REPUBLIC OF ESTONIA
MINISTRY OF THE ENVIRONMENT

GREENHOUSE GAS EMISSIONS IN ESTONIA 1990-2021
NATIONAL INVENTORY REPORT

SUBMISSION TO THE UNFCCC SECRETARIAT

Common Reporting Formats (CRF) 1990–2021

Estonia 2023

PREFACE

Estonia's National Inventory Report (NIR) to the European Commission contains following parts:

Description of the greenhouse gas emission inventory according to the revised UNFCCC reporting guidelines (24/CP.19) containing description of the organization of the national greenhouse gas inventory, IPCC and other methods applied in calculation of the year 2020 emissions and exemptions to the previous inventories. A summarizing table of the emissions data for the years 1990–2021 is included as well as the description of current emission trends.

The Estonian Environmental Research Centre (Ms Hanna-Lii Kupri, Ms Sirly-Ann Meriküll, Mr Karl Salumets, Ms Anette Iital, Ms Reelika Mägi, Ms Kadi Meltz, Ms Kristin Puusepp, and Mr Stanislav Štõkov) 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 Report.

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

The Ministry of the Environment 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 the Environment.

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

Contact in the Ministry of the Environment is:

Ms Kristiina Joon
Adviser in Climate Department
Tel. +372 626 3107
Fax +372 626 2801
kristiina.joon@envir.ee

Contact in the Estonian Environmental Research Centre is:

Ms Cris-Tiina Pärn
Adviser
Tel. +372 5265 945
Fax +372 611 2901
cris-tiina.parn@klab.ee

Ministry of the Environment
Narva mnt 7a
15172 Tallinn
Estonia

Estonian Environmental Research Centre
Marja 4d
10617 Tallinn
Estonia

Table of Contents

EXECUTIVE SUMMARY

ES.1. Background information on greenhouse gas inventories and climate change

ES.1.1 Background information on climate change

According to available information the impacts of climate change in Estonia are expected not to be as acute as in many other countries in the European Union (notably in southern Europe) and around the world, and some effects can be considered positive. Even though climate change is not likely to be as extreme in Estonia, we expect a continued rise in temperatures and a resulting decrease in ice and snow cover; more frequent heat waves and droughts in summer; more health problems and forest fires caused by longer heat waves; more storms and power failures; more floods; changes in vegetation, species, and habitats; invasions of alien species (incl. new plant pests and infectious agents); and other adverse effects.

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.

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.

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 several 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.

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[1].

[1] Estonia's Seventh National Communication under the UN Framework Convention on Climate Change. (2017). Ministry of the Environment. Estonian Environmental Research Centre. Tallinn.

ES.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. 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 national emission and removal-related trends

ES.2.1 GHG inventory

In 2021, the total emissions of GHGs (with indirect CO_2), measured as CO_2 eq., were 15 497.75 kt, and without LULUCF 12 615.17 kt. From 1990 to 2021 emissions with LULUCF decreased by 57.63%. Table ES. 1 shows the trend in total emissions without LULUCF during the period 1990–2021. Figure ES. 1. shows greenhouse gas emissions trends in 1990–2021 (with indirect CO_2), with LULUCF and without LULUCF in CO_2 eq.

In 2021, the most important GHG in Estonia was carbon dioxide (CO_2), contributing 83.6% to total national GHG emissions expressed in CO_2 eq. (with LULUCF, including indirect CO_2), followed by methane (CH_4), 7.9%, and nitrous oxide (N_2O), 7.2%. Fluorocarbons (so-called 'F-gases') account for about 1.2% of total emissions (see Table ES.2). The Energy sector accounted for 67.22% of total GHG emissions (with LULUCF), followed by LULUCF (18.6%), Agriculture (10.22%), Waste (2.05%) and Industrial processes and product use (1.91%) (including indirect CO_2).

[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)

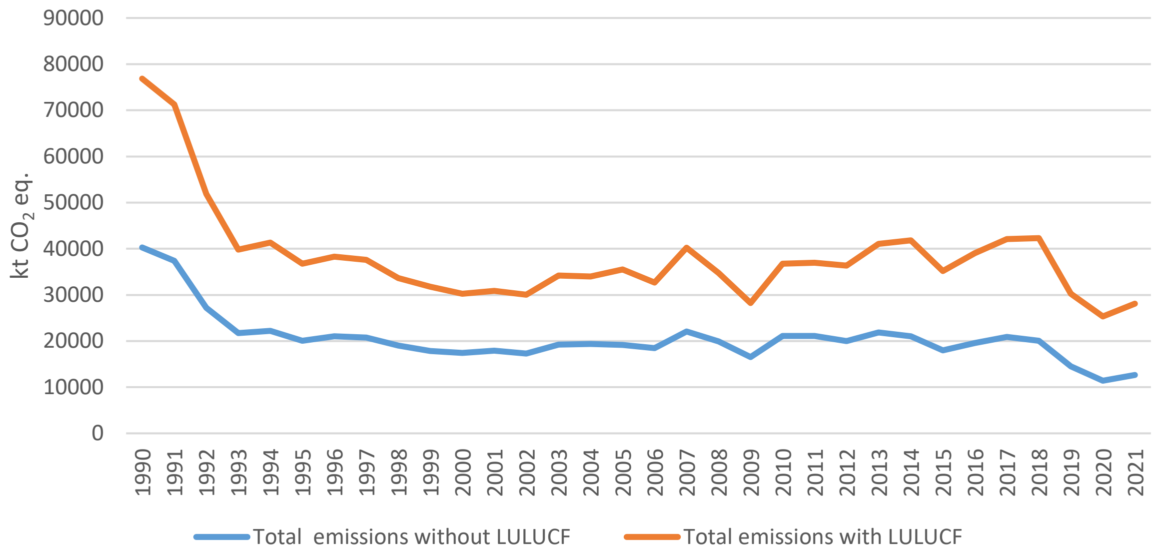


Figure ES. 1. Estonia's greenhouse gas emissions in 1990–2021 (with indirect CO_2), with LULUCF and without LULUCF, kt CO_2 eq.

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

GREENHOUSE GAS EMISSIONS	**Base year (1990)**	**1995**	**2000**	**2005**	**2010**	**2018**	**2019**	**2020**	**2021**	**Change from base to latest reported year**
	kt CO_2 equivalent									**%**
CO_2 emissions without net CO_2 from LULUCF	36919.61	18061.32	15481.72	17096.81	18975.45	17884.84	12323.98	9238.88	10419.92	-71.78
Indirect CO2 (from NMVOCs reported under IPPU 2.D.3 Solvent use and road paving with asphalt) *	18.4	17.4	16.5	18.5	11.3	17.8	20.3	23.7	30.5	65.6
CH_4 emissions without CH_4 from LULUCF	2152.38	1349.32	1323.80	1312.32	1298.22	1143.58	1156.23	1144.51	1152.94	-46.43
N_2O emissions without N_2O from LULUCF	1204.38	623.63	570.38	602.23	665.31	772.95	835.04	840.74	849.03	-29.50
HFCs	NO	26.49	74.74	128.15	170.73	225.99	219.67	179.92	190.21	100.00
PFCs	NO	NO	NO	NO,NA	NO	NO	NO	NO	NO	0.00
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
SF_6	NO	3.17	2.69	1.11	1.89	2.75	2.93	3.03	3.07	100.00
NF_3	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
Total (without LULUCF)	40276.36	20063.92	17453.34	19140.62	21111.60	20030.10	14537.85	11407.08	12615.17	-68.68
Total (with LULUCF)	36580.89	16718.72	12774.80	16386.82	15628.93	22287.35	15687.34	13916.16	15497.75	-57.63
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**Base year (1990)**	**1995**	**2000**	**2005**	**2010**	**2018**	**2019**	**2020**	**2021**	**Change from base to latest reported year**
	kt CO_2 equivalent									**%**
1. Energy	36184.55	17588.23	14981.50	16639.96	18739.76	17594.70	12035.79	9233.15	10418.13	-71.21
2. Industrial processes and product use	963.14	632.76	690.74	720.31	533.62	621.29	614.00	289.29	295.94	-69.27
3. Agriculture	2723.70	1405.61	1158.69	1212.06	1302.23	1480.33	1559.55	1569.74	1583.94	-41.85
4. Land use, land-use change and forestry	-3695.48	-3345.20	-4678.54	-2753.80	-5482.66	2257.25	1149.49	2509.07	2882.57	-178.00
5. Waste	404.97	437.33	622.40	568.29	535.98	333.79	328.51	314.91	317.16	-21.68

*Indirect CO_2 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 NIR and in CRF Reporter sectoral table 2(I). A-Hs2.

