to cropland.

Carbon stock change in mineral soils

The *Tier 2* method and Equation 6.9 were applied to estimate changes in soil organic carbon stocks in Cropland remaining cropland mineral soils. Only aggregate land use and cropland management data were available. First, croplands were divided into long-term cultivated, perennial (orchards) and set aside areas. The areas of long-term cultivated lands and orchards were obtained from Statistics Estonia. As definitions for arable lands and methods for data gathering have changed during the inventory period, the estimation of long-term cultivated areas for 1990−2002 is based on the interpolated data. The remaining area of croplands was assumed to be out of active use or under permanent cultural grasslands that are also considered as set aside areas in calculations.

Equation 6.9

$$\Delta C_{Mineral} = \frac{\left(SOC_0 - SOC_{(0-T)}\right)}{D}$$

where

$$SOC = \frac{\sum_i \left(SOC_{REF} \times F_{LU_i} \times F_{MG_i} \times F_{I_i} \times A_i\right)}{A_{Mineral}}$$

Where:

$\Delta C_{Mineral}$ =	annual change in carbon stocks in mineral soils, tonnes C yr^{-1};
SOC_0 =	soil organic carbon stock in the last year of an inventory time period, tonnes C ha^{-1};
SOC_{0-T} =	soil organic carbon stock at the beginning of the inventory time period, tonnes C ha^{-1};
D =	default time period (20 years) for transition between equilibrium SOC values;
$A_{Mineral}$ =	the area of Cropland on mineral soil, ha;
$A_{Mineral_0}$ =	the area of Cropland on mineral soil in the last year of the inventory period, ha;
SOC_{REF} =	the reference carbon stock, tonnes C ha^{-1} (Table 6.17);
F_{LU} / F_{MG} / F_I =	stock change factors for land-use systems/ management regime/ input of organic matter, dimensionless (Table 6.17);
A =	land area of the stratum being estimated, ha; and
i =	set of management systems.

Based on the expert judgement from the Centre of Estonian Rural Research and Knowledge (former Agricultural Research Centre), cultivation of multiannual forage crops was assumed to have high C input, and areas under bare fallow, vegetables, potatoes, and fodder roots low input; the remaining crops had medium input. The shares of areas with different input regimes were acquired from Statistics Estonia and Agricultural Registers and Information Board, but due to the lack of data, it was not possible to identify the land category 'high input with manure'. Areas with different land use and input regimes within the Cropland remaining cropland category are presented in Table 6.15 and their relative shares in Figure 6.19.

[294] Kõlli, R., Asi, E., Köster, T. (2004). Organic carbon pools in Estonian forest soils. Baltic Forestry 10, 19–26.

Table 6.15. Areas with different land use and input regimes on mineral soils within the Cropland remaining cropland category in 1990 and 2023

Land use	Area in 1990, kha	Area in 2023, kha
Long-term cultivated	891.92	651.22
High input	405.83	128.91
Medium input	419.20	515.49
Low input	66.89	6.81
Perennial	9.20	1.38
Set aside	122.77	277.44
Total CL rem CL, mineral soil	1 023.90	930.04

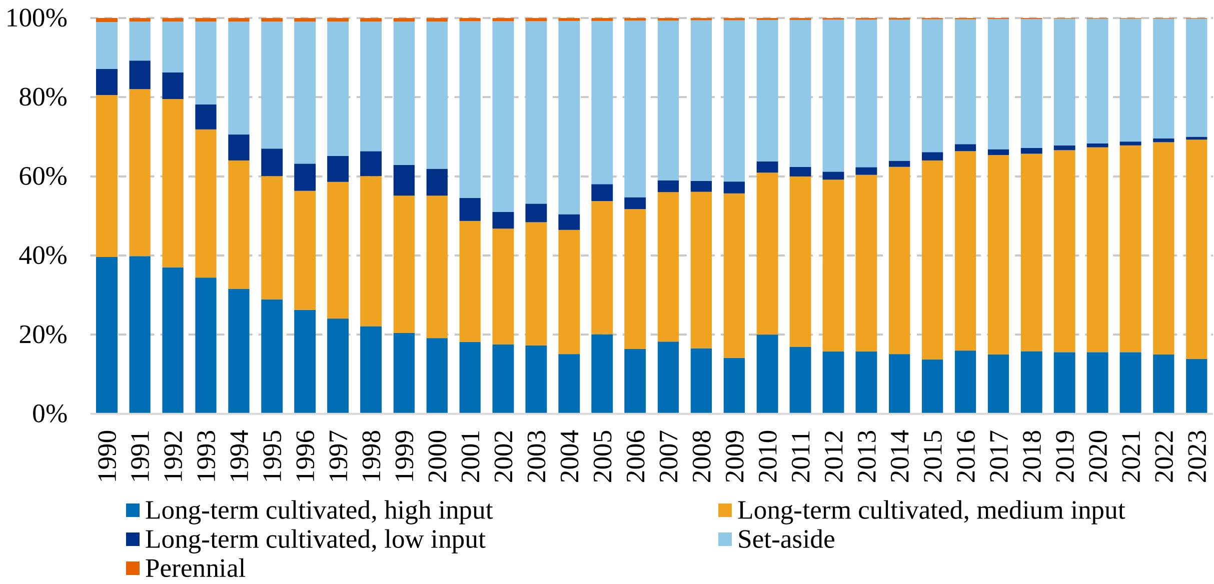

Figure 6.19. Relative shares of areas with different land use and input regimes within the Cropland remaining cropland category (mineral soils) in 1990–2023, %

Table 6.16 shows the share of different cropland tillage practices in Estonia. According to the observations of the Centre of Estonian Rural Research and Knowledge (former Estonian Crop Research Institute), traditional tillage was prevailing practice until 1999. Farm structure surveys (FSS)[295] that also included information about tillage practices, were carried out in Estonia in 2010, 2016 and 2023 by Statistics Estonia. Shares of different tillage practices for the period 2000–2009, 2011–2015 and 2017–2022 were interpolated linearly.

Table 6.16. Proportions of different tillage practices in crop lands and related stock change factors (F_{MG})

Tillage practice	Full tillage	Reduced tillage	No-till
Proportion of cropland area 1990–1999[296]	1.00	0	0
Proportion of cropland area 2010[297]	0.73	0.18	0.09

[295] Glossary: Farm structure survey (FSS). [www] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Farm_structure_survey_(FSS) (19.12.2024).
[296] Expert judgement by the Centre of Estonian Rural Research and Knowledge (former Estonian Crop Research Institute) (documented in archive).
[297] PMS602: Tillage by legal form of holder and tillage method. Statistical database, Statistics Estonia. [www] https://andmed.stat.ee/en/stat/Lepetatud_tabelid__Majandus.%20Arhiiv__Pellumajandus.%20Arhiiv__pellumajanduse-struktuuriuuringud_2001-2016__tootmismeetodid/PMS602 (19.12.2024).

Tillage practice	Full tillage	Reduced tillage	No-till
Proportion of cropland area 2016[297]	0.54	0.33	0.13
Proportion of cropland area 2023[298]	0.37	0.56	0.08
F_{MG}[299]	1.00	1.04	1.09

From the 2024 submission, Estonia uses updated default stock change factors for land use (F_{LU}), input (F_I) and management (F_{MG}) from the 2019 Refinement to the 2006 IPCC Guidelines. In Estonian conditions, changes in F_{MG} values have the most important effect, as the impact of reduced tillage and no-till practices significantly decreases compared to the 2006 IPCC Guidelines. This is in line with the study conducted in Estonia by Putku and Penu (2018)[300] which found no statistical differences in the SOC stocks of the 0–25 cm soil layer between conventional and no-till practices.

When using default stock change factors, management practices are expected to influence soil C stocks to a depth of 30 cm; therefore, SOC_{REF} was estimated based on the measured SOC stocks in the humus cover of Estonian arable soils (Kõlli et al. 2009). The mean thickness of the humus cover in mineral arable land varied from 18 to 29 cm depending on the soil type (Kõlli & Ellermäe 2003[301]), and its measured area weighted mean SOC stock (67.85 t C ha^{-1}) was assumed to refer to the mean SOC stock of the long-term cultivated areas with medium input in 1990 (Table 6.17).

Table 6.17. Stock change factors, SOC_{REF} and estimated SOC stocks for different management categories in Cropland

Land use	**Stock change factors[302]**			**SOC_{REF} t C ha^{-1}**	**IPCC 2006 default SOC_{REF}[303], t C ha^{-1}**	**Average SOC stocks, t C ha^{-1}**	
	F_{LU}	**F_{MG}**	**F_I**			**1990**	**2023**
Long-term cultivated							
High input	0.70	1–1.03	1.11	96.93	93.30	75.32	77.50
Medium input	0.70	1–1.03	1.0			67.85	69.82
Low input	0.70	1–1.03	0.92			62.42	64.23
Perennial	0.72					69.79	69.79
Set aside	0.82					79.48	79.48

Changes in mineral soil SOC stocks due to land-use conversions from Forest land and Grassland to cropland were obtained from the literature (Kõlli et al. 2010) and divided by 20 years to find the annual C stock change. Emission factors were estimated separately for different soil types

[298] PMS649: Soil management practices on outdoor arable land by type. Statistical database, Statistics Estonia. [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajanduslike-majapidamiste-struktuur__tootmismeetodid/PMS649 (28.11.2024).

[299] IPCC 2019 Refinement, Volume 4, Chapter 5: Cropland, page 5.27, Table 5.5 (Temperate/Boreal, moist).

[300] Putku, E., Penu, P. 2018. The status of soil organic carbon in no-till and conventional tillage fields. *In:* Alaru, M. (ed.) Agronomy 2018. Tartu: Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Estonian Crop Research Institute, pp. 15–21.

[301] Kõlli, E., Ellermäe, O. (2003). Humus status of postlithogenic arable mineral soils. Agronomy Research, 1, 161–174.

[302] IPCC 2019 Refinement, Volume 4, Chapter 5: Cropland, page 5.27, Table 5.5 (Temperate/Boreal, moist).; Annual F_{MG} values are calculated based on the proportion of tillage practices and updated default F_{MG} factors (Table 6.16).

[303] IPCC 2006 Guidelines, Volume 4, Chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories, page 2.31, Table 2.3 (Cold temperate, moist).

and the weighted average EF was calculated based on the distribution of soil types in previous land use (data from Kõlli et al. 2009). For Settlements converted to cropland subcategory, 2004–2023 average implied emission factor for Cropland remaining cropland was applied. EFs for mineral and organic soil are presented in Table 6.18.

Table 6.18. Cumulative land-use changes to Cropland in 2023 and soil emission factors

Land-use category	**Area, kha**	**%**	**EF mineral soil, t C ha^{-1} yr^{-1}**	**EF organic soil[304], t C ha^{-1} yr^{-1}**	**EF litter[305], t C ha^{-1} yr^{-1}**
Cropland remaining cropland	961.15	-	-0.038[306]	-5.0	-
Forest land→ Cropland	2.40	8.3	-0.930	-	-1.25
Grassland→ Cropland	26.39	91.0	-0.904	-5.0	NA
Wetlands→ Cropland	NO	-	-	-5.0	NA
Settlements→ Cropland	0.20	0.7	0.065[307]	-	NA
Total Land to cropland	29.00	100.0			

It was assumed that the mineral soil C pool was in balance in 1990, *i.e.*, no changes in land use or management occurred during 20 years prior to 1990. This is a valid assumption since the management of agricultural lands was relatively stable in this period. Cropland SOC stock started to increase after the collapse of the Soviet Union in 1991 (Figure 6.16) when a significant part of agricultural land was abandoned. Since accession to the European Union in 2004, the share of cultivated areas has been growing (Figure 6.19) and the average SOC stock is on a declining trend. However, mineral soils on arable land continued to sequester carbon until 2020 due to changes in management practices.

Carbon stock change in drained organic soils

All croplands on organic soil are considered drained in Estonia. The *Tier 1* method and was applied to estimate CO_2 emissions from cultivated organic soils, both for the Cropland remaining cropland and Land converted to cropland subcategories. The default emission factor from the 2006 IPCC Guidelines (Table 6.18) was implemented due to the lack of country-specific data.

Emissions from organic soils have been relatively stable over the years (Figure 6.16) since the area of cultivated organic soils has not changed considerably (35.32 kha in 1990 to 32.71 kha in 2023).

6.5.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Cropland subcategory, please see Annex A.II.4 LULUCF, Cropland (4.B) chapter.

6.5.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5. The QC/QA plan for the LULUCF sector includes the QC activities described in the 2006 IPCC Guidelines Volume 1, Chapter 6. The activities are carried out every year during the inventory. The QC checklist is used during the inventory.

[304] IPCC 2006 Guidelines, Volume 4, Chapter 5: Cropland, page 5.19, Table 5.6 (Boreal/Cool Temperate).
[305] National Inventory Report Sweden 2024: Annexes, page 146, Table A3:2.14.
[306] Implied emission factor (IEF) in 2023, varies between years.
[307] 2004–2023 average IEF for Cropland remaining cropland, mineral soils.

Country-specific cropland reference soil organic carbon stock (SOC_{REF}) for mineral soil was compared with the estimate following the IPCC 2006 methodology for verification purposes (Table 6.17). The estimate that Cropland mineral soils have mostly been C sinks since 1990 is supported by the study by Tammik et al. 2018[308]. They found that the average mineral soil SOC stock in soil monitoring fields (mainly under cereal-based crop rotations) has increased since the beginning of soil monitoring (1983–1986) from 64.6 t ha^{-1} to 77.6 t ha^{-1}.

6.5.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

A quantitative overview of recalculations is shown in Table 6.19, except for recalculations of N_2O emissions which are presented in Chapter 6.10.5. The entire time series of activity data are annually recalculated for all areas of land categories and land-use conversions since new data about land-use transitions is collected every year and new estimates are integrated into overall activity data. In addition, average C stock losses in living biomass and dead wood after land use change from Forest land and Grassland to Cropland category were also updated. In the 2025 submission, C stock gains in biomass due to land conversion to croplands were estimated for the first time. SOC changes in mineral soils on Cropland remaining cropland have been recalculated for the period 2017–2022 due to new data about tillage practices in 2023 (see Chapter 6.5.2). On deforested areas, updated emission factors for litter were applied.

Table 6.19. Quantitative overview of recalculations compared to the 31.12.2024 submission

		Cropland remaining cropland C stock change, kt			**Land converted to cropland** C stock change, kt				**Total net CO_2, kt**
		Living biomass	Mineral soils	Organic soils	Living biomass	DOM	Mineral soils	Organic soils	
1990	Previous submission	0.31	NO	-164.87	NO	NO	NO	NO	603.38
	Current submission	0.31	NO	-176.59	NO	NO	NO	NO	646.36
	Difference %	**NO**	**-**	**7.1**	**-**	**-**	**-**	**-**	**7.1**
2005	Previous submission	-4.02	115.17	-150.88	-0.05	NO	-1.48	-1.03	155.06
	Current submission	-4.02	115.39	-162.60	-0.14	NO	-1.48	-1.03	197.55
	Difference %	**NO**	**0.2**	**7.8**	**187.0**	**-**	**NO**	**NO**	**27.4**
2020	Previous submission	-2.92	23.75	-145.74	-1.63	-2.86	-22.15	-7.98	584.90
	Current submission	-2.92	28.66	-156.81	-2.72	-2.58	-22.62	-7.98	612.14
	Difference %	**NO**	**20.7**	**7.6**	**67.1**	**-9.8**	**2.1**	**NO**	**4.7**
2021	Previous submission	-0.49	-19.99	-145.59	-1.62	-3.00	-22.75	-7.98	738.50
	Current submission	-0.49	-13.75	-156.34	-2.70	-2.79	-23.49	-7.98	760.94
	Difference %	**NO**	**-31.2**	**7.4**	**66.7**	**-6.9**	**3.3**	**NO**	**3.0**
2022	Previous submission	NO	-49.00	-145.43	-1.61	-3.14	-23.14	-7.98	844.41
	Current submission	NO	-41.35	-155.88	-2.67	-3.00	-24.15	-7.98	861.73
	Difference %	**NO**	**-15.6**	**7.2**	**65.8**	**-4.3**	**4.4**	**NO**	**2.1**

[308] Tammik, K., Kauer, K., Astover, A., Penu. P. (2018). The dynamics of organic carbon stock in Estonian arable soils 1989–2016. *In:* Alaru, M. (ed.) Agronomy 2018. Tartu: Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Estonian Crop Research Institute, pp. 30–35.

6.5.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

Estonia is working on specifying the estimates of land categories. First, the project by the University of Tartu aims to develop a new methodology for compiling annual land use change matrices (considering soil types and the presence of drainage). The methodology includes both land use change information of the NFI plots as well as their current land use status, i.e., land use change estimates are calibrated with information on the current situation. Second, as the transition period for conversions between land categories is 20 years, Estonia seeks to assess land use changes in the period 1970–1990 to refine the area estimates for 1990–2009.

In 2024, a project for developing a governance system for land and soil management[309] was launched. The project aims to update and consolidate land use-related datasets and to develop higher tier methodologies for estimating SOC changes in all land-use categories. The project has already initiated the updating of the Estonian soil map (2024–2026). In 2025, a project was initiated with the goal of implementing Tier 3 methodology in the cropland and grassland categories to assess changes in carbon stocks and GHG fluxes in mineral and organic soils.

Two research projects have recently concluded: "Creation of a map layer of operational ditches and development of GHG emission factors for ditches", and "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland" (LIFE OrgBalt, LIFE18 CCM/LV/001158). Both projects aim to improve the GHG accounting methods and activity data for organic soils. Results will be evaluated and implemented in the GHG inventory.

6.6. Grassland (CRT 4.C)

6.6.1. Category description

The Grassland category includes CO_2 emissions and removals from living biomass, dead wood, mineral and organic soils, and non-CO_2 emissions from biomass burning (see Chapter 6.11). Net emissions from Grassland were -175.41 kt CO_2 eq. in 2023 (Figure 6.20). The Grassland category has been a CO_2 sink since 1990, mainly due to C sequestration in living biomass in Grassland remaining grassland areas and to mineral soils after land-use change to grasslands.

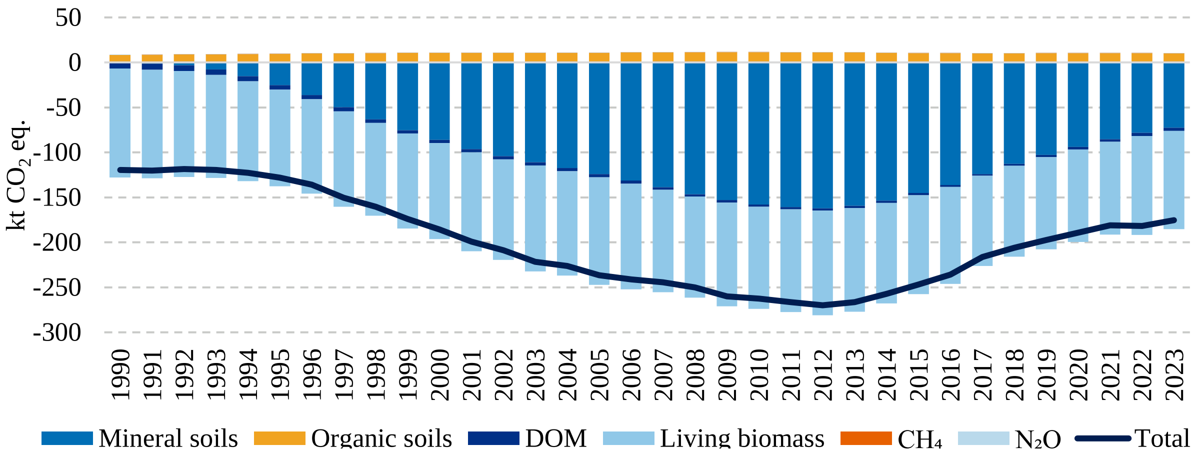

Figure 6.20. Annual GHG emissions (+) and removals (-) from the Grassland category in 1990−2023, kt CO_2 eq.

[309]Maa- ja mullakasutuse teadus-arendusprojekt. [www] https://keskkonnaportaal.ee/et/teemad/muld-ja-maahoive/maa-ja-mullakasutuse-teadus-arendusprojekt (29.11.2024).

The area of the Grassland category in 2023 was 270.78 kha, which constituted 6.0% of the overall Estonia's land area. The area of grasslands has decreased by 10.0% compared to the 1990 initial area (Table 6.6, Figure 6.21). These changes result mostly from the reallocation of grasslands to the Forest land category as their growing stock increases and the tree crown cover begins to meet the Forest land definition. The area of grasslands category has mainly increased at the expense of croplands; the change in land use from Grassland to Cropland has been significantly smaller than the reverse process.

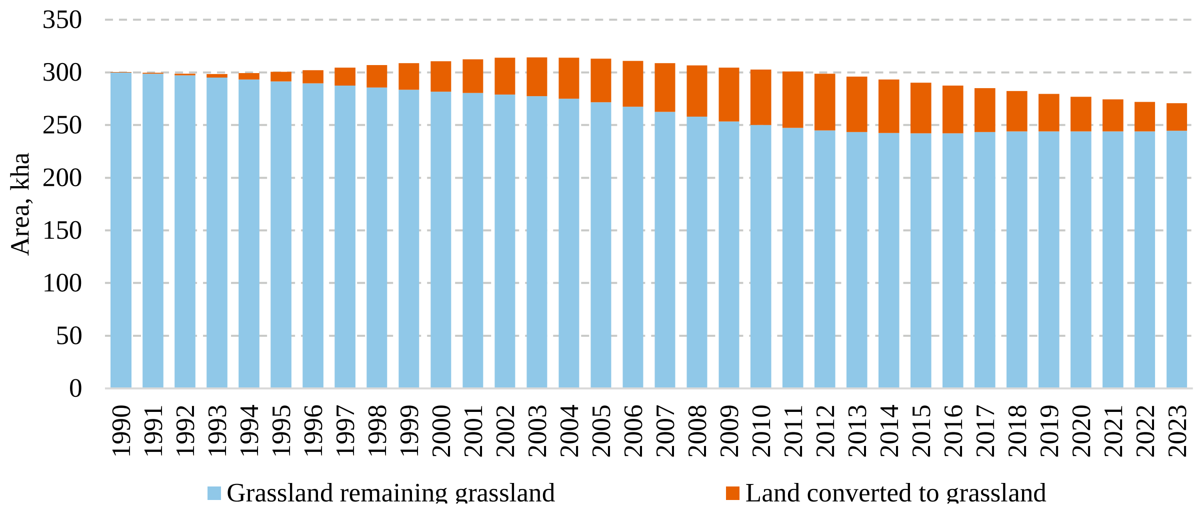

Figure 6.21. Grassland area in Estonia in 1990–2023, kha

6.6.2. Methodological issues

Living biomass

For the Grassland remaining grassland category, C stock changes in the living biomass were calculated for all NFI permanent plots that have remained under Grassland category between two consecutive NFI visits using the stock-difference method (Equation 6.10, *Tier 3*):

Equation 6.10[310]

$$\Delta C = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

Where:

ΔC = annual carbon stock change in the pool, tonnes C yr^{-1};
C_{t_1} = carbon stock in the pool at time t_1, tonnes C; and
C_{t_2} = carbon stock in the pool at time t_2, tonnes C.

Calculation of living biomass C stocks in NFI plots is described in Chapter 6.4.2.

Average annual C stock change per hectare (Table 6.20) was multiplied by the area of Grassland remaining grassland category to estimate the total C stock change in living biomass for the category.

[310] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.10, Equation 2.5.

The stock-difference method also comprises carbon loss from biomass burning, thus CO_2 emissions from burning are not presented separately, but included in general carbon stock change figures.

On land converted to grasslands, changes in carbon stock are calculated as a sum of increase in carbon stock due to biomass growth and changes due to actual conversion (Equation 6.11). Only the change in woody biomass was considered.

Equation 6.11[311]

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION}$$

Where:

ΔC_B = annual change in carbon stocks in biomass on land converted to other land-use category, tonnes C yr^{-1};

ΔC_G = annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, tonnes C; and

$\Delta C_{CONVERSION}$ = initial change in carbon stocks in biomass on land converted to other land-use category, tonnes C.

$\Delta C_{CONVERSION}$ is relevant only for the Forest land converted to grassland subcategory. C losses in biomass occur in the year of transition and are estimated according to Equation 6.8. C_{BEFORE} and C_{AFTER} values were estimated on permanent NFI plots, where conversion from Forest land to Grassland have taken place during the NFI cycle; average value (Table 6.20) is used in calculations. Other conversion types were assumed to have no change in biomass in the year of conversion. After the transition, growing stock was assumed to increase at a rate of 0.369 m^3 ha^{-1} yr^{-1}. Average growing stock and deadwood volume increase rates have been calculated based on all the NFI sample plots classified as Land converted to grassland. Growing stock was converted to C by applying the average woody biomass C stock/growing stock ratio estimated on Grassland remaining grassland plots (0.303 t C m^{-3}). Resulting value (Table 6.20) was multiplied by the area of each conversion type to estimate the total C stock change (ΔC_G) in living biomass for the respective subcategory.

Table 6.20. Average annual change in living biomass and dead wood C stocks in Grassland remaining grassland and Land converted to grassland categories, t C $ha^{-1}yr^{-1}$

C pool	**Grassland remaining grassland**	**Forest land converted to grassland ($\Delta C_{CONVERSION}$ ha^{-1})**	**Land converted to grassland (ΔC_G ha^{-1})**
Living biomass	0.110	-9.387	0.112
Dead wood	0.006	-0.708	0.004

Figure 6.22 illustrates annual changes in the living biomass carbon pool on Grassland remaining grassland and Land converted to grassland subcategories. Small emissions due to land-use change arise from deforestation (Forest land converted to grassland), but in most years the increase in biomass after the change in land use exceeds biomass losses.

311 After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.20, Equation 2.15.

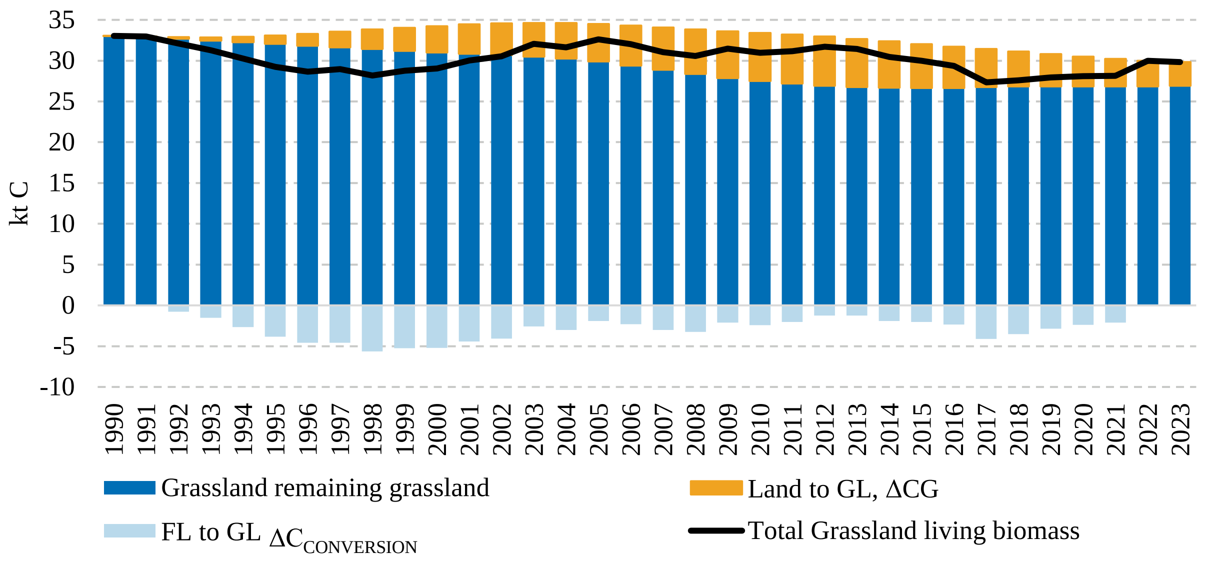

Figure 6.22. Carbon stock changes in Grassland living biomass in 1990–2023, kt C

Dead organic matter

The DOM pool consists of dead wood and litter pools. Changes in the dead wood C stocks on grasslands were estimated using the same methods and equations as for the living biomass. Calculation of dead wood C stocks on NFI plots is described in Chapter 6.4.2. Table 6.20 shows average changes in C stocks on Grassland remaining grassland, $\Delta C_{CONVERSION}$ on Forest land converted to grassland and ΔC_G on Land converted to grassland areas. ΔC_G is a product of the annual dead wood volume increase after land transition (0.017 m^3 ha^{-1} yr^{-1}) and the average dead wood C stock/dead wood volume ratio on GL-GL plots (0.249 t C m^{-3}).

Estonia does not have sufficient country-specific data regarding forest and grassland litter stocks; thus, it was assumed that on Grassland remaining grassland areas the litter C stocks are in equilibrium (*Tier 1* method). For the Land converted to grassland subcategory, the UNFCCC in-country review (2012) recommended the use of the litter emission factor from Sweden (Table 6.21) to avoid underestimation of emissions from deforestation. The average litter C stock in Sweden (25 t C ha^{-1}) was estimated based on the samples taken from the O or H horizons and is similar to the Estonian value (Kõlli et al. 2004). It was assumed, that 10% of the litter layer will decompose during 20 years after forest land conversion to grassland.

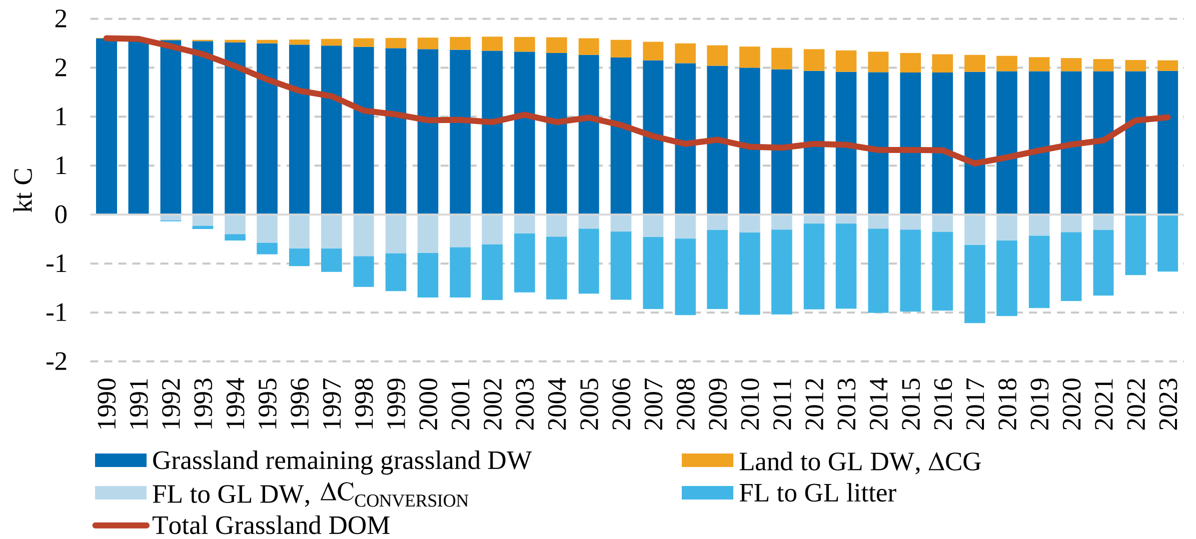

Figure 6.23. Carbon stock changes in Grassland dead wood (DW) and litter in 1990–2023, kt C

As can be seen from Figure 6.23, C sequestration in the dead wood exceed DOM losses due deforestation and in total, Grassland dead organic matter pool has been a small CO_2 sink.

Mineral soils

Changes in soil organic carbon stocks in Grassland remaining grassland mineral soils were estimated using Equation 6.9 (*Tier 2* method), where the reference C stock (SOC_{REF}) equaled 107.3 t C ha^{-1}, which is the average grassland mineral soil C stock in Estonia (Kõlli et al. 2007)[312]. Default stock change factors for land-use systems ($F_{LU;}$ F_{LU} = 1 for permanent grasslands), management regime (F_{MG}) and input of organic matter ($F_{I;}$ applies only to improved grassland) from the 2006 IPCC Guidelines[313] were applied in calculations. All grasslands were assumed to be nominally managed throughout the time series (F_{MG} = 1), since grasslands are not actively managed in Estonia, nor are additional inputs added to grassland soils. As a result, no changes have been reported in mineral soil C stocks on Grassland remaining grassland areas.