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	36919.61	2152.378	1204.378	NO	NO	40276.36255
	%	91.67%	5.34%	2.99%			100%
1995	kt	36919.60621	2152.377884	1204.378457	NO	NO	40276.36255
	%	91.67%	5.34%	2.99%			100%
2000	kt	18061.32	1349.32	623.63	26.49	3.17	20063.92
	%	90.02%	6.73%	3.11%	0.13%	0.02%	100%
2005	kt	15481.72	1323.80	570.38	74.74	2.69	17453.34
	%	88.70%	7.58%	3.27%	0.43%	0.02%	100%
2010	kt	17096.81	1312.32	602.23	128.15	1.11	19140.62
	%	89.32%	6.86%	3.15%	0.67%	0.01%	100%
2015	kt	18975.45	1298.22	665.31	170.73	1.89	21111.60
	%	89.88%	6.15%	3.15%	0.81%	0.01%	100%
2019	kt	15824.00	1151.48	778.26	216.43	2.42	17972.59
	%	88.05%	6.41%	4.33%	1.20%	0.01%	100%
2020	kt	12323.98	1156.23	835.04	219.67	2.93	14537.85
	%	84.77%	7.95%	5.74%	1.51%	0.02%	100%
2021		9238.88	1144.51	840.74	179.92	3.03	11407.08
		80.99%	10.03%	7.37%	1.58%	0.03%	100%

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

ES.3.1. GHG inventory

The greenhouse gas emissions and removals are divided into the following sectors according to Decision 24/CP.19 of the Conference of the Parties to the UNFCCC on the revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention: Energy (CRF 1), Industrial processes and product use (CRF 2), Agriculture (CRF 3), Land use, land-use change and forestry (LULUCF) (CRF 4) and Waste (CRF 5).

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

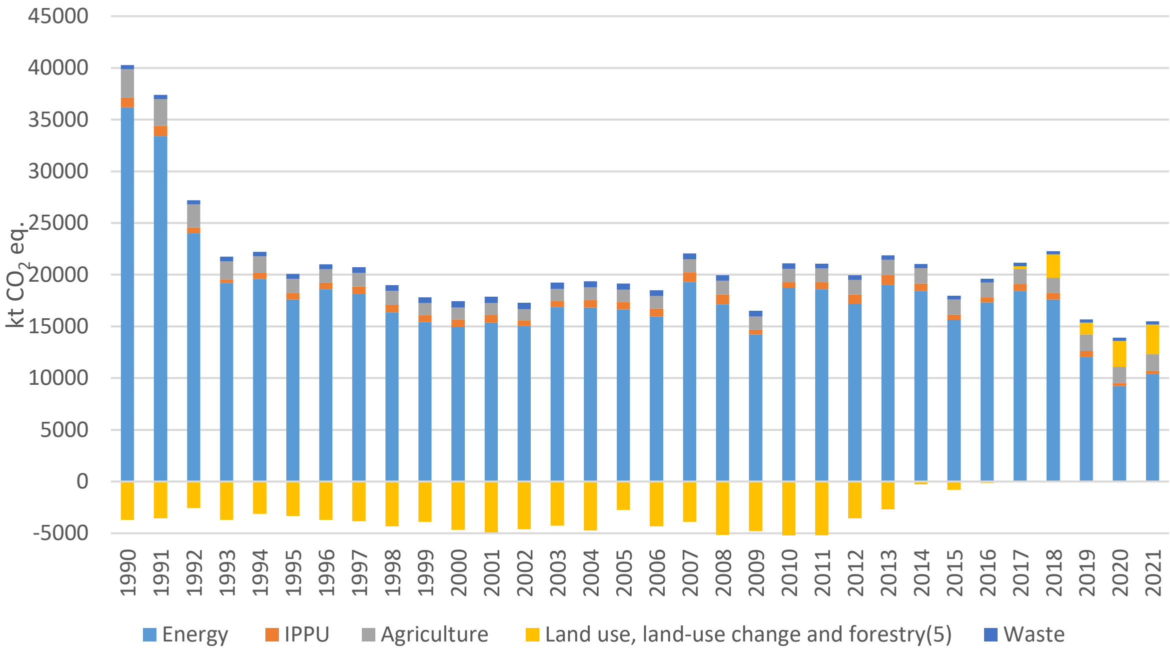


Figure ES. 2. Greenhouse gas emissions trends by sector, kt CO_2 eq.

The Energy sector is the most significant source of greenhouse gas emissions in Estonia with 67.2% share of the total emissions (with LULUCF) in 2021. Since the base year, total GHG emissions from Energy sector in Estonia have decreased by 71.2%. The key driver for the fall in emissions is the transition from a planned economy to a market economy. The GHG emissions increase in 2021 comparing to previous year was mainly from the energy industries, because of colder winter and higher electricity prices.

Agriculture is the second most significant source of greenhouse gas emissions in Estonia. In 2021 the agriculture sector contributed 10.2% of the total emissions (with LULUCF). Since the base year emissions have decreased by 41.9%, mostly due to the decreasing livestock population and quantities of synthetic fertilizers and manure applied to agricultural fields.

The Waste sector contributed 2.05% of the total greenhouse gas emissions (with LULUCF) in 2021. The total emissions in CO_2 eq. from the Waste sector decreased by 21.7% compared to the base year.

In 2021 Industrial processes and product use greenhouse gas emissions contributed 1.9% of the total greenhouse gas emissions (with LULUCF) in Estonia. Emissions have decreased by 69.3%

between 1990 and 2021 because of closing of some relevant industries and reduced output of the remaining industries. 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 2021, the LULUCF sector acted as a CO_2 source, totaling with emissions 2882.6kt CO_2 eq. Since 1990, net removals have decreased by 178%.

ES.4. Other information (e.g. indirect GHGs)

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

1. Solvent use (Chapter 4.5.3.2);
2. Road paving with asphalt (Chapter 4.5.3.3).

1. INTRODUCTION

1.1. Background information on greenhouse gas inventories and climate change

1.1.1. Background information on climate change

According to WMO State of the Global Climate 2021[3]) the global mean temperature for 2021 was 1.08 ±0.13 °C above pre-industrial levels. The most recent seven years, 2015 to 2021, were the seven 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 Statement on the State of the Global Climate in 2021. [www] https://library.wmo.int/doc_num.php?explnum_id=11178 (27.02.2023)

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.

Even though climate change is not likely to be as extreme in Estonia as in many other countries in the EU (notably in southern Europe) and around the world, and although some effects can be considered positive, we expect a continued rise in temperatures and a resulting decrease in ice and snow cover; more frequent heat waves and droughts in summer; more health problems and forest fires caused by longer heat waves; more storms and power failures; more floods; changes in vegetation, species and habitats; invasions of alien species (incl. new plant pests and infectious agents); and other adverse effects[4].

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. In response to the UNFCCC and the Kyoto Protocol requirements Estonia has prepared the present emission National Inventory Report (NIR).

Single national entity with overall responsibility for the Estonian greenhouse gas inventory is the Estonian Ministry of the Environment (MoE). 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 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 2014–2021 inventory were produced in collaboration between the MoE, Estonian Environment Agency (EstEA) and EERC, responsibilities between different institutions are shown in Figure 1.1.

This report presents the national inventory of greenhouse gas emissions and removals from 1990 to 2021. 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 (NOx), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2) were also included in inventory data.

The report and associated Common Reporting Format (CRF) tables were prepared in accordance with the UNFCCC reporting guidelines on annual inventories. In accordance with the decision adopted at COP27, the UNFCCC secretariat made available, on 27 January 2023, a version of the CRF Reporter for generating CRF tables using the 100-year time-horizon global

[4] Estonia’s Seventh National Communication under the UN Framework Convention on Climate Change. (2017). Ministry of the Environment. Estonian Environmental Research Centre. Tallinn.

warming potential values, excluding the value for fossil methane, listed in table 8.A.1 in the contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Estonia has produced the CRF tables for the 2023 submission with the CRF Reporter software (v6.0.10_AR5) and therefore also all the emissions presented in the 2023 NIR are calculated using GWPs from the IPCC Fifth Assessment Report. The methodology used in calculations of emissions is harmonized with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines).

The structure of this NIR follows the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (Decision 24/CP.19). 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 2022. Chapters 3–8 give information of GHG emission trends from the base year 1990 to year 2022 for the following sectors: Energy, Industrial processes and product use, 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. Annex 1 contains the assessment of uncertainty. Annex 2 gives information on detailed methodological descriptions for individual source or sink categories. Assessment of completeness of inventory estimates is presented in Annex 3. Annex 4 presents the description of Kyoto Protocol Units and Information on Changes in National Registry (chapter 12 and 14 of until 2022 submissions). Annex 5 contains the Standard Independent Assessment Report.

1.2. A description of the national inventory arrangements

1.2.1. Institutional, legal and procedural arrangements

Institutional arrangements

Single national entity with overall responsibility for the Estonian greenhouse gas inventory is Ministry of the Environment (MoE). 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 the MoE. The inventory will continue to be produced in collaboration between the MoE, EERC and EstEA as until now.

The MoE is responsible for:

- 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 implementation of the QA/QC plan and final QA/QC of the inventory;
- sending the final inventory to the MoE and approving the inventory before the official submissions;

- reporting the greenhouse gas inventory to the EC and to the UNFCCC, including the National Inventory Report and CRF tables on behalf of MoE;
- 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 CRF Reporter and prepare the sectoral parts of the NIR. 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 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 MoE 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 the MoE

Legal arrangements

In accordance with §143 of the Atmospheric Air Protection Act (RT I, 05.07.2016, 1), activities for the reduction of climate change are organised by the Ministry of the Environment 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 Environment (RT I 2009, 63, 412), the MoE is responsible for climate change related tasks and according to §23 section 8, 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 MoE, the department is responsible for organizing and coordinating GHG emission reporting activities under the UNFCCC, the Kyoto Protocol and the European Union legislation. In the beginning of 2018 with an aim to improve/optimize the inventory compiling process in Estonia, MoE 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 organization established for general interest, all of the shares in which are held by the Republic of Estonia. EERC belongs to the government area of the Ministry of the Environment. Any changes to and the approval of the statutes of the EERC are the responsibility of the Ministry of Environment.

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.

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

The Estonian Environment Agency (EstEA), institution that is responsible for the LULUCF estimates, is a state authority administered by MoE, 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[5].

Procedural arrangements

The three core institutions: MoE, 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;
- discussion on methodologies and possible changes in the future;
- 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.

[5] Official Statistics Act: https://www.riigiteataja.ee/en/eli/517122019002/consolide

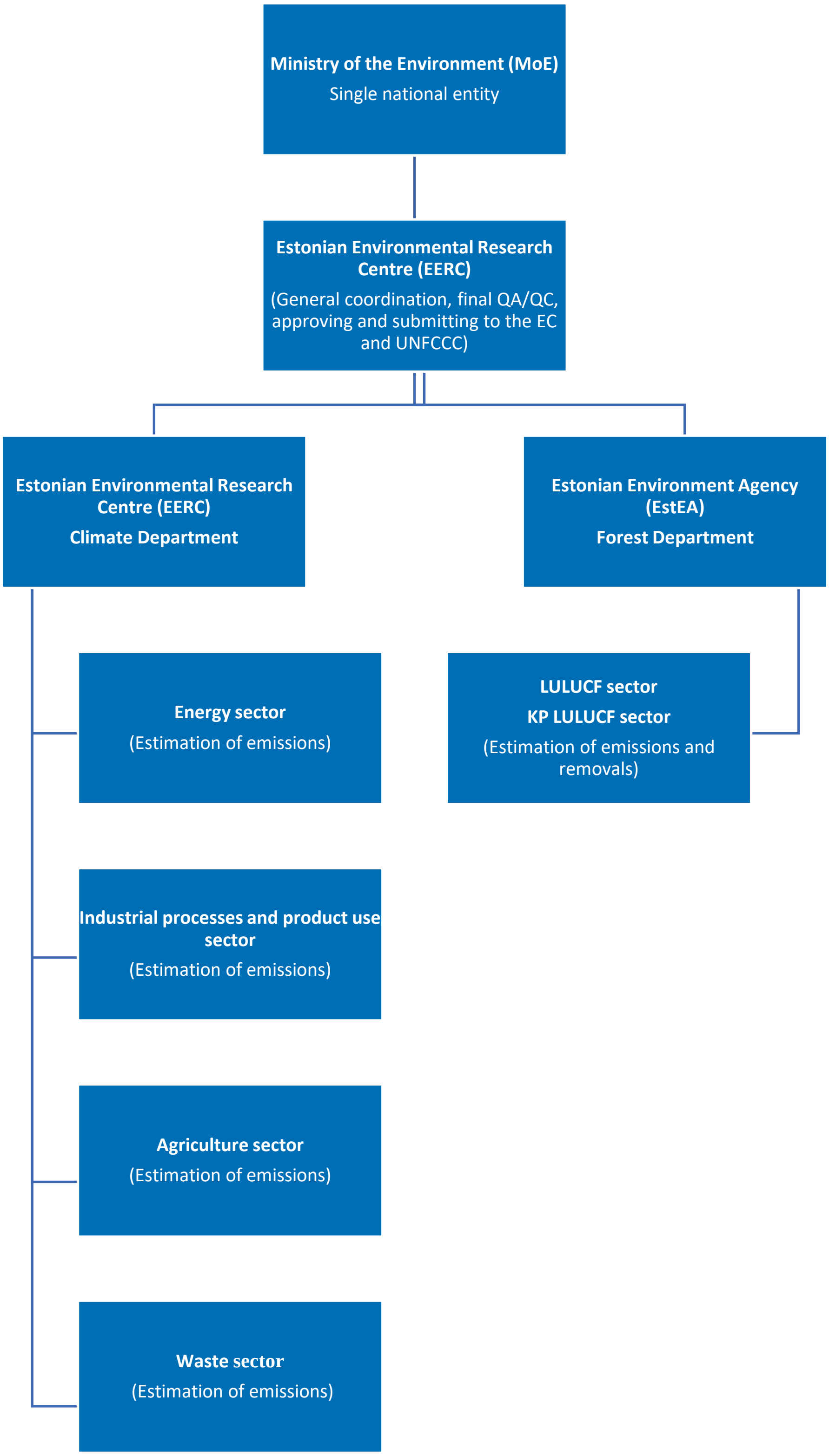


Figure 1.1. National System for GHG inventory in Estonia

1.2.2. Overview of inventory planning, preparation and management

1.2.2.1. Inventory planning

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.

The EERC and the MoE have developed an inventory production plan that sets out the schedule for inventory preparation. The schedule, which is annually reviewed, forms part of Estonia's QA/QC plan and must be followed by all core institutions (MoE, EERC and EstEA). The inventory production plan is presented in Table 1.1. More detailed information about Estonia's QA/QC plan is presented in the section 1.2.3.

Table 1.1. Inventory production plan for the

Activity	Responsible	Deadline
Annual meeting: Will be discussed how the previous inventory cycle has been, what should be improved/changed; new contracts, etc	*All*	*April 15*
Independent experts (based on contract agreements) carry out QA of the inventory and submit the results to EERC. Inventory experts analyze the results and implement changes as appropriate.	Independent experts	June-Dec
Coordinators check general information included in NIR and update if necessary	EERC	June-Sep
Sectoral experts implement possible changes based on the result of QA / UNFCCC review	Independent experts	Febr. 15
Collection of activity data	EERC, EstEA	*Starting from Sept*
Sectoral experts notify the EERC and MoE of the planned methodological changes, reasons for changes and how they plan to incorporate the UNFCCC review results to the next report	EERC, EstEA	Nov. 15
Annual meeting: Sectoral experts notify the EERC and MoE of the planned methodological changes, reasons for changes, overview of the planning of the new inventory cycle and how they plan to incorporate the UNFCCC review results to the next report. MoE and EERC give an overview of the new requirements, plans, etc	*All*	*Nov. 11*
Sectoral experts´ complete data entry to the CRF Reporter and notify the EERC	EERC, EstEA	Dec. 16
QC checks are carried out (CRF Reporter) and documented by inventory coordinator (EERC) and sent to the sectoral experts	EERC	Dec. 19
Sectoral experts send the necessary data for uncertainty analysis to EERC	EERC, EstEA	Dec. 28
Sectoral experts provide the draft NIR to the EERC. Prior to this the QC checks should be carried out and documented	EERC, EstEA	Dec. 28

Activity	Responsible	Deadline
EERC performs the key category analysis and uncertainty analysis and sends the results to the sectoral experts and independent experts	EERC, EstEA	Jan. 5
EERC perform QC of the NIR and send the comments to the sectoral experts and independent experts for review	EERC	Jan. 11
Sectoral experts send their comments and possible changes on the CRF tables according to the QA/QC (performed by independent experts and EERC) to EERC. EERC sends comments to independent experts	EERC	Jan. 12
EERC compiles the abridged NIR according to the submitted sectoral parts and sends it to the sectoral experts for approval	EERC	Jan. 12
Reporting to the EU (CRF tables and draft NIR)	EERC	Jan. 15
Abridged NIR is sent to different departments of MoE and other relevant insitutions for approval	EERC	Jan. 18
The abridged NIR along with the CRF tables is uploaded to the MoE webpage	MoE	Jan. 18
MoE different departments and other relevant institutions carry out QA of the CRF tables and NIR and submits the results to the EERC	EERC	Febr. 9
EERC submits the results of the MoE and other relevant institutions QA to the sectoral experts and independent expert	EERC	Febr. 9
Sectoral experts send their comments and possible changes according to the QA/QC (performed by the MoE and independent experts) to EERC, MoE. EERC sends comments to independent experts	EERC, EstEA	Febr. 12
Annual meeting: The comments given during the inventory preparation and the last UNFCCC review report will be looked through. Also, questions/problems that have been raised will be discussed before the submission to the EU	*All*	*Before March 15*
Answers to the EU initial check and if possible then corrections are made to the inventory	All	Jan.15 - March 15
Reporting to the EC (CRF tables and NIR)	EERC	March 15
Reporting to the UNFCCC	EERC	April 15
NIR and CRF tables are uploaded to the MoE webpage	MoE	April 22
Sectoral experts present complete archives to EERC	EERC, EstEA	May 3

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.

1.2.2.2. Inventory preparation and management

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. Quality assurance, quality control and verification plan

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.

The Estonia's QA/QC plan consist of seven parts: (1) production plan (see Table 1.1); (2) annual meetings; (3) QA/QC checks; (4) QA results documentation form; (5) archiving structure; (6) response tables to the review process and (7) a list of planned activities and improvements.

All institutions involved in the inventory process (MoE, 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 reviews and any national reviews undertaken.

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.

1.2.3.1. Quality control procedures

The QC procedures used in Estonia's GHG inventory comply with 2006 IPCC Guidelines. General inventory QC procedures[6] include routine checks of the integrity, correctness and completeness of data, identification of errors and deficiencies, documentation and archiving of inventory data and quality control actions. Once the experts have implemented the QC procedures, they complete the QA/QC checklist for each source/sink category, which provides

---

[6] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance/Quality Control and Verification, pages 6.10–6.11, table 6.1.

a record of the procedures performed. The QA/QC checklists are part of Estonia's QA/QC plan. Also, assessment of completeness is evaluated.

EERC checks the QC checklists completed by EERC experts and EstEA. When EERC disagrees with the information provided in the checklists then the errors are discussed, and changes are made if necessary.