SOC changes for land conversion from Forest land and Cropland to grassland were calculated according to Equation 6.9 where changes in SOC stocks were obtained from the literature (Kõlli et al. 2010). Emission factors were estimated separately for different soil types and the weighted average EF was calculated based on the distribution of soil types in the original land use (from Kõlli et al. 2009). In case of other conversions on mineral soil, it is expected that soil C stocks are not reduced due to land use change, and as a conservative approach, the C stocks were assumed to remain stable (Table 6.21). Total C sequestration in grassland mineral soils can be seen in Figure 6.24.

Table 6.21. Cumulative land-use changes to Grassland in 2023, soil and litter emission factors

Land-use category	**Area, kha**	**%**	**EF mineral soil, t C ha^{-1} yr^{-1}**	**EF organic soil[314], t C ha^{-1} yr^{-1}**	**EF litter, t C ha^{-1} yr^{-1}**
Grassland remaining grassland	244.71	-	-	-0.25	-
Forest land→ Grassland	4.66	17.9	0.159	-0.25	-0.125[315]
Cropland→ Grassland	19.21	73.7	1.080	-0.25	NA
Wetlands→ Grassland	0.32	1.2	No emissions, soil C is not considered lost after LUC to Grassland	-0.25	NA
Settlements→ Grassland	0.46	1.8		NA	NA
Other land→ Grassland	1.43	5.5		NA	NA
Total Land to grassland	26.08	100.0			

CO_2 emissions from drained organic soils

The *Tier 1* method and were implemented to estimate the loss of carbon from drained organic grassland soils. The default emission factor from the 2006 IPCC Guidelines (Table 6.21) was applied due to the lack of country-specific data.

Total area of grassland organic soils and the sub-area of drained soils were obtained from the NFI database. The proportion of drained organic soils from the total organic soil area has varied

[312] Kõlli, R., Köster, T., Kauer, K. (2007). Organic matter of Estonian grassland soils. Agronomy Research 5, 109–122.
[313] IPCC 2006 Guidelines, Volume 4, Chapter 6: Grassland, page 6.16, Table 6.2 (Temperate/Boreal).
[314] IPCC 2006 Guidelines, Volume 4, Chapter 6: Grassland, page 6.17, Table 6.3 (Boreal/Cold Temperate)
[315] National Inventory Report Sweden 2024: Annexes, pages 144–145.

from 15.4–17.8% in the Grassland remaining grassland subcategory during 1990–2023. All organic soils falling under Land converted to grassland are considered drained in calculations.

Emissions from grassland organic soils have increased by 18.2% compared to the base year (from 8.49 to 10.03 kt CO_2), mainly due to the increased area of land conversion to grasslands (Figure 6.24).

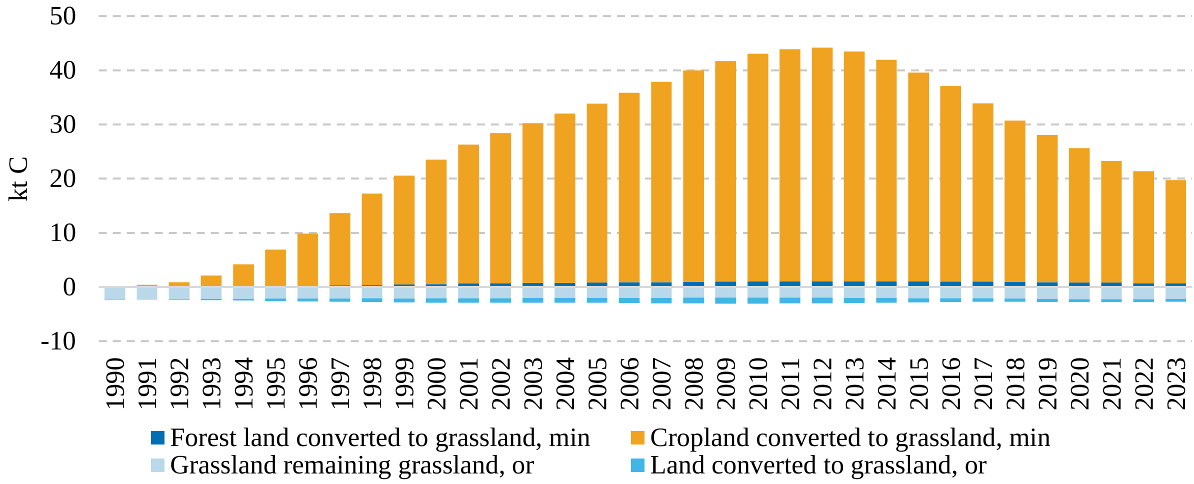

Figure 6.24. Carbon stock changes in Grassland soils in 1990–2023, kt C

6.6.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Grassland subcategory, please see Annex A.II.4 LULUCF, Grassland (4.C) chapter.

6.6.4. Category-specific QA/QC and verification, if applicable

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5. The QC/QA plan for the LULUCF sector includes the QC activities described in the 2006 IPCC Guidelines Volume 1, Chapter 6. The activities are carried out every year during the inventory. The QC checklist is used during the inventory.

6.6.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

A quantitative overview of recalculations is shown in Table 6.22. Activity data from NFI, such as land areas and average C stock changes in living biomass and dead wood, are updated every year. C stock changes in DOM for Land converted to grassland have changed compared to the previous submission also because of updated EF for litter.

Table 6.22. Quantitative overview of recalculations compared to the 31.12.2024 submission

		Grassland remaining grassland C stock change, kt			Land converted to grassland C stock change, kt				Total net CO_2, kt
		Living biomass	DOM	Organic soils	Living biomass	DOM	Mineral soils	Organic soils	
1990	Previous submission	33.42	2.11	-2.28	0.02	0.001	0.09	-0.02	-122.23

		Grassland remaining grassland C stock change, kt			Land converted to grassland C stock change, kt				Total net CO_2, kt
		Living biomass	DOM	Organic soils	Living biomass	DOM	Mineral soils	Organic soils	
	Current submission	33.01	1.80	-2.29	0.02	0.001	0.09	-0.02	-119.57
	Difference %	**-1.2**	**-14.6**	**0.7**	**0.02**	**1.1**	**NO**	**NO**	**-2.2**
2005	Previous submission	30.27	1.91	-2.00	2.66	-3.97	33.85	-0.92	-226.60
	Current submission	29.89	1.63	-2.01	2.71	-0.64	33.85	-0.92	-236.55
	Difference %	**-1.2**	**-14.6**	**0.8**	**1.9**	**-83.9**	**NO**	**NO**	**4.4**
2020	Previous submission	27.41	1.73	-2.21	1.17	-4.26	25.45	-0.54	-178.70
	Current submission	26.85	1.46	-2.23	1.25	-0.75	25.65	-0.54	-189.57
	Difference %	**-2.0**	**-15.3**	**0.8**	**7.5**	**-82.4**	**0.81**	**1.4**	**6.1**
2021	Previous submission	27.51	1.74	-2.22	1.18	-4.06	22.90	-0.52	-170.60
	Current submission	26.85	1.46	-2.24	1.28	-0.71	23.28	-0.54	-181.13
	Difference %	**-2.4**	**-15.6**	**0.8**	**8.8**	**-82.7**	**1.6**	**3.0**	**6.2**
2022	Previous submission	27.61	1.74	-2.23	3.05	-3.59	20.83	-0.51	-171.98
	Current submission	26.85	1.46	-2.24	3.12	-0.50	21.37	-0.53	-181.64
	Difference %	**-2.8**	**-15.9**	**0.4**	**2.4**	**-86.0**	**2.6**	**4.6**	**5.6**

6.6.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

Planned improvements for the Grassland category are the same as for Cropland (Chapter 6.5.6).

6.7. Wetlands (CRT 4.D)

6.7.1. Category description

Wetlands covered 9.4% (425.07 kha) of the Estonia's land territory in 2023. The area of wetlands decreased until the beginning of the 1990s, since then the area has remained stable (Table 6.23). A decrease in the wetlands area has taken place mostly due to the drainage of mires for agricultural and forestry purposes. Net emissions from Wetlands were 1 084.29 kt CO_2 eq. in 2023. Emissions derive mainly from peat extraction, especially horticultural peat (Figure 6.25), and only a small part (9.38 kt CO_2) from land conversion to other wetlands. Emissions related to peat extraction fluctuate between years due to variation in off-site emissions from the horticultural use of peat.

Table 6.23. Area of Wetlands in Estonia in 1990–2023, kha (NFI)

Year	Unmanaged wetlands	Peat extraction areas	Flooded land	Other wetlands	Total wetlands
1990	397.34	27.76	6.18	0.04	431.33
2005	393.65	25.15	6.18	0.70	425.68
2020	387.76	26.89	6.18	4.44	425.26

Year	Unmanaged wetlands	Peat extraction areas	Flooded land	Other wetlands	Total wetlands
2021	387.38	26.92	6.18	4.64	425.12
2022	387.06	27.04	6.18	4.78	425.06
2023	386.84	27.17	6.18	4.88	425.07

Wetlands remaining wetlands are divided to unmanaged and managed areas. The unmanaged wetlands category consists of natural lakes, rivers, and undrained mires that do not fulfil the definition of Forest land. Unmanaged wetlands are excluded from the CRT Table 4.D and instead reflected in Table 4.1, as recommended by the ERT[316]. Peat extraction sites and flooded areas are considered managed wetlands, as well as land that has been converted to or regressed to wetlands. The latter areas (except for lands converted for peat extraction or to flooded land) are report in CRT Table 4.D under subcategories Land converted to other wetlands and Other wetlands remaining other wetlands for areas where conversion occurred more than 20 year ago.

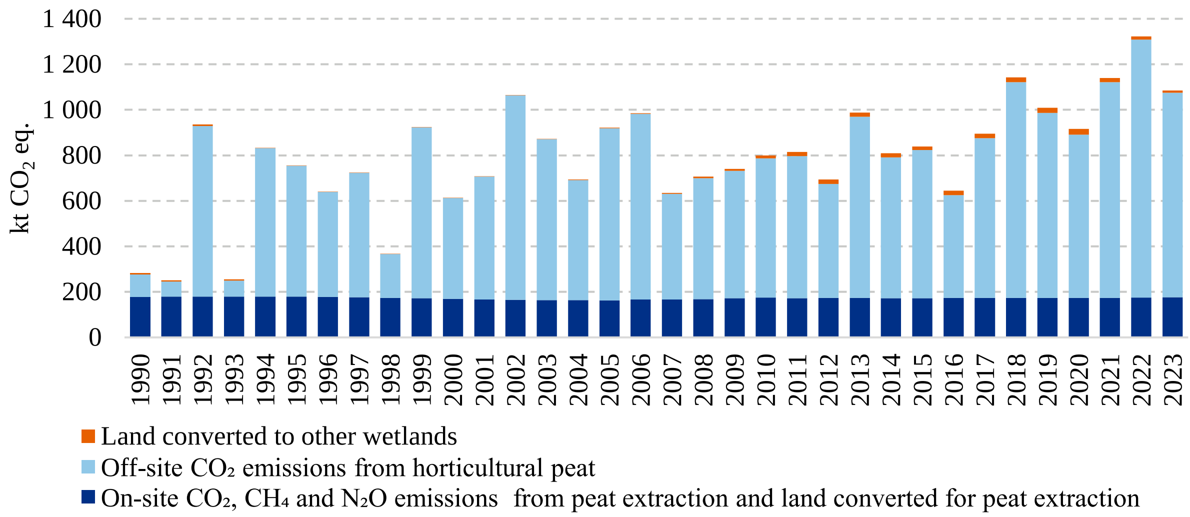

Figure 6.25. Annual GHG emissions from the Wetlands category in 1990−2023, kt CO_2 eq.

Activity data for the estimation of emissions related to peat extraction were obtained from the NFI, Estonian Land and Spatial Development Board and Statistics Estonia. In 2023, the total area of peat extraction fields was 27.17 kha (Table 6.23). The transition period for the Land being converted for peat extraction category is five years, as recommended in the 2006 IPCC Guidelines.

6.7.2. Methodological issues

Living biomass and dead organic matter

There are no living biomass or dead organic matter pools in peat extraction areas and flooded land, and C stock changes in these pools are not reported under the Other wetlands remaining other wetlands subcategory due to the lack of methodologies and data. However, C losses in living biomass and dead wood pools occur in the year of land conversion to wetlands and were estimated using Equation 6.8. It was assumed that all biomass will be lost after the land-use change. C_{BEFORE} values were estimated for Forest land and Grassland converted to wetlands categories as average C stocks in NFI plots, where such conversions have occurred (Table 6.24).

[316] FCCC/ARR/2016/EST L.3

Calculation of living biomass and dead wood C stocks on NFI plots is described in Chapter 6.4.2. For Cropland converted to other wetlands, average biomass C stock for the Cropland category was applied, calculated as described in Chapter 6.5.2.

Table 6.24. Average living biomass and dead wood C stock losses after Forest land, Cropland and Grassland conversion to wetlands, t C ha^{-1}

C pool	Forest land converted to peat extraction	Forest land converted to other wetlands	Cropland converted to other wetlands	Grassland converted to other wetlands
Living biomass	-3.420	-32.341	-3.290	-1.611
Dead wood	0	-3.436	NA	0

In the case of Forest land conversion to peat extraction, it was assumed that the forest belongs to the bog forest site type. Litter production in bog forests is small and litter layer is normally inseparable from the peat layer. This is confirmed by the data from the BioSoil soil survey, which was part of the International Cooperative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) and conducted in Level I monitoring plots across Europe between 2004 and 2008[317]. Therefore, no losses in litter pool were expected. For Forest land converted to Other wetlands, Swedish emission factor for litter was applied (Table 6.25).

Land-use change to wetlands and peat extraction sites intensified after 2005, causing also higher reductions in living biomass, DOM and soil C pools (Figure 6.26). Deforestation to wetlands, and therefore also C losses due to land-use change have decreased in recent years.

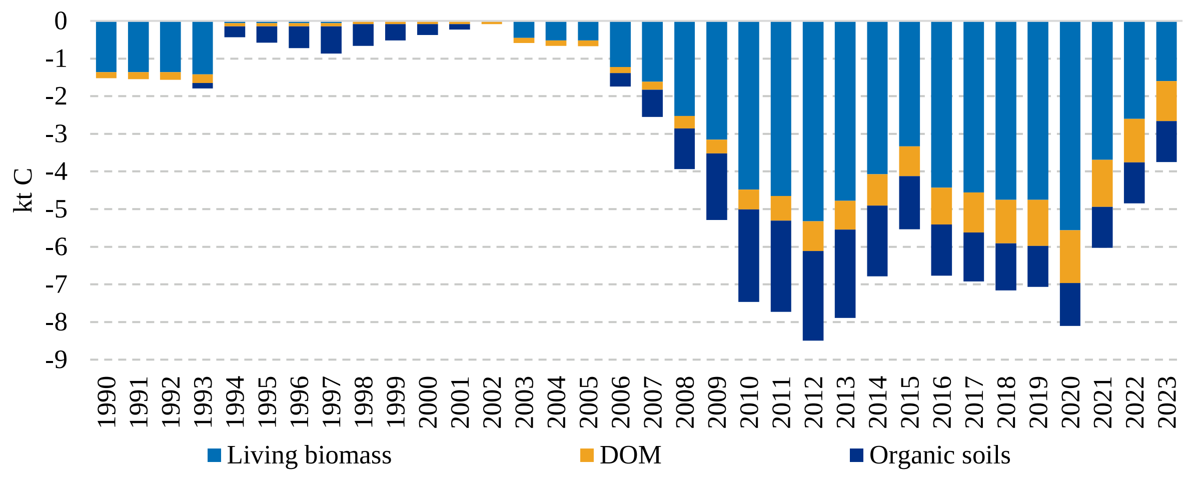

Figure 6.26. Carbon loss in living biomass, dead organic matter and soil after land conversion to peat extraction sites and other wetlands in 1990–2023, kt C

CO_2 emissions from peat extraction

CO_2 emissions from peat extraction areas comprise on-site emissions from peat surface and off-site emissions from the horticultural use of peat. On site soil C losses from peatlands and from land cleared for peat extraction were calculated using a country-specific emission factor by

[317] Data is available upon request through the Programme Co-ordinating Centre of ICP Forests (see http://icp-forests.net/page/plots-data).

Salm et al. 2012 (Table 6.25). Equation 6.12 was implemented for estimating off-site CO_2-C emissions.

Equation 6.12[318]

$$CO_2\text{-}C_{WW_{peat_{off-site}}} = \frac{Wt_{dry\_peat} \times Cfraction_{wt\_peat}}{1000}$$

Where:

CO_2-$C_{WW\ peat\ off\text{-}site}$ = off-site CO_2-C emissions from peat removed for horticultural use, kt C yr^{-1};

Wt_{dry_peat} = dry weight of extracted peat, tonnes yr^{-1}; and

$Cfraction_{wt\_peat}$ = carbon fraction of dry peat by weight, tonnes C (tonnes of dry peat)$^{-1}$ (country-specific value 0.495).

The amount of peat removed for horticultural use was calculated as the difference of total peat production and the primary production of energy peat. In 2023, 897.2 kt of peat was extracted, (data from the Estonian Land and Spatial Development Board (former Estonian Land Board)[319]), of which the production of energy peat (including energy peat for export) was 71 kt[320]. Estimated production of horticultural peat was 826.2 kt in 2023, which is 20.7% less than in the previous year. A notional moisture content of 40%[321] was used to estimate dry mass of peat. Carbon content in dry peat was analyzed from samples taken from 14 peat production areas in 2023 (methodology EVS-EN 15936).

Cumulative land-use changes to peat extraction sites and other wetlands and applied emission factors are presented in Table 6.25. Emission estimates are illustrated in Figure 6.25 and Figure 6.26.

Table 6.25. Cumulative land-use changes to wetlands and peat extraction sites in 2023, soil and litter emission factors

Land-use category	**Area, kha**	**EF soil, t C ha^{-1} yr^{-1}**	**EF litter, t C ha^{-1} yr^{-1}**
Peat extraction			
Peat extraction remaining peat extraction	26.54	-1.741[322] (on-site C emissions) -10.98[323](total C emissions)	NA
Forest land→Peat extraction Wetlands→ Peat extraction	0.06 0.56	-1.741	NA[324] NA
Flooded land			
Flooded land remaining flooded land	6.18	NA	NA

[318] After IPCC 2006 Guidelines, Volume 4, Chapter 7: Wetlands, page 7.11, Equation 7.5

[319] Roosalu, R. (2024). Eesti Vabariigi 2023. aasta maavaravarude koondbilansid (seisuga 31.12.2023. a). Tallinn: Maa-amet. [www] https://geoportaal.maaamet.ee/docs/geoloogia/koondbilanss_2023_seletuskiri.pdf (18.12.2024).

[320] Data from Statistics Estonia, KE0230: Energy balance sheet by type of fuel or energy (Eurostat methodology). [www] https://andmed.stat.ee/en/stat/majandus__energeetika__energia-tarbimine-ja-tootmine__aastastatistika/KE0230 (18.12.2024). Emissions related to the usage of peat for energy generation are reported under the Energy sector (Chapter 3).

[321] Regulation No. 52 of 17 December 2018 of Minister of the Environment. [www] https://www.riigiteataja.ee/akt/114012020009?leiaKehtiv (18.12.2024).

[322] Salm et al. 2012

[323] Implied EF in 2023, varies between years depending on off-site CO_2 emissions.

[324] Litter stocks are considered negligible in the bog forest type.

Land-use category	Area, kha	EF soil, t C ha^{-1} yr^{-1}	EF litter, t C ha^{-1} yr^{-1}
Land to flooded land	NO	-	-
Other wetlands			
Other wetlands remaining other wetlands	0.38	NA	NA
Forest land→ Other wetlands Cropland→ Other wetlands Grassland→ Other wetlands Peat extraction→ Other wetlands Settlements→ Other wetlands	1.85 0.19 0.41 0.37 1.68	no emissions, soil C is not considered lost after LUC to other wetlands	-0.495[325] NA NA NA

Non-CO_2 emissions from peat extraction areas

Equation 6.13 with a country-specific emission factor by Salm et al. 2012 (*Tier 2*) was implemented for estimating CH_4 emissions from organic soils managed for peat extraction.

Equation 6.13

$$CH_{4\,WW_{peatExtraction}} = \left(A_{peatExtraction} \times EF_{CH_4}\right) \times \frac{16}{12} \times 10^{-6}$$

Where:

$CH_{4\ WWpeatExtraction}$ = emissions of CH_4 from peatlands managed for peat extraction, kt CH_4 yr^{-1};

$A_{peatExtraction}$= area of peat soils managed for peat extraction, including abandoned areas in which drainage is still present, ha; and

EF_{CH_4} = emission factor for organic soils managed for peat extraction, kg CH_4 ha^{-1} yr^{-1} (Table 6.25).

Equation 6.14 with a country-specific emission factor by Salm et al. 2012 (*Tier 2*) was used for estimating N_2O emissions from peat extraction sites.

Equation 6.14[326]

$$N_2O_{WW_{peatExtraction}} = \left(A_{peatExtraction} \times EF_{N_2O\text{-}N}\right) \times \frac{44}{28} \times 10^{-6}$$

Where:

$N_2O_{WW_{peatpxtraction}}$ = direct N_2O emissions from peatlands managed for peat extraction, kt N_2O yr^{-1};

$A_{peatExtraction}$ = area of peat soils managed for peat extraction, ha; and

$EF_{N_2O\text{-}N}$ = emission factor for organic soils managed for peat extraction, kg N_2O-N ha^{-1} yr^{-1} (Table 6.26).

325 Since there are no country-specific EF nor Swedish EF for land converted to Wetlands, the same litter emission factor as under land converted to Settlements was applied (National Inventory Report Sweden 2024: Annexes, page 146, Table A3:2.14).

326 After IPCC 2006 Guidelines, Volume 4, Chapter 7: Wetlands, page 7.15, Equation 7.7.

In 2023, non-CO_2 emissions from peat extraction areas were 4.35 t CH_4 and 8.11 t N_2O. Both emissions have decreased by 2.1% compared to the base year.

6.7.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Wetlands subcategory, please see Annex A.II.4 LULUCF, Wetlands (4.D) chapter.

6.7.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the LULUCF sector according to the IPCC *Tier 1* method. The activities are carried out every year during the inventory. The QC check list is used during the inventory.

Country-specific soil emission factors for peat extraction areas were compared with default factors from the IPCC 2013 Wetlands supplement (Table 6.26). CO_2-C and N_2O-N emission factors fall within 95% confidence intervals, but Estonian EF for CH_4 is significantly smaller compared to the default value. When new publications become available, the EFs will be re-evaluated.

Table 6.26. Comparison of country-specific (Salm et al. 2012) and IPCC default emission factors for peatlands managed for peat extraction

EF (kg ha^{-1} yr^{-1})	**CO_2-C**	**CH_4-C**	**N_2O-N**
country-specific	1 741	0.12	0.19
IPCC default	1 100 … 4 200[327]	1.2 … 8.25[328]	-0.03 … 0.64[329]

6.7.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

Updated data from the NFI, like land areas and biomass losses due to land use changes, were used for estimating GHG emissions from peatlands and land converted to wetlands. C stock losses in biomass due to conversion of croplands to wetlands were estimated for the first time in the 2025 submission. These updates have resulted in minor recalculations of GHG emissions from the Wetlands category (Table 6.27).

Table 6.27. Quantitative overview of recalculations compared to the 31.12.2024 submission

Wetlands TOTAL emissions		**CO_2, kt**	**CH_4, t**	**N_2O, t**
1990	Previous submission	272.33	4.25	7.94
	Current submission	279.63	4.44	8.29
	Difference %	**2.7**	**4.4**	**4.4**
2005	Previous submission	912.32	3.84	7.16
	Current submission	919.74	4.02	7.51
	Difference %	**0.8**	**4.9**	**4.9**
2020	Previous submission	881.53	4.13	7.71
	Current submission	913.76	4.30	8.03
	Difference %	**3.7**	**4.1**	**4.1**

[327] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.14, Table 2.1.
[328] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.26, Table 2.3.
[329] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.34, Table 2.5.

Wetlands TOTAL emissions		CO_2, kt	CH_4, t	N_2O, t
2021	Previous submission	1119.82	4.13	7.70
	Current submission	1137.28	4.31	8.04
	Difference %	**1.6**	**4.3**	**4.3**
2022	Previous submission	1305.14	4.13	7.70
	Current submission	1320.11	4.33	8.07
	Difference %	**1.1**	**4.8**	**4.8**

6.7.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

Estonia is working on specifying the estimates of land categories. First, the project by the University of Tartu aims to develop a new methodology for compiling annual land use change matrices (considering soil types and the presence of drainage). The methodology includes both land use change information of the NFI plots as well as their current land use status, i.e., land use change estimates are calibrated with information on the current situation. Second, as the transition period for conversions between land categories is 20 years, Estonia seeks to assess land use changes in the period 1970–1990 to refine the area estimates for 1990–2009.

A research project to specify the activity data and emissions from drainage diches has recently been completed. Results of the project will be evaluated and implemented in the GHG inventory.

New scientific research has been launched to improve the GHG accounting methods for peatlands managed for peat extraction and for restored extraction sites. The project will be carried out by the University of Tartu in 2024–2028.

6.8. Settlements (CRT 4.E)

6.8.1. Category description

Settlements, including all built-up areas, covered 7.6% (345.03 kha) of Estonia's territory in 2023. The area of settlements has been increasing continuously in Estonia (Figure 6.27) mainly on behalf of forest lands (Table 6.6 and Table 6.29). Carbon flows on Settlements remaining settlements have not been estimated due to the lack of detailed data. It is assumed that there is no change in C stocks in biomass and that C inputs equal outputs in mineral soils. Total emissions from the Settlements category were 340.04 kt CO_2 eq. in 2023 (Figure 6.28).

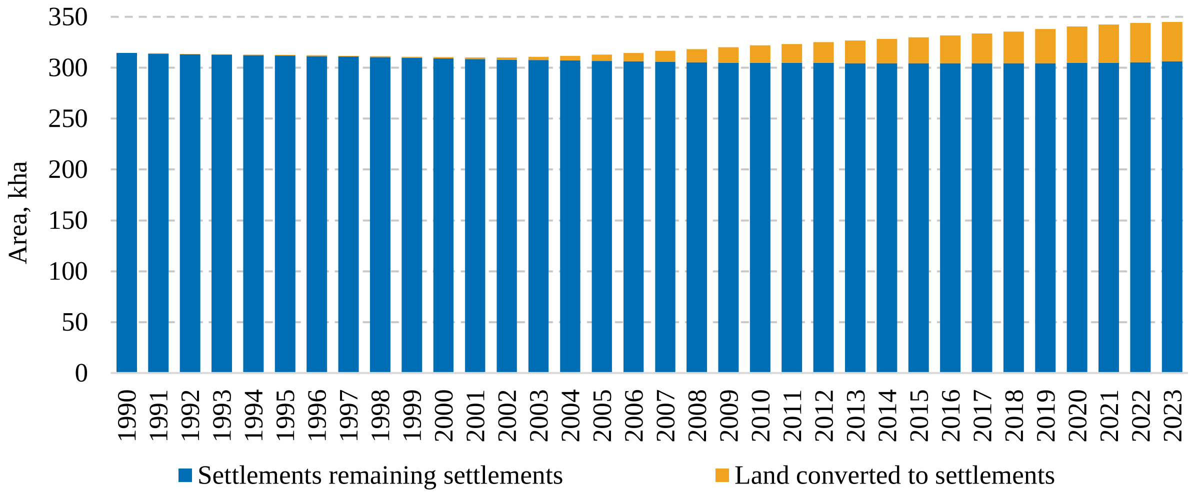

Figure 6.27. Area of Settlements in Estonia in 1990–2023, kha

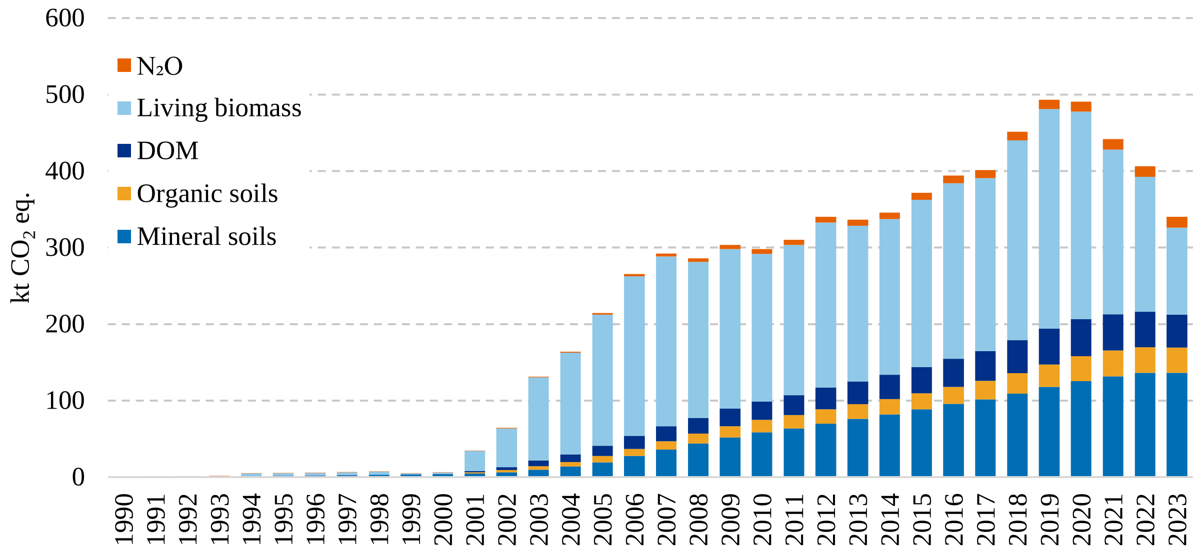

Figure 6.28. Emissions related to land conversion to settlements, 1990–2023, kt CO_2 eq.

6.8.2. Methodological issues

C losses in living biomass and dead wood due to land conversion to Settlements were calculated using Equation 6.8, where C_{AFTER} was equal to zero. C_{BEFORE} values were estimated for Forest land and Grassland converted to settlements categories as average C stocks in NFI plots, where such conversions have occurred (Table 6.28). Calculation of living biomass and dead wood C stocks on NFI plots is described in Chapter 6.4.2. For Cropland converted to settlements, average biomass C stock for the Cropland category was applied, calculated as described in Chapter 6.5.2. Due to missing country-specific data, EF from Sweden was implemented for litter (Table 6.29).

Table 6.28. Average living biomass and dead wood C stock losses after Forest land, Cropland and Grassland conversion to settlements, t C ha^{-1}

C pool	Forest land converted to settlements	Cropland converted to settlements	Grassland converted to settlements
Living biomass	-53.528	-3.290	-1.089
Dead wood	-2.856	NA	-0.074

As it was not possible to stratify Land converted to settlements areas as suggested in the 2006 IPCC Guidelines[330], it was conservatively assumed that all converted area is paved over and that 20% of the mineral soil carbon relative to the previous land use will be lost within 20 years. The average SOC stock in mineral forest soils in Estonia is 108.0 t C ha^{-1} (Kõlli et al. 2004)[331], in Grassland category 107.3 t C ha^{-1} (Kõlli et al. 2007)[332], and in Cropland 88.2 t C ha^{-1} (Kõlli et al. 2009)[333]. It was also assumed that SOC stocks in Other land category are negligible and

[330] IPCC 2006 Guidelines, Volume 4, Chapter 8: Settlements, page 8.24.
[331] Kõlli, R., Asi, E., Köster, T. (2004). Organic carbon pools in Estonian forest soils. Baltic Forestry 10, 19–26.
[332] Kõlli, R., Köster, T., Kauer, K. (2007). Organic matter of Estonian grassland soils. Agronomy Research 5, 109–122.
[333] Kõlli, R., Ellermäe, O., Köster, T., Lemetti, I. Asi, E., Kauer, K. (2009). Stocks of organic carbon in Estonian soils. Estonian Journal of Earth Sciences, 58, 95–108.

therefore also no changes in C stocks occur after land use change. For organic soils, the same EF as for cultivated organic soils was used[334].

Table 6.29. Cumulative land-use changes to settlements in 2023, soil and litter emission factors. (Assumptions are described in the text.)

Land-use change	kha	%	EF mineral soil, t C ha^{-1}	EF organic soil t C ha^{-1}	EF litter t C ha^{-1}
Forest land→ Settlements	20.46	52.7	-1.080	-5.0	-0.495[335]
Cropland→ Settlements	9.13	23.5	-0.882	-5.0	NA
Grassland→ Settlements	8.19	21.1	-1.073	-	NA
Wetlands→ Settlements	0.18	0.5	-	-5.0	NA
Other land→ Settlements	0.89	2.3	NO	-	NA
Total Land to settlements	38.86	100.0			

6.8.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Settlements subcategory, please see Annex A.II.4 LULUCF, Settlements (4.E) chapter.