In addition to the general inventory QC procedures, Estonia applied category-specific QC procedures on some source/sink categories in the 2023 submission, focusing on key categories and on those categories in which significant methodological changes and/or data revisions occurred. More detailed information can be found under sectoral chapters.

After the sectoral experts have completed entering data to the CRF Reporter, EERC carries out some general (including visual) checks on the data entered. When the CRF tables are complete, the experts start preparing the sectoral chapters of the NIR. These parts are sent to the compiler (EERC) who adds the introduction part and puts the draft NIR together. The compiler arranges the different chapters into one uniform document and makes sure that the structure of the report follows the UNFCCC guidelines. All figures on emissions and removals in tables and text are checked to make sure that they are consistent with those reported in the CRF. The sectoral experts and the inventory compiler also check that all methodological changes, recalculations, trends in emission, and removals are well explained.

In addition, the QA/QC of Member States' submissions conducted under the European Union GHG monitoring mechanism (e.g., completeness checks, consistency checks and comparison across Member States) produces valuable information on errors and deficiencies, and the information is considered before Estonia submits its final annual inventory to the UNFCCC.

1.2.3.2. Quality assurance procedures

The objective of QA implementation is to involve reviewers that can conduct an unbiased review of the inventory and who may have a different technical perspective. It is important to use QA reviewers who have not been involved in preparing the inventory. These reviewers should preferably be independent experts from other agencies or national experts, or groups not closely connected to national inventory compilation.

Estonia's GHG inventory is checked annually by one or more independent experts. From the 2009 to 2012 submission all data collected by institutions involved in the inventory process was checked by an independent expert from Tallinn University of Technology (TalTech). The 2013–2020 inventory submissions were reviewed in parts by the EERC, TalTech, University of Tartu, Estonian University of Life Sciences (EULS) and other national experts. The 2021 submission was checked by experts from TalTech, and other national experts. The findings of the independent experts are looked through by experts (in collaboration with the EERC) and adjustments carried out as a result, if necessary.

When the draft NIR is completed, it is sent to the MoE Climate, Forestry, Environmental Management, and Water Department to ensure that the submitted data is officially valid. The NIR draft is uploaded to the MoE website www.envir.ee where all the interested parties can comment on it. The inventory is also checked by other Ministries and institutions. The inventory will be sent to the Energy and Transport Departments in the Ministry of Economic Affairs and Communications, to the Agricultural Environment Bureau in the Ministry of Rural Affairs, and Statistics Estonia. Statistics Estonia is routinely involved in the quality checking of the data used in inventory. Also, the draft inventory is annually sent to Statistics Estonia for quality checking.

UNFCCC reviews are part of QA. The reviews are performed by a team of experts (sectoral experts and generalist) from other countries. They examine the data and methods that Estonia is using and check the documentation, archiving system and national system. In conclusion they report whether Estonia's overall performance is in accordance with current guidelines. The review report indicates the specific areas in which the inventory needs improvements. Estonia's 2018 GHG inventory was a subject of an in-country review performed by the UNFCCC experts. The review of Estonia's 2022 submission was carried out as a centralized review from 12 to 17 September 2022.

The GHG inventories submitted by Member States in 2016–2022 were subject to annual review of national greenhouse gas inventory data pursuant to Article 19(2) of Regulation (EU) No 525/2013. The review was performed in two steps. Step 1 was combined with the 'EU QA/QC procedures' (i.e., initial checks) and was carried out by the EU inventory team (ETC/ACM, JRC, Eurostat). All findings from the initial checks that were relevant for the Effort Sharing Decision (ESD) and that were not resolved within the initial check phase were followed up in the second step of the review. Step 2 of the ESD review of 2017–2022 was performed by TERT. In 2020, the European Commission carried out according to the review process established under the MMR IR and to Article 4(3) of the Effort Sharing Regulation (2018/842) a comprehensive review of Member States' GHG inventories for the years 2005 and 2016 to 2018.

1.2.3.3. Archiving

It is a 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 CRF, recalculations of previous estimates, submissions to the UNFCCC and EC and NIR-s. The archiving system is located in EERC server which undergoes a daily backup, and the backups are securely saved.

During the Twinning Light project with Finland in 2009 'Improving the quality of Estonia's National Greenhouse Gas Inventory' a new improved archiving system was developed. The archiving system consists of two parts: data related (1) to the CRF and (2) to the NIR. 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 NIR. Also, all submissions to the UNFCCC and EC are archived. Materials used in the 2010 inventory submission were archived for the first time according to the new archiving system. The archiving system was modified after the first trial to make it better and remove all the inconsistencies that came up. The materials used in the 2011 and 2012 inventory submission were archived according to the improved archiving system.

Estonia's archiving structure is structured in a way that all relevant materials used in the 2013–2021 inventory submission (e.g., XML files provided by the inventory compilers to the producers of the CRF 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 CRF 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 files, draft NIR's, QA/QC documents, aso), 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.

1.2.3.4. Verification activities

The European Union Emissions Trading System (EU ETS) is one of the key policy instruments implemented in the EU to achieve its climate policy objectives. The EU ETS is a cornerstone of the Europeans Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively.

The EU ETS works on the 'cap and trade' principle. The overall volume of greenhouse gases that can be emitted each year by the power plants, factories and other companies covered by the system is subject to a cap set at EU level. Within this Europe-wide cap, companies receive or buy emission allowances which they can trade if they wish.

Businesses must monitor and report their EU ETS emissions for each calendar year and have their emission reports checked by an accredited verifier. They must surrender enough allowances to cover their total emissions by 30 April of the following year[7].

The EU ETS reports' data can be used, in aggregated form, to draw category specific conclusions regarding the completeness and consistency of certain parts of the GHG inventories. Comparison of EU ETS emissions with emissions reported in national GHG inventory was carried out for year 2021 (please see Annex XII Consistency with ETS).

Detailed information about verification activities can be found under the sectoral chapters.

1.2.3.5. Treatment of confidential issues

In most Industrial processes categories, there is only one major manufacturer in Estonia. This is the reason why not all data can be disclosed in the NIR.

Activity data used in calculations in carbon balances are collected from private companies and are therefore considered confidential. Activity data on oil shale, shale oil, and oil shale gases production by oil companies and calculations of carbon balances are not part of the national inventory report and are allocated in the archive. The data is made available during the review process for the review team if requested.

[7] European Commission. The EU Emissions Trading System (EU ETS). [www] https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en (27.02.2023).

1.2.4. Changes in the national inventory arrangements since previous annual GHG inventory submission

Changes in national inventory arrangements since the previous annual inventory are described in Chapter 13.

1.3. Inventory preparation, and data collection, processing, and storage

1.3.1. Inventory preparation

The UNFCCC and the European Union (EU) Governance Regulation require Estonia to submit annually a NIR and CRF tables. The annual submission contains emission estimates for the years between 1990 and the year before last year. The 2023 submission contains estimates for the years 1990–2021.

The organization of the preparation and reporting of Estonia's greenhouse gas inventory and the duties of its different parties are detailed in the previous section (1.2.1). Single national entity with overall responsibility for the Estonian greenhouse gas inventory is MoE. The inventory is produced in collaboration between the MoE, EERC and EstEA.

Under the EU monitoring mechanism, the annual inventory must be submitted to the Commission by 15 January. Member States may then complement and update their submission by 15 March. The official greenhouse gas inventory is submitted to the UNFCCC Secretariat by 15 April.

1.3.2. Data collection, processing, and storage

The inventory process for the next inventory cycle starts with an examination of previous years and an analysis of the available datasets to improve the inventory through new knowledge and the activity data developed.

The sectoral experts from EERC and EstEA are collecting data and preparing the estimates for the national inventory. The main sources of data are official Estonian statistics (Statistics Estonia, Estonian Animal Recording Center), official European statistics (Eurostat) and companies' annual emission reports.

SE collects statistical data based on the Official Statistics Act §9.

The data collected from other institutions and private companies is done by sectoral experts that have personal contacts to receive the data.

The data sources for each sector are described below.

Energy

Activity data used in the estimates is obtained mainly from SE.

SE publishes: Energy related data in the statistical database of the homepage of SE (Joint Questionnaire) dataset. The data received from SE covers all fuels used in 7 main end-use sectors (Energy industries, Manufacturing industries and construction, Transport, Commercial/institutional, Residential, and Agriculture/forestry/fisheries) and in sub-sectors of the main end-use sectors.

Other information sources used in estimates of GHG emissions from energy sector are:

- The Environmental Board – EU ETS data on production and consumption of oil shale, semi-coke gas and generator gas.
- Eesti Energia AS (Estonian Power Ltd.) – data on oil shale consumption for pulverized combustion and for circulating fluidized bed combustion, data on use of oil shale semi–coke gas in the Estonian Power Plant.
- Eesti Energia Narva Õlitööstus AS (Estonian Power Narva Oil Industry Ltd.) in Narva – oil shale consumption for shale oil production; shale oil, and semi-coke gas production data.
- Viru Keemia Grupp AS (VKG) (Viru Chemistry Group Ltd.) in Kohtla-Järve – oil shale consumption for shale oil production; shale oil, semi-coke gas, and generator gas production data.
- Kiviõli Keemiatööstuse OÜ (Kiviõli Oil Shale Processing and Chemicals Plant Ltd.)– oil shale consumption for shale oil production; shale oil, semi-coke gas, and generator gas production data.
- Estonian Environment Agency (EstEA) – CH_4 and N_2O emission estimations from Civil aviation and Road transport using the COPERT 5 model for calculation of emissions from Transport.
- EstEA – activity data on Road transport fossil and liquid biofuels consumption in Estonia from COPERT 5 model.
- EstEA – number of vehicles and road traffic mileage in Road transport.
- EstEA – activity data on waste oils, plastics, and solid waste in 1.A.2.f
- The Environmental Board – activity data on municipal solid waste in 1.A.1.a
- Estonian Transport Administration – number of off-road vehicles in Manufacturing industries and construction and Other sectors

Industrial processes and product use

Activity data used in the estimates are obtained from SE, production plants, and in case of F-gases from national and international companies (including what they have registered in FOKA database for F-gas equipment and service), associations, public institutions etc.