6.8.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the LULUCF sector according to the IPCC *Tier 1* method. The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

6.8.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

A quantitative overview of recalculations is shown in Table 6.30, except for recalculations of N_2O emissions which are presented in Chapter 6.10.5. Activity data from NFI, such as land areas and average C stock losses in living biomass and dead wood after land use change from Forest land and Grassland to Settlements, are updated every year. In addition, C stock losses in biomass due to conversion of croplands to settlements were estimated for the first time in the 2025 submission.

Table 6.30. Quantitative overview of recalculations in the Settlements compared to the 31.12.2024 submission

Land converted to settlements		C stock change, kt				Total Settlements net CO_2, kt
		Living biomass	DOM	Mineral soils	Organic soils	
1990	Previous submission	NO	NO	NO	NO	NO
	Current submission	NO	NO	NO	NO	NO
	Difference %	-	-	-	-	-

[334] IPCC 2006 Guidelines, Volume 4, Chapter 5: Cropland, page 5.19, Table 5.6 (Boreal/Cool Temperate).
[335] National Inventory Report Sweden 2024: Annexes, page 146, Table A3:2.14.

Land converted to settlements		C stock change, kt				Total Settlements net CO_2, kt
		Living biomass	DOM	Mineral soils	Organic soils	
2005	Previous submission	-44.64	-3.87	-5.28	-2.23	205.40
	Current submission	-46.73	-3.65	-5.28	-2.23	212.25
	Difference %	**4.7**	**-5.8**	**NO**	**NO**	**3.3**
2020	Previous submission	-60.68	-12.75	-33.40	-8.85	424.15
	Current submission	-74.02	-13.21	-34.25	-8.85	477.86
	Difference %	**22.0**	**3.6**	**2.6**	**NO**	**12.7**
2021	Previous submission	-42.75	-12.02	-34.62	-9.20	361.49
	Current submission	-58.73	-12.88	-35.94	-9.20	428.04
	Difference %	**37.4**	**7.1**	**3.8**	**NO**	**18.4**
2022	Previous submission	-28.48	-11.31	-35.34	-9.10	308.85
	Current submission	-48.11	-12.64	-37.18	-9.10	392.43
	Difference %	**68.9**	**11.7**	**5.2**	**NO**	**27.1**

6.8.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

Estonia is working on specifying the estimates of land categories. First, the project by the University of Tartu aims to develop a new methodology for compiling annual land use change matrices (considering soil types and the presence of drainage). The methodology includes both land use change information of the NFI plots as well as their current land use status, i.e., land use change estimates are calibrated with information on the current situation. Second, as the transition period for conversions between land categories is 20 years, Estonia seeks to assess land use changes in the period 1970–1990 to refine the area estimates for 1990–2009.

In 2024, a project for developing a governance system for land and soil management was launched. The project aims to update and consolidate land use-related datasets and to develop higher tier methodologies for estimating SOC changes in all land-use categories. The project has already initiated the updating of the Estonian soil map (2024–2026).

6.9. Other land (CRT 4.F)

6.9.1. Category description

The Other land category includes all land that does not fall into the five previously described land-use categories, comprising 1.1% (48.91 kha) of the total Estonia's land territory. In the 2025 submission, CO_2 emissions from Forest land, Cropland and Grassland conversion to Other land are reported. It was assumed that the change in land use from Wetlands to Other land would not lead to changes in C stocks, and land conversions from Settlements to Other land have not occurred. In addition, N_2O emissions from N mineralization and leaching associated with land-use change to Other land are estimated (methodology described in Chapter 6.10).

Conversions to the Other land category have taken place since 2004 according to the NFI, mainly from Forest land (Table 6.32) resulting in high emissions from the living biomass C pool (Figure 6.29). Total emissions from Land converted to other land were estimated at 39.11 kt CO_2 eq. in 2023.

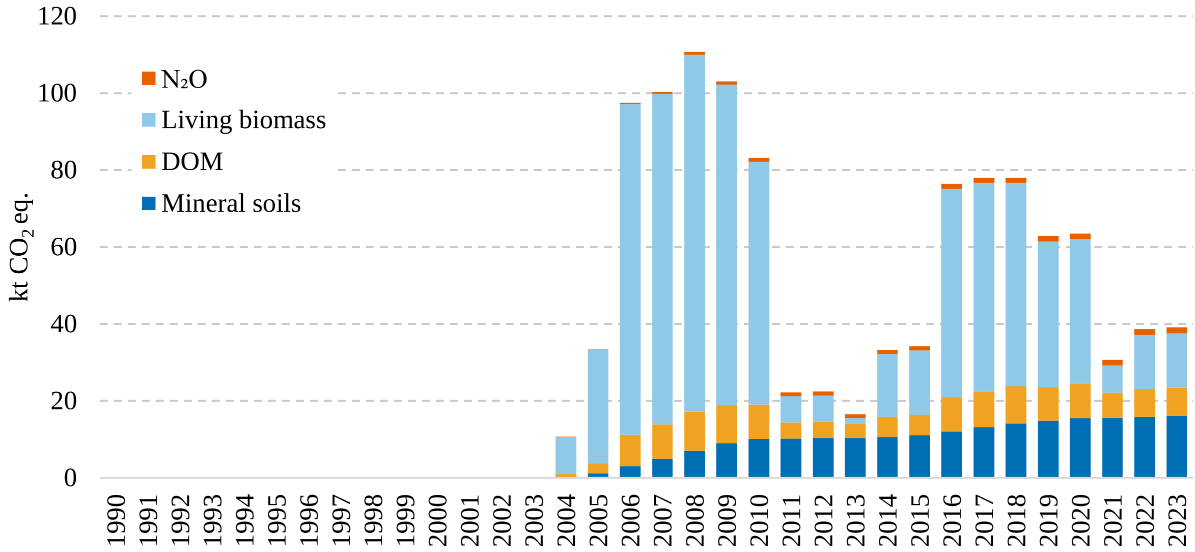

Figure 6.29. Emissions related to land-use changes to other land, 1990–2023, kt CO_2 eq.

6.9.2. Methodological issues

C losses in living biomass and dead wood resulting from land conversion to Settlements were calculated using Equation 6.8, where C_{AFTER} was equal to zero. C_{BEFORE} values were estimated for Forest land and Grassland converted to other land categories as average C stocks in NFI plots, where such conversions have occurred (Table 6.31). Calculation of living biomass and dead wood C stocks on NFI plots is described in Chapter 6.4.2. For Cropland converted to other land, average biomass C stock for the Cropland category was applied, calculated as described in Chapter 6.5.2.

Table 6.31. Average living biomass and dead wood C stock losses after Forest land, Cropland and Grassland conversion to other land, t C ha^{-1}

C pool	Forest land converted to other land	Cropland converted to other land	Grassland converted to other land
Living biomass	-61.946	-3.290	0
Dead wood	-5.232	NA	0

Land use change to other land has not resulted in a complete loss of soil SOC stocks. For instance, Forest land to other land conversions observed in NFI plots include deforestation areas where future land use is unknown, former quarries where afforestation has not been successful, etc. Also, land use changes to areas with a closed regime are included under Other land. As land-use change may cause some losses in soil carbon, the same emission factors for litter and mineral soils are applied as in the case of Land converted to settlements, i.e. it was assumed that 20% of the mineral soil carbon relative to the previous land use will be lost within 20 years (Table 6.32).

Table 6.32. Cumulative land-use changes to Other land in 2023, soil and litter emission factors[336]

Land-use change	kha	%	EF mineral soil, t C ha^{-1}	EF litter, t C ha^{-1}
Forest land→ Other land	3.36	78.0	-1.080	-0.495
Cropland→ Other land	0.57	13.2	-0.882	NA
Grassland→ Other land	0.26	5.9	-1.073	NA
Wetlands→ Other land	0.12	2.8	NO	NA
Total Land to other land	4.31	100.0		

6.9.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Other land subcategory, please see Annex A.II.4 LULUCF, Other land (4.F) chapter.

6.9.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the LULUCF sector according to the IPCC *Tier 1* method. The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

6.9.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

Updated activity data, growing stocks and deadwood volumes from the NFI were used for estimating carbon losses due to land conversion to Other land. In addition, a new methodology for estimating C stock losses in living biomass for Cropland converted to other land has been applied, causing minor recalculations. In Table 6.33 a quantitative overview of recalculations is shown, except for recalculations of direct and indirect N_2O emissions which are presented in Chapter 6.10.5.

Table 6.33. Quantitative overview of recalculations compared to the 31.12.2024 submission

		C stock change, kt			Total Other land net CO_2, kt
		Living biomass	DOM	Mineral soils	
1990	Previous submission	NO	NO	NO	NO
	Current submission	NO	NO	NO	NO
	Difference %	**-**	**-**	**-**	**-**
2005	Previous submission	-7.70	-0.73	-0.30	32.01
	Current submission	-8.08	-0.74	-0.30	33.44
	Difference %	**4.9**	**1.6**	**NO**	**4.5**
2020	Previous submission	-10.09	-2.43	-4.24	61.44
	Current submission	-10.22	-2.45	-4.24	62.00
	Difference %	**1.3**	**0.6**	**NO**	**0.9**
2021	Previous submission	-1.89	-1.76	-4.27	29.07
	Current submission	-1.92	-1.76	-4.27	29.17
	Difference %	**1.3**	**0.2**	**NO**	**0.4**
2022	Previous submission	-1.89	-1.78	-4.30	29.25
	Current submission	-3.84	-1.96	-4.34	37.16
	Difference %	**102.7**	**10.2**	**0.8**	**27.1**

[336] Same as for Land converted to settlements.

6.9.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

Planned improvements for the Other land category are the same as for Settlements (Chapter 6.8.6).

6.10. N_2O emissions from N mineralization and leaching (CRT 4(III))

6.10.1. Category description

The change of land use or management of mineral soil often enhances mineralization of nitrogen in soil organic matter, resulting in nitrous oxide emissions. In Estonia, soil organic matter losses from mineral soil occur after land conversions to Forest land, Cropland, Settlements and Other land. In some years, management changes also cause carbon emissions from the Cropland remaining cropland category, but associated N_2O emissions from this category are reported under the Agriculture sector (CRT 3.D).

In 2023, direct N_2O emissions from N mineralization were 20.59 kt CO_2 eq. As Estonia is situated in the humid region where annual precipitation exceeds evapotranspiration, some of the mineralized N is lost from soil through leaching and runoff. Since Estonian forests and other non-agricultural lands are not fertilized, this is the only source of indirect N_2O emissions in the LULUCF sector. In 2023, indirect N_2O emissions equaled 4.63 kt CO_2 eq. Most of the N_2O emissions from N mineralization occurred due to the expansion of Settlements (Figure 6.30).

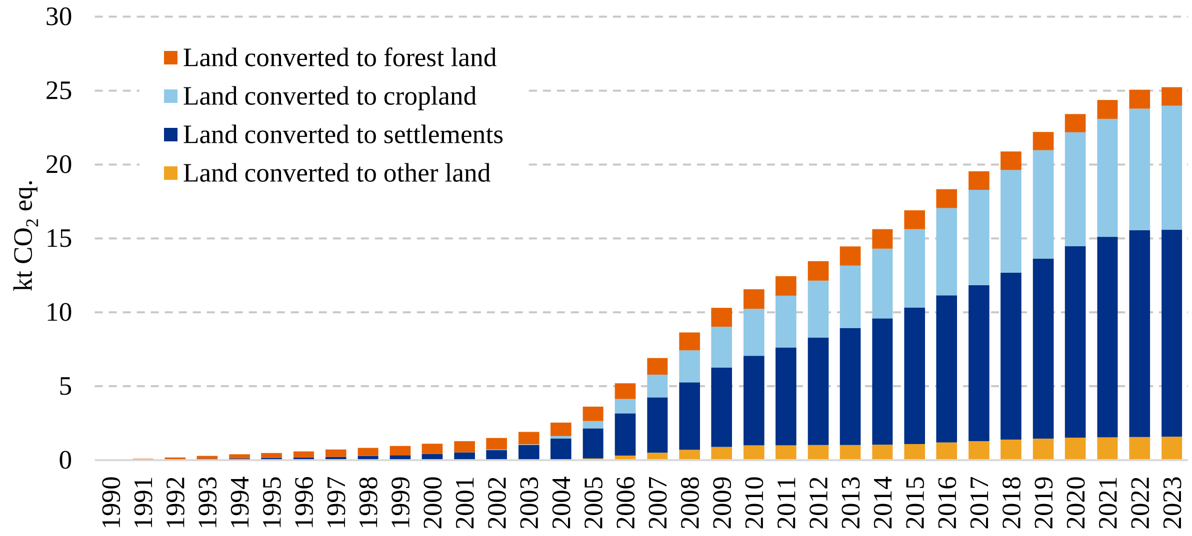

Figure 6.30. N_2O emissions from nitrogen mineralization and leaching, 1990-2023, kt CO_2 eq.

6.10.2. Methodological issues

Direct N_2O emissions from N mineralization

The *Tier 1* method (Equation 6.15) with default emission factors was applied for calculating direct N_2O emissions from N mineralization associated with the loss of soil organic matter resulting from the change of land use.

Equation 6.15[337]

$$N_2O_{Min} = F_{SOM} \times EF_1 \times \frac{44}{28}$$

where

$$F_{SOM} = \sum_{LU}\left[\left(\Delta C_{Mineral,LU} \times \frac{1}{R}\right) \times 1000\right]$$

Where:

N_2O_{Min} = annual direct N_2O emissions from N mineralization, kg N_2O yr^{-1};

EF_1 = emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input$)^{-1}$. IPCC 2006 default factor 0.01[338] was applied;

F_{SOM} = the net annual amount of N mineralized in mineral soils as a result of the loss of soil carbon through a change in land use or management, kg N yr^{-1};

$\Delta C_{Mineral,\ LU}$ = average annual loss of soil carbon for each land-use type (LU), tonnes C;

R = C:N ratio of the soil organic matter. A default value of 10 was used for Cropland and 15 for other land-use categories; and

LU = land use and/or management system type.

Indirect N_2O emissions from leaching/runoff (CRT 4(IV))

Indirect N_2O emissions from leaching and runoff were estimated using Equation 6.16 (*Tier 1*).

Equation 6.16[339]

$$N_2O_{(L)} = F_{SOM} \times Frac_{LEACH\text{-}(H)} \times EF_5 \times \frac{44}{28}$$

Where

$N_2O_{(L)}$ = annual amount of N_2O produced from leaching and runoff of N mineralized in managed soils, kg N_2O yr^{-1}:

F_{SOM} = annual amount of N mineralized in mineral soils associated with the loss of soil C from soil organic matter as a result of changes in land use, kg N yr^{-1} (from Equation 6.15);

$Frac_{LEACH\text{-}(H)}$ = fraction of all N mineralized in managed soils that is lost through leaching and runoff, kg N (kg of N additions$)^{-1}$. A default value of 0.30[340] was applied in calculations; and

EF_5 = emission factor for N_2O emissions from N leaching and runoff, kg N_2O-N (kg N leached and runoff$)^{-1}$. IPCC 2006 default value 0.0075[340] was used.

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[337] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.10, Equation 11.2, and page 11.16, Equation 11.8.

[338] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.11, Table 11.1.

[339] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.21, Equation 11.10.

[340] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.24, Table 11.3.

6.10.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of N_2O emissions from N mineralization and leaching subcategory, please see Annex A.II.4 LULUCF, N_2O emissions from N mineralization and leaching (CRT 4(III)) chapter.

6.10.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the LULUCF sector according to the IPCC *Tier 1* method. The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

6.10.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

A quantitative overview of recalculations is shown in Table 6.34. Changes in estimated N_2O emissions compared to the previous submission result from the recalculation of mineral soil C stock changes in Forest land (Chapter 6.4.5), Cropland (Chapter 6.5.5), Settlements (Chapter 6.8.5), and Other land (Chapter 6.9.5) categories.

Table 6.34. Quantitative overview of recalculations of N_2O emissions from N mineralization and leaching/runoff compared to the 31.12.2024 submission

N_2O emissions, t		Land converted to			
		Forest land	**Cropland**	**Settlements**	**Other land**
1990	Previous submission	0.1081	NO	NO	NO
	Current submission	0.11	NO	NO	NO
	Difference %	**NO**	**-**	**-**	**-**
2005	Previous submission	3.66	1.90	7.68	0.43
	Current submission	3.66	1.90	7.68	0.43
	Difference %	**NO**	**NO**	**NO**	**NO**
2020	Previous submission	4.54	28.43	47.67	5.76
	Current submission	4.71	29.03	48.87	5.76
	Difference %	**3.9**	**2.1**	**2.5**	**NO**
2021	Previous submission	4.53	29.21	49.34	5.80
	Current submission	4.79	30.16	51.19	5.80
	Difference %	**5.9**	**3.3**	**3.7**	**NO**
2022	Previous submission	4.49	29.71	50.30	5.85
	Current submission	4.84	31.01	52.85	5.89
	Difference %	**7.8**	**4.4**	**5.1**	**0.7**

6.10.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

Planned improvements regarding the estimates of land-use category areas and GHG emissions from soils are described in Chapters 6.4.6, 6.5.6 and 6.8.6.

6.11. Non-CO_2 emissions from biomass burning (CRT 4(IV))

6.11.1. Category description

This category includes CH_4 and N_2O emissions from biomass burning on wooded lands after wildfires. CO_2 emissions caused by wildfires are included in living biomass emission estimates, thus CO_2 emissions are not reported under the current category to avoid double accounting.

Controlled burning is not a common practice in Estonia. Furthermore, the standpoint of the public and national authorities is opposed to prescribed burnings. For example, pursuant to the Forest Act, local administrations shall implement measures to prevent forest fires, and according to the Estonian Fire Safety Act, it is forbidden to burn dead grass through the year.

6.11.2. Methodological issues

CH_4 and N_2O emissions from biomass burning are reported under the Forest land and Grassland categories, the latter also includes wildfires occurring in Wetlands. The notation key "NE" is used for the Cropland and Settlements categories, as a disproportionate amount of effort would be required to collect the activity data for estimating emissions that would be insignificant in terms of the overall level and trend in national emissions. This argument is based on the fact that according to the latest inventory submission, the average level of emissions from biomass burning reported in the period 1990–2023 is 0.95 kt CO_2 eq. that constitutes less than 0.01% of the national total GHG emissions (without LULUCF) and that the average GHG emissions from the biomass burning in Cropland and Settlements have a very low likelihood to exceed that, as the biomass density and the area in case of Settlements is considerably lower compared to the Forest land.

Information about wildfires is acquired from the Estonian Rescue Service (ERS), which reports the location and type of fire occurred for all forest and terrain fires. EstEA will pick out the wildfires that are over 0.1 ha and inventory those areas to improve and verify data and emissions related to the wildfires. Exact location (georeferenced, area), land use and mass of fuel available for combustion (includes biomass, ground litter and deadwood) are determined during fieldwork. Sometimes the location of a wildfire reported by the ERS is imprecise, in which case EstEA field workers examine the nearby area and try to locate the exact place of the fire (Figure 6.31). The detected burnt area is separated into several land-use categories, if necessary. Wildfires reported in 2023 are indicated in Figure 6.32.

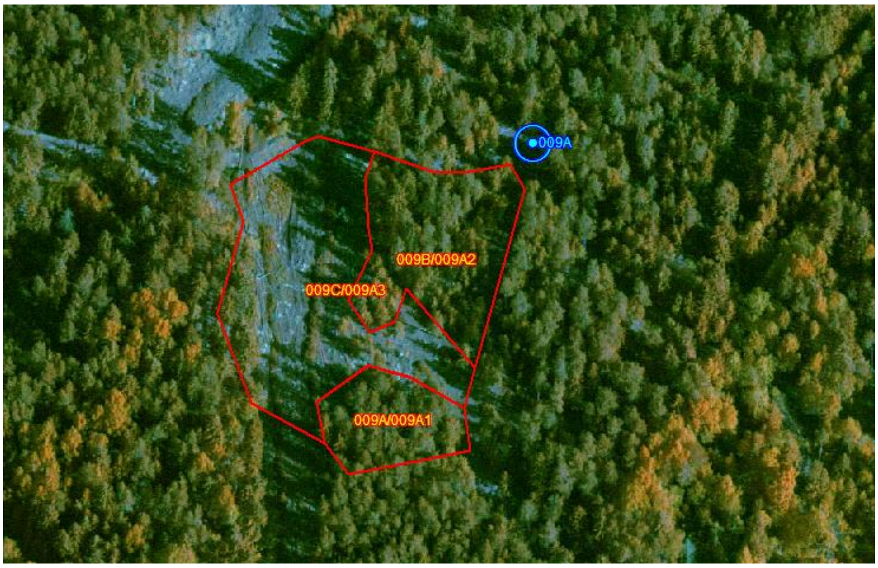

Figure 6.31. Reported fire location (blue circle), actual location (red border) and data analyses

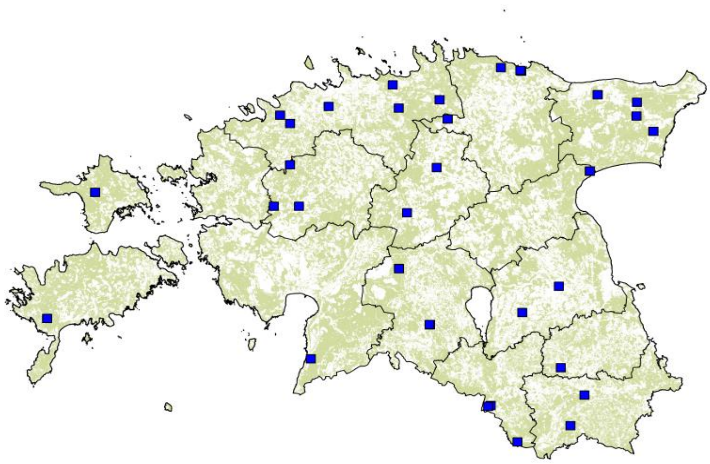

Figure 6.32. Reported wildfires in Estonia in 2023

The *Tier 2* method and Equation 6.17 were used to estimate the emissions of non-CO_2 greenhouse gases. The mass of available fuel (living biomass and DOM) and combustion efficiency are determined during fieldwork starting from 2012.

Equation 6.17[341]

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

Where:

L_{fire} = quantity of GHG released due to wildfire, tonnes of GHG;
A = area burnt, ha;
M_B = mass of 'available' fuel, kg dry matter ha^{-1};[342]
C_f = combustion efficiency (or fraction of the biomass combusted), dimensionless; for 1990–2011 the value 0.15[343] was applied; starting from 2012, C is estimated during field inventory;
G_{ef} = emission factor, g (kg dry matter burnt)$^{-1}$.

Emission factors used for biomass burning emission calculations are shown in Table 6.35.

According to ERS and EstEA wildfires occurred on 74.75 ha of forests and 0.41 ha of Grasslands in 2023 (Figure 6.33). Fluctuations in the area burnt are caused mainly by the weather conditions in different years (e.g. extremely hot and dry summers).

Table 6.35. Emission factors (G_{ef}, g kg^{-1} dry matter burnt) used for estimation of non-CO_2 greenhouse gas emissions from fires [344]

Land-use category	**CH_4**	**N_2O**
Forest land	6.1	0.06
Grassland, Wetland	2.3	0.21

[341] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.42, Equation 2.27.
[342] For 1990–2011 year-specific average forest biomass growing stock was used as the basis for M_B.
[343] IPCC 2006 Guidelines, Volume 4, Chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories, page 2.48, Table 2.6 (Boreal forest, surface fire).
[344] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.47, Table 2.5 (Savanna and grassland, Biofuel burning).

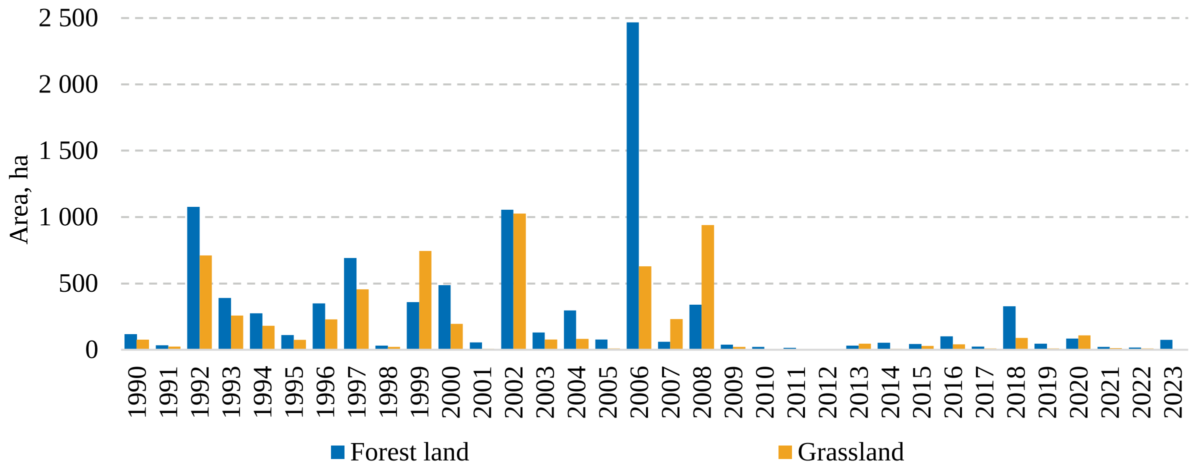

Figure 6.33. Annual area of Forest land and Grassland (incl. WL areas) affected by fires in 1990−2023, ha

The total amount of CH_4 and N_2O released after wildfires in 2023 was 5.22 t and 0.05 t, respectively. Non-CO_2 emissions from Grassland wildfires are rather insignificant compared to the Forest land, since there is approximately 10 times less growing biomass on Grasslands.

6.11.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Non-CO_2 emissions from biomass burning subcategory, please see Annex A.II.4 LULUCF, Non-CO_2 emissions from biomass burning (CRT 4 (IV)) chapter.

6.11.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the LULUCF sector according to the IPCC *Tier 1* method. The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

Activity data obtained from the Estonian Rescue Service is verified and corrected, if necessary, during field inventory carried out by the Estonian Environment Agency.

6.11.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

There are no category-specific recalculations.

6.11.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

There are no planned category-specific improvements.

6.12. Harvested wood products (CRT 4.G)

6.12.1. Description

Harvested wood products (HWP) include all wood products in use in Estonia. The carbon balance has been calculated using the production approach for HWP. HWP are divided into Solid wood products (sawn wood and wood panels), Paper products (paper and paperboard) and

Bleached-Chemi-Thermo-Mechanical aspen pulp (Aspen BCTMP)[345]. Pulp is an input for paper production. All Bleached semi-chemical wood pulp production is exported. The changes in roundwood stocks and their carbon balance are not considered in the reporting. The carbon balance of HWP in solid waste disposal sites is also excluded from the estimate. As Estonia lacks activity data for the years 1990 and 1991, an extrapolation that was recommended by the ERT in 2018[346] was made to get estimates for these years (Chapter 6.12.2).

The net emissions form the HWP category in 2023 were -502.07 kt CO_2 and the net emissions during the reporting period are shown in Figure 6.34. Increases in removals in HWP are associated with the increase in harvest rates. As a result of the estimated total HWP balance during periods when consumption was low (1990–1994), the HWP pool became a source of CO_2. Main part of the HWP sink is from the Wood panels and Sawn wood subcategory. Due to the short half-life values for the Paper and paperboard and Bleached semi-chemical wood pulp subcategories the contribution and impact to the carbon cycle is short-term and small for those pools.

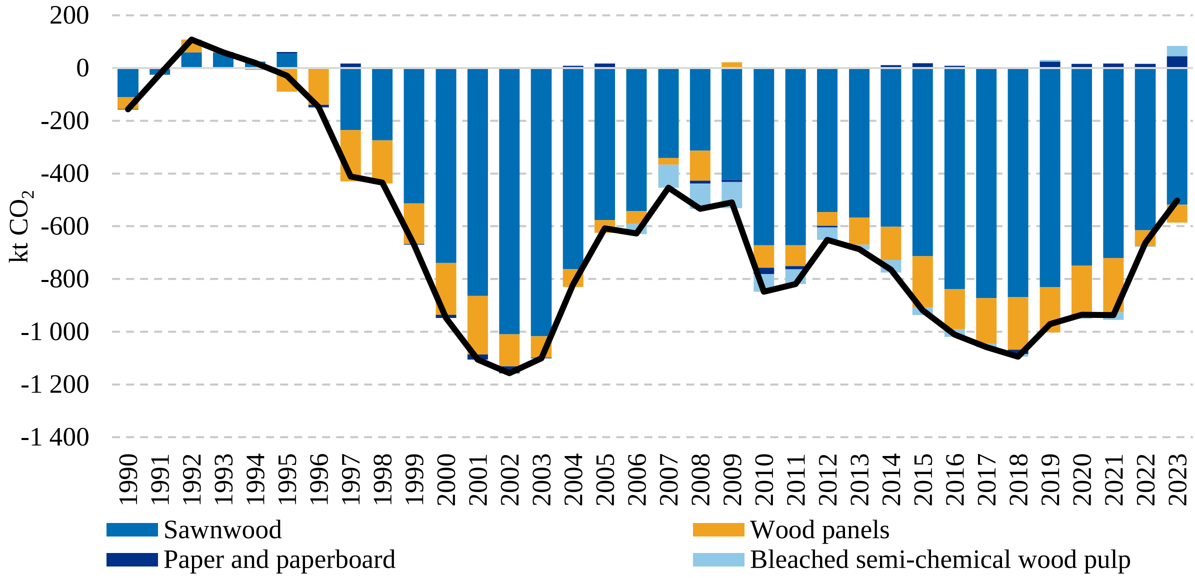

Figure 6.34. Net emissions from HWP categories of Solid wood, Paper and paperboard and Bleached semi-chemical wood pulp in Estonia in 1990–2023, kt CO_2

6.12.2. Methodological issues

For calculating annual changes in carbon stocks and associated CO_2 emissions and removals from the HWP pool, Chapter 2.8 from the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement) was applied. However, under the Convention reporting, CO_2 emissions due to roundwood production in deforested land were not accounted using the instantaneous oxidation method but were reported similarly to HWP originating from other areas.

Estimation of the annual fraction of feedstock for HWP originating from domestic harvest was calculated using equations 2.8.1–2.8.3[347], resulting values are presented in Table 6.36. Forestry data originates from the NFI and foreign trade data comes from Statistics Estonia. In order to

[345]Bleached semi-chemical wood pulp is defined as code 4705 00 00 in Combined Nomenclature 2024 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302364) (06.01.2025)
[346] FCCC/ARR/2018/EST KL.12
[347] IPCC 2013 KP Supplement, pp. 2.115 & 2.116

use equations 2.8.4–2.8.6[348], production data from Statistics Estonia were applied. The inherited emissions are included starting from 1990; initial C stocks in 1990 were simulated using equation 2.8.6 and average inflow values during the period 1990–1994. Default conversation factors (Table 6.37) and half-lives from Table 2.8.2[349] were used to calculate Paper and paperboard and Solid wood removals (*Tier 2* method). C stock changes in Bleached semi-chemical wood pulp were estimated with the country-specific C conversion factor (0.4275 t C m^{-3}) for 2006–2022. The following inputs were used in the calculations: the water content of the wood pulp is 10%, the wood content from t.d.m wood pulp is 95% and the carbon content of wood dry mass is 50%. Inherited emissions are included in the HWP estimations.