CO_2 emissions from Mineral industry (2.A) are reported in six sub-sectors: Cement production (2.A.1), Lime production (2.A.2) and Glass production (2.A.3), Ceramics (2.A.4.a) (bricks, tiles and lightweight gravel production) and in years 2012–2017 limestone use for flue gas desulphurisation (2.A.4.d). Emissions from subsector Other uses of soda ash (2.A.4.b) have been taken into account under subsector 2.C.5 Lead production.

Activity data on cement, lime production, glass production, lightweight gravel production, and limestone use for flue gas desulphurisation were collected partly from the industry and partly from EU ETS reports. Data on bricks and roof tiles production were collected from production plants and taken partly from industrial statistics.

Under subsector 2.C Metal Industry Estonia reports CO_2 emissions from 2.C.5 Lead production. The emissions are aggregated with CO_2 emissions of soda ash use of rare and rare earth metal industry. The reason for aggregation is that there is only production plant in either field of activity or data on production is confidential. Most data is supplied by the production plants, although some historical data is obtained from Statistics Estonia.

Under Non-energy products from fuels and solvent use (2.D), CO_2 emissions from Lubricants use (2.D.1), Paraffin wax use (2.D.2), and Urea based catalysts for motor vehicles (2.D.3) were reported as well as NMVOCs and indirect CO_2 from solvent use and road paving from asphalt. Data on international trade of lubricants and paraffin waxes were provided by SE and Eurostat. Data on production of lubricants, paraffin waxes and candles were received from SE. Data on urea-based catalysts for vehicles was calculated on basis of diesel fuel consumption of certain motor vehicles. Diesel fuel consumption of different types of vehicles was modelled and calculated by EstEA.

NMVOC emissions from Solvent use and Road paving with asphalt (2.D.3) were calculated by EstEA. Emissions from point sources are gathered from the Environmental Decisions Information System KOTKAS and the emissions for diffuse sources were calculated from the data received and gathered from SE and Eurostat using international emission factors and expert opinions.

Data on hot asphalt mix production was received from the Estonian Asphalt Pavement Association (ESPA) for the years 1990–2021.

Product uses as substitutes for ODS (2.F) covers HFCs from Refrigeration and air conditioning (2.F.1), Foam blowing agents (2.F.2), Fire protection (2.F.3) and Aerosols (2.F.4). In these sub-sectors data were collected from national and international companies (including what they have registered in FOKA database for F-gas equipment and service), associations, public institutions, Estonian Transport Administration etc.

Under Other product manufacture and use (2.G), SF_6 in Electrical equipment (2.G.1) and Accelerators (2.G.2) were reported as well as historically used SF_6 in Adiabatic properties (2.G.2.d). Data on SF_6 in Electrical equipment were provided by the electricity network operators. Data on SF_6 in Accelerators were provided by respective service providers. Subcategory 2.G.3 covers N_2O in Medical applications and use in consumer goods. Activity data used to estimate N_2O emissions from product use were collected from wholesalers, and Eurostat (international trade data). For historical data population size was used (from Statistics Estonia).

Agriculture

Activity data used in the agriculture sector GHG estimates were obtained mainly from SE. SE publishes the data annually by July–November.

The data received from SE includes:

- number of livestock (by livestock category and sub-category).
- data on milk production per cow.
- production, yields, and sown areas of field crops (by crop type).
- volume of N fertilizers, compost and lime applied to agricultural soils.
- import - export of urea fertilizers.

Other information sources used in the estimates of GHG emissions from agriculture sector are:

- Agricultural Registers and Information Board (ARIB) (population of horses).
- Estonian Animal Recording Centre (data on milk production, fat and protein content in milk, percentage of cows that give birth, number of dairy cattle populations by dairy-cattle breed).
- Estonian Environmental Decisions Information system KOTKAS (data on manure management systems).
- Scientific publications (model of gross intake by pigs, feed digestibility of cattle and swine, nitrogen content of feed, etc.).
- National Forest Inventory (NFI) (activity data on organic soils).
- EstEA (activity data on sewage sludge and compost applied to agricultural soils, 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, average winter months air temperature).

- Nitrofert Ltd. (plant specific activity data were used on urea fertilizers produced in Estonia); and
- Estonian Agricultural Board (marketing activity data of lime and urea fertilizers).

All NO_x and NMVOC emissions reported under the 3.B and 3.D sub-sectors are provided by EstEA.

LULUCF

National Forest Inventory (NFI) is the primary information source for the LULUCF sector. NFI is carried out by the Estonian Environment Agency (EstEA) and collects following data:

- area (including distribution of organic and mineral soil) of forest land, cropland, grassland, wetlands, settlements, and other land;
- dynamics of land-use changes;
- volume of woody biomass (including living biomass and deadwood) on different land use and land-use change categories; and
- felling volumes.

Activity data on wildfires is obtained from the Estonian Rescue Service and EstEA. In 2012, EstEA started annual fieldwork to record wildfire locations, determining the precise area and biomass burned. Information about foreign trade and production of Harvested wood products (HWP) is provided by Statistics Estonia, NFI, Estonian Forest and Wood Industries Association, and Food and Agriculture Organization of the United Nations (FAO).

Within Cropland category, areas with different land use, management and input regimes are specified using data from Statistics Estonia, Estonian Agricultural Registers and Information Board (processor of the Land Parcel Identification System), and Centre of Estonian Rural Research and Knowledge. Data for estimating off-site CO_2 emissions from peat removed for horticultural use are obtained from Statistics Estonia and Estonian Land Board.

Waste

Activity data for calculating CH_4 emissions from Solid waste disposal include data on solid waste generation and disposal 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 Environment, and published in Tableau, managed by The Information Technology Centre of the Ministry of the Environment (KeMIT). The data on population is obtained from the SE dataset. The composition of municipal solid waste is based on the Municipal Solid Waste Sorting Studies of 2000, 2008 2013 and 2020. Activity data on CH_4 recovery is derived from Estonia's Annual Questionnaire on renewables and Waste 2013 (REN Estonia) and from EstEA.

Activity data for calculating CH_4 and N_2O emissions from Composting is submitted through Environmental Decisions Information System KOTKAS, stored in Data Warehouse and published in Tableau. Data from Tableau is further processed by EERC to ensure the quality of the data.

Activity data for calculating CO_2, CH_4, and N_2O emissions from incineration is submitted through Environmental Decisions Information System KOTKAS, stored in Data Warehouse and published in Tableau. Activity data on the amount of waste incineration without energy recovery is based on the company's reports and is revised by EERC to ensure the quality of the data. Activity data on the amount of waste open burned is based on the expert judgement given by MoE. Activity data on the population of Estonia is obtained from the SE dataset. Composition of municipal solid waste incinerated is based on the waste composition from the Municipal Solid Waste Sorting Studies of 2000, 2008, 2013 and 2020.

Activity data for calculating CH_4 emissions from Domestic wastewater is based on the national inventory of wastewater treatment types in low density settlements (Infragate, 2014). The rate of wastewater treated aerobically in 1990–1997 is interpolated based on a MoE expert judgement and starting from 1998 data has been obtained from EstEA. Data on population is obtained from the SE dataset. The calculation of CH_4 emission originating from the Industrial wastewater is based on the plant specific information gathered from a yeast factory, which is the only industrial facility treating its wastewater anaerobically. For calculating N_2O emission, the annual per capita protein consumption data was taken from FAO statistical database. The nitrogen in sludge is calculated based on the data obtained from the dataset of Tableau.

Archiving

All institutions are responsible for archiving the data they collect and the estimates they calculate. But it is necessary to have a central archiving system located at a single location. EERC bears the responsibility of archiving and Estonia's central inventory archive is located there.

1.4. Brief general description of methodologies and data sources used

1.4.1. GHG inventory

The methodologies used for the Estonia's greenhouse gas inventory are consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). 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 1.2.

Table 1.2. 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
A. Fuel combustion	T1, T2, T3	D, CS, PS	Joint Questionnaire dataset made by Statistics Estonia and Annual Yearbooks; 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 and Annual Yearbooks; Statistics Estonia statistical database; data

IPCC category	Methodology	Emission factor	Activity data
			of energy companies; EU ETS and solid municipal waste data from The Environmental Board
A.2. Manufacturing industries and construction	T1, T2, T3	D, CS, PS	Joint Questionnaire dataset made by Statistics Estonia and Annual Yearbooks; 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 and Annual Yearbooks; 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
B. Chemical industry	T3	PS	Statistics Estonia; plant specific data
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	D, CS	National and international companies, Statistics Estonia, Eurostat
3. Agriculture	IPCC 2006	IPCC 2006	Statistics Estonia, National Forest Inventory, EstEA, plant specific data, Agriculture and Food Board, Estonian Animal Recording Centre, Agricultural Registers and Information Board
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
D. Agricultural soils	T1	D	Statistics Estonia, EstEA; EstEA
G. Liming	T1	D	Statistics Estonia, Agriculture and Food Board

IPCC category	Methodology	Emission factor	Activity data
H. Urea application	T1	D	Statistics Estonia, plant specific data, Agriculture and Food Board
4. LULUCF	IPCC 2006	IPCC 2006	National Forest Inventory (EstEA); Statistics Estonia; Estonian Rescue Service; Land Parcel Identification System; Centre of Estonian Rural Research and Knowledge; Estonian Land Board, Estonian Forest and Wood Industries Association; FAO
A. Forest land	T1, T2	D, CS, OTH	National Forest Inventory; Estonian Rescue Service
B. Cropland	T1, T2	D, CS, OTH	National Forest Inventory; Statistics Estonia; Land Parcel Identification System; Centre of Estonian Rural Research and Knowledge
C. Grassland	T1, T2	D, CS, OTH	National Forest Inventory; Estonian Rescue Service
D. Wetlands	T2	D, CS, OTH	National Forest Inventory; Estonian Rescue Service; Statistics Estonia; Estonian Land Board
E. Settlements	T1, T2	D, CS, OTH	National Forest Inventory
F. Other land	T1, T2	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); Statistics Estonia, FAOSTAT
A. Solid waste disposal	T2	D	EstEA, KeMIT (waste data depository); Statistics Estonia
B. Biological treatment of solid waste	T1	D	EstEA, KeMIT (waste data depository)
C. Incineration and open burning of waste	T1, T2a	D	EstEA, KeMIT (waste data depository)
D. Wastewater treatment and discharge	T1	D	EstEA, KeMIT (waste data depository); Statistics Estonia, FAOSTAT

T1 – IPCC *Tier 1*; T2 – IPCC *Tier 2*; T3 – IPCC *Tier 3*; CS – country-specific; D – IPCC default value, PS – plant specific; OTH – other

1.5. Brief description of key categories

1.5.1. GHG inventory

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 2021), the trend of emissions (change between 1990 and 2021) 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 1.3.

Table 1.3. Summary overview of Tier 1 and Tier 2 key categories

Sector	Pollutant	Base Year emissions	2021	Without LULUCF Summary	With LULUCF Summary
1.A.1.a Energy Industries/Public Electricity and Heat Production - Liquid Fuels	CO_2	3518.60	62.49	L1 (1990); L1 (2021); T1;	L1 (1990); L1 (2021); T1;
1.A.1.a Energy Industries/Public Electricity and Heat Production - Solid Fuels	CO_2	22017.06	4880.50	L1 (1990); L1 (2021); T1; L2; T2;	L1 (1990); L1 (2021); T1;
1.A.1.a Energy Industries/Public Electricity and Heat Production - Gaseous Fuels	CO_2	1811.98	313.90	L1 (1990); L1 (2021); T1;	L1 (1990); L1 (2021); T1;
1.A.1.a Energy Industries/Public Electricity and Heat Production - Peat	CO_2	842.88	21.10	L1 (1990); T1;	L1 (1990); T1;
1.A.1.a Energy Industries/Public Electricity and Heat Production - Other Fuels (Waste)	CO_2	0.00	124.15	L1 (2021); L2;	L1 (2021);
1.A.1.c Energy Industries/Manufacture of Solid Fuels and Other Energy Industries - Solid Fuels	CO_2	78.38	1545.47	L1 (2021); T1; L2; T2;	L1 (2021); T1;
1.A.2.c Manufacturing Industries and Construction/Chemicals - Liquid Fuels	CO_2	228.63	2.70	L1 (1990); T1;	L1 (1990); T1;
1.A.2.c Manufacturing Industries and Construction/Chemicals - Gaseous Fuels	CO_2	156.10	11.94	L1 (1990);	L1 (1990);
1.A.2.d Manufacturing Industries and Construction/Pulp, Paper and Print - Liquid Fuels	CO_2	145.24	0.71	L1 (1990); T1;	L1 (1990); T1;
1.A.2.d Manufacturing Industries and Construction/Pulp, Paper and Print - Gaseous Fuels	CO_2	0.00	55.65	L1 (2021);	L1 (2021);
1.A.2.e Manufacturing Industries and Construction/Food Processing, Beverages and Tobacco - Liquid Fuels	CO_2	695.49	22.24	L1 (1990); T1;	L1 (1990); T1;
1.A.2.e Manufacturing Industries and Construction/Food Processing, Beverages and Tobacco - Gaseous Fuels	CO_2	0.00	60.09	L1 (2021);	L1 (2021);
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Liquid Fuels	CO_2	448.15	0.09	L1 (1990); T1;	L1 (1990); T1;
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Solid Fuels	CO_2	595.12	0.00	L1 (1990); T1; T2;	L1 (1990); T1;
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Gaseous Fuels	CO_2	0.00	33.48	L1 (2021);	L1 (2021);
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Other Fuels	CO_2	0.00	51.34	L1 (2021); L2;	L1 (2021);
1.A.2.g Manufacturing Industries and Construction/Other - Liquid Fuels	CO_2	702.34	87.77	L1 (1990); L1 (2021); T1;	L1 (1990); L1 (2021); T1;
1.A.2.g Manufacturing Industries and Construction/Other - Solid Fuels	CO_2	194.01	0.71	L1 (1990); T1;	L1 (1990); T1;
1.A.2.g Manufacturing Industries and Construction/Other - Gaseous Fuels	CO_2	286.15	65.82	L1 (1990); L1 (2021);	L1 (1990); L1 (2021);
1.A.3.b Transport/Road Transportation - Liquid Fuels	CO_2	2234.91	2255.93	L1 (1990); L1 (2021); T1; L2;	L1 (1990); L1 (2021); T1;

Sector	Pollutant	Base Year emissions	2021	Without LULUCF Summary	With LULUCF Summary
1.A.3.c Transport/Railways - Liquid Fuels	CO_2	142.27	43.03	L1 (1990); L1 (2021);	L1 (2021);
1.A.4.a Other Sectors/Commercial/Institutional - Liquid Fuels	CO_2	139.79	64.11	L1 (2021);	L1 (2021);
1.A.4.a Other Sectors/Commercial/Institutional - Gaseous Fuels	CO_2	18.65	184.10	L1 (2021); T1;	L1 (2021); T1;
1.A.4.b Other Sectors/Residential - Liquid Fuels	CO_2	246.88	21.87	L1 (1990); T1;	L1 (1990); T1;
1.A.4.b Other Sectors/Residential - Solid Fuels	CO_2	336.77	2.35	L1 (1990); T1; T2;	L1 (1990); T1;
1.A.4.b Other Sectors/Residential - Gaseous Fuels	CO_2	131.64	139.51	L1 (2021); T1;	L1 (2021); T1;
1.A.4.b Other Sectors/Residential - Peat	CO_2	308.79	0.00	L1 (1990); T1; T2;	L1 (1990); T1;
1.A.4.c.i Other Sectors/Agriculture/Forestry/Fishing/Stationary - Liquid Fuels	CO_2	487.05	23.14	L1 (1990); T1;	L1 (1990); T1;
1.A.4.c.ii Other Sectors/Agriculture/Forestry/Fishing/Off-road vehicles and other machinery - Liquid Fuels	CO_2	87.08	179.08	L1 (2021); T1;	L1 (2021); T1;
2.A.1 Cement production	CO_2	483.04	0.00	L1 (1990); T1;	L1 (1990); T1;
2.A.2 Lime production	CO_2	129.69	46.75	L1 (2021);	L1 (2021);
2.B.1 Ammonia production	CO_2	307.73	0.00	L1 (1990); T1;	L1 (1990); T1;
2.D.3 Other - Solvent use	Indirect CO_2	18.40	30.55	L1 (2021);	L1 (2021);
2.D.3 Other - Road paving with asphalt	Indirect CO_2	0.05	0.04	L1 (2021);	L1 (2021);
2.F.1.a Commercial Refrigeration	HFC	0.00	43.89	L1 (2021);	L1 (2021);
2.F.1.c Industrial Refrigeration	HFC	0.00	36.71	L1 (2021);	L1 (2021);
3.A.1 Enteric Fermentation - Dairy Cattle	CH_4	821.09	367.01	L1 (1990); L1 (2021); T1; L2;	L1 (1990); L1 (2021);
3.A.1 Enteric Fermentation - Non-Dairy Cattle	CH_4	533.89	226.38	L1 (1990); L1 (2021); T1; L2;	L1 (1990); L1 (2021);
3.B.1.1 Manure Management - Dairy Cattle	CH_4	39.96	80.62	L1 (2021); T1;	L1 (2021); T1;
3.B.1.1 Manure Management -Non-Dairy Cattle	CH_4	20.06	53.84	L1 (2021); T1;	L1 (2021);
3.B.1.3 Manure Management - Swine	CH_4	115.84	51.05	L1 (2021);	L1 (2021);
3.D.1.1 Direct Soil Emissions - Inorganic N Fertilizers	N_2O	299.99	194.75	L1 (1990); L1 (2021); T1; L2; T2;	L1 (1990); L1 (2021); T1;