Table 6.36. Key variables used in calculations: C stocks in HWP subcategories at the beginning of year, share of industrial roundwood for the domestic production of HWP originating from domestic forests (f_{IRW}) and share of domestically produced pulp for the domestic production of paper and paperboard (f_{PULP})

Year	Initial stock in Solid wood[350], t C	Initial stock in Paper and paperboard, t C	Initial stock in Bleached semi-chemical wood pulp, t C	Total initial stock in HWP, t C	f_{IRW}[351]	f_{PULP}[352]
1990	5 731 831	46 355	NO	5 778 186	1.000	0.998
1991	5 774 449	46 358	NO	5 820 807	1.000	0.998
1992	5 780 616	46 359	NO	5 826 975	1.000	0.998
1993	5 751 147	46 361	NO	5 797 508	1.000	0.998
1994	5 734 743	46 348	NO	5 781 091	0.999	0.999
1995	5 729 438	46 354	NO	5 775 792	0.866	0.998
1996	5 739 105	44 529	NO	5 783 633	0.912	0.999
1997	5 776 781	47 243	NO	5 824 023	0.898	0.885
1998	5 893 855	42 480	NO	5 936 335	0.827	0.990
1999	6 013 326	41 416	NO	6 054 742	0.829	0.990
2000	6 195 442	42 175	NO	6 237 616	0.895	0.989
2001	6 450 634	45 416	NO	6 496 050	0.893	0.922
2002	6 746 846	50 928	NO	6 797 773	0.897	1.000
2003	7 055 447	57 978	NO	7 113 426	0.854	0.996
2004	7 354 884	58 750	NO	7 413 634	0.688	1.000
2005	7 581 142	56 307	NO	7 637 449	0.577	0.985
2006	7 751 686	51 692	NO	7 803 378	0.592	0.963
2007	7 912 797	51 062	10 666	7 974 525	0.589	0.997
2008	8 012 872	50 985	34 433	8 098 291	0.802	0.994
2009	8 129 423	53 837	60 665	8 243 925	0.924	0.998
2010	8 238 972	56 321	87 584	8 382 877	0.914	0.999
2011	8 445 426	63 203	105 726	8 614 355	0.909	0.980
2012	8 650 165	66 811	120 984	8 837 960	0.936	0.878

[348] IPCC 2013 KP Supplement, pp. 2.118, 2.120 & 2.121
[349] IPCC 2013 KP Supplement, Chapter 2.8.3.2, p. 2.123, Table 2.8.2.
[350] Data about production of the particular HWP commodities are provided by the Statistics Estonia and Estonian Wood Industries Association
[351] Data from NFI (production of industrial roundwood) and Statistics Estonia (import and export of roundwood)
[352] Data from Statistics Estonia

Year	Initial stock in Solid wood[350], t C	Initial stock in Paper and paperboard, t C	Initial stock in Bleached semi-chemical wood pulp, t C	Total initial stock in HWP, t C	f_{IRW}[351]	f_{PULP}[352]
2013	8 813 341	68 497	133 999	9 015 837	0.938	0.822
2014	8 996 008	67 681	139 408	9 203 096	0.947	0.742
2015	9 194 558	64 729	152 424	9 411 711	0.943	0.653
2016	9 442 032	59 700	160 609	9 662 340	0.965	0.646
2017	9 712 080	57 211	168 757	9 938 047	0.962	0.688
2018	9 997 293	57 032	172 311	10 226 636	0.953	0.816
2019	10 288 464	61 808	175 013	10 525 285	0.942	0.493
2020	10 561 755	55 217	173 274	10 790 246	0.922	0.585
2021	10 819 400	51 045	174 969	11 045 413	0.863	0.494
2022	11 071 951	46 236	182 929	11 301 117	0.881	0.544
2023	11 256 357	41 971	183 576	11 481 904	0.899	0.00
2024	11 416 275	29 678	172 880	11 618 833	-	-

A simple customised approach was developed to gain estimates for 1990 and 1991. An extrapolation for the 1990 and 1991 felling volume and production of industrial roundwood (IRW) was made. Production figures in 1990 for sawn wood, insulating board, fibreboard (compressed), particle board and plywood originate from Statistics Estonia. Production data for these commodities for 1991 is an average of the years 1990 and 1992. Foreign trade data for IRW and production data of veneer sheets, wood pulp, paper and paperboard of 1992 was repeated for 1990 and 1991.

Table 6.37. Default conversion factors for default HWP categories and their subcategories[353]

HWP categories	Density ($t\ m^{-3}$)	Carbon fraction	C conversion factor ($t\ C\ m^{-3}$)
Sawn wood (aggregate)	0.458	0.5	0.229
Coniferous sawn wood	0.45	0.5	0.225
Non-coniferous sawn wood	0.56	0.5	0.28
Wood-based panels (aggregate)	0.595	0.454	0.269
Hardboard (HDF)	0.788	0.425	0.335
Insulating board (Other board, LDF)	0.159	0.474	0.075
Fibreboard compressed	0.739	0.426	0.315
Medium-density fibreboard (MDF)	0.691	0.427	0.295
Particle board	0.596	0.451	0.269
Plywood	0.542	0.493	0.267
Veneer sheets	0.505	0.5	0.253
	($t\ t^{-1}$)		**($t\ C\ t^{-1}$)**
Paper and paperboard	0.9		0.386
Bleached semi-chemical wood pulp	0.95		0.428

353 IPCC 2013 KP Supplement, Chapter 2.8.3.1, page 2.122, Table 2.8.1 (except for Bleached semi-chemical wood pulp).

6.12.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Harvested wood products subcategory, please see Annex A.II.4 LULUCF, Harvested wood products (CRT 4.G) chapter.

6.12.4. Category-specific QA/QC and verification, if applicable

A complete Quality Assurance (QA) and Quality Control (QC) was carried out for the LULUCF sector according to the IPCC *Tier 1* method. The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

6.12.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process and impacts on emission trends

Activity data (mostly deforestation time series) is being updated and if necessary, corrected each year. In Table 6.38, a quantitative overview of recalculations has been shown.

Table 6.38. Quantitative overview of recalculations compared to the 31.12.2024 submission

		Harvested wood product, C stock change, kt			**TOTAL** HWP net CO_2, kt
		Solid wood	**Paper and paperboard**	**Bleached semi-chemical wood pulp**	
1990	Previous submission	42.62	0.002	NE	-156.27
	Current submission	42.62	0.002	NE	-156.27
	Difference %	**NO**	**NO**	**-**	**NO**
2005	Previous submission	170.54	-4.61	NE	-608.41
	Current submission	170.54	-4.61	NE	-608.41
	Difference %	**NO**	**NO**	**-**	**NO**
2020	Previous submission	257.40	-4.18	1.67	-934.58
	Current submission	257.64	-4.17	1.69	-935.61
	Difference %	**0.1**	**-0.1**	**1.6**	**0.1**
2021	Previous submission	251.29	-4.83	7.81	-932.33
	Current submission	252.55	-4.81	7.96	-937.58
	Difference %	**0.5**	**-0,5**	**1.9**	**0.6**
2022	Previous submission	179.31	-4.37	0.04	-641.58
	Current submission	184.41	-4.27	0.65	-662.89
	Difference %	**2.8**	**-2.4**	**1720.0**	**3.3**

6.12.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

There are no planned category-specific improvements.

7. WASTE (CRT SECTOR 5)

7.1. Overview of the sector (e.g. quantitative overview and description, including trends and methodological tiers by category) and background information

Waste management in Estonia is based on the EU and national legislation and the National Waste Management Plan for years 2023-2028[354]. The main purpose of the national waste policy has been to reduce the volume of waste deposited in landfills, increase the potential of recoverable waste, and minimise the hazardousness of waste to the limit. The National Waste Management Plan supports the Waste Act, which stipulates waste-related requirements and rules.

Table 7.1 summarizes the data on approaches and emission factors employed in estimations of GHG emissions from each sub-category of the Waste sector. Due to the lack of national research on sectors country-specific emission factors, the default values of IPCC 2006 Guidelines have mostly been applied in calculations. The process of choosing among methods relies on the decision trees described in IPCC 2006 Guidelines.

Table 7.1. Methods and emission factors used in estimations of emissions from the Waste sector

	Method applied / EF used		
GHG SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**
5. WASTE			
5.A Solid waste disposal		T2/D	
5.B.1 Composting		T1/D	T1/D
5.D Wastewater treatment and discharge		T1/D	T1/D

T1 – Tier 1 method, T2 – Tier 2 method, D – IPCC 2006 default value.

CO_2 eq. emissions from the Waste sector were 300.13 kt in 2023 and covered 2.76% of total GHG emissions in 2023 (Figure 7.1).

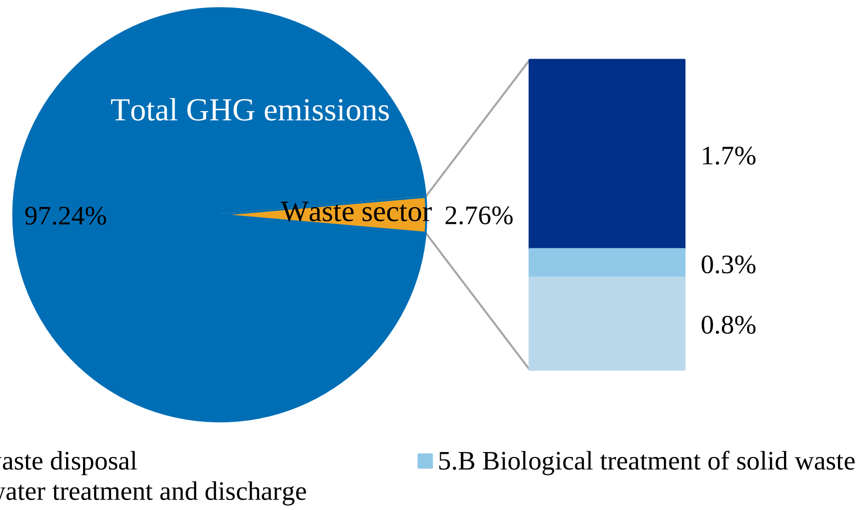

Figure 7.1. CO_2 eq. emissions from the Waste sector compared to total GHG emissions in Estonia in 2023, %

[354] MoC. (2023). Riigi jäätmekava 2023-2028. [www] https://kliimaministeerium.ee/media/12031/download (28.12.2024).

Total CO_2 eq. emissions from the Waste sector in 2023 decreased by 4.2% compared to 2022. Compared to the base year of 1990, the amount of CO_2 eq. emissions in 2023 were 26.5% smaller. Compared to the base year, CO_2 eq. emissions from Solid waste disposal (SWD) have decreased by 23.4%, from Wastewater treatment and discharge by 44.4%. On the other hand, CO_2 eq. emissions from Biological treatment of solid waste have, compared to the base year of 1990, increased by 456.1%. Emissions from Waste incineration and Open burning in 2023 were 0.54 kt CO_2 eq and were not reported due to being only 0.004% of the national total emissions and therefore considered insignificant.

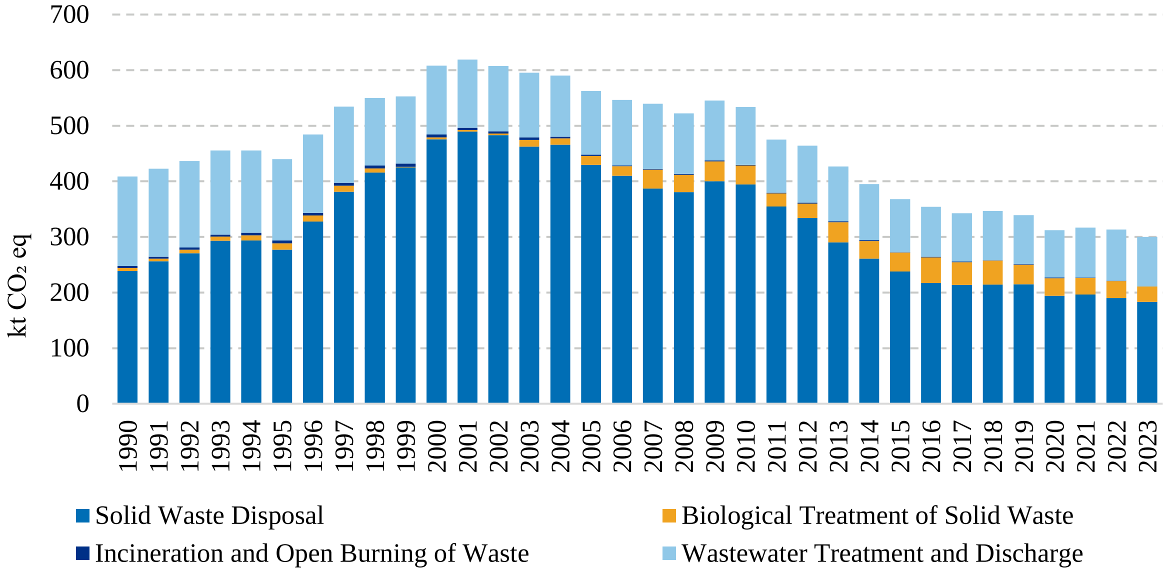

Figure 7.2. Trends of GHG emissions in the Waste sector by source categories in 1990–2023, kt CO_2 eq.

As seen in Figure 7.2 and Table 7.2, GHG emissions from the Waste sector are in decreasing trend. Low CO_2 eq. emissions in 1995 are related to decreasing CH_4 emissions from paper and sludge disposal. The highest CO_2 eq. in 2000–2001 is related to the significant increase in emissions mainly from Solid waste disposal. The increasing trend of emission until 2001 is linked to the high amount deposited organics and food waste which were deposited due to low rate of waste sorting. Emissions from waste incineration have been marginal during the whole period compared to other activities involved. The decrease of GHG emissions from the Waste sector after 2004 relates to the increasing amount of CH_4 recovery from landfills. Emissions decrease starting from 2009 is connected with the financial crisis during 2007–2008. The financial crisis did not affect the Waste sector immediately, because companies had a raw material reserve. The total CO_2 eq. in 2011 decreased significantly compared to previous years, mainly because of the change in the national currency, which raised prices in the country and therefore changed consumption habits and reduced waste generation. Also, opening the Iru waste incineration plant in 2013 had a decreasing effect on the amount of deposited waste trend.

Due to the COVID-19 pandemic, emissions decreased sharply in 2020, as the amount of generated waste decreased. Emissions increased a bit in 2021, but still remained below the 2019 level. The slight increase in 2021 total emissions is mainly driven by 5A (SWD) and 5D (Wastewater treatment) subcategories. In SWD emissions increased, because less landfill gas was collected and therefore methane recovery rate was lower compared to 2020. In addition, emissions in wastewater treatment subcategory increased as the population of low density settlements increased based on recent census. The lowest CO_2 eq. emissions occurred in 2023, which was mainly connected to the decreasing amount of biogenic waste deposited in landfills.

Table 7.2. GHG emissions from the Waste sector in Estonia in 1990–2023, kt

Year	SWD	Waste incineration and Open burning of waste			Biological treatment of solid waste		Wastewater treatment and discharge			Total CO_2 eq. emissions (AR5)
		non-biogenic			Composting		Domestic wastewater		Industrial wastewater	
	CH_4	CO_2	CH_4	N_2O	CH_4	N_2O	N_2O	CH_4	CH_4	CO_2 eq.
1990	8.55	2.25	0.05	0.0008	0.11	0.007	0.13	4.51	NO	408.57
2005	15.33	1.46	0.03	0.0005	0.37	0.022	0.10	2.84	0.29	562.55
2020	6.93	0.50	0.01	0.0002	0.73	0.044	0.11	1.95	0.04	312.40
2021	7.01	0.60	0.01	0.0001	0.68	0.041	0.12	2.04	0.06	316.65
2022	6.79	0.33	0.01	0.0001	0.69	0.041	0.12	2.04	0.16	313.18
2023	6.55	NE, NO	NE, NO	NE, NO	0.63	0.038	0.12	1.99	0.07	300.13

NO – not occurring, NE – not estimated

NH_3 emissions are based on the data reported in NEC/CLRTAP inventories by the Estonian Environment Agency (EstEA). Total NH_3 emissions presented in Figure 7.3 include emissions from SWD, Biological treatment of solid waste, Industrial waste incineration, Cremation, Industrial and domestic wastewater treatment, and Other waste handling. The total NH_3 emissions from these categories in 2023 were 0.2 kt, remining on a similar level as the previous years. The emissions are mainly calculated by using actual emissions data reported by the companies as well as by using the EMEP/EEA Guidebook 2023[355].

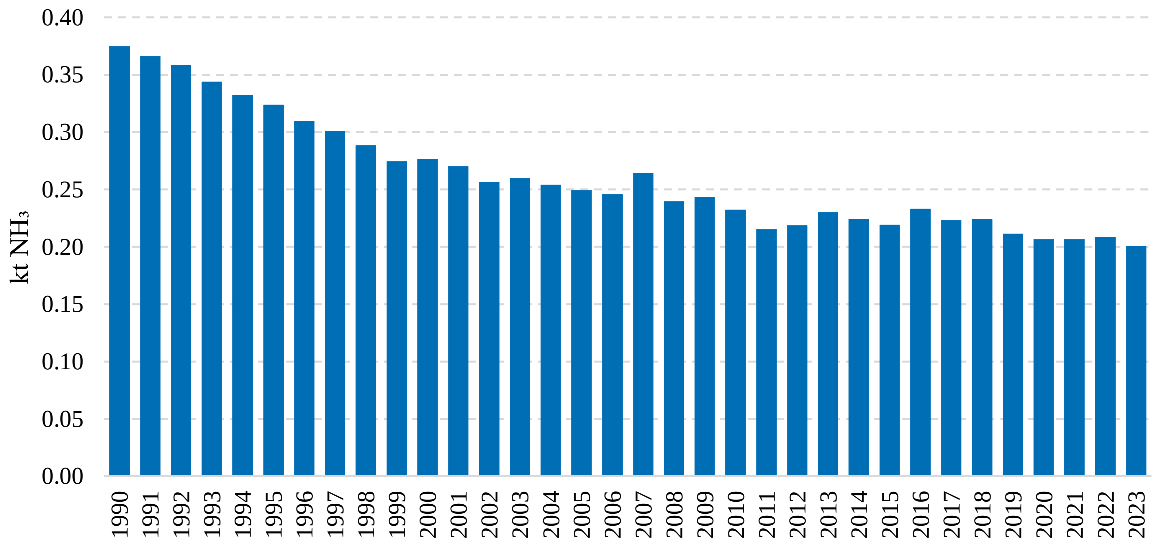

Figure 7.3. NH_3 emissions from SWD, Biological treatment of solid waste, Industrial waste incineration, and Industrial and domestic wastewater treatment, kt

[355] EMEP/EEA air pollutant emission inventory guidebook – 2023. [www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2023 (28.02.2025).

7.2. Solid waste disposal (CRT 5.A)

7.2.1. Category description

In 2023, Estonia had five functioning landfills (Tallinn Recycling Center, Uikala, Väätsa, Torma and Paikre) classified as managed SWD sites and three landfills for industrial waste. These landfills conform fully to environmental and technical requirements and standards and are capable of servicing more than one county or service area. Due to the strict requirements established for waste landfilling, the number of landfills started decreasing, from 157 landfills in 2001 to five landfills in 2015. Landfills closed for waste depositing were conditioned in accordance with the requirements by the end of 2015.

As seen in Figure 7.4, the quantities of emitted methane from SWD is decreasing.

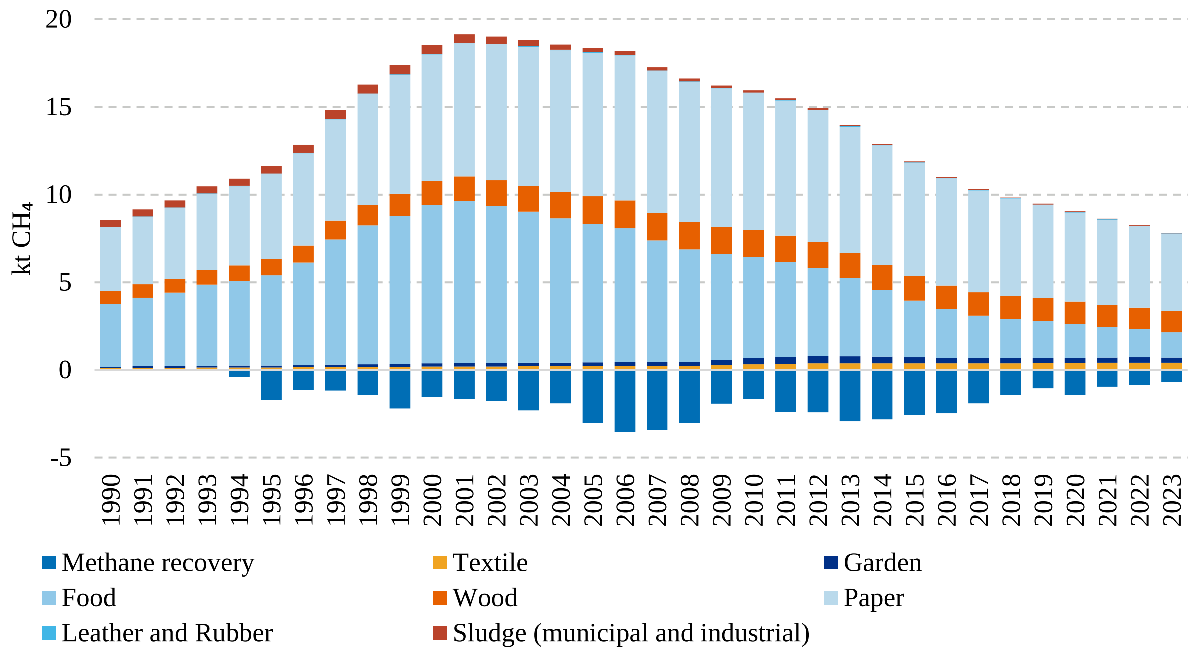

Figure 7.4. CH_4 emissions and recovery from landfills in Estonia in 1990–2023, kt CH_4

Estonia's total CH_4 emissions from SWD into landfills in 2023 amounted to 6.55 kt CH_4 (Table 7.3). Compared to 2022, emissions were 3.63% lower, mostly because waste disposal decreased. Figure 7.5 shows CH_4 emissions from SWD with and without energy recovery.

Table 7.3. Quantities of CH_4 emissions and recovery from biodegradable solid waste deposited in landfills in 1990–2023, kt

Year	Organic/ Food	Garden	Paper	Wood	Textile	Sludge (municipal + industrial)	Leather	Recovery	Total CH_4 emissions from SWD sites
1990	3.6	0.1	3.6	0.7	0.1	0.38	0.03	NO	8.55
2005	7.9	0.2	8.2	1.6	0.2	0.26	0.03	-3.0	15.33
2020	1.9	0.3	5.1	1.3	0.4	0.05	0.02	-1.4	6.93
2021	1.8	0.3	4.9	1.2	0.4	0.04	0.02	-1.0	7.01
2022	1.6	0.3	4.6	1.2	0.4	0.04	0.02	-0.9	6.79
2023	1.5	0.3	4.4	1.2	0.4	0.03	0.02	-0.7	6.55

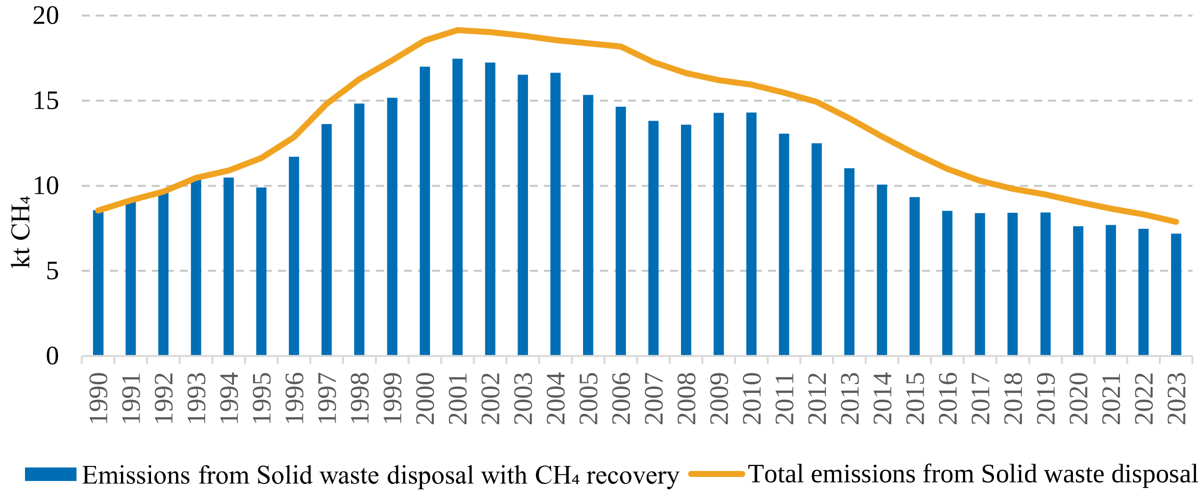

Figure 7.5. CH_4 emissions from SWD with and without energy recovery, kt CH_4

7.2.2. Methodological issues

Choice of methods

To estimate CH_4 emissions from SWD in landfills, the First Order Decay (FOD) approach, which is IPCC 2006 *Tier 2* method, was used. The FOD method with default parameters and country-specific activity data were used due to the unavailability of country-specific key parameters.

Activity data

Activity data for waste generation and depositing used in the calculation is collected from EstEA, which checks the accuracy of data reported by waste handling companies. Starting from 2020 companies submit their waste data through Environmental Decisions Information System KOTKAS, managed by Environmental Board. Reports are stored in Data Warehouse, managed by Ministry of the Climate, and published in Tableau[356] managed by The Information Technology Centre of the Ministry of the Environment (KeMIT). Tableau provides information about the entire waste stream, including waste at the beginning of the year, imported, and exported waste, generated waste, recycled waste, incinerated waste, composting of biodegradable waste and the amount of waste left in stock at the end of the year. It is possible that the amount of waste at the end of one year does not correspond to the amount of waste at the beginning of the subsequent year. This distinction is a result of different aspects including the following:

- The waste reporting obligation is new for the company. If a company's waste permit is enforced in 2023, then the amount of waste generated by this company will be included in the total amount of waste at the beginning of 2023 and is not included in the stock of waste at the end of 2022 (because this company did not have the obligation to report waste in 2022).

[356] The Information Technology Centre of the Ministry of the Environment Waste data visualizing system (Tableau). [www] https://tableau.envir.ee/views/Avalikud_pringud_2020-2022/Riigitasand?%3Aembed=y&%3Aiid=4&%3AisGuestRedirectFromVizportal=y (16.11.2023).

- The company does not have to submit waste reports because its waste reporting obligation has ended (the company has changed the profile of its activities etc.). If the company's waste reporting obligation ended in 2022, then the amount of waste is counted in the stock at the end of 2022. This waste is not included in the stock at the beginning of 2023, as this waste will be given to other waste companies which will report the waste as '*received from the company*'. This amount of waste will be accounted for in total waste generation.
- The company has discovered that the data submitted the previous year was given in wrong units. In this case, they correct the error at the beginning of the subsequent year.
- The company is making an inventory at the beginning of the year and if there have been any inconsistencies in the quantities reported at the end of the previous year, then the company corrects the data at the beginning of the subsequent year. If such changes are made, they are tracked and there will be a comment about them in the online waste reporting system.

Differences between the activity data at the end of one year and at the beginning of the following year are characteristic of the national system; nevertheless, all waste data has been considered in doing emission calculations. The matter of activity data at the end of one year and at the beginning of the following year has been discussed with the National Audit Office of Estonia, who is aware of the current situation but has not proposed a method for enhancing the reporting system.

The amount of imported waste in 2023 was 111 373 tonnes, of which the majority was inert (33%), metal (31%), glass (15%), plastic (8%), and paper waste (7%) (Figure 7.6. Imported waste in Estonia in 2023, %). The rest of the imported waste (6%) included rubber, wood, waste fuel, oil, pottery, textile and chemicals. Imported waste is reused, for example, in road construction and filling quarries, wood, glass and plastic packaging is reused. Metal waste is collected, sorted and pre-treated, then exported. All imported waste is recycled and therefore is not a part of the waste sector emission calculation (observation by the 2022 ERT to include the information).

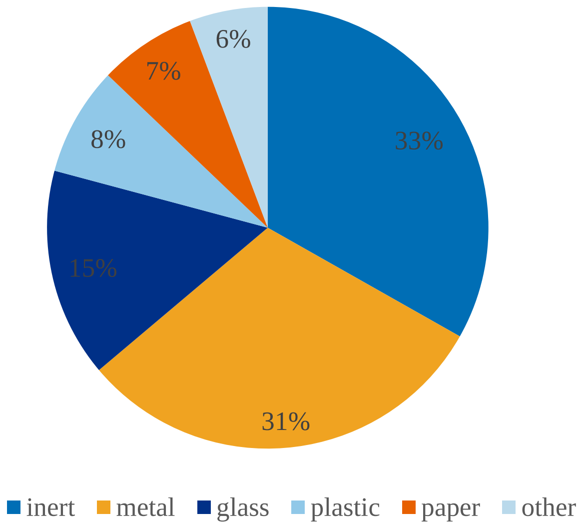

Figure 7.6. Imported waste in Estonia in 2023, %

EstEA started to collect data in accordance with the Estonian waste classification in 1992, but in 1999, the adapted classification system changed, and the European Waste Catalogue was adopted. The data for 1990–1991 was interpolated based on the data of 1992–1998. The forecast function of the Excel software was used to calculate the quantities of waste generated in the period of 1990–1991. For the period of 1950-1990 (historical data needed in the waste model) no data on the generated and deposited waste amount is available. For industrial waste generation, excel forecast function using the data of generated waste and GDP was used and for deposition, an average deposition percentage was used. For MSW waste an extrapolation using population and GDP was done. Data on population and GDP is obtained from the dataset of the SE.

The quantity of total waste generated in 2023 was about 17.2 million tonnes, which is 24.32% lower than in 2022. The proportion of degradable and inert waste generated in 2023 was 4.23% and 92.80%, respectively. The proportion of separately collected waste was 1.67% of the total waste generated. The annual trend of inert and degradable waste generated in Estonia in 1990–2023 is presented in Figure 7.7.

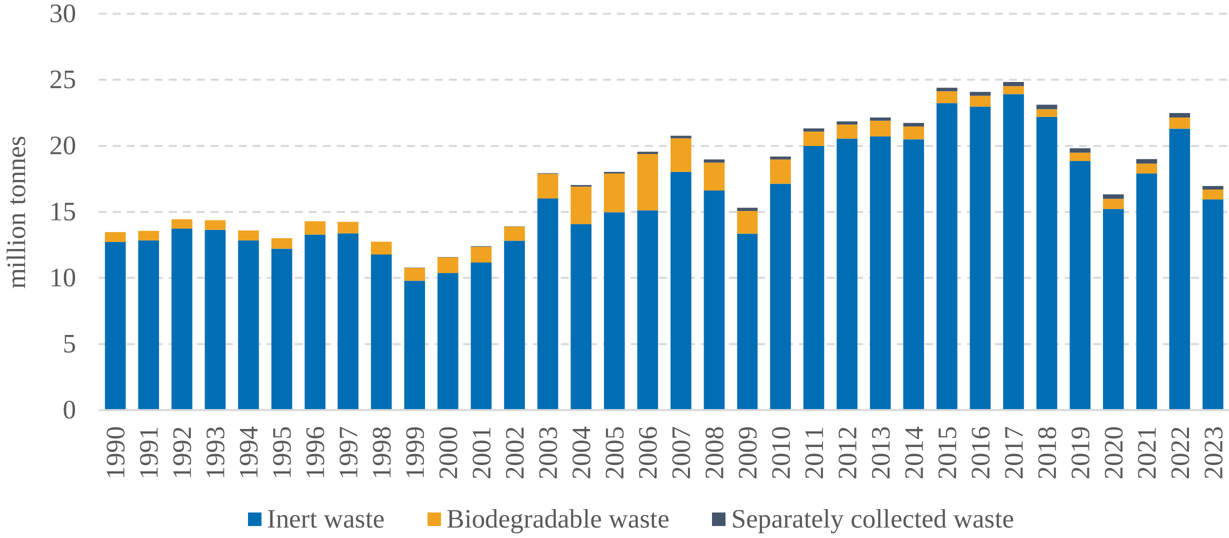

Figure 7.7. Quantities of waste generated in Estonia in 1990–2023, million tonnes

In 2023, waste generated by the oil shale industry constituted 71.6% of the total waste generated. The waste of the oil shale industry includes waste from mining and physical-chemical treatment, thermal processes, and other oil shale waste[357]. In comparison, the waste of the oil shale industry in 2022 covered 75.4% of the total waste generated, so the amount of waste from oil shale mining from the total waste generated has decreased 3.8% compared to 2022. Waste from the oil shale industry is not taken into account in the estimation of GHG emissions from SWD.

The quantity of municipal waste (MSW) generated in 2023 was about 256 772 tonnes in addition to a separately collected fraction, which amounted to 49 677 tonnes. The total amount of MSW generated was about 1.5% of the total waste generated. The total amount of waste deposited in landfills was 5.97 million tonnes, from which MSW comprised 34.8 thousand tonnes and industrial waste 5.93 million tonnes (Table 7.4 and Table 7.5). Separately collected MSW and deposited MSW are shown separately in Table 7.4, as the deposited MSW is calculated based on the mixed MSW sorting studies (Table 7.9). Separately collected MSW is separately reported in Tableau.

[357] Waste from the treatment of oil shale and coal, e.g., pitch. Starting from 2018 submission, oil shale fly and bottom ash are also included under oil shale waste; in previous submissions, these were reported under inert waste.

Table 7.4. Quantities of MSW deposited in SWD sites, kt

Year	Food	Garden	Paper	Wood	Textile	Sludge	Inert	Nappies	Deposited MSW	Separately collected and deposited MSW
1990	147.3	3.5	88.5	11.5	3.1	5.1	95.8	NE	349.8	NO
2005	152.2	3.6	91.5	11.9	3.3	0.2	99.1	NE	361.6	6.7
2020	12.3	4.5	9.0	0.7	3.1	NO	20.7	2.6	52.8	7.7
2021	12.8	4.6	9.3	0.7	3.2	NO	21.5	2.7	54.8	10.7
2022	8.1	2.9	5.9	0.4	2.0	NO	13.6	1.7	34.7	3.5
2023	8.1	2.9	5.9	0.4	2.0	NO	13.7	1.7	34.8	2.8

NO – not occurring, NE – not estimated

Table 7.5. Quantities of industrial waste deposited in SWD sites, kt

Year	Organic	Textile	Wood	Paper	Leather	Rubber	Sludge	Inert*
1990	36.0	0.7	11.5	2.8	0.5	NO	46.3	10 187.0
2005	4.6	1.2	5.9	NO	NO	NO	1.0	11 058.9
2020	6.8	0.8	0.2	0.0	0.2	NO	1.2	5 922.5
2021	5.4	0.7	0.2	0.0	0.1	NO	0.9	6 444.2
2022	4.8	0.8	0.2	0.0	0.1	NO	0.6	7 353.0
2023	3.1	0.8	0.1	0.1	0.0	NO	1.9	5 930.5

NO – not occurring; * Inert waste includes materials that do not result in CH_4 emissions when landfilled – chemicals, inert clinical waste, glass waste, inert waste, metal waste, oil shale waste, plastic waste, pottery and car tyres.

The quantity of Degradable Organic Carbon (DOC) generated in 2023 (Figure 7.8) increased by approximately 10.5% compared to the base year of 1990. In comparison with the year 2022, the amount of DOC has decreased by about 19%, due to decreased waste generation. The ratio of DOC landfilled to DOC generated has increased from 2.9% to 3.4%.

Calculated DOC content values for Municipal in Table 7.6 and Table 7.8 are presented to describe the conditions in Estonia – how organic carbon content has changed over time in MSW waste as a `group of different waste materials´. This estimation is based on the mixed municipal waste sorting studies and no waste content measurements have been made. The GHG calculations are done separately for all waste groups (e.g., food waste, garden, paper, textile etc) and therefore MSW is also divided to different waste groups. Estonia uses IPCC 2006 Guideline's default DOC contents for the FOD model in emission calculations (Table 7.8).

Table 7.6. DOC content of mixed MSW in Estonia in 1950–2023

	1950–1999	2000–2007	2008–2011	2012–2018	2019-onward
DOC content in MSW	0.20	0.20	0.16	0.14	0.15

Waste generated in DOC tonnes in 1990–2001 increased slightly due to the increasing amount of municipal, organic and industrial wood waste, while the share of other types of waste was smaller. A notable decrease in generated DOC tonnes in 2002 was caused by a sharp decrease in industrial wood waste while the share of other types of waste increased slightly. A notable increase in the amount of waste generated in DOC tonnes in 2003–2008 was caused by the high but fluctuating generation of industrial wood waste. During this period, separately collected paper and wood waste were also in an increasing trend. On the other hand, the share of municipal waste started to decrease. The decline in generated waste in 2009 is connected to a sharp decrease in industrial wood waste, which, after the increase in 2010, started to decrease again in 2014. During the period of 1990–2000, a high volume of generated waste was deposited in landfills. The decrease in landfilled waste % in 1999–2001 was connected to the decreasing trend of depositing municipal and organic waste, including sludge from industrial and municipal sources. The increase in landfilled waste % in 2002 was connected to the increase in the generation of municipal waste and industrial sludge.

In calculations Estonia uses Boreal and Temperate Wet Climate zone constants, because according to the Estonian Environmental Agency, the mean annual temperature in Estonia (1991-2020) is 6.4 degrees and precipitation is almost twice as much as evaporation, so the climate is wet.

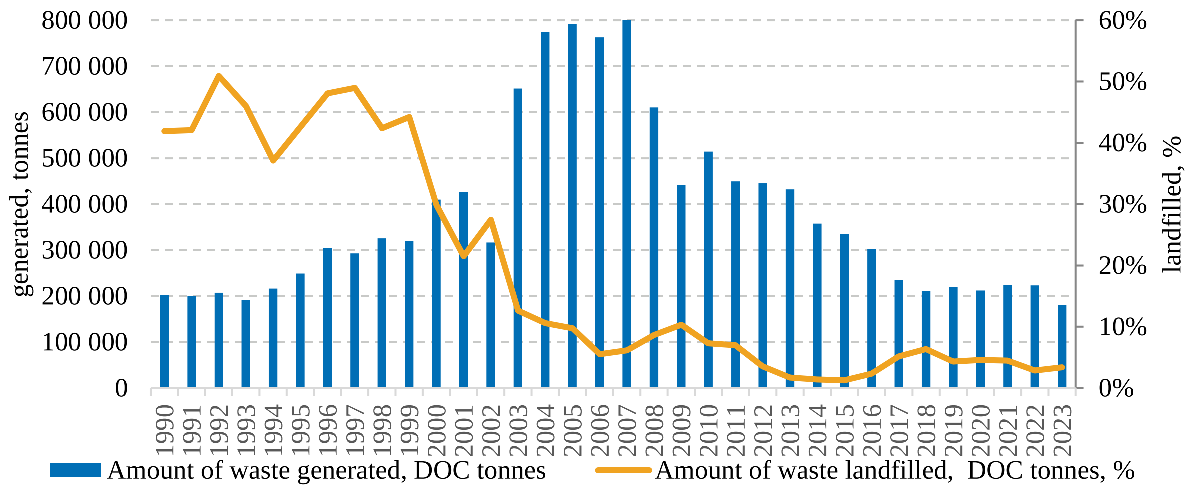

Figure 7.8. Quantity of DOC generated (tonnes) and ratio of DOC landfilled to DOC generated (%) in 1990–2023

Collecting landfill gas

The data on the amount of recovered methane in landfills 1994–2006 is based on REN-Estonia – an annual questionnaire on renewables and waste. Starting from 2007, data was obtained from EstEA's information system for ambient air pollution sources ´OSIS´ which is starting from 2019 replaced with database KOTKAS. From the information given by SE, the REN-Estonia report includes for the years 1994-2006 only landfills reporting biogas flaring. From the REN-Estonia report, it is possible to have the total amounts (not the amount per landfill). The control calculation has been made to validate the numbers between REN-Estonia report and KOTKAS, the results showed the same numbers and timeseries consistency between the two sources is therefore covered. The total amount of CH_4 recovered in 2023 was 0.69 kt (Figure 7.9).

The amount of CH_4 is calculated using a density of 0.717 and the CH_4 composition of 55%.

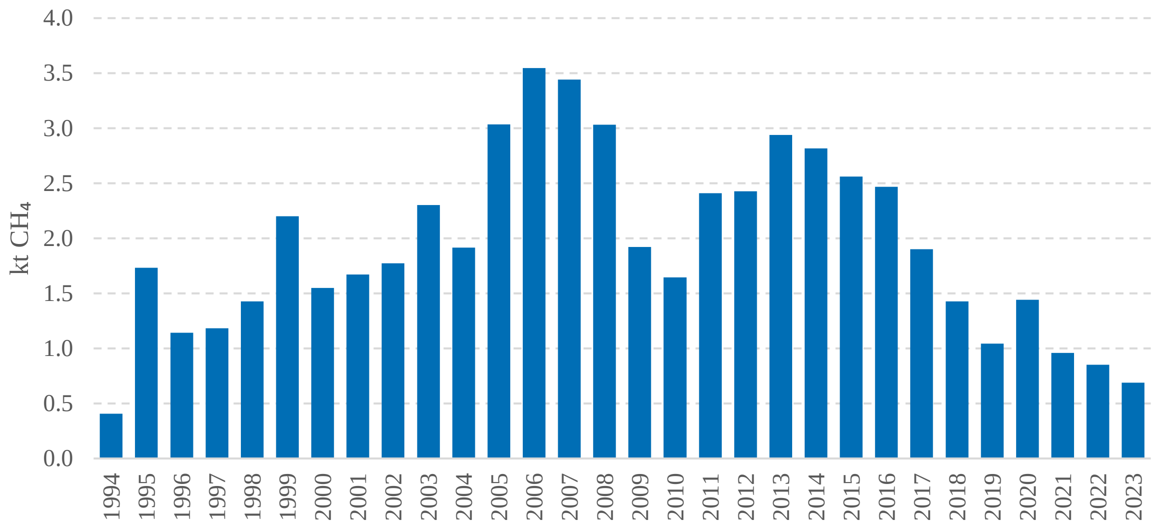

Figure 7.9. CH_4 recovered from landfills in 1994–2023, kt

Methane recovery in landfills started in 1994. In 1994–2006, only one landfill in Estonia collected and recovered methane (Pääsküla landfill in Tallinn). The amount of reused CH_4 during this period fluctuated due to changes in the quantity of waste generated and the percentage of organic waste in the total amount of waste generated. Jõelähtme landfill started to collect landfill gas in 2007. The decrease in recovered CH_4 in 2008 was caused by the decrease in recovered CH_4 from Pääsküla landfill. Additionally, Väätsa landfill and Paikre landfill started to collect biogas in 2009 and 2010, respectively. In 2013, Viljandi and Uikala landfill started to burn biogas and Aardlapalu landfill started to burn biogas with energy recovery in 2014. Burning in Viljandi landfill ended in 2018. Torma landfill started to burn biogas in 2018. The decrease of CH_4 recovered from landfills is mostly related to the decrease in the amounts of biodegradable waste being deposited in landfills.

The amount of recovered landfill gas, waste recycled and unstable population, which fluctuates during the time, also affect the implied emission factor (IEF) of CH_4.

Emission factors

Emission factors used in the calculations of emissions from SWD sites are default emission factors from IPCC 2006 Guidelines (Table 7.7). Methane generation rate constants used in the calculations are default values from IPCC 2006 Guidelines (Table7.7).

Table 7.7. Emission factors and parameters used in calculations

Factor/Parameter	Value
MCF – anaerobic[358]	1
MCF – uncategorised SWD sites[338]	0.6
DOCf[359]	0.5
F[360]	0.5
OX	0.09
Methane generation rate constant[361]	
k1 = paper/textile waste	0.06

[358] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.14, table 3.1.
[359] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.13.
[360] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.15.
[361] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.17, table 3.3.

Factor/Parameter	Value
k2 = wood	0.03
k3 = organic / garden and park waste	0.1
k4 = food waste / sewage sludge	0.185
k5 = industrial waste	0.09

Table 7.8. Default DOC content of different waste types (wet basis)[362]

Waste group	DOC content (fraction)
Municipal solid waste	
Food/Grease	0.15
Municipal	see Table 7.6
Garden	0.2
Paper	0.4
Textile	0.24
Wood	0.43
Municipal sludge	0.05
Industrial waste	
Organic	0.15
Textile	0.24
Wood	0.43
Paper	0.4
Leather	0.39
Rubber	0.39
Industrial sludge	0.045

Calculations in the FOD model are based on the country-specific data about the waste composition of MSW (Table 7.9). Four studies have been carried out in Estonia about waste composition in MSW: in 2000, 2008, 2013 and 2020. The period of 1950–1999 is retroactively covered with composition data derived from studies carried out in Estonia in 2000; the period of 2000–2007 is covered with data from a study carried out in 2000. The period of 2008–2011 is covered with data from a study carried out in 2008, the period of 2012-2018 is covered with data from a study carried out in 2012. Starting from 2019, the MSW composition from the study of 2020 was used.

Calculations made under SWD comprise managed and uncategorised disposal sites. CH_4 emissions in 1990–1993 are derived from uncategorised disposal sites; emissions since 2009 are derived only from managed disposal sites, while CH_4 emissions in 1994–2008 were generated in both managed and uncategorised waste disposal sites. In 1994–2008, a managed disposal site was considered Pääsküla landfill in Tallinn, where landfill gas was recovered. A type of uncategorised waste management was chosen, as there is no accurate data available, or research conducted in Estonia about the distribution of waste by waste management type (unmanaged shallow or unmanaged deep). CH_4 emissions from both landfill types are reported together in the NID, as the waste model used for calculations does not allow reporting emissions separately.

[362] IPCC 2006 Guidelines, Volume 5, Chapter 2: Waste generation, composition and management data, pages 2.14, 2.16, table 2.4 and 2.5.

Table 7.9. Composition of MSW, %

	1950–1999[363]	**2000–2007**[343]	**2008–2011**[364]	**2012–2018**[365]	**2019-onward**[366]
Organic household waste and non-defined non-separated waste	43.1	43.1	36	31.8	31.7
Paper and cardboard	25.3	25.3	18	13.5	17.0
Wood	3.3	3.3	1	2	1.3
Textiles	0.9	0.9	4	5.1	5.8
Inert	27.4	27.4	41	47.6	39.2
Nappies	-	-	-	-	5

The composition of furniture waste (Table 7.10) is based on an expert judgement and a study carried out by the Stockholm Environment Institute Tallinn Centre[367].

Table 7.10. Composition of furniture waste, % in 1990–2023

Composition of furniture waste	**%**
Wood	49.3%
Textile	24.3%
Metal	12.2%
Plastic	14.2%

7.2.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Solid waste disposal subcategory, please see Annex A.II.5 Waste, Solid waste disposal (5.A) chapter.

7.2.4. Category-specific QA/QC and verification, if applicable

Complete Quality Assurance (QA) and Quality Control (QC) were carried out pursuant to the procedures described in IPCC 2006 Guidelines[368]. In addition, the specific documentation and reporting recommendations relevant to SWD described in Section 3.8 of Chapter 3 of IPCC 2006 Guidelines have been considered when carrying out QC activities.

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

[363] Vaania, (2000). Study on the composition of municipal solid waste including different regions in Estonia (in Estonian).
[364] SEI Tallinn, (2008). Analysis of Estonian municipal waste (including separate packaging waste and biodegradable waste) composition and quantity. Study on municipal waste sorting (in Estonian). [www] https://envir.ee/media/5317/download (16.11.2024).
[365] SEI Tallinn, (2013). Final report – Study on the composition of municipal waste, separately collected paper and packaging and WEEE in 2013 in Estonia (in Estonian). [www] https://envir.ee/media/5291/download (16.11.2024).
[366] SEI Tallinn, (2020). Final report – Study on the composition of municipal waste, separately collected paper and packaging and WEEE in 2020 in Estonia (in Estonian). [www] https://envir.ee/media/5318/download (16.11.2024).
[367] SEI Tallinn (2014). Improving the recycling system of municipal waste in Tallinn based on the examples of best practices. [www] http://www.tallinn.ee/R4R_study_Tallinn (16.11.2024).
[368] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance / Quality Control and Verification.

7.2.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process

In accordance with the 2022 ERT review's recommendation ARR2022/A.7, Estonia received an expert judgement for the evaluation about sewage sludge generation and usage in the period of 1990-1998 previously made by the former GHG inventory compiler Tallinn University of Technology (TalTech). The amount of sludge deposited in landfills changed for those years and the CH_4 and N_2O emissions from depositing of solid waste were recalculated (Table 7.11). As the methodology used for the calculation of the emissions considers the gradual break-down of the deposited waste and the emissions released over time (through First Order Decay), the emissions of all the subsequent years were also affected by the changes in data for 1990-1998. Additionally, minor rounding errors found in the calculations affecting MSW generation were corrected for the years 2008 and 2013.

Additionally, the Statistics Estonia updated the data on GDP for all the years starting from 2001 as a result of a routine five-yearly review across the European Union, the aim of which is to ensure international methodological comparability of macro statistics.

The emissions shown in the table below are final and include all the recalculations and corrections mentioned.

Table 7.11. Amount of sludge deposited, GDP, and recalculated CH_4 emissions

	2024 submission			2025 submission		
	amount of sludge deposited (kt)	**GDP (mln US dollars)**	**CH_4 emissions from depositing (kt)**	**amount of sludge deposited (kt)**	**GDP (mln US dollars)**	**CH_4 emissions from depositing (kt)**
1990	50.98	no change	8.54865	51.49	no change	8.54864
1991	53.64		9.14432	43.53		9.14510
1992	120.47		9.67522	45.50		9.66031
1993	48.30		10.59398	44.06		10.46737
1994	127.39		10.60441	48.99		10.49274
1995	33.18		10.15189	52.36		9.89448
1996	305.87		11.88462	50.62		11.70836
1997	155.90		14.24818	54.95		13.62445
1998	74.73		15.54375	55.30		14.83863
1999	no change		15.79931	no change		15.17694
2000			17.50414			16.98688
2001		6 258	17.90363		6 253	17.47373
2002		7 397	17.60492		7 399	17.24763
2003		98 92	16.81973		9 894	16.52278
2004		12 162	16.89226		12 165	16.64546
2005		14 112	15.53920		14 115	15.33409
2006		17 037	14.81317		17 040	14.64270
2007		22 478	13.96576		22 479	13.82409
2008		24 442	13.70593		24 443	13.58818
2009		19 711	14.44256		19 712	14.29137
2010		19 542	14.20710		19 543	14.08097
2011		23 215	12.78326		23 305	12.67785
2012		23 019	12.02133		23 238	11.93306
2013		25 115	10.44353		25 451	10.36947

	2024 submission			2025 submission		
	amount of sludge deposited (kt)	**GDP (mln US dollars)**	**CH_4 emissions from depositing (kt)**	**amount of sludge deposited (kt)**	**GDP (mln US dollars)**	**CH_4 emissions from depositing (kt)**
2014		26 634	9.38479		27 056	9.32058
2015		22 891	8.54386		23 312	8.48969
2016		24 073	7.80653		24 561	7.75994
2017		26 925	7.68235		27 470	7.64215
2018		30 626	7.68497		31 224	7.65018
2019		31 291	7.70354		31 875	7.67333
2020		31 435	6.95646		31 927	6.93013
2021		36 864	7.03219		37 203	7.00915
2022		37 920	6.81263		38 374	6.79240

7.2.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

The activity data is kept under consideration and will be updated as necessary.

One specific improvement currently in work in the Solid waste disposal category is the division of activity data for waste deposited in uncategorized and managed landfills to enable reporting them separately. So far, the accumulative emissions from both types of landfills have been reported under the managed landfills category since 1994. The issue became apparent thanks to the checks done under the EU Governance regulation. Together with this improvement, the waste generation per capita calculation will also be improved for the historical period of 1950-1990 in the waste model.

7.3. Biological treatment of solid waste (CRT 5.B)

7.3.1. Category description

Emissions of CH_4 and N_2O from Biological treatment of solid waste include emissions from composting both municipal and industrial waste.

Total emissions from composting of solid waste in 2023 comprised 0.63 kt CH_4 and 0.04 kt N_2O emissions (Figure 7.10). The sharp increases in the quantities of CH_4 emissions since 2003 are related to the large quantities of wood, sludge and organic waste composted during these years. High emissions in 2009 are due to a considerable effect from organic waste composting. The decline in composted waste since 2010 was caused by the opening of the Iru waste incineration facility. Furthermore, the slightly larger amount of landfilled sludge starting from 2010 also contributed to the decreasing emissions from composting. In 2016, the amount of waste composted increased due to the increased amount of composted sludge, garden and wood waste. Compared to 2022, the emissions from composting have decreased slightly in 2023 due to less waste being composted and less biodegradable waste being produced.

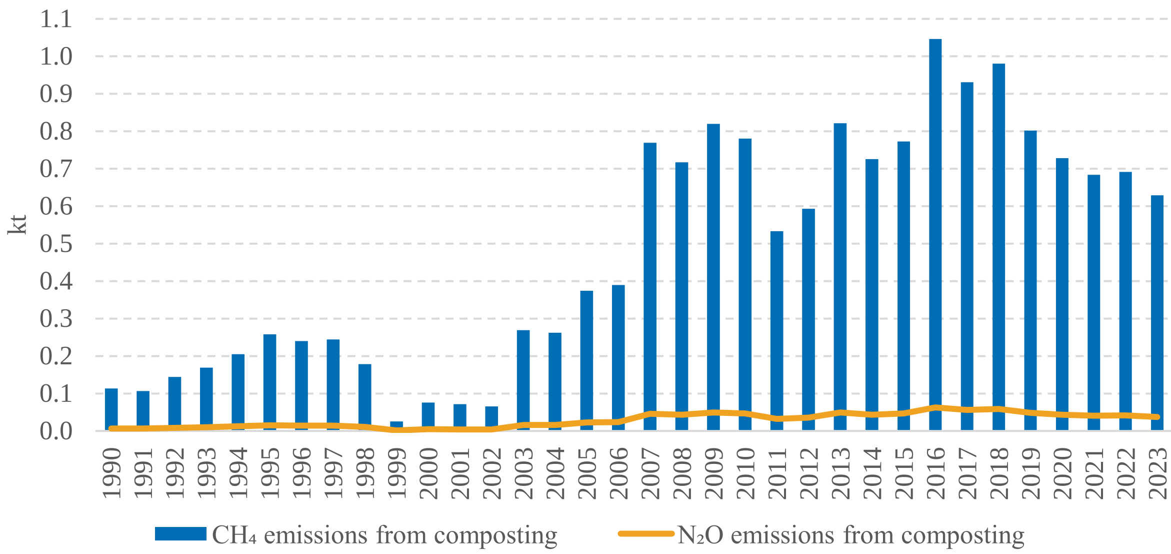

Figure 7.10. CH_4 and N_2O emissions from composting in 1990–2023, kt

In the 2024 submission, biogas production was considered for the first time in the national inventory emission calculations. This is a result of a project (2020-2023) during what Estonia developed a methodology to estimate GHG emissions from the production of biomethane from agricultural (and waste) sources. Emissions are allocated under Energy, Agriculture and Waste sectors. Emissions from biogas use will be reported under the Energy sector, emissions from biogas production from manure are reported under Agriculture sector and from waste sources are reported under the Waste sector (5.B.2) as anaerobic digestion also includes some co-digestates added to the manure into the biogas reactor.

Estonia launched anaerobic digestion in biogas facilities in 1994 and has estimated unintentional leakages due to process disturbances or during other unexpected events by using IPCC 2006 default value of 5% of the generated CH_4. Waste as co-substrates in agricultural biogas facilities has been added from 2014. Based on the IPCC 2006 Guidelines, N_2O emissions from anaerobic digestion at biogas facilities are assumed to be negligible.

On the basis of decision 18/CMA.1 Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement paragraph 32[369] Party may use the notation key “NE” when the estimates would be insignificant. The CH_4 calculations from anaerobic digestion resulted in a percentage lower than 0.02 for each year starting from 1994. For 2023, the CH_4 emissions from anaerobic digestion were 0.06 kt and were considered insignificant as they were only 0.03% of the total national emissions.

7.3.2. Methodological issues

Choice of methods

In order to estimate emissions from composting, IPCC 2006 *Tier 1* approach (Equation 7.1 and Equation 7.2) was used. In addition, 40% of dry weight in compostable waste is included in the calculations based on the remark in IPCC 2006[370] noting it is assumed that the moisture content in wet waste is 60%.

[369] Paragraph 32 – emissions should only be considered insignificant if the likely level of emissions is below 0.05% of the total national GHG emissions (without LULUCF).
[370] IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.6, table 4.1, remark

Equation 7.1[371]

$$CH_4\ Emissions = \sum_i (M_i \times EF_i) \times 10^{-3} - R$$

Where:

CH_4 emissions =	total CH_4 emissions in inventory year, kt CH_4;
M_i =	mass of organic waste treated by biological treatment type *i*, kt;
EF =	emission factor for treatment *i*, g CH_4/kg waste treated;
R =	total amount of CH_4 recovered in inventory year, kt CH_4;
i =	composting or anaerobic digestion.

Equation 7.2[372]

$$N_2O\ Emissions = \sum_i (M_i \times EF_i) \times 10^{-3}$$

Where:

N_2O emissions =	total N_2O emissions in inventory year, kt N_2O;
M_i =	mass of organic waste treated by biological treatment type *i*, kt;
EF =	emission factor for treatment *i*, g N_2O/kg waste treated;
i =	composting or anaerobic digestion.

Activity data

The quantities of waste biologically treated in 2023 are used as activity data. Waste handling companies are obligated to report the amount of waste biologically treated to EstEA, which processes data and checks its accuracy. In 2023, 62 896 tonnes (dry weight) of waste were composted. Companies report the waste amounts in wet weight basis which in the composting calculations are recalculated to dry weight. Inert waste and petroleum product waste consist of oils and stone; waste from the oil shale industry and plastic waste are not considered in the estimates. Abbreviation NO indicates that the waste type was not biologically treated.

Table 7.12. Quantities of waste composted in 1990–2023, tonnes dry weight[373]

Year	MSW	Organic waste	Paper	Sludge	Textiles	Wood	Total
1990	NO	1 500	NO	8 651	58	1 101	11 310
2005	NO	1 543	NO	27 056	NO	8 832	37 431
2020	NO	5 092	NO	42 939	NO	24 767	72 797
2021	NO	5 820	NO	34 783	NO	27 800	68 403
2022	NO	7 488	NO	35 211	NO	26 417	69 116
2023	NO	3 483	NO	40 199	NO	19 214	62 896

NO – not occurring

[371] IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.5, equation 4.1.
[372] IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.5, equation 4.2.
[373] The data of 1990–1994 was interpolated as there is no waste reporting data available for those years. An expert judgement which was taken during the compilation of 2008 NIR by the Tallinn University of Technology compiling the waste sector inventory that time. The rough estimation for the period of 1990-1994 is that about 5% yearly increase of organic and wood waste is representing the historical conditions. Because there was no consistent information on the textile waste for that period therefore it remained on the level of 1995. The sludge data for 1990-1998 is based on an expert judgement received in 2024.

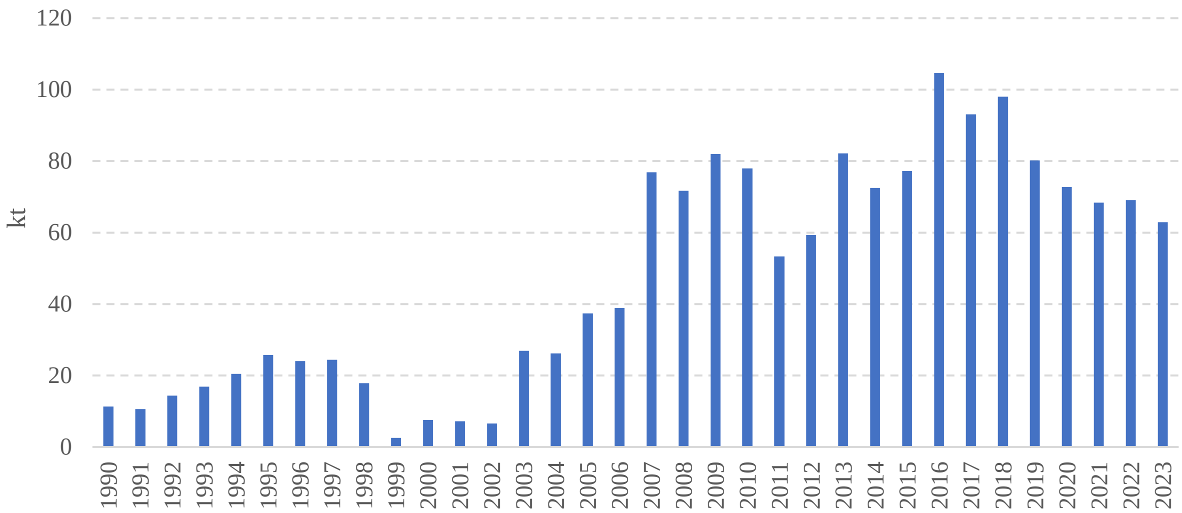

Figure 7.11. Composted organic waste in 1990–2023 (kt, dry weight)

As seen in Figure 7.11 in the amount of organic waste used in composting was marginal in the first decade of the period but started to grow rapidly in 2003 and has increased significantly – from 11 310 tonnes (dry weight) in 1990 to 104 642 tonnes (dry weight) in 2016. The decline in composted waste since 2010 was caused by the opening of a waste incineration plant. In addition, the increased amount of sludge landfilled in 2011 and 2012 also decreased the amount of composted waste. In general, the volume of waste for composting has increased significantly in recent years due to the adopted Landfill directive 1999/31/EC, in which the percentage limitation on the quantities of organic waste deposited in landfills is enacted by time periods. The increase in the amount of waste composted in 2016 is connected to the growth of recycling, the slight increase in 2018 is connected to the decreased amount of landfilled sludge. The decrease of composted waste in 2020-2023 is mostly caused by the opening of three biogas facilities in Estonia and using sludge and one using biowaste from households for biogas production. Compared to 2022, the quantities of composted waste have decreased by 9.0%.

Emission factors

IPCC 2006 Guidelines default dry weight emission factors are used in the composting calculations (Table 7.13).

Table 7.13. Default emission factors for calculating CH_4 and N_2O emissions from composting[374]

CH_4 emission factor (g CH_4/kg waste treated, dry weight)	**N_2O emission factor (g N_2O/kg waste treated, dry weight)**
10	0.6

7.3.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Biological treatment of solid waste subcategory, please see Annex A.II.5 Waste, Biological treatment of solid waste (5.B) chapter.

[374] IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.6, table 4.1.

7.3.4. Category-specific QA/QC and verification, if applicable

Complete QA and QC were carried out pursuant to the procedures described in IPCC 2006 Guidelines[375]. In addition, the specific documentation and reporting recommendations relevant to SWD described in Section 3.8 of Chapter 3 of IPCC 2006 Guidelines have been taken into account when carrying out QC activities, as the activities are also applicable to Biological treatment of waste.

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

7.3.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process

In accordance with the 2022 ERT review's recommendation ARR2022/A.7, Estonia received an expert judgement for the evaluation about sewage sludge generation and usage in the period of 1990-1998 made previously made by the former GHG inventory compiler Tallinn University of Technology (TalTech). The amount of sludge composted changed for those years and the CH_4 and N_2O emissions from composting were recalculated (Table 7.14).

Table 7.14. Amount of sludge composted and the recalculated CH_4 and N_2O emissions

	2024 submission			2025 submission		
	Composted sludge (kt dry weight)	**total annual CH_4 emissions from composting (kt)**	**total annual N_2O emissions from composting (kt)**	**Composted sludge (kt dry weight)**	**total annual CH_4 emissions from composting (kt)**	**total annual N_2O emissions from composting (kt)**
1990	0.051	0.027	0.002	8.651	0.113	0.007
1991	0.051	0.028	0.002	7.833	0.106	0.006
1992	0.051	0.030	0.002	11.444	0.144	0.009
1993	0.051	0.031	0.002	13.829	0.169	0.010
1994	0.051	0.033	0.002	17.248	0.205	0.012
1995	0.051	0.036	0.002	22.256	0.258	0.015
1996	0.000	0.024	0.001	21.632	0.240	0.014
1997	0.041	0.045	0.003	19.980	0.244	0.015
1998	0.031	0.008	0.000	17.080	0.179	0.011

7.3.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

The activity data is kept under consideration and will be updated as necessary.

7.4. Waste incineration and open burning (CRT 5.C)

Emissions from waste incineration with energy recovery are reported under the Energy sector.

In the waste sector, the emissions from the subcategory Incineration and open burning of waste are no longer reported due to the emissions from this category being insignificant. In 2023, no

[375] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance/Quality Control and Verification.

incineration of waste without energy recovery occurred and the related emissions were therefore 0. The emissions from open burning of waste were 0.004% of the national total GHG emissions.

The activity data and the emissions for 1990-2022 from incineration of waste without energy recovery and open burning of waste can be seen in the CRT tables 5.C.1 and 5.C.2 accordingly, the methodology used for the calculations can be seen in the previous NID submissions.

On the basis of decision 18/CMA.1 Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement paragraph 32[376] Party may use the notation key "NE" when the estimates would be insignificant.

7.5. Wastewater treatment and discharge (CRT 5.D)

7.5.1. Category description

Total CH_4 emissions from Wastewater treatment and discharge in 2023 consisted of 1.99 kt from domestic wastewater handling (Figure 7.12) and 0.07 kt from industrial wastewater handling (Figure 7.13).

CH_4 emissions from domestic wastewater handling in 2023 have decreased minimally compared to 2022 due to slightly more people being connected to wastewater treatment plants.