Sector	Pollutant	Base Year emissions	2021	Without LULUCF Summary	With LULUCF Summary
3.D.1.2a Direct Soil Emissions - Animal Manure Applied to Soils	N_2O	123.82	72.13	L1 (2021); L2; T2;	L1 (2021);
3.D.1.4 Direct Soil Emissions - Crop Residue	N_2O	168.30	124.12	L1 (1990); L1 (2021); T1; L2; T2;	L1 (1990); L1 (2021);
3.D.1.6 Direct Soil Emissions - Cultivation of Organic Soils	N_2O	140.73	135.96	L1 (2021); T1; L2; T2;	L1 (2021); T1;
3.D.2.1 Indirect Emissions - Atmospheric Deposition	indirect N_2O	62.11	37.03	L1 (2021); L2; T2;	L1 (2021);
3.D.2.2 Indirect Emissions - Nitrogen Leaching and Run-off	indirect N_2O	141.49	91.49	L1 (1990); L1 (2021); T1; L2; T2;	L1 (2021);
5.A Solid waste disposal	CH_4	239.36	196.90	L1 (1990); L1 (2021); T1; L2; T2;	L1 (1990); L1 (2021); T1;
5.D.1 Domestic wastewater	CH_4	126.22	57.15	L1 (2021); L2;	L1 (2021);
4.A.1. Forest Land remaining Forest Land - living biomass	CO_2	-4025.42	1822.20		L1 (1990); L1 (2021); T1; L2; T2;
4.A.1. Forest Land remaining Forest Land - mineral soils	CO_2	-967.94	-981.81		L1 (1990); L1 (2021); T1; L2; T2;
4.A.1. Forest Land remaining Forest Land - organic soils	CO_2	696.72	703.64		L1 (1990); L1 (2021); T1; L2; T2;
4.A.2.2. Grassland converted to Forest Land - living biomass	CO_2	-3.89	-161.04		L1 (2021); T1; L2; T2;
4.D Forest Land 4(II) Emissions and removals from drainage and rewetting	N_2O	236.42	241.51		L1 (1990); L1 (2021); T1; L2; T2;
4.D Forest Land 4(II) Emissions and removals from drainage and rewetting	CH_4	72.69	75.13		L1 (2021); L2
4.B.1 Cropland remaining Cropland - mineral soils	CO_2	0.00	-81.71		L1 (2021); L2
4.B.1 Cropland remaining Cropland - organic soils	CO_2	604.74	536.31		L1 (1990); L1 (2021); T1; L2; T2;

Sector	Pollutant	Base Year emissions	2021	Without LULUCF Summary	With LULUCF Summary
4.B.2.2 Grassland converted to Cropland - mineral soils	CO_2	0.00	74.40		L1 (2021); L2
4.C.2.1 Forest Land converted to Grassland - living biomass	CO_2	0.00	43.93		L1 (2021); L2
4.C.2 Land converted to Grassland – mineral soils	CO_2	-0.32	-81.90		L1 (2021); T1; L2; T2;
4.D.1.1 Peat extraction remaining Peat extraction - organic soils	CO_2	298.50	1437.61		L1 (1990); L1 (2021); T1; L2; T2;
4.E.2.1 Forest Land converted to Settlements – living biomass	CO_2	0.00	114.47		L1 (2021); L2
4.E.2.1 Forest Land converted to Settlements (min+org soils)	CO_2	0.00	92.45		L1 (2021); L2
4.F.2.1 Forest land converted to Other land – soils	CO_2	0.00	63.46		L1 (2021); L2
Wood panels and sawnwood	CO_2	-156.26	-936.12		L1 (1990); L1 (2021); T1; L2; T2;
5.A Solid waste disposal	CH_4	239.36	196.90	L1 (1990); L1 (2021); T1; L2; T2;	L1 (1990); L1 (2021); T1;
5.D.1 Domestic wastewater	CH_4	126.22	57.15	L1 (2021); L2;	L1 (2021);

L – level assessment
T – trend assessment
1 – Tier 1
2 – Tier 2

1.6. General uncertainty evaluation, including data on the overall uncertainty for the inventory totals

1.6.1. GHG inventory

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 1.

The uncertainty estimate of the 2023 inventory submission to the European Commission 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 1.4 shows the estimated uncertainties for total greenhouse gas emissions in 1990 and 2021 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 1.4. Uncertainty in total 2023 inventory submission

	Combined as % of total national emissions in		**Introduced into the trend in total national emissions in 2021**
	1990	**2021**	
	Uncertainty [%]		
Without LULUCF	3.54	7.52	1.91
With LULUCF	7.33	13.03	6.54

1.7. General assessment of completeness

1.7.1. GHG inventory

Estonia has provided estimates for all significant IPCC source and sink categories according to the detailed CRF classification. Estimates are provided for the following gases: CO_2, N_2O, CH_4, F-gases (HFC, PFC, SF_6 and NF_3[8]), NMVOC, NOx, CO and SO_2.

Assessment of completeness is presented in Annex 3.

The geographical coverage of the inventory is complete.

[8] NF_3 emissions do not occur in Estonia.

2. TRENDS IN GREENHOUSE GAS EMISSIONS

2.1. Description and interpretation of aggregated GHG emission trends

This chapter provides the trends in GHG emissions and removals by sinks in Estonia for the years 1990–2021.

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 (NOx), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), and sulphur dioxide (SO_2).

Estonia's base year for calculating the emissions of CO_2, CH_4, N_2O, and fluorinated gases is 1990[9].

Total emissions of greenhouse gases in Estonia (without LULUCF) decreased steadily from 40 276.36 kt CO_2 eq. in 1990 to 12 615.17 kt CO_2 eq. in 2021 (Figure 2.1). From 1990 to 2021 emissions without LULUCF decreased by 68.68%. 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 57.63% from 36 580.88 kt CO_2 eq. in 1990 to 15 497.75 kt CO_2 eq.

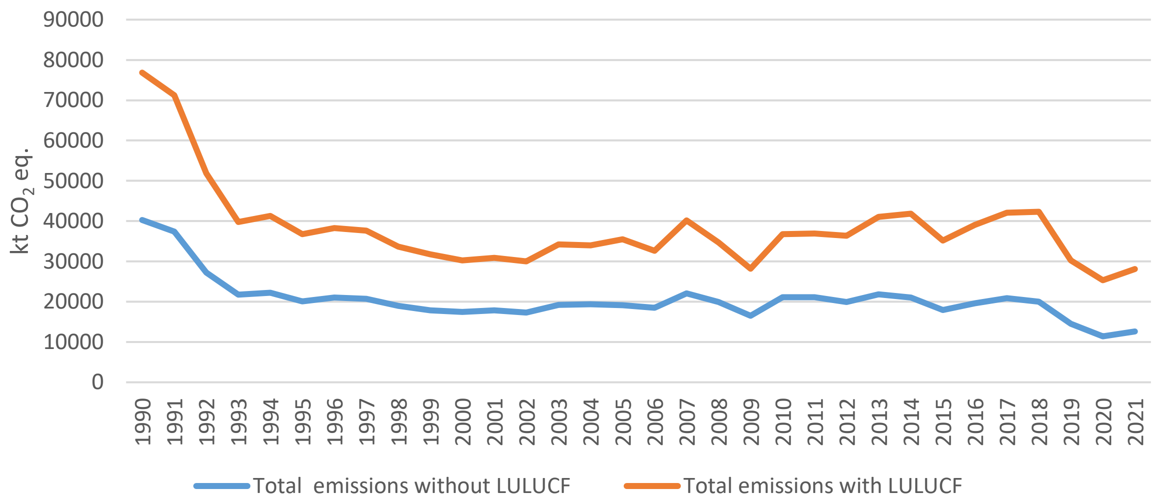


Figure 2.1. Overall development of greenhouse gases in Estonia (with indirect CO_2), without LULUCF, kt CO_2 eq.

In 2021 the most important GHG in Estonia was carbon dioxide (CO_2), contributing 83.6% to total national GHG emissions (with LULUCF) expressed in CO_2 eq. (including indirect CO_2), followed by methane (CH_4), 7.9%, and nitrous oxide (N_2O), 7.2%. Fluorocarbons (so-called 'F-gases') account for about 1.2% of total emissions (Figure 2.2). Figure 2.2 also includes the GHG gas allocation for total GHG emissions without LULUCF.

[9] Estonia's base year for F-gases under the Kyoto Protocol is 1995 (and for NF_3).

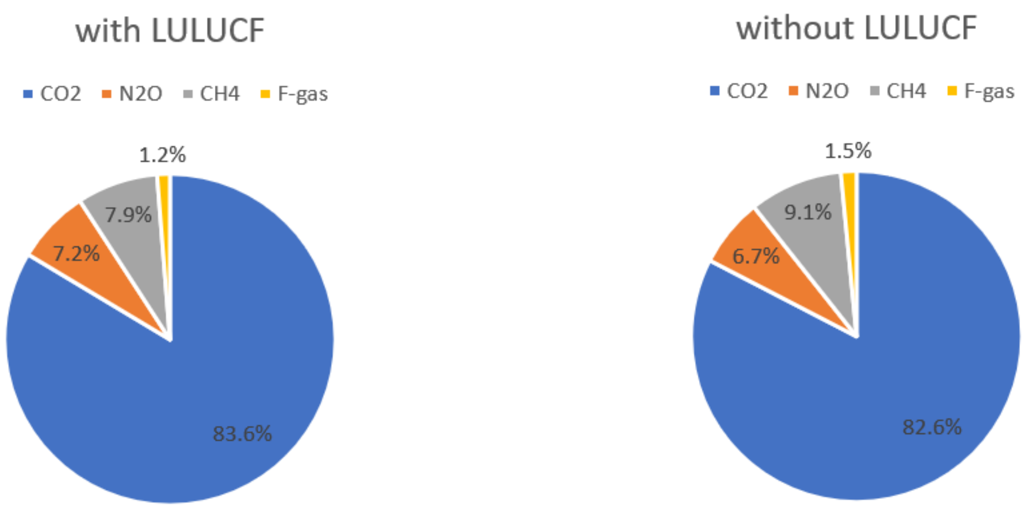


Figure 2.2. GHG emissions by gas in 2021 with and without LULUCF, %

Figure 2.3 shows GHG emission trends by gas in 1990 to 2021. CO_2 emissions (with LULUCF, with indirect CO_2) decreased by 60.64% from 32 912.4 kt in 1990 to 12 955.1kt in 2021, 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 44.8% from 2 225.5 kt CO_2 eq. in 1990 to 1 228.3 kt CO_2 eq. in 2021, 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 22.3% from 1 443 kt CO_2 eq. in 1990 to 1121.1 kt CO_2 eq. in 2021, 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 193.3 kt CO_2 eq. in 2021, 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 2021 was 190.2 kt CO_2 eq. and SF_6 emissions 3.1 kt CO_2 eq.