The most common wastewater treatment method in developed countries including Estonia is centralised aerobic wastewater treatment which consists of primary, secondary and tertiary treatment. Centralised wastewater treatment (e.g., Paljassaare wastewater plant in Tallinn) for domestic and industrial wastewater takes place as follows:

Wastewater from households and commercial institutions is collected by collecting systems to the main pumping station where primary mechanical clearance takes place. After that the wastewater is channeled to the wastewater treatment plant where physical barriers remove larger solids from water as well as greases, oils and sand. During the secondary treatment coagulants are added and settled organic particulates are removed. Tertiary/biological treatment includes biodegradation by microorganisms in an aerobic environment and activated sludge processes with the effluent of phosphorous and nitrogen. Biogas anaerobic digestion of sludge is reused to heat up the buildings situated in the plant's territory as well as in several wastewater treatment processes. Treated wastewater is led into the sea 3 km from the coast with a pipeline reaching 26 m below sea level. A similar wastewater treatment is also used in other Estonian cities. Centralised aerobic treatment plants are not included in the calculations of CH_4 emissions from wastewater as the methane correction factor, based on the IPCC 2006 Guidelines, is considered 0.

The source of domestic CH_4 is divided between anaerobic wastewater systems which include latrines septic systems with filtration systems or infiltration systems and anaerobic shallow lagoons. The decrease in domestic CH_4 emissions in 1990 and 2007 was caused by the increasing development of centralised aerobic treatment plants. The fluctuation of CH_4 emissions from a domestic source is also related to the amount of new residential buildings that at first used anaerobic treatment for their wastewater treatment and later connected to the centralised wastewater treatment system. Since 2000 investments into wastewater treatment systems have led to a decreasing trend in CH_4 emissions.

[376] Paragraph 32 – emissions should only be considered insignificant if the likely level of emissions is below 0.05% of the total national GHG emissions (without LULUCF).

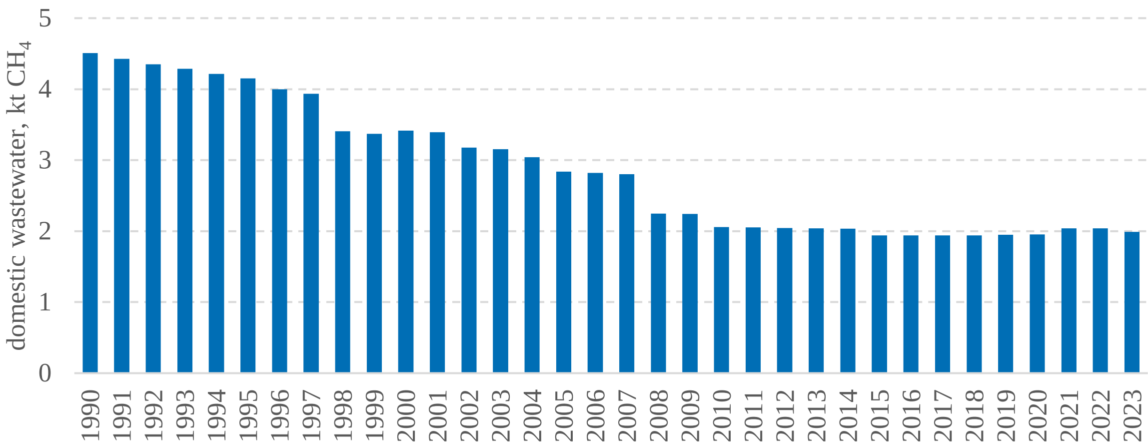

Figure 7.12. CH_4 emissions from domestic wastewater handling in 1990–2023, kt CH_4

Industrial wastewater CH_4 (Figure 7.20) is emitted from a single company in Estonia which has treated its wastewater anaerobically since 2000. CH_4 emissions in 2000 and 2001 were calculated with interpolated activity data on the amount of wastewater data from the period of 2002–2005. Interpolation for industrial wastewater quantities for the years 2000 and 2001 was necessary because cooling water was reported together with industrial wastewater. Fluctuations in later years were caused by the fluctuation in industry production and the amount of generated wastewater. The company changed the production structure due to labour shortage in 2021. Production emphasize was given to premium products and the share of standard products was decreased. In 2022 the company applied for a new environmental permit due to the changed production technology. According to the revised permit, starting from 2010, not all wastewater goes directly to the wastewater treatment plant, but part of it is produced as a co-product – vinasse. The small peak of emissions in 2022 was related to slightly higher production.

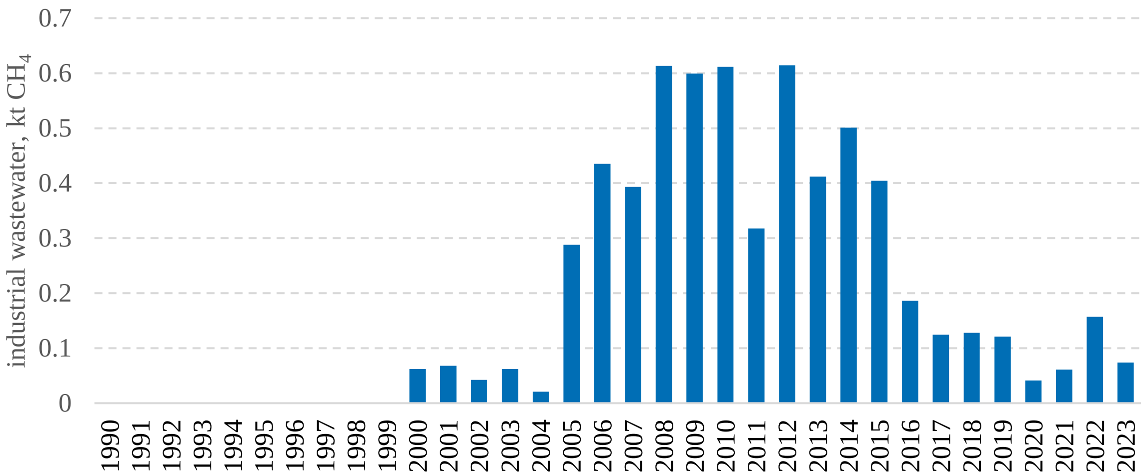

Figure 7.13. CH_4 emissions from industrial wastewater handling in 1990–2023, kt CH_4

N_2O emissions from domestic sources are presented in Figure 7.14. The total amount of N_2O emissions from wastewater in 2023 was 0.12 kt. The minor fluctuation in the time series is related to changes in the amount of nitrogen removed with sludge and protein consumption values per capita.

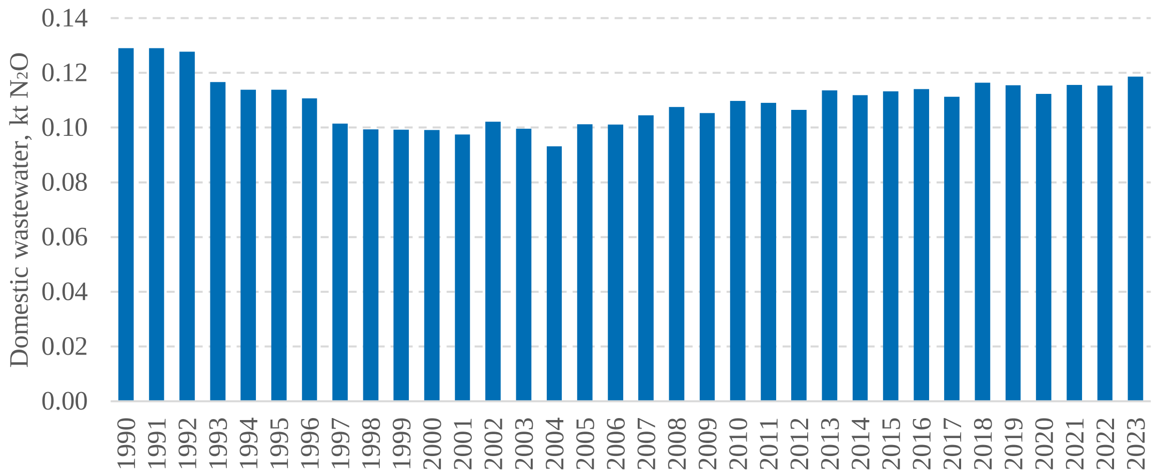

Figure 7.14. N_2O emissions from domestic wastewater handling in 1990–2023, kt N_2O

7.5.2. Methodological issues

Choice of methods

The calculation of CH_4 emissions from domestic and industrial wastewater and N_2O from wastewater is based on IPCC 2006 *Tier 1* method due to unavailable country-specific parameters.

CH_4 emission calculations from domestic sources were done by using Equation 7.3, Equation 7.4 and Equation 7.5. CH_4 emission calculations from industrial sources were done by using Equation 7.4, Equation 7.5 and Equation 7.7.

Equation 7.3[377]

$$CH_4 Emissions = \sum \left(TOW_j \times EF_j\right) - S - R$$

Equation 7.4[378]

$$CH_4\ Emissions = \sum_i [(TOW_i - S_i) \times EF_i - R_i]$$

Equation 7.5[379]

$$EF_{j/i} = B_o \times MCF_{j/i}$$

Where:

CH_4 Emissions =	CH_4 emissions in inventory year kg CH_4/yr;
TOW_i =	total organically degradable material in wastewater from industry *i* in inventory year kg COD/yr;
i =	industrial sector;
j =	each treatment/discharge pathway or system;

[377] Equation proposed by TERT.
[378] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.20, equation 6.4.
[379] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.12, equation 6.2.

S_i = organic component removed as sludge in inventory year kg COD/yr;
$EF_{j/i}$ = emission factor for domestic wastewater or industry *I*;
R_i = amount of CH_4 recovered in inventory year kg CH_4/yr;
B_o = methane correction factor fraction;
$MCF_{j/i}$ = methane correction factor.

Equation 7.6 is used for calculating TOW in domestic wastewater and Equation 7.7 for calculating TOW in industrial wastewater. The correction factor for additional industrial BOD discharged into sewers is not included in domestic/commercial wastewater TOW calculations. CH_4 emissions are calculated from uncollected wastewater treatment systems with no additional industrial wastewater.

Equation 7.6[380]

$$TOW = P_j \times BOD_j \times 0.001 \times 365$$

Where:

TOW = total organic matter in wastewater in inventory year kg BOD/yr;
P_j = country population in inventory year (person);
BOD_j = country-specific BOD per capita in inventory year g/person/day
j = each treatment/discharge pathway or system;
0.001 = conversion from g BOD to kg BOD.

Equation 7.7[381]

$$TOW_i = P_i \times W_i \times COD_i$$

Where:

TOW_i = total biodegradable material in wastewater for industry *i* kg COD/yr;
i = industrial sector;
P_i = total industrial product for industrial sector *i* t/yr;
W_i = wastewater generated m^3/t product;
COD_i = chemical oxygen demand (industrial degradable organic component in wastewater) kg COD/m^3.

N_2O emission calculations from domestic sources were done by using Equation 7.8 and Equation 7.9.

Equation 7.8[382]

$$N_2O\ Emissions = N_{EFFLUENT} \times EF_{EFFLUENT} \times 44/28$$

Where:

N_2O Emissions = N_2O emissions in inventory year kg N_2O/yr;
$N_{EFFLUENT}$ = nitrogen in the effluent discharged into aquatic environments kg N/yr;
$EF_{EFFLUENT}$ = emission factor for N_2O emissions from discharged effluent into wastewater kg N_2O-N/kg N.

The factor 44/28 is the conversion of kg N_2O-N into kg N_2O.

[380] Equation proposed by TERT.
[381] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.22, equation 6.6.
[382] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.25, equation 6.7.

Equation 7.9[383]

$$N_{EFFLUENT} = (P \times PROTEIN \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM}) - N_{SLUDGE}$$

Where:

$N_{EFFLUENT}$ =	total annual quantity of nitrogen in the wastewater effluent kg N/yr;
P =	human population;
Protein =	annual protein consumption per capita kg/person/yr;
F_{NPR} =	fraction of nitrogen in protein;
$F_{NON-CON}$ =	factor for non-consumed protein added to the wastewater;
$F_{IND-COM}$ =	factor for industrial and commercial protein co-discharged into the sewer system;
N_{SLUDGE} =	nitrogen removed with sludge (default = zero) kg N/yr.

Activity data

The calculation of CH_4 emissions from Domestic wastewater is based on the national inventory of wastewater treatment types in low population settlements[384]. As suggested by the ESD review team in 2017, the balance scheme of wastewater pathways was added (Figure 7.15) which are also shown in Table 7.21 and Table 7.22.

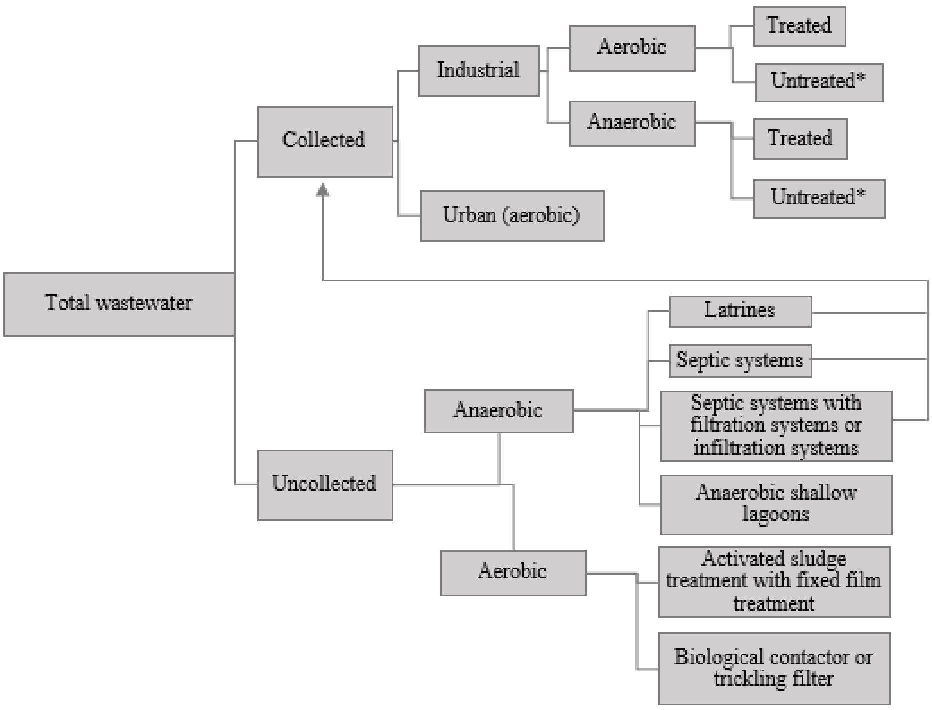

Figure 7.15. Typical balance of wastewater pathways for domestic wastewater in Estonia

[383] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.25, equation 6.8.
[384] Table is based on a study by Infragate, (2014). Hajaasustuse reovee kohtkäitlussüsteemide inventuuri aruanne. [www] https://kliimaministeerium.ee/sites/default/files/documents/2021-10/Hajaasustuste%20reovee%20kohtkäitlussüsteemide%20inventuuri%20aruanne_0.pdf (08.01.2025)

This inventory covers the time series of the domestic wastewater treatment types in low population settlements with 50 or less persons. CH_4 emission calculations from domestic sources include anaerobic wastewater treatment systems (Tabel 7.15):

- latrines (LT);
- septic systems (SEP);
- septic systems (SEP) with filtration systems (FS) or infiltration systems (IF);
- anaerobic shallow lagoons (ASL).

Latrines and septic systems are emptied into the centralised aerobic wastewater systems based on necessity and local government regulations.

Aerobic systems used for wastewater handling but not included in CH_4 calculations are:

- activated sludge treatment (AST) with fixed film treatment (FFT);
- biological contactor or trickling filter (BC/TF)

Table 7.15. Wastewater treatment systems in low population settlements, %

Year	AST + FFT	AST	ASL	BC/TF	LT (1–6 persons)	LT (6 or more persons)	SEP	SEP+ FS	SEP+ IF	Total %
1990	NO	0.7	2.4	0.4	23.4	2.3	59.6	0.1	11.2	100
2005	0.06	0.8	1.9	0.7	19.2	2.2	56.1	0.5	18.7	100
2020	0.07	0.7	1.5	0.7	15.9	1.8	48.1	1.1	30.1	100
2021	0.07	0.7	1.5	0.7	15.7	1.8	47.5	1.1	31.0	100
2022	0.07	0.7	1.5	0.7	15.5	1.7	46.9	1.1	31.9	100
2023	0.07	0.7	1.5	0.7	15.2	1.7	46.3	1.1	32.7	100

NO – not occurring

Anaerobic wastewater treatment systems in high population settlements (Table 7.16) (from 51 persons) have been interpolated on the national inventory of wastewater treatment types in low population settlements. The rate of wastewater treated aerobically in 1990–1997 is interpolated and based on the expert judgement of MoC. Data from 1998–2023 has been obtained from EstEA.

Table 7.16. Wastewater treatment systems in high population settlements, %

Year	LT (1–6 persons)	SEP SEP+FS SEP+IF	Centralised aerobic treatments	Total %
1990	11.4	25.8	62.8	100
2005	5.7	20.3	74	100
2020	3.1	13.9	83	100
2021	3.2	14.8	82	100
2022	3.2	14.8	82	100
2023	3.0	14.0	83	100

Data on population is obtained from the dataset of the SE.

The calculations of CH_4 emissions from Industrial wastewater are based on plant-specific information gathered from a yeast factory which is the only industrial facility treating its wastewater anaerobically. Other industrial companies are either connected to the sewer systems and their wastewater is treated in centralised aerobic treatment plants (well-managed with MCF 0) or they have their own well-managed aerobic treatment systems (MCF 0).

The generated CH_4 was flared in 2000–2009 and starting from 2010 CH_4 was recovered for energy. Degradable Organic Carbon (DOC) used in the calculations is calculated based on the cleaning efficiency. COD concentration in 2000–2004 was calculated based on the BOD concentration because there is no plant-specific COD data on that period. In addition, industrial wastewater quantity interpolation for years 2000 and 2001 was necessary due to the reporting accuracy of that period as cooling water was reported together with industrial wastewater. Starting from 2005 plant-specific COD concentrations were included in the calculations. In 2022 the company applied for a new environmental permit due to the changed production technology. According to the revised permit, starting from 2010, not all wastewater goes directly to the wastewater treatment plant, but part of it is produced as a co-product – vinasse, therefore the COD concentrations became lower.

For calculating N_2O emissions, the Estonian population data obtained from the dataset of the SE and the annual protein consumption per capita from FAO statistical database[385] were used as activity data. Nitrogen in sludge was calculated based on the data obtained from the dataset of EstEA. As industrial and commercial wastewater in Estonia is co-discharged into the domestic sewer system, the default $F_{IND-COM}$ fraction of 1.25 is applied to Equation 7.9 for calculating total nitrogen in the effluent.

Emission factors

The IPCC 2006 Guidelines default emission factors used in calculations are presented in Table 7.17.

Table 7.17. Emission factors and parameters used in the calculations of Wastewater treatment and discharge

	Value
CH_4 from domestic wastewater	
Bo (kg CH_4/kg BOD)[386]	0.6
Degradable organic component (g BOD/person/day)[387]	60
MCF anaerobic lagoon[388]	0.2
MCF septic system[381]	0.5
MCF latrines[381]	0.7
MCF centralised wastewater treatment[381]	0
CH_4 from industrial wastewater	
Bo (kg CH_4/kg COD)[389]	0.25
MCF[390]	0.8
N_2O from wastewater[391]	
F_{NRP} (kg N/year)	0.16
$F_{NON-CON}$	1.4
$F_{IND-COM}$	1.25
$EF_{EFFLUENT}$ (kg N_2O-N/kg-N)	0.005

The default value for the parameter $F_{NON-CON}$ (factor for non-consumed protein added to the wastewater) for developed countries using garbage disposal has been used due to the possibility that people wash food waste down the collecting system. It is necessary to consider this possibility. In 1990's it was popular for households to have a garbage disposal unit to shred

[385] FAOSTAT New food Balances database [www] http://www.fao.org/faostat/en/#data/FBS (28.12.2024)
[386] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.12, table 6.2.
[387] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.14, table 6.4.
[388] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.13, table 6.3
[389] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.21.
[390] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.21, table 6.8
[391] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.27, table 6.11.

food waste and lead it into the wastewater system. Nowadays this type of technology is not so popular, and some local governments prohibit the activity with the public water supply and sewerage regulation. Nevertheless, the possibility of washing food down the collecting system has to be considered when calculating N_2O emissions.

7.5.3. Uncertainty assessment and time-series consistency

For uncertainty assessment of Wastewater treatment and discharge subcategory, please see Annex A.II.5 Waste, Wastewater treatment and discharge (5.D) chapter.

7.5.4. Category-specific QA/QC and verification, if applicable

Complete QA and QC were carried out pursuant to the procedures described in IPCC 2006 Guidelines[392]. In addition, fundamental QA/QC procedures regarding activity data on wastewater treatment types in domestic wastewater and facility-specific data for industrial wastewater have been carried out.

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.5.

7.5.5. Category-specific recalculations, if applicable, including explanatory information and justifications for recalculations, changes made in response to the review process

In accordance with the 2022 ERT review's recommendation ARR2022/A.7, Estonia received an expert judgement for the evaluation about sewage sludge generation and usage in the period of 1990-1998 previously made by the former GHG inventory compiler Tallinn University of Technology (TalTech). As a result, the amount of sludge applied to the fields changed for those years and the N_2O emissions from domestic wastewater treatment were recalculated (Table 7.18).

Table 7.18. Amount of sludge used in fields and recalculated N_2O emissions

	2024 submission		2025 submission	
	amount of sludge (tonnes)	**total annual N_2O emissions from domestic wastewater treatment (kt)**	**amount of sludge (tonnes)**	**total annual N_2O emissions from domestic wastewater treatment (kt)**
1990	7434	0.12972	24 287	0.12907
1991	7825	0.12947	20 860	0.12896
1992	8237	0.12839	25 227	0.12773
1993	9081	0.11720	23 509	0.11664
1994	14 306	0.11464	34 890	0.11385
1995	27 073	0.11377	27 000	0.11378
1996	30 041	0.11055	26 800	0.11068
1997	30 028	0.10123	23 000	0.10150
1998	12 724	0.09971	22 000	0.09935

Due to the updated protein consumption information from FAOSTAT, N_2O emissions from domestic wastewater were recalculated (Table 7.19).

[392] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance / Quality Control and Verification.

Table 7.19. Protein consumption per capita and recalculated N_2O emissions

	2024 submission		2025 submission	
	protein consumption (kg/capita /year)	**total annual N_2O emissions from domestic wastewater (kt)**	**protein consumption, (kg/capita/year)**	**total annual N_2O emissions from domestic wastewater (kt)**
2014	38.701	0.11180	38.705	0.11181
2015	39.267	0.11321	39.274	0.11323
2016	39.508	0.11409	39.515	0.11412
2017	38.887	0.11127	38.891	0.11128
2018	40.562	0.11642	40.566	0.11643
2021	40.738	0.11627	40.486	0.11554
2022	40.738	0.11637	40.373	0.11530

7.5.6. Category-specific planned improvements, if applicable (e.g. methodologies, activity data, emission factors), including those in response to the review process

The activity data is kept under consideration and will be updated as necessary.

8. OTHER (CRT SECTOR 6)

Estonia does not report any emissions under the Other sector.

9. INDIRECT CARBON DIOXIDE AND NITROUS OXIDE EMISSIONS

9.1. Description of sources of indirect emissions in the GHG inventory

Estonia has chosen to report indirect CO_2 emissions calculated from NMVOC emissions from the CRT subcategory 2.D.3. This subcategory consists of

- Solvent use;
- Road paving with asphalt.

The indirect CO_2 emissions are reported under the aforementioned subcategory on CO_2 emission rows.

Information on how the indirect CO_2 emissions were calculated is provided in Chapters 4.5.1. Solvent use and 4.5.1. Road paving with asphalt.

Information regarding indirect N_2O emissions in the agriculture and LULUCF sectors are reported under Agriculture and LULUCF sectoral chapters.

10. RECALCULATIONS AND IMPROVEMENTS

10.1. Explanations and justifications for recalculations, including in response to the review process

Explanations and justifications for the recalculations performed for this submission are given in Table 10.1.

Table 10.1. Recalculations made for the 2024 inventory submission by the CRT category and their implications

SECTOR	IPCC CATEGORY	RECALCULATION
Energy	1.A.1 Energy industries	Recalculation for year 2022 in 1.A.1.a sub-category was carried out and this increased 2022 emission by 209.11 kt CO_2 eq. The reason for this recalculation was an error in the oil shale generator gas emission calculations.
IPPU	2.A.2 Lime production	Recalculations were done for the years 1990-1996 due to the change in the emission factor values. The UNFCCC 2022 review suggested to use implied emission factor for the plants for which company-based data was not available. Implied emission factors were calculated based on the data received from other companies operating in 1990-1996.
	2.D.3 Solvent use	Recalculations have been made in Solvent use NMVOC emissions and therefore also changes in indirect CO_2 emissions 2006-2014 and 2017-2022 in the categories 2D3a (2020, 2022), 2D3d (2022), 2D3g (2006-2014), 2D3i (2020-2022) and 2G (2017-2022). Recalculations were due to moving SNAP codes under correct SNAP and changes in the data from the Statistics Estonia for several years.
	2.D.3 Urea based catalysts for motor vehicles	Recalculations have been made in the emissions of urea-based catalysts for motor vehicles for years 2006, 2008-2022 due to changes in the activity data.
Agriculture	3.A Enteric fermentation	The average winter temperature for Mature males for 2022, the Cfi (energy needed for maintenance) parameter for Bovine animals (aged 1-2 years) for the years 2020-2022, and the fat content in milk for Mature females for the years 2021-2022 were corrected due to a copying error in the previous submission.
	3.B.1 Manure management, CH_4 emissions; 3.B.2 Manure management, N_20 emissions	The number of rabbits for the years 2017-2019; 2021-2022 were corrected due to an interpolation error in the previous submission. Poultry annual average population numbers were corrected for emission calculations for the years 1990-

SECTOR	IPCC CATEGORY	RECALCULATION
		2022 due to an overestimation of the total annual average population in the previous submissions. Values for MMS splits for mature female cattle for the years 2001-2022 were updated due to correcting the share of Pasture, Range and Paddock (PRP) manure in manure management system distribution for mature female cattle – database for calculating these values changed.
	3.D Agricultural soils, direct N_20 emissions	Emissions from Animal manure applied to soils (CRT 3.D.1.b.i) and from Urine and Dung deposited by grazing animals (CRT 3.D.1.c) were recalculated for the whole time-series due to recalculations and corrections made in 3.B Manure management category. Emissions from Sewage sludge applied to Soils (CRT 3.D.1.b.ii) and Other organic fertilizers applied to soils (CRT 3.D.1.b.iii) were recalculated due to the revised amount of sewage sludge and compost applied to soils in 1990-1998. The N_2O emissions from Mineralization/Immobilization Associated with the Loss/Gain of Soil Organic Matter (CRT 3.D.1.e) for the years 1991-1992 and 2021-2022, and from Cultivation of organic soils (CRT 3.D.1.g) for the whole timeseries were updated in the framework of the NFI (see Chapter 6 LULUCF). This impacts also the direct N_2O.
LULUCF	4.A Forest land	The entire time series of activity data from NFI is annually recalculated for all areas of land categories and land-use conversions since new data about land-use transitions is collected every year and new estimates are integrated into overall activity data. Also, C stocks in living biomass and dead wood in Forest land and Grassland are updated annually. EFs for mineral soils in Forest land remaining forest land and litter for conversion areas have been updated. Changes in methodology for estimating C stock changes dead wood.
	4.B Cropland	Recalculated activity data from NFI. New data about tillage practices were applied for estimating C stock changes in mineral soils in the Cropland remaining cropland subcategory. New methodology for estimating C gains in living biomass on Wetlands and Settlements converted to cropland areas. Updated EF for litter.

SECTOR	IPCC CATEGORY	RECALCULATION
	4.C Grassland	Recalculated activity data from NFI and updated EF for litter.
	4.D Wetlands	Updated activity data from NFI. .New methodology for estimating C losses in living biomass on Cropland converted to wetlands areas.
	4.E Settlements	Updated activity data from NFI. New methodology for estimating C losses in living biomass on Cropland converted to settlements areas.
	4.F Other land	New methodology for estimating C losses in living biomass on Cropland converted to other land areas.
	4.G Harvested wood products	Updated activity data.
Waste	5.A Solid Waste Disposal	In accordance with the 2022 ERT review's recommendation ARR2022/A.7, Estonia received an expert judgement about sewage sludge usage for 1990-1998. Additionally, the GDP data was updated by Statistics Estonia for the period 2001-2022 as a result of a routine review to ensure international comparability of macro statistics. The updated info affected the CH_4 emissions for 1990-2022.
	5.B Biological Treatment of Solid Waste	In accordance with the 2022 ERT review's recommendation ARR2022/A.7, Estonia received an expert judgement for the usage of sewage sludge for 1990-1998 that changed the amount of composted sludge for those years and resulted in a recalculation of emissions from Biological treatment of solid waste in 1990-1998.
	5.D.1 Domestic wastewater	In accordance with the 2022 ERT review's recommendation ARR2022/A.7, Estonia received an expert judgement about sewage sludge usage for 1990-1998 that changed the amount of sludge applied to the fields and resulted in a recalculation of N_2O emissions for 1990-1998.
		Due to the updated protein consumption information from FAOSTAT, N_2O emissions from domestic wastewater were recalculated for years 2014-2022 (excluding 2019 and 2020 for which the FAOSTAT data did not change).

10.2. Implications for emission and removal levels

As a result of the continuous improvement of Estonia's GHG inventory, emissions of some sub-categories have been recalculated based on updated data or revised methodologies. For the national total CO_2 equivalent emissions (with indirect CO_2 and without LULUCF), the general impact of the improvements and recalculations performed depend on the year. The changes for the whole time-series are shown in Table 10.2.

The entire time series of LULUCF sector's activity data is annually recalculated for all areas of land categories and land-use conversions since new data about land-use transitions is collected every year and new estimates are integrated into overall activity data. In addition, number of methodological changes and previous error corrections in the current submission have resulted in recalculations of emissions/removals (Table 10.3).

Table 10.2. Recalculation performed in 2025 submission for years 1990–2022 in kt CO_2 eq. Differences in % between 2024 December submission and 2025 submission.

	National Total GHG emissions without LULUCF			
	Submission 2024	**Submission 2025**	**Recalculation difference**	**Recalculation difference,**
	kt CO_2 eq.			**%**
1990	40 273.58	40 277.58	4.00	0.01%
1991	37 398.49	37 402.96	4.46	0.01%
1992	27 212.19	27 221.59	9.41	0.03%
1993	21 747.88	21 758.73	10.85	0.05%
1994	22 220.20	22 232.88	12.68	0.06%
1995	20 057.12	20 069.53	12.41	0.06%
1996	20 998.02	21 012.96	14.95	0.07%
1997	20 708.90	20 711.36	2.46	0.01%
1998	18 983.76	18 981.97	-1.79	-0.01%
1999	17 820.07	17 811.74	-8.33	-0.05%
2000	17 441.80	17 436.38	-5.42	-0.03%
2001	17 875.08	17 872.41	-2.67	-0.01%
2002	17 287.03	17 286.47	-0.56	0.00%
2003	19 219.74	19 221.00	1.26	0.01%
2004	19 356.25	19 358.95	2.70	0.01%
2005	19 132.89	19 136.76	3.87	0.02%
2006	18 478.01	18 483.22	5.20	0.03%
2007	22 029.26	22 034.11	4.85	0.02%
2008	19 930.14	19 935.63	5.49	0.03%
2009	16 494.96	16 498.90	3.94	0.02%
2010	21 096.26	21 100.20	3.93	0.02%
2011	21 053.64	21 058.64	5.00	0.02%
2012	19 941.95	19 947.29	5.34	0.03%
2013	21 819.40	21 824.85	5.45	0.02%
2014	20 981.39	20 987.27	5.88	0.03%
2015	17 913.77	17 920.95	7.18	0.04%
2016	19 533.13	19 539.23	6.11	0.03%
2017	20 761.23	20 767.06	5.83	0.03%
2018	19 950.29	19 955.58	5.28	0.03%
2019	14 508.11	14 512.46	4.34	0.03%
2020	11 343.38	11 337.32	-6.06	-0.05%
2021	12 578.98	12 568.18	-10.80	-0.09%
2022	13 951.55	14 149.11	197.57	1.42%

Table 10.3. Recalculation difference of Estonia's 2025 GHG emissions compared to the 2024 December submission by sector, kt CO_2 eq.

	Submission 2024		Submission 2025		Recalculation difference, %	
	1990	**2022**	**1990**	**2022**	**1990**	**2022**
Energy	36 182.02	11 769.50	36 182.03	11 978.01	0.00%	1.77%
IPPU	963.14	274.99	952.36	274.92	-1%	0%
Agriculture	2 723.45	1 593.02	2 734.62	1 583.00	0.41%	-0.63%
LULUCF	-5 235.27	339.29	-4 970.05	198.20	-5.07%	-41.58%
Waste	404.97	314.03	408.57	313.18	1%	-0.27%

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

It is a high general priority in the considerations leading to recalculations back to 1990 to have and preserve the consistency of the activity data and emissions time-series. Therefore, activity data, emissions factors and methodologies are carefully chosen to represent the emissions for the time-series correctly. Often considerations regarding the consistency of the time-series have led to recalculations for single years when activity data and/or emissions factors have been changed or corrected. Furthermore, when new sources are considered, activity data and emissions are as far as possible introduced to the inventories for the whole time-series based on preferably the same methodology.

10.4. Areas of improvement and/or capacity-building in response to the review process

Table 10.4 summarises the sectoral improvement needs for the forthcoming inventories recognised by the Estonian experts responsible for the calculations. More detailed information about planned improvements can be found under the sectoral chapters.

Table 10.5 summarises Estonia's responses to the 2015/2016/2018 and 2020 inventory review report (FCCC/ARR/2022/EST) and observations from the 2022 review report.

Table 10.4. Sector-specific improvement needs of Estonia's national greenhouse gas inventory

SECTOR	IPCC CATEGORY	IMPROVEMENTS
Energy	1.A.1 Energy industries	Verification measurements of specific CH_4 and N_2O emission factors (e.g. for solid biomass) for large combustion plants (over 50 MW) in the energy sector are planned for 2025.
Agriculture	3.A Enteric fermentation, 3. B Manure management	Estonia is working on developing country-specific methane conversion factors for animal manure sent to biogas digesters.
		Estonia is planning an inventory development project to measure CH_4 emissions for the most represented ruminants in Estonia and thus develop county-specific emission factors.

SECTOR	IPCC CATEGORY	IMPROVEMENTS
	3.D Agricultural Soils	Estonia is planning an inventory development project to develop county-specific emission factors for emission calculations from Crop residues and Grazing.
		What is more, Estonia is planning an inventory development project to develop country-specific emission factors for emission calculations from Cultivation of organic soils.
LULUCF		Estonia is working on specifying the estimates of land categories, which affects the whole LULUCF sector.
		Estonia has implemented a research project to specify the activity data and emissions from drainage diches in all land use categories.
		Estonia has launched a project for developing a governance system for land and soil management. The project aims to update and consolidate land use-related datasets and to develop higher tier methodologies for estimating SOC changes in all land-use categories.
	4.A Forest land	Various remote sensing projects for forest resources have been launched with the purpose of annually calculating country-wide tree cover maps. Several completed, ongoing and planned NFI developments support more accurate estimates of annual biomass C stock changes.
		Project “Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland” aims to improve the GHG accounting methods and activity data for nutrient-rich organic soils in the temperate cool & moist climate region. GHG emissions from nutrient-poor drained organic forest soils are specified during the project “Assessment of emissions and carbon stock dynamics in Estonian drained organic forest soils in the national greenhouse gas inventory”.
	4.B Cropland 4.C Grassland	Project “Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland” aims to improve the GHG accounting methods and activity data for nutrient-rich organic soils in the temperate cool & moist climate region.
	4.D Wetlands	Scientific research has been launched to improve the GHG accounting methods for peatlands managed for peat extraction and for restored extraction sites.

SECTOR	IPCC CATEGORY	IMPROVEMENTS
Waste	5.A Solid Waste Disposal	Estonia is working on the division of activity data for waste deposited in uncategorized and managed landfills to enable reporting them separately. So far, the accumulative emissions from both types of landfills have been reported under the managed landfills category since 1994. The issue became apparent thanks to the checks done under the EU Governance regulation. Together with this improvement, the waste generation per capita calculation will also be improved for the historical period of 1950-1990 in the waste model.

Table 10.5. Response to the review of the 2015/2016/2018 and 2020 inventory submissions

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
Uncertainty analysis (G.4, 2020) Convention reporting adherence	Report in the NIR on methods and underlying assumptions used for the uncertainty assessment for the purpose of helping to prioritize efforts to improve the accuracy of the national inventory in the future and to guide decisions on methodological choice in accordance with paragraph 42 of the UNFCCC Annex I inventory reporting guidelines. Addressing. The Party documented in its NIR (section 1.6, pp.44–45) the general method used for the uncertainty analysis. In section 1.2.1, under "Procedural arrangements", Estonia stated that sectoral uncertainty estimates, among other inputs (e.g. recommendations from previous review reports), are used to prioritize its efforts to improve the accuracy of the inventory. On the basis of the sectoral method used, the share in total emissions and the uncertainty (in per cent), Estonia evaluates on a case- by-case basis whether a higher-tier method can be applied. Estonia uses the IPCC tier 1 methodology to estimate the total uncertainty of the inventory by aggregating the uncertainty of AD and EFs for each source category and GHG. During the review, the Party clarified that experts provide information on potential improvements to methods and underlying assumptions used in the uncertainty assessment. This information is discussed in an annual inventory meeting of the experts with the inventory coordinators, who evaluate the possibilities for improvement and forward the evaluation to the Ministry of the Environment to initiate a discussion on funding. The NIR serves as the main means of documentation for the methods and assumptions used in the uncertainty assessment and all sectors follow the same structure in the report except energy, for which information on uncertainty is included in section 3.2.4.3. To enhance transparency, Estonia indicated that it will harmonize the reporting on uncertainty for the energy sector with that of other sectors in its next annual submission. The ERT considers that the recommendation has not yet been fully addressed because the Party has not yet reported on methods and underlying assumptions used in the uncertainty assessment consistently for all sectors.	ARR2022/G.2	To enhance transparency, the structure on reporting on uncertainty analysis was harmonized, since 2024 submission Estonia has reported sectoral uncertainty assessment and relevant information regarding this in one chapter in the NID Annex document in Annex II.		NID Annex II
Uncertainty analysis (G.5, 2020) Convention reporting adherence	Perform the quantitative uncertainty assessment for the base year including and excluding LULUCF, following approach 1 from the 2006 IPCC Guidelines (vol. 1, chap. 3), and report the results in the NIR (e.g. using the structure provided in the 2006 IPCC Guidelines (vol. 1, table 3.3)). Addressing. The Party reported in its NIR (sections 1.6 and 10) that lack of AD is the reason for not being able to estimate specific uncertainty percentages for the base year. During the review, the Party clarified that the availability of base-year information has been affected by the institutional changes that have taken place since the country regained independence in 1991. The Party's next steps to resolve this issue are through GHG inventory development projects currently ongoing in different categories, after which the sectoral experts will update inventory AD and EF values, including associated uncertainty values for the base year. The ERT considers that the recommendation has not yet been fully addressed because the Party has not yet reported base-year uncertainty for the inventory with and without LULUCF.	ARR2022/G.3	Estonia has included uncertainty analysis for the inventory with LULUCF in Annex II Table Annex II. 2.		NID Annex II Table Annex II. 2.

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
1. General (energy sector) – other fossil fuels – CO2 (E.4, 2020) (E.7, 2018) (E.11, 2016) (E.10, 2015) Transparency	Report which categories' non-biogenic waste is included under which fuel types in the reference approach in a more transparent manner. Addressing. The Party reported in its NIR (table 3.9, p.80) a list of non-biogenic waste types. For the sectoral approach, waste oils are allocated to category 1.A.2.f (non- metallic minerals) and MSW to category 1.A.1.a (public electricity and heat production). However, the ERT noted that the NIR (section 3.2.1) does not include information on which categories' non-biogenic waste is included under which fuel types for the reference approach, which will explain the differences in the carbon EF reported in NIR table 3.9 and CRF table 1.A(b). During the review, the Party clarified that MSW is included in the reference approach under non-biogenic waste used in the production of heat and electricity. The ERT considers that the recommendation has not yet been fully addressed because the Party has not yet reported in its NIR (section 3.2.1) which categories' non-biogenic waste is included under which fuel types for the reference approach, for example whether the fossil part of waste that is reported under categories 1.A.1.a and 1.A.2.f in the sectoral approach is all reported under non-biogenic waste in the reference approach or reported under other fuel categories, as explained during the 2015 review. Such an explanation would help to improve the understanding of the carbon EF reported in CRF table 1.A(b).	ARR2022/E.1	Since 2023 submission NID includes detailed information on non-biogenic waste and under which fuel types in the reference approach it is included.		Chapter 3.2.1
1.A.3.b Road transportation – liquid fuels – CO2, CH4 and N2O (E.7, 2020) (E.15, 2018) (E.18, 2016) (E.17, 2015) Transparency	Explain how data from different sources (Statistics Estonia and the Estonian Transport Administration) are rearranged in a way that ensures consistency across the three data sets (number of vehicles, annual road traffic mileage and the division used in COPERT). Addressing. The Party reported in its NIR the number of vehicles in the country (table 3.25, p.99) and road traffic mileage (table 3.26, p.100). However, the ERT noted that the Party did not include in the NIR a transparent explanation of how data from different sources are rearranged to ensure consistency across the three data sets (number of vehicles, annual road traffic mileage and the division used in COPERT). During the review, the Party clarified that emissions from road transport are estimated, using COPERT V, by the Estonian Environment Agency. The Agency collects data on the number of vehicles and annual mileage per vehicle from the Estonian Transport Administration and data on fuel consumption from Statistics Estonia. The statistics on fuel consumption are inputted into COPERT V by distributing them between vehicle categories on the basis of annual mileage per vehicle category from odometer readings taken during annual technical inspections to maintain a balance between calculated and statistical fuel consumption. The Party indicated that this explanation will be included in the next annual submission. The ERT considers that the recommendation has not yet been fully addressed because the Party, while it provided the required explanation during the review, has not yet included it in the NIR.	ARR2022/E.8	Since 2023 submission NID includes the explanation on how the number of vehicles, annual road mileage and the division used in COPERT model is used to ensure data consistency across these three datasets		Chapter 3.2.6.2

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
1.A.3.b.iv Motorcycles – gasoline – CO_2, CH_4 and N_2O (E.23, 2020) Consistency	Work with the national vehicle registry to report the correct number of motorcycles for 1990–2012 by including mopeds under the motorcycles category (e.g. by using a data gap filling technique in accordance with the 2006 IPCC Guidelines (vol. 1, chap. 5, p.5.14)); and revise the estimated emissions under motorcycles (subcategory 1.A.3.b.iv) using the updated AD for 1990–2012, ensuring time-series consistency and documenting the estimates in the NIR. Addressing. The Party corrected in its NIR the AD for 1990–2012 for the number of motorcycles (table 3.25, p.99) and their mileage (table 3.26, p.100). The estimated emissions for subcategory 1.A.3.b.iv (motorcycles) were revised using the corrected AD. However, the ERT noted that the NIR does not include an explanation of the data gap filling technique that was used to correct the number of motorcycles reported. During the review, the Party explained that an analysis of the high statistical number of motorcycles in use during 1990–1994 was carried out, and as a result, the number of vehicles was corrected to ensure that the data no longer include vehicles that are not in use. The number of mopeds for 1995–2012 was adjusted on the basis of the corrections to the number of motorcycles for 1990–1994. The Party indicated that more	ARR2022/E.10	Since 2023 submission NID includes a detailed explanation that the number of motorcycles was adjusted for 1995-2012 based on the corrections for 1990-1994 period		Chapter 3.2.6.2
1.A.3.b.iv Motorcycles – gasoline – CO_2 (E.11, 2020) (E.26, 2018) Transparency	Report in the NIR the differences between the number of motorcycles reported by the national vehicle registry and the number of motorcycles used for estimating emissions in COPERT, and explain the underlying reasons for the differences, when applicable. Addressing. The Party reported in its NIR (table 3.25, p.99) the number of motorcycles and mopeds used in COPERT and explained in its NIR (table 10.8, p.430) the method used for calculating the number of motorcycles. During the review, the Party clarified that the number of motorcycles in the national vehicle registry includes motorcycles that have been disposed of, while data used in COPERT have been corrected to exclude such motorcycles. The ERT considers that the recommendation has not yet been fully addressed because the Party has not yet included in the NIR (section 3.2.5.3) the differences between the number of motorcycles reported by the national vehicle registry and the number of motorcycles used in COPERT or the reasons for these differences.	ARR2022/E.11	Since 2023 submission NID includes a detailed explanation about the number of motorcycles used in COPERT and in national registry		Chapter 3.2.6.2
1.A.4 Other sectors – liquid fuels – CO_2, CH_4 and N_2O (E.25, 2020) Accuracy	Work with Statistics Estonia to collect AD on total liquid fuel consumption for the subcategories commercial/institutional (1.A.4.a), residential (1.A.4.b) and agriculture/forestry/fishing (1.A.4.c), ensure the accuracy of the AD and recalculate emissions for all years (1990–2018). Not resolved. The Party reported in its NIR (section 3.2.6.2, p.117) that Statistics Estonia collects AD on total liquid fuel consumption for the subcategories 1.A.4.a, 1.A.4.b and 1.A.4.c by sending questionnaires to all companies with at least 50 employees and by sending questionnaires to a random selection of smaller companies. The ERT noted that this may lead to an overestimation or underestimation of the AD and emissions if only the smallest or largest fuel users are covered by each questionnaire. During the review, the Party clarified that Statistics Estonia has been notified of the issue and is looking into improving the accuracy of the data.	ARR2022/E.14		Statistics Estonia is using Eurostat methodology for a survey sampling for energy consumers and a random selection procedure for smaller companies (https://www.stat.ee/en/find-statistics/methodology-and-quality/esms-metadata/20206#18-Statistical-processing-17). For this reason, the methodology used covers a significant part of this sector	

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
				and is the best possible method for data gathering.	
1.B.2.a Oil – CH4 (E.16, 2020) (E.19, 2018) (E.21, 2016) (E.20, 2015) Transparency	Fill in AD in the columns “Unit” and “Value” of the row “Distribution of oil products” in CRF table 1.B.2 instead of reporting these values as “NA”, and change the notation keys in the other cells to “NA”.	ARR2022/E.15	The issue has been fixed for 2023 submission in CRF tables. The “kt” under the column “unit” has been fixed for "NE"		CRF 1.B.2.a.Oil Distribution for oil products
International navigation – liquid fuels – CO2, CH4 and N2O (E.1, 2020) (E.20, 2018) Consistency	Revise fuel consumption estimates for international navigation and ensure their time-series consistency. Not resolved. The Party reported recalculations for 1990–2019 in NIR table 3.4 (p.65), which were made owing to the use of the updated Joint Questionnaire data set from Statistics Estonia. However, the Party continued to report in its NIR (section 3.2.2, p.64) that the almost 200 per cent increase in emissions between 2011 and 2012 was caused by an AD-related change in the methodology used by Statistics Estonia. During the review, the Party clarified that Statistics Estonia has been notified of the issue and is looking into improving the time-series consistency of the data on fuel consumption for international navigation. The ERT considers that the recommendation has not yet been addressed because the AD-related change in methodology results in a time series that is not consistent, as described in section 3.2.2 of the NIR and as shown by the reported sharp increase in emissions between 2011 and 2012.	ARR2022/E.16		The Statistics Estonia is aware of the large variations in liquid fuels reported under International navigation and have been notified to look into the matter. The Statistics Estonia is correcting the data when they carry out the revision, but the timeline for the revision is not set.	

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
Fuel combustion – reference approach – all fuels – CO_2 Transparency	The Party reported in its NIR (section 3.2.1, p.64) that the difference in total CO_2 emissions between the reference approach and the sectoral approach is 29.6 per cent. However, CRF table 1.A(c) lists this difference as 41.99 per cent. The ERT noted that the difference in CO_2 emissions between the two approaches is largest for solid fuels (72.08 per cent for 2020) and other fuels (56.12 per cent for 2020). In the NIR (section 3.2.1, p.64), the Party explained that in the case of solid fuels, the amount of emitted CO_2 is different, as the sectoral approach considers that some of the oil shale is turned into shale oil, and this process has a smaller CEF than the combustion of oil shale (some of the carbon is transferred into shale oil), while in the reference approach calculations all the carbon in oil shale is combusted. The ERT noted that a quantitative analysis of the differences is not included in the NIR. The ERT noted that these differences are due to an overestimation in the reference approach and no issues related to the sectoral approach were identified. During the review, the Party clarified there is an error in the NIR (section 3.2.1, p.64) and that the difference in emissions between the approaches is 41.99 per cent, as reported in CRF table 1.A(c). The ERT recommends that the Party report in the NIR the correct difference in total CO_2 emissions from fuel combustion (per cent) between the reference approach and the sectoral approach and expand the explanation for the difference between the two approaches by including a quantitative explanation of the CO_2 calculations of oil shale and shale oil in the reference approach and the sectoral approach, as described in NIR section 3.2.1.	ARR2022/E.17	The difference in total CO_2 emissions between SA and RA approach was corrected for the 2024 submission.		NID 2025 Chapter 3.2.1. Comparison of the sectoral approach with the reference approach

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
Comparison with international data – liquid fuels – CO2, CH4 and N2O Transparency	The Party reported in CRF table 1.A(b) a total liquid fuel consumption of 44,790 TJ for 2019 and 43,970 TJ for 2020. However, the IEA values for consumption of the same fuels are –526 TJ for 2019 and –1,663 TJ for 2020. The ERT noted that the Party did not provide the energy balance for the most recent year in the NIR as annex 4 as required by the UNFCCC Annex I inventory reporting guidelines. The ERT also noted that the Estonian energy balance is available online (https://andmed.stat.ee/en/stat/majandus energeetika energia-tarbimine- ja-tootmine aastastatistika/KE0240).There is a large difference between the stock change of shale oil for 2019 and 2020 reported in these statistics and in CRF table 1.A(b): the energy statistics include a stock change for oil shale of 0 TJ for 2019 and 2020, while CRF table 1.A(b) contains a stock change for shale oil of –1,132.00 kt (–44,464.96 TJ) for 2019 and –1,114.48 kt (–44,121.56 TJ) for 2020. During the review, the Party clarified that the fuel consumption data reported in CRF table 1.A(b) are provided by Statistics Estonia, which also provides data to IEA. The Party indicated that Statistics Estonia has confirmed that the data used for the inventory and the data provided to IEA are the same. The ERT recommends that the Party (1) include the national energy balance for the most recent year in the NIR as annex 4 and (2) compare the national energy statistics with the AD reported in CRF table 1.A(b) and either correct the AD so that the values are consistent or describe transparently in the NIR any differences between them. The ERT encourages the Party to explore the differences between the data used for the annual inventory submission and the data submitted to IEA and report on them in the NIR.	ARR2022/E.18	Shale oil is reported under Liquid fuels Shale Oil in 1.A(b) in CRF tables and under Other hydrocarbons in the energy balance. The production of secondary fuels (which shale oil is) is not accounted for in the energy balance and in 1.A.(b) and Estonia exports most of its produced shale oil and this causes a negative apparent consumption of shale oil in the energy balance. This is the reason there is a negative value reported in the stock change in 1.A.(b) as there is no consumption reported and the calculated consumption in CRF has to be zero. The explanation was added into Chapter 3.2.1. Estonia is using Joint Questionnaire (JQ) dataset made by Statistics Estonia instead of national energy balance since NIR 2021 submission as JQ allowed for a more accurate redistribution of fuels between sectors. Joint Questionnaires data data can be accessed via Statistics Estonia website (https://www.stat.ee/) or can be shared as Excel files upon request.		Chapter 3.2.1 Comparison of the sectoral approach with the reference approach

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
1.A.1.a Public electricity and heat production – other fossil fuels – CO2, CH4 and N2O Transparency	The Party reported, as an information item in CRF table 1.A(a)s4, the total emissions from waste incineration, with energy recovery divided into biogenic and fossil fuel emissions (with the same value of 1,198.37 TJ and the same emissions for both portions). However, no further explanation of which fuel types these emissions are included under was provided in the documentation box of CRF table 1.A(a)s4 or in the NIR. Additionally, the Party reported in its NIR (section 3.2.4.1, p.67) that emissions from the Iru waste-to-energy plant are included under "Other fossil fuels" under category 1.A.1.a in CRF table 1.A(a)s1. The ERT noted, upon comparing the consumption of "Other fossil fuels" under category 1.A.1.a in CRF table 1.A(a)s1 with the information item in CRF table 1.A(a)s4 (total emissions from waste incineration with energy recovery), that the Party included the biogenic portion of the waste under "Other fossil fuels" under category 1.A.1.a in CRF table 1.A(a)s1. The ERT also noted that the plant-specific CEF for MSW, as reported in NIR table 3.9, is 17.94 GJ/t, but it is not clear from the NIR whether this value includes only the fossil portion of the MSW or both the fossil and the biogenic portions. During the review, the Party clarified that the emissions from waste incineration with energy recovery reported in CRF table 1.A(a)s4 are included under category 1.A.1.a (public electricity and heat production) in CRF table 1.A(a)s1. The ERT recommends that the Party allocate the biogenic portion of the waste incinerated with energy recovery to "Biomass" under category 1.A.1.a (public electricity and heat production) in CRF table 1.A(a)s1 and transparently report in the NIR on the derivation of the EFs for MSW for "Other fossil fuels" and "Biomass" of the same category.	ARR2022/E.19	Since 2023 submission NID includes more detailed explanation on the fossil and biogenic part of waste reported under 1.A.1.a Public heat and power production		Chapter 3.2.4.2 Methodological issues
1.A.2.g Other (manufacturing industries and construction) – biomass – CO2, CH4 and N2O Transparency	The ERT noted a significant decrease in biomass consumption, from 4,022 TJ for 2015 to 341 TJ for 2016, was reported in CRF table 1.A(a)s2 for category 1.A.2.g (other (manufacturing industries and construction)). During the review, the Party clarified that Statistics Estonia explained that this decrease results from the introduction of new technologies and the switch to a different fuel in the wood and wood products industry. The ERT recommends that the Party explain in the NIR the drivers of the trend in biomass consumption by manufacturing industries and construction and the reasons for any significant inter-annual variation.	ARR2022/E.20	The reason provided by Statistics Estonia for the significant inter-annual variation is that 2016 CHP plants using wood were completed in the sector and this means that any wood burned in these CHP plants were no longer reported under 1.A.2.g, but in the transformation sector (1.A.1.a) instead. This explanation was also added to the NID Chapter 3.2.5.2.		Chapter 3.2.5.2 Methodological issues

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
2.F.1 Refrigeration and air conditioning – HFCs (I.7, 2020) (I.7, 2018) (I.10, 2016) (I.9, 2015) Accuracy	Continue to seek to collect more complete, accurate AD and EF data in order to improve the database and improve the accuracy and completeness of the estimates, and report on progress. Addressing. The Party reported in its NIR (p.173) the issue with the completeness of AD and EFs for commercial and industrial refrigeration, which leads to high uncertainties. Inventory compilers and environmental inspectors collect AD in the commercial and industrial refrigeration sectors. The uncertainty of AD has decreased since the 2020 submission, while the uncertainty of EFs has not improved. The database for fluorinated gas equipment and servicing was overhauled in 2021, but still needs further improvement because the use of the database by service companies is low. During the review, the Party clarified that discussions on and development of the method to calculate emissions for the commercial and industrial refrigeration sectors are ongoing. The ERT does not have any data that might lead to lower uncertainties in the AD and EFs used to calculate emissions and that would allow it to evaluate potential underestimations thereof, but it compared the per capita emissions of Estonia with those of neighbouring countries with similar climatic, economic and urban planning conditions and found that Estonia's were not significantly lower. The ERT concludes that any possible underestimation would be below the threshold for application of an adjustment in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with decision 4/CMP.11 (5.78–10.97 kt CO2 eq for 2013–2020) and therefore the issue is not included in the list of potential problems and further questions raised. The ERT considers that the recommendation has not yet been fully addressed because, while the Party has improved the uncertainty of the AD, it has not yet improved the uncertainty of the EFs in comparison with those used for the previous annual submissions.	ARR2022/I.3	Continuous work in progress improving AD through HFC database (FOKA). Renewed FOKA database has now less errors and is functioning better. Currently different institutions work on the subject how to remind owners of the equipment and maintenance companies most efficiently about continuous obligation to add their maintenance data to the database: information letters are sent and it is considered to add automatic reminders to the database functionality. Throughout these actions AD should be more complete.		
2.F.1 Refrigeration and air conditioning – HFC- 143a (I.8, 2020) Transparency	Ensure that CRF table 2(II)B-Hs2 includes the correct AD for HFC-143a filled into new manufactured products for industrial refrigeration for 2016 and include an explanation of significant inter-annual changes in AD in the next annual submission. Addressing. The Party reported in the NIR (pp.176–178) of its 2021 submission recalculations of HFC-143a for industrial refrigeration for 2016, but the inter-annual change between 2010 and 2011 noted by the previous ERT is still reported in the 2022 submission. During the review, the Party clarified that the AD for HFC-143a filled into new manufactured products for 2016 were corrected and that an explanation of these recalculations is included in the 2021 NIR (section 4.6.1.3.5). The ERT considers that the recommendation has not yet been fully addressed because the Party did not include in the NIR an explanation of the significant inter-annual changes for HFC-143a filled into new manufactured products for industrial refrigeration (e.g. a 261.3 per cent increase between 2010 and 2011).	ARR2022/I.4	Explanation was included to 2024 submission about significant inter-annual changes in AD (HFC-143a filled into new manufactured products) for industrial refrigeration for 2010-2011.These years were not under discussion during review week and were not addressed as ERT recommendation in ARR2020 where this issue was raised initially and were also not under discussion during the 2022 centralized review.		NID 2024, Chapter 4.6.5. Category-specific recalculations (2.F.1.c Industrial refrigeration)

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
2.A.2 Lime production – CO_2 Transparency	The Party reported in its NIR (p.134) that EFs based on actual CaO and MgO content measured by one of the bigger lime plants in the country have been available since 2005. As the EFs from that lime plant differ significantly from the default EFs available in the 2006 IPCC Guidelines (vol. 3, table 2.4), EFs for 1990– 2004 were established as mean values from the EFs for 2005–2008. The ERT noted that the significant differences between country- or plant-specific EFs and default EFs from the 2006 IPCC Guidelines should be explained in line with the 2006 IPCC Guidelines (vol. 1, chap. 6, p.6.13). During the review, the Party clarified that the percentage of CaO and MgO in lime differs from year to year because of differences in the quality of the raw material. The EFs for CaO and MgO were calculated on the basis of the ratio of the molecular weight of CO_2 to CaO or MgO. The Party explained that the recalculations made for the 2010 submission (2010 NIR section 4.2.2.5, on source-specific recalculations) following a recommendation in a previous review report (FCCC/ARR/2009/EST, para. 93) showed differences in the emissions estimated using plant-specific EFs and those estimated using default EFs.	ARR2022/I.6	Explanation of differences on the emission factors for different years and comparison with the 2006 IPCC Guidelines default emission factors have been included in the NID since 2024 submission.		Chapter 4.2.2 Methodological issues (under Emission factors, section 2.A.2 Lime production, Table 4.9)
2.A.2 Lime production – CO_2 Transparency	The Party reported in its NIR (p.134) that its method for calculating emissions from lime production is consistent with the tier 2 methodology and that four different EFs were used in the calculations. The ERT noted that in the NIR (section 4.2.2.3, on uncertainties and time-series consistency), no description is included of how the use of different EFs affects time-series consistency. During the review, the Party clarified that for 1990–1996, production data from Statistics Estonia and the IPCC default EF were used to calculate emissions for those plants for which it did not receive company- specific information and that emissions for 1990–1996 were recalculated by applying plant-specific EFs from two production plants. Emissions for 1997–2007 were recalculated owing to better AD and plant-specific EFs becoming available. The ERT noted that the 1990–1996 plant-specific EFs from the two production plants could be used to calculate an implied EF for those plants for which company-specific information was not received. The ERT recommends that the Party improve the justification in the NIR for using IPCC default EFs for some plants for 1990–1996 and for why it considers them more appropriate than a country-specific implied EF for 1990–1996.	ARR2022/I.7	According to the ERT finding Estonia performed recalculation for the 2025 submission by replacing default EF-s with country-specific implied EF-s for the years 1990-1996 for the plants for which country-specific information was not received.		Chapter 4.2.2 Methodological issues (under Emission factors in the category 2.A.2 Lime production) and chapter 4.2.5. Category-specific recalculations, table 4.12.
2.B.1 NH_3 production – CO_2 Comparability	The Party reported in its NIR (p.147) that it used plant-specific EFs for calculating CO_2 emissions from NH_3 production throughout the time series and that these NH_3 production EFs varied between 1.276 and 1.516 t CO_2/t NH_3 produced. The ERT noted that the EFs reported by Estonia are outside the range of default EF values in the 2006 IPCC Guidelines (vol. 3, table 3.1); that is, 1.694–3.273 t CO_2/t NH_3. During the review, the Party clarified that the difference is attributable to the fact that the default EFs in table 3.1 of the 2006 IPCC Guidelines take into account natural gas used as both fuel and feedstock. The Party noted that it explained in the NIR (section 4.3.1.2)	ARR2022/I.8	The explanation how double accounting is avoided currently and why natural gas used is accounted separately as feedstock and for process is added to NID chapter 4.3.2 since 2024 submission: *Estonia was accounting under*		Chapter 4.3.2. (Methodological issues, Choice of methods, 2.B.1 Ammonia production)

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
	that under the IPPU sector, Estonia accounts only for emissions from the natural gas used as feedstock for primary steam reforming. The amount of natural gas combusted is reported under the energy sector (category 1.A.2.c) as it is possible to obtain separate data on natural gas that is used for non-fuel and fuel purposes from Statistics Estonia. Thus, the plant-specific EFs are lower than the default EFs in table 3.1 of the 2006 IPCC Guidelines. The ERT noted that this is not in line with the 2006 IPCC Guidelines (vol. 3, chap. 3.2.2, p.3.11), which state that "in the case of NH3 production no distinction is made between fuel and feedstock emissions with all emissions accounted for in the IPPU Sector". The ERT recommends that the Party report all CO2 emissions from NH3 production (category 2.B.1) under the IPPU sector in accordance with the 2006 IPCC Guidelines (vol. 3, chap. 3.2.2, p.3.11) and ensure that the related fuel consumption is excluded from the emissions reported under the energy sector in order to avoid double counting		*Industrial processes and product use sector only the natural gas used as feedstock for primary steam reforming. The amount of natural gas combusted was reported under Energy sector 1.A.2.c. The reason for such accounting is that it would be very difficult to subtract the combusted gas from the Joint Questionnaire dataset. In the Joint Questionnaire dataset provided by Statistics Estonia, it is not possible to split by single plants.*		
2.D.1 Lubricant use – CO2 Transparency	The Party reported in NIR figure 4.4 (p.155) the emissions from lubricant use. The ERT noted that the emissions decreased from about 16 kt CO2 eq for 1990 to about 3 kt CO2 eq for 2020 and no explanation for this decrease was provided. During the review, the Party clarified that AD on lubricants are obtained from Statistics Estonia and Eurostat; both data sources have similar information on imports and exports. Import numbers declined steadily from 1990 to 2006, which has made the biggest impact on the overall trend. The ERT recommends that the Party include the description of the trend in lubricant use and associated emissions in the NIR (section 4.5.1.4). The ERT encourages the Party to conduct category-specific QA/QC and verification for this category and to explain the significant decrease in lubricant imports over the time series.	ARR2022/I.9	Additional information is added to the NID Chapter 4.5.4. under 'Lubricant use' since 2024 submission: *Activity data on lubricants are obtained from Statistics Estonia and Eurostat and both data sources have similar information on imports and exports. Import numbers declined steadily from 1990 to 2006, which has made the biggest impact on the overall trend. The amount of lubricants used shows that less lubricants are needed on the market. 2020-2022 data show an increase in usage of lubricants and therefore rise in CO_2 emissions.*		Chapter 4.5.4. Category-specific QA/QC, 2.D.1 Lubricant use)

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
2.F.1 Refrigeration and air conditioning – HFC-134a Transparency	The Party reported in NIR table 4.17 (under section 4.6.1.3.5, on category-specific recalculations) that the HFC-134a filled into new equipment for industrial refrigeration amounts to 1.2 kt and the quantity in stock is 4.98 kt for 2019. However, the ERT noted that in CRF table 2(II)B-Hs2, HFC-134a filled into new equipment for industrial refrigeration is reported as 1.31 t and the average annual stock as 10.66 t for the same year. During the review, the Party clarified that the data in NIR table 4.17 are on recalculations of HFC-134a that were not in different blends of HFCs but in a pure form. The amount of HFC-134a in different blends stayed the same. In contrast, the amounts reported in the CRF table are calculated as the sum of HFC-134a in pure form and in blends. The ERT recommends that the Party provide in the NIR, in the AD section for category 2.F.1, in tabular format, if appropriate, information on how the values for HFC-134a filled into new equipment and in stock for industrial refrigeration reported in CRF table 2(II)B-Hs2 were calculated, including an indication of whether they are based on individual HFCs or blends thereof that are used in the country.	ARR2022/I.10	Estonia presented information in NID 2024 on how the R-134a values were calculated in pure form and in blends that summed up in CRF table 2(II)B-Hs2 in Tabel 4.23.		NID 2024, Chapter 4.6.5 (Category-specific recalculations), table 4.23
3.B.4 Other livestock – CH4 and N2O (A.5, 2020) (A.7, 2018) Accuracy	Correct the allocation of poultry manure, taking into account the findings from the new study by the Estonian University of Life Sciences or, if the study does not provide the necessary information, change the allocation from pasture/range/paddock to dry lot. Addressing. The Party reported in NIR table 5.33 (p.258) that the allocation of poultry manure is 99.41 per cent solid waste and 0.59 per cent pasture, range and paddock. In CRF table 3.B(a)s2, 100 per cent solid storage and dry lot is reported. The ERT considers that the recommendation has not yet been addressed because the Party has not yet reported N2O emissions in CRF table 3.B(b) that are consistent with NIR table 5.33 and that the allocation of poultry manure is 99.41 per cent solid waste and 0.51 per cent pasture, range and paddock.	ARR2022/A.2	In accordance with the 2022 ERT review's Recommendation ARR2022/A.2, since 2022 submission, the issue has been fixed in the Inventory report. Data reported in CRT 3.B.4.g section is consistent with what is reported in the inventory document, Chapter 5.3.2. Methodological issues, Activity data section, under "3.B.2 and 3.B.4 Manure management of sheep and other livestock".		Chapter 5.3.2.

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
3.B Manure management – CH4 Transparency	The Party reported in its NIR (pp.219 and 250, table 5.26 and figure 5.12) that the total CH4 emissions from livestock manure management were 5.97 kt for 2014, decreasing to 5.25 kt for 2016 and increasing to 6.52 kt for 2020. The Party indicated that the main reason for this trend is "the recovering pork production in Estonia during the recent years after the outbreak of African swine fever in 2015" (NIR p.250). The ERT noted that no supporting documentation was provided to justify the reasons for the trend in the swine and dairy cattle annual population. During the review, the Party clarified that the dairy cattle and swine populations started to decrease from 2014 owing to the economic sanctions imposed by the Russian Federation on the EU and because of the African swine fever outbreak in the country in 2015, which reiterated the explanation included in the NIR (p.219): "Economic sanctions imposed by Russia on the EU starting from August 2014 have had an impact on the dairy industry resulting with a decline in production. Consequently, the number of dairy cattle in 2020 had fallen by 11.8% in comparison with 2014. The number of swine has fallen by 11.5% in 2020 compared to 2014 because of African swine fever outbreak in the region in 2015". The ERT recommends that the Party include in the NIR the reasons for the trend in livestock populations between 2014 and 2020, which led to a reduction and then increase in CH4 emissions from manure management, for example by providing more information on the impacts of and recovery from the 2015 outbreak of African swine fever in the country (in the case of swine) and on the economic sanctions imposed by the Russian Federation on the EU from 2014 onward (in the case of dairy cattle).	ARR2022/A.6	In accordance with the 2022 ERT review's Recommendation ARR2022/A.6, since 2024 submission, the Inventory Document includes more detailed information about the decline in swine and cattle population over the years. More information on the impact of African swine fever outbreak and economic sanctions imposed by Russia on the EU is included.		Chapter 5.1.
3.D.a.2.b Sewage sludge applied to soils – N2O Transparency	The Party reported in its NIR (p.283, including table 5.56) that the methodology for treating sewage sludge according to the R10 category (which is one of the country-specific categories under which sludge is treated) for 1990–1998 was developed by the Tallinn University of Technology, which compiled the GHG inventory until 2012. During 1990–1998, limited waste-related data were gathered by the predecessor of the Estonian Environment Agency (the Estonian Environment Information Centre) and, therefore, an assumption was made that 50 per cent of the total amount of sewage sludge generated was applied to agricultural land. The ERT noted that no justification for the assumption that 50 per cent of the total amount of sewage sludge generated was applied to agricultural land is included in the NIR. During the review, the Party clarified that the assumption is based on historical data on the use of sewage sludge and was originally made by the Tallinn University of Technology. The ERT recommends that the Party include in the NIR supporting documentation to justify the assumption that, for 1990–1998, 50 per cent of the total amount of sewage sludge generated was applied to agricultural land.	ARR2022/A.7	In accordance with the 2022 ERT review's Recommendation ARR2022/A.7, Estonia has been developing an expert judgement for the evaluation that 50% of the total amount of generated sewage sludge was used for improving the environmental situation and 50% was composted in the years 1990-1998. The previous evaluation was originally provided by the Tallinn University of Technology. An authorized engineer in water supply and sewerage, Aare Kuusik (PhD) conducted the evaluation, by using all		Chapter 5.4.2

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
			available preserved materials from archives to compile an expert opinion on the usage of sewage sludge in the years 1990-98 and conducted an evaluation on the amounts of sludge being used on agricultural lands and the amounts composted during these years. New, corrected amounts of sewage sludge and compost applied to agricultural lands during the years 1990-98 are used for th emission calculations in the 2025 Inventory. The complete expert judgement, including the references to supporting documents, are stored in the Inventory archive (in Estonian).		
3.F Field burning of agricultural residues – CH4 and N2O Transparency	The Party reported in its NIR (p.298) that CH4 and N2O emissions from the field burning of agricultural residues were reported as "NO" for the whole time series. It also reported that it is feasible that it has been overestimating emissions for 1990–2006 by applying the IPCC default value for the fraction of residues burned in the field for previous submissions. During the review, the Party acknowledged that the text in the NIR may be confusing and indicated that it will improve the description for this category in the next NIR. Since the 2015 submission, Estonia has applied the notation key "NO" for the entire time series for this category because in 2004 the burning of crop residues was prohibited by Estonian law and, prior to this, the Estonian Ministry of Rural Affairs does not consider that there was widespread burning of crop residues. The ERT recommends that the Party investigate the probability that some field burning of agricultural residues does occur (because there may not be 100 per cent compliance with the law prohibiting the burning of crop residues) and include in the NIR the findings, which may take the form of expert judgment or a relevant document, in order to justify the reporting of CH4 and N2O emissions for this category as "NO".	ARR2022/A.8	In accordance with the 2022 ERT review's Recommendation ARR2022/A.8, Estonia has investigated the probability of potential field burning of agricultural residues and has found out that no burning of agricultural residues has been performed as it is prohibited by the law in the country. Since 2023 submission, the inventory report includes a renewed expert judgement of the issue.		Chapter 5.5.

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
3.G Liming – CO2 Transparency	The Party reported in its NIR (p.299) that the emissions from limestone application were calculated using sales records for clinker dust, chalk and powdered limestone. The fraction of calcium carbonate in cement clinker dust (49.48 per cent) was obtained from the only cement plant operating in Estonia. The ERT noted that the method used to calculate this fraction was not clearly reported in the NIR. During the review, the Party clarified that it received a calculation sheet from the cement plant in which different components of clinker dust and their proportions were shown. Therefore, using the burning residue percentage (80.92 per cent) and the CaO percentage in burning residue (51.92 per cent), which were both calculated by the cement plant, it was possible to calculate the fraction of calcium carbonate in the cement clinker dust. The Party indicated that it will add this clarification to the next NIR. The ERT recommends that the Party include in the NIR an explanation of how the value of the calcium carbonate content of cement clinker dust used in estimating CO2 emissions from liming was derived, along with supporting documentation to justify the value used.	ARR2022/A.9	In accordance with the 2022 ERT review's Recommendation ARR2022/A.9, since 2023 submission, the inventory report now includes an expert judgement of the assumption for CaCO3 content in cement clinker dust used in estimating CO2 emissions from liming (documented in the archive).		Chapter 5.6.2.
3.H Urea application – CO2 Accuracy	The Party reported in its NIR (p.302) that as the Agriculture and Food Board has not collected data on the amounts of marketed urea fertilizers since 2019, the CO2 emissions from urea application for 2018 were also used as the 2019 and 2020 values. During the review, the Party clarified that the study referred to in the NIR included conducting a comparison of the data on urea fertilizers used in Estonia from IFASTAT and the data used in the inventory from Statistics Estonia and Nitrofert (a urea fertilizer producer). The Party noted that, unfortunately, highly significant discrepancies were found in the historical time series of data from IFASTAT that were not explained by the manager of IFASTAT. Therefore, using IFASTAT data to update Estonia’s fertilizer time series was considered not possible. Estonia has contacted mineral fertilizer manufacturers and resellers to obtain data on the amount of urea fertilizers sold in Estonian markets each year. The Party will evaluate the possibility of using the manufacturers’ data for reporting urea fertilizer use in the 2023 submission. The ERT noted that based on the AD time series, there is no underestimation of emissions in 2019 and 2020. The ERT recommends that the Party ensure reliable and consistent AD across the time series, include information on its activities to obtain urea fertilizer use data and report on the results of its evaluation of the manufacturers’ data in the next annual submission.	ARR2022/A.10	Estonia has been working on finding a new data source for estimating CO2 emissions from Urea application for the years 2019-2021. Different databases have been investigated, but no institution in Estonia that collects national data on urea consumption have been identified. In accordance with the 2022 ERT review's Reccommentation ARR2022/A.10, urea resellers and manufacturers have been contacted and their sales data have been validated. Additionally, Estonian inventory team had capacity building consultations with external experts facilitated by Umweltbundesamt (UBA) within the Effort Sharing Regulation sectors capacity-building support, on the proposed approach to implement the manufacturers' sales data to Estonia’s emission estimates. The external experts concluded		Chapter 5.7.2.

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
			that the switch to a new database can be done directly, without any modeling. Data on urea fertilizers sold to Estonian markets can be used from 2016 (the year that the data is available) and assumed that all urea sold on Estonian markets is used on Estonian agricultural lands. Therefore, since 2024 submission, the emissions from urea application starting from 2016 have been calculated using the manufacturers' and resellers' data on sold fertilizers to Estonian markets.		
4. General (LULUCF) – CO_2, CH_4 and N_2O (L.2, 2020) (L.3, 2018) Accuracy	Acquire land-use change data for 1970–1990 and recalculate N_2O emissions for the entire reporting period. Addressing. Land-use change assumptions or data for 1970–1990 are not documented in the NIR (see also ID# L.12 in table 5). The N_2O emissions have been recalculated for the entire reporting period, but on the basis of updated and corrected land-use change data for 1991–2020 rather than by acquiring data for 1970–1990. During the review, the Party clarified that the Estonian Land Board has started digitalizing old orthophotos and that as these data become available Estonia will use them to report on 1970–1990 land-use changes in NFI plots. The ERT, while noting that the information provided during the review demonstrates that the Party has made progress in addressing this recommendation, considers that it should describe its progress in future NIRs. The ERT also notes that this recommendation is relevant to all GHGs, not only N_2O.	ARR2022/L.1	Estonia is still working to estimate land-use change areas for this period. Estonia has made some progress tracking historic land-use on NFI plots and obtaining total areas of land categories in 1970. However, land-use changes between 1970–1990 need further analysis before this data could be used in the inventory compilation.		

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
4.A Forest land – CO2 (L.15, 2020) Transparency	Provide additional information in the NIR on time-series management of NFI data to allocate AD to individual years with a view to ensuring that estimates remain accurate and reliable as recalculations occur. Addressing. The ERT noted that NIR figure 6.11 still shows large inter-annual CSC for living biomass in forest land remaining forest land. As noted by the previous ERT, this seems to be in contradiction with a stock difference method, which usually smooths inter-annual variation as it gives only one value for an entire inventory cycle for any given plot. The NIR (p.439) points to sections 6.1.3 and 6.2 as addressing this issue by clarifying how plot data are aggregated to determine the national total. The ERT considers that these sections are not yet fully transparent. On p.321 (section 6.2), the Party mentions summing estimates for “each given area” but does not specify what these areas are. On p.314 (section 6.1.3), it states that “the average standing volume is calculated for every year based on the 15-year trend”. During the review, the Party clarified that the procedure applied for estimating CSC in living biomass involves (1) estimating the standing volume on each plot; (2) summing all plots to obtain the total national standing volume for each year; (3) regressing the standing volume against time over a 15-year window centred on each year; (4) estimating a “smoothed standing volume” for each year as 75 per cent of the regressed value for the year plus 25 per cent of the actual value for the year; and (5) computing the difference with the standing volume in year y – 1 to obtain the reported CSC in living biomass for year y. The ERT considers that the recommendation has not yet been fully addressed because the Party has not yet provided in its NIR a fully transparent explanation of how it estimates CSC for living biomass in forest land remaining forest land. The ERT considers that the issue could be resolved by detailing in the NIR the procedure outlined during the review, including, ideally, providing equations that allow the ERT to track how Estonia goes from standing stock in each NFI plot to reported CSC in living biomass for a specific year.	ARR2022/L.5	Estonia has implemented the gain-loss method for estimating C stock changes in living biomass since the 2024 submission and no longer applies the smoothing. This will eliminate the need for recalculations in case the trend changes. New methodology has been described in the NID.		Chapter 6.4
4. General (LULUCF) – CO2, CH4 and N2O Accuracy	The Party reported in its NIR (pp.318–319) and showed in NIR figures 6.9 and 6.10 that the area of land converted to forest land is very small for the 1990s and is associated with a decreasing area in forest land remaining forest land. The ERT noted that this pattern could be the result of an implicit assumption that there was no conversion to forest land prior to 1990; however, this assumption is neither stated nor justified in the NIR. More generally, assumptions made on land-use changes between 1970 and 1990 are not explicitly described in the NIR. During the review, Estonia declared that it was still in the process of collecting data on pre-1990 areas and practices. Because Estonia has chosen the default transition period of 20 years for conversions between land categories, data or assumptions on land-use changes necessarily start in 1970 to estimate areas of land categories in 1990 (in line with the 2006 IPCC Guidelines, vol. 4, p.4.33), even if Estonia has not yet acquired data for 1970– 1990 (see also ID# L.1 in table 3). The ERT recommends that the Party transparently describe in the NIR the assumptions made on land-use changes between 1970 and 1990, possibly by including a representative land-transition matrix for that period,	ARR2022/L.12	Estonia is still working to estimate land-use change areas for this period. Estonia has made some progress obtaining total areas of land categories for the 1970–1990. However, land-use change data for this period needs further analysis before it could be used in the inventory compilation.		

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
	and, if the area subject to land-use changes is not nil, recalculate all estimates accordingly for 1990–2009.				
4. General (LULUCF) – CO2 Accuracy	The Party reported in its NIR (p.326) that it uses EFs from the 2020 Swedish NIR for estimating CO2 emissions from the drainage of organic soils. The ERT noted that the Swedish EFs are weighted averages of IPCC default EFs from the Wetlands Supplement (p.2.11); for forest land, they are weighted by the shares of boreal/poor, boreal/rich and temperate forest soils in Sweden. Similar weightings are applied for other land uses. The ERT considers that the application of these Swedish EFs by Estonia is not justified as Estonia lies entirely in the temperate zone according to the maps in the 2006 IPCC Guidelines (p.3.47). During the review, the Party clarified that its experts considered that using the default EFs from the 2006 IPCC Guidelines (vol. 4, chap. 4, p.4.53) for the temperate zone would be appropriate. The ERT agrees that this is in line with the UNFCCC Annex I inventory reporting guidelines, noting that using the more recent and more detailed default EFs from the Wetlands Supplement would likely improve the accuracy of the emission estimates. The ERT recommends that the Party use EFs that are better suited to Estonia's national soils and climate than the EFs currently in use (from the Swedish NIR) for estimating CO2 emissions from the drainage of organic soils; for example, the ERT considers that the IPCC default EFs from the Wetlands Supplement (p.2.11) would be appropriate.	ARR2022/L.13	The default EFs from the 2006 IPCC Guidelines were applied for drained organic soils since the 2023 submission. Estonia has ongoing research projects to develop country-specific EFs.		Chapter 6.4, Chapter 6.5, Chapter 6.6, Chapter 6.8

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
4.A Forest land – CO_2 Transparency	The Party reported in its NIR (p.321) country-specific values for BCEFs. The ERT noted that these BCEFs present a counter-intuitive pattern because they are approximately stable per growing stock level, whereas BCEFs normally tend to decrease substantially with increasing growing stock level. For example, the changes in the BCEFs from the <20 m3 class to the 21–50 m3 class are very small (the <20 m3 value is even lower than the 21–50 m3 value for pine), whereas this change is commonly around –50 per cent (e.g. default values from the 2006 IPCC Guidelines (vol. 4, pp.4.50–4.51)). During the review, the Party clarified that the stable trend is the result of a fitted regression (BCEF as a function of stand volume) based on 165 pine, 127 spruce and 117 birch sample trees. The ERT recommends that the Party demonstrate in its NIR that the regression performed (BCEF as a function of stand volume) is accurate by providing the equation and parameters used together with graphical or numerical evidence that residuals are evenly distributed around zero along a representative range of growing stock levels. The ERT notes that, for example, a graph showing the regression curve for each tree type (i.e. pine, spruce and birch) together with points for each measured tree and an indicator of the fit (e.g. adjusted R-squared) would address the issue.	ARR2022/L.14	Estonia has updated the models for estimating BCEF values. More information is provided in Annex A.V.4		Annex A.V.4
4.A Forest land – CO_2 Accuracy	The Party reported in its NIR (p.321) weighted averages for BCEFs for each subcategory of forest land, as well as BCEF values per tree species and growing stock level. However, the NIR does not clearly state which of these two sets of values are used in the calculations. During the review, the Party clarified that it applied each weighted average to all the plots for a subcategory rather than applying different BCEFs corresponding to the growing stock level of each plot. The ERT notes that by doing so, the Party risks overestimating emissions from harvest, as the average is higher than the value for plots with a high growing stock level. The ERT recommends that the Party either demonstrate that the risk of overestimating emissions from harvest is negligible when using a weighted average BCEF value for each subcategory of forest land or apply a set of BCEFs adapted to the variation in BCEF values per growing stock level.	ARR2022/L.15	Estonia has improved the method for calculating C stock changes in living biomass since the 2024 submission. According to the new methodology, tree biomass is calculated for each NFI plot, using the BCEFs applicable for specific growing stock level. The same approach is also applied to estimate biomass losses from harvests, using information on pre-harvest growing stocks on NFI plots.		Chapter 6.4

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
4.A.1 Forest land rem aining forest land – CO2 Accuracy	The Party reported in its NIR (p.319) that annual felling is generally the first-order driver of CSCs in forest land remaining forest land in the short to medium term (one to five years). The ERT noted that the time series for harvesting was not provided in the NIR. Comparing a time series of harvest values downloaded from FAOSTAT with overall removals in forest land (NIR figure 6.10 (p.119)), the ERT noted three major concerns: (a) Consistently with the narrative in the NIR (p.312), the comparison indicates that the end of the planned economy led to a substantial increase in harvested amounts in the 1990s (500 per cent between 1992 and 2001). One would therefore expect removals to have fallen steadily over that period, which is, however, not the case in the reported time series; (b) The maximum in removals occurred in 2003 and corresponded to a local maximum in harvest statistics. In general, a peak in harvest corresponds to lower removals. A similar feature, although less pronounced, occurred in 2018, when removals increased whereas harvest reached its all-time maximum. Usually, local maximums in removals correspond to local minimums in harvest and vice versa; (c) Since 2010, harvest statistics and removals have been broadly correlated at the 10-year timescale by an overall increasing trend in harvest and an overall decreasing trend in removals. However, at the five-year timescale, this is not the case: harvest rose sharply between 2008 and 2012, whereas removals also increased over that period, and, after a short plateau, harvest rose again sharply between 2014 and 2018, whereas removals were broadly stable. During the review, the Party offered three explanations for these concerns: (1) harvest is not the only factor affecting CSC in forest biomass, which depends also on the forest age structure and change in forest land area, as well as on the relative impact of changes in these factors over time; (2) the smoothing procedure cuts off the peaks in 2003 and 2018; and (3) the unfinished NFI cycles generate uncertainties in the most recent years of the time series. The ERT understands that because the NFI cycle is five years long, unfinished NFI cycles can blur the estimates for the last four reported years (2017–2020 in the case of the 2022 submission). However, a harvest lower than the increment justifies net removals, not a flat trend in removals, and smoothing justifies lower peaks than expected, but not opposite local extremes in harvest and CSCs. In addition, the Party clarified that it was using both permanent and temporary plots to estimate CSCs via the stock difference method. The ERT notes that using temporary plots together with the stock difference method could introduce a substantial random component in the estimates of CSCs. Indeed, when the stock difference method is applied to permanent plots, the estimate only reflects the change in stock, whereas when it is applied to temporary plots, the estimate also reflects the random change in sampled plots. Therefore, the ERT notes that the inconsistencies between the reported CSCs and the harvested volumes might be the result of an inaccurate smoothing procedure (see also ID# L.5 in table 3). The ERT recommends that the Party (1) provide in the NIR a transparent description of the counteracting forces that prevail over harvest as the main drivers of inter-annual (or short-term) changes in harvest levels or reconsider its smoothing procedure so that it better reflects short-term (at least on a five-year timescale) changes in harvest levels and (2) report in the NIR harvest statistics for the entire reporting period, possibly in the same figure (graph) as the one displaying total emissions/removals for the category (figure 6.10 (p.319) in the 2022 NIR).	ARR2022/L.16	Estonia has improved the method for calculating C stock changes in living biomass and switched to the gain-loss methodology, which directly takes into account harvest rates. Annual losses of biomass from clear fellings are shown in Figure 6.12 and felling volumes in Figure 6.13.		Chapter 6.4

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
4.A.2 Land converted to forest land – CO2 Accuracy	The Party reported in its NIR (p.325) that its EFs for CSCs in mineral soils in cropland converted to forest land and grassland converted to forest land were derived from a published article (Kõlli et al., 2010). During the review, the Party provided the ERT with the article together with the calculation sheet describing how the figures from the articles were combined into the reported EFs. The ERT noted that the calculation method is in line with the 2006 IPCC Guidelines (vol. 4, chap. 2, p.2.38). However, the ERT also noted that the soil types for which no data were available were misrepresented as "no change in soil carbon" rather than being noted as "no data" and that the shares of forest per soil type did not add up to 100 per cent. The ERT recommends that the Party correct the estimates for CSCs in mineral soils in cropland converted to forest land and grassland converted to forest land by correcting the errors in the calculation sheet used to estimate the EFs for CSCs in mineral soils in cropland converted to forest land and grassland converted to forest land (by noting "no data" rather than "0" for soil types for which no data are available and ensuring that the shares of forest per soil type add up to 100 per cent) and report on the associated recalculations of emissions in the NIR.	ARR2022/L.17	Country-specific factors for mineral soils in conversion areas were corrected and calculations have been updated since the 2023 submission.		Chapter 6.4, Chapter 6.5, Chapter 6.6
4.E.2 Land converted to settlements – CO2 Accuracy	The Party reported in its NIR (p.357) that it uses EFs from the 2020 Swedish NIR for CSCs in mineral soils for all subcategories of land converted to settlements, with the exception of forest land converted to settlements. The ERT noted that this is in principle reasonable, provided that Estonia has assessed that (1) the neighbouring country (in this case Sweden) is likely to be comparable for the given EFs and (2) the neighbouring country's EFs were obtained in line with the 2006 IPCC Guidelines. In this case, at least the first condition might not apply, as reported soil carbon stocks in Estonia and Sweden are very different in several categories (e.g. cropland and forest land). The ERT also noted that the reported EFs are very counter- intuitive: the EF for cropland converted to settlements is substantially lower than those for forest land converted to settlements and grassland converted to settlements despite soil carbon stocks being substantially higher in forest land and grassland compared with cropland. Similarly, the EF for forest land converted to settlements is three times lower than the EF for grassland converted to settlements despite the fact that Estonia considers that the transition from forest land to grassland results in negligible soil carbon changes in mineral soils. During the review, the Party noted that it has not validated the assumptions that the proportions of land-use groups within the different subcategories and the effects of land-use changes on soil carbon stocks in Estonia and Sweden are similar. The ERT recommends that the Party verify that the Swedish and Estonian situations are similar for the EFs in the land converted to settlements categories and that the Swedish EFs were obtained in line with the 2006 IPCC Guidelines, and if either of these conditions is violated, use a different set of EFs, possibly in conjunction with a tier 1 method for estimating emissions until an accurate higher-tier method can be properly justified.	ARR2022/L.18	Estonia no longer uses Swedish EFs to estimate CSC in mineral soils for Land converted to settlements subcategories. Instead, it is assumed that 20% of the initial country-specific average SOC stock is lost after land use change, which is the default value from the 2006 IPCC Guidelines for the settlement area that is paved over.		Chapter 6.8

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
4.G HWP – CO2 Transparency	The Party reported in its NIR (p.370) several sources of data used in equations 2.8.1–2.8.6 from the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, but did not provide the numerical values of a few key variables (e.g. total stock in HWP, share of industrial roundwood for the domestic production of HWP originating from domestic forests and share of domestically produced pulp for the domestic production of paper and paperboard). During the review, the Party clarified the description in the NIR by providing the source of data for each variable in the IPCC equations as well as the numerical values of a few key variables (e.g. total stock in HWP, share of industrial roundwood for the domestic production of HWP originating from domestic forests and share of domestically produced pulp for the domestic production of paper and paperboard) for a selection of years, including 1990. The ERT recommends that the Party provide in the NIR the source of the data as well as numerical values for each key variable in the equations used for estimating CO2 emissions for this category (equations 2.8.1–2.8.6 from the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol).	ARR2022/L.19	Since 2023 submission Estonia has added in the NIR a table (Table 6.36) providing numerical values for key variables as well as relevant data sources.		Chapter 6.12
5. General (waste) – CH4 (W.6, 2020) Transparency	Correct the information in the NIR and make sure that each category appears only once in the key category analysis.	ARR2022/W.1	Resolved. The Party updated the NIR (p.43) so that each category and gas appear only once in the key category analysis in table 1.2. The key categories and gases for the waste sector are 5.A (solid waste disposal on land) (CH4), 5.D.1 (domestic wastewater) (CH4) and 5.D.1 (domestic wastewater) (N2O).		NID Table 1.2
5. General (waste) – CO2 (W.7, 2020) Convention reporting adherence	Improve QC procedures and report consistent information in the NIR and the CRF tables. Addressing. The Party reported in CRF table 5.C and NIR annex 4 (p.92) consistent information for subcategories 5.C.1.1 (waste incineration – biogenic) and 5.C.2.1 (open burning of waste – biogenic). However, for subcategory 5.A.1.a (managed waste disposal sites – anaerobic), the Party reported the CO2 emissions as "NA" in annex 4 (p.92) to the NIR but as "NO" in CRF table 5.A. The ERT considers that the recommendation has not yet been fully addressed.	ARR2022/W.2	Correction has been made in the 2021 submission		CRT 5.A.1.a, 5.C.1.a, 5.C.2.a

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
5.D Wastewater treatment and discharge – N2O (W.8, 2020) Accuracy	Correct the protein consumption data (kg/person/year) on the basis of the new data from the Food and Agriculture Organization of the United Nations and revise the N2O estimates for 2018 for its next annual submission.	ARR2022/W.3	Resolved. The Party reported in CRF table 5.D under additional information that the protein consumption value of 37.36 kg/person/year was used for the 2020 calculation. The ERT notes that this is consistent with the latest data from the Food and Agriculture Organization of the United Nations. The Party used this value to estimate N2O emissions. In the NIR 2022 (p.412), the Party reported that the annual protein consumption per capita value was obtained from FAOSTAT. Recalculations has been made.		NID 2022, Table 7.32
5.A Solid waste disposal on land – CH4 Transparency	The Party reported in its NIR (pp.380 and 397) that its waste stream includes imported and exported waste and clarified that all waste data have been considered in the emission calculations. However, no details on the two streams are provided in the NIR. During the review, the Party clarified that when preparing the inventory, the entire waste stream, including waste that is generated, imported, exported, recycled and landfilled, is checked. The majority of the imported waste types (e.g. different metals) are reported by Estonian recycling companies. Historically, only a small part of the imported waste has been landfilled; this waste, while it is included in the waste model calculation, is inert waste for which CH4 emissions are not calculated. The ERT recommends that the Party provide in the NIR a thorough description of imported waste, including its amount, characteristics and how it is accounted for in the calculations of CH4 emissions for this category.	ARR2022/W.4	Explanation has been added since 2023 submission.		Chapter 7.2.2
5.A Solid waste disposal on land – CH4 Convention reporting adherence	The Party reported in NIR table 7.7 that the IPCC default value of DOCf was used and in CRF table 5.A the DOCf for anaerobic managed waste disposal sites was reported as 13.84. The ERT noted that this is not in accordance with the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.13), which provide a default value of 0.5 for DOCf. During the review, the Party clarified that an error occurred in reporting, namely that the MSW DOC was reported as DOCf in CRF table 5.A. The default fraction of 0.5 from the 2006 IPCC Guidelines was, however, used in the calculations. The ERT recommends that the Party correct the DOCf value for anaerobic managed waste disposal sites reported in CRF table 5.A (i.e. to the default value from the 2006 IPCC Guidelines) in the next annual submission.	ARR2022/W.5	Correction has been made in CRF/CRT.		CRT 5.A.1.a

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
5.A Solid waste disposal on land – CH4 Transparency	The Party reported in NIR table 7.7 (p.385) that k values are 0.06, 0.03, 0.1, 0.185 and 0.09 for paper/textile, wood, organic/garden and park, food and sewage, and industrial waste respectively. However, the NIR provides no justification on the choice of the values used from table 3.3 of the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.17). The ERT noted that the k values are those from the boreal and temperate climate zone for wet waste. During the review, the Party clarified that it plans to include climate zone information in the methodological section of the waste sector chapter in the next NIR and noted that according to the Estonian Environment Agency, the mean annual temperature in Estonia (1991–2020) was 6.4 °C and precipitation is almost twice as much as evaporation, so the climate is wet. The ERT recommends that the Party provide in its NIR an explanation of the reason for its choice of climate zone when selecting k values for waste.	ARR2022/W.6	Climate zone information has been added since 2023 submission.		Chapter 7.2.2
5.A Solid waste disposal on land – CH4 Transparency	The Party reported in its NIR (p.385) that default DOC content factors from the 2006 IPCC Guidelines were used in emission calculations. The ERT noted that NIR table 7.11 (p.386) includes country-specific DOC content factors for mixed MSW divided into five periods. The ERT also noted that NIR table 7.1 (p.373) states that default EFs were used. During the review, the Party clarified that NIR table 7.1 should include both country-specific and default EFs for estimating CH4 emissions because the DOC values are calculated using data from national MSW studies that take place periodically. The ERT recommends that the Party include in NIR table 7.1 that country-specific EFs are used for estimating CH4 emissions from MSW disposal on land and provide in the NIR information about the way in which these country-specific DOC content factors in MSW have been calculated.	ARR2022/W.7	It is correct, that IPCC 2006 Guidelines waste DOC content is used for GHG emission calculation, therefore Table 7.1 is correct. Unfortunately there was miscommunication during the review week. Municipal waste DOC values were calculated and included to reflect how carbon content has changed over time in MSW waste as a group of different waste materials. This estimation is based on the mixed municipal waste sorting studies and no waste content measurements have been made. The GHG calculations are done separately for all waste groups (e.g. food waste, garden, paper, textile etc) and therefore MSW is also divided to different waste groups.		Chapter 7.1

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non-implementation	Chapter/section in the NIR/NID
5.B.1 Composting – CH4 Transparency	The Party reported in NIR table 7.15 (p.391) the quantities of MSW composted in 2003, 2014 and 2017. For the other years of the time series, the notation key NO was used for composted MSW. During the review, the Party clarified that for 2003, 2014 and 2017, a waste management company reported composted waste with an MSW code, which is not common practice, and therefore switched to reporting the quantities of waste under the respective waste groups in future years. The ERT recommends that the Party include information on the composting of MSW across the time series. The ERT encourages the Party to provide a description of composted waste practices in its next annual submission.	ARR2022/W.8	Description of composted waste practices has been added in NIR since 2023 submission. Full timeline of the quantities of composted MSW can be seen in CRT 5.B.1.a		Chapter 7.3.2, CRT 5.B.1.a
KP-LULUCF	As KP 2nd period is over, the observations are no longer topical.				