NF_3 emissions do not occur in Estonia.

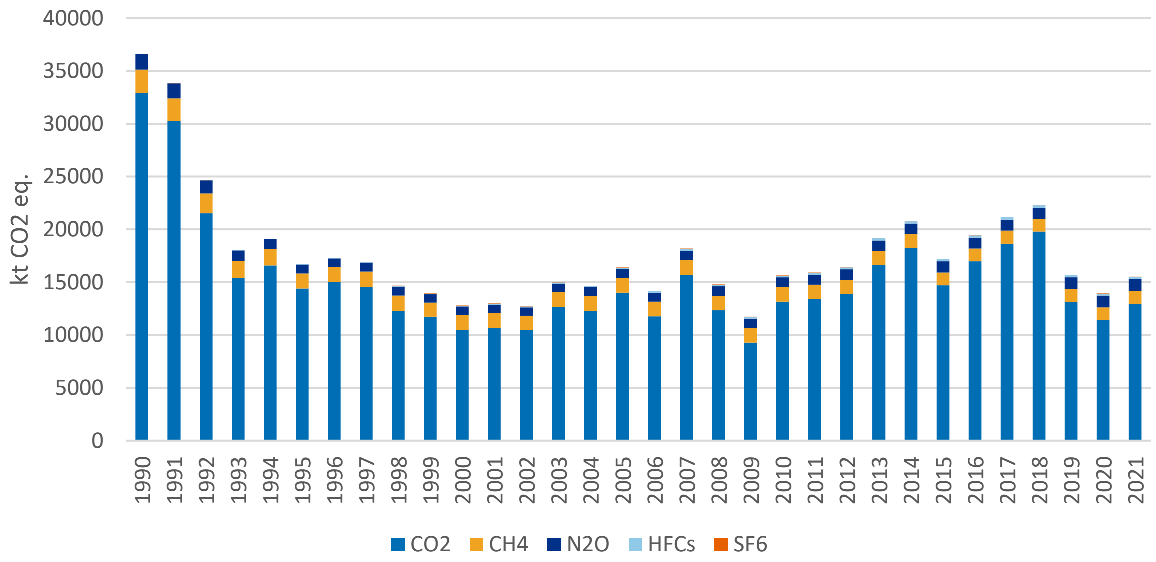


Figure 2.3. Estonia's greenhouse gas emissions by gas 1990–2021 (with LULUCF), kt CO_2 eq.

Air pollutant emissions reported in the CR are mostly based on the data reported in UNECE/CLRTAP 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 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 2019. More detailed information about methodologies used for estimating the indirect GHG emissions are presented in relevant sectoral chapters in the NIR. Figure 2.4 shows indirect GHG emission trends in 1990 to 2021.

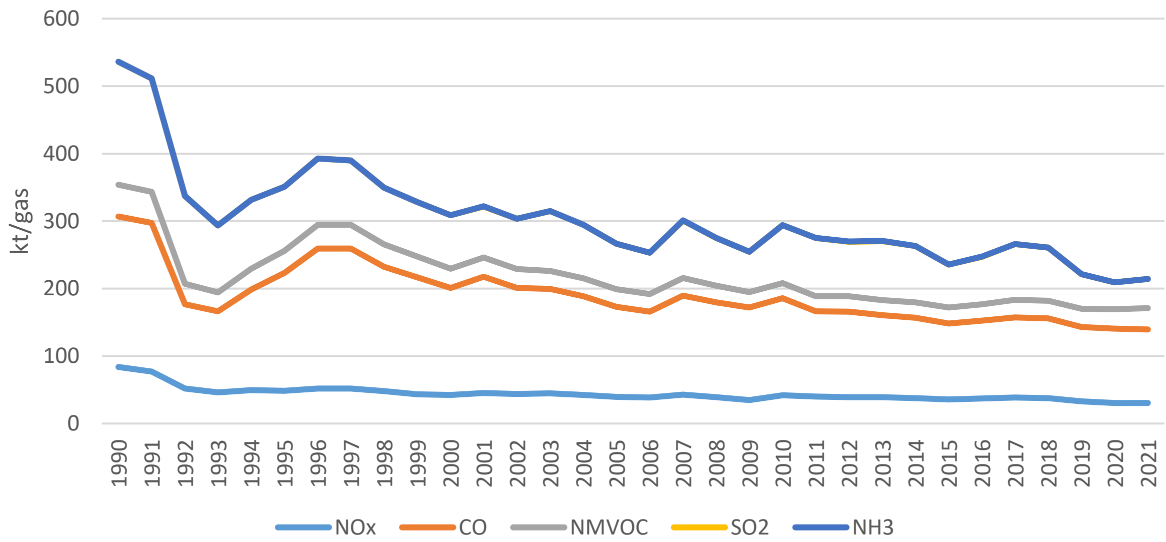


Figure 2.4. Indirect GHG emission trends in 1990 to 2021.

2.2. Description and interpretation of emission trends by sector

Greenhouse gas emissions by IPCC sectors are presented in Figure 2.5. The largest contribution is the Energy sector, which contributed 67.22% of total greenhouse gas emissions in 2021 (with LULUCF). The second largest sector is Agriculture, which accounted for 10.2 % of the total emissions in 2021 followed by the Waste and the Industrial processes and product use sectors accounted for 2.05% and 1.91% of total emissions in 2021.

Over the period 1990–2021 (Figure 2.5), emissions from the Energy sector decreased by 71.2%, emissions from the Industrial processes and product use sector decreased by 69.3% and emissions from the Agriculture sector decreased by 41.9%. Emissions from the Waste sector decreased by 21.7%. In 2021, the LULUCF sector acted as a CO_2 source, totaling with emissions 2882.6 kt CO_2 eq. Since 1990, net removals have decreased by 178%.

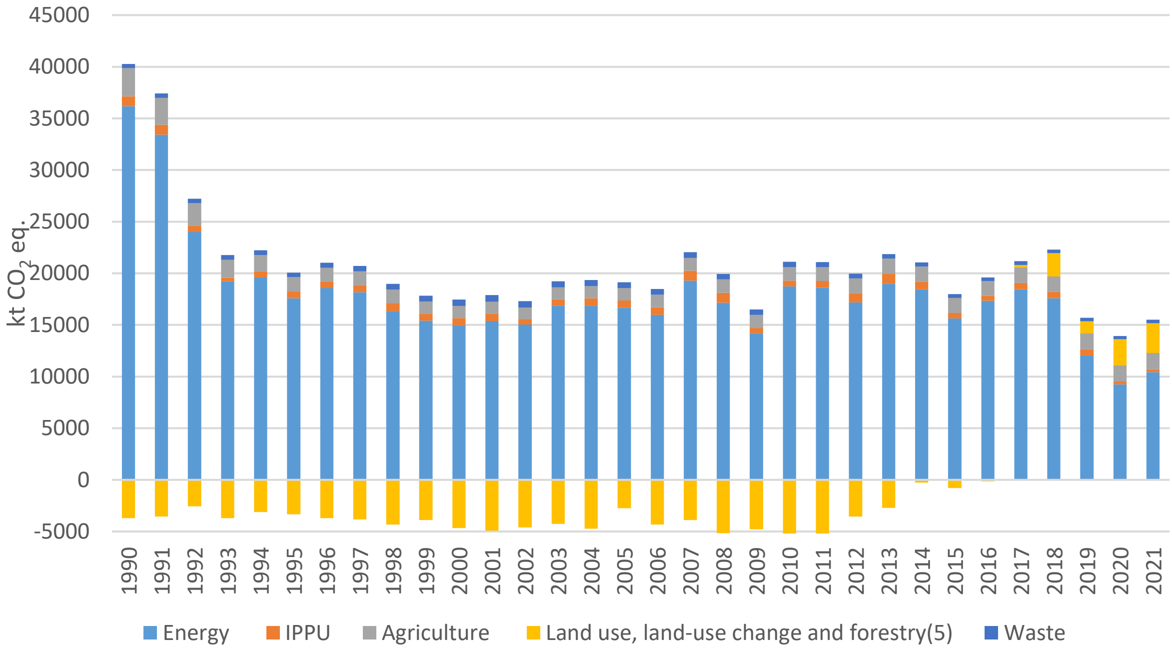


Figure 2.5. Greenhouse gas emission trends, by sectors, kt CO_2 eq.

The following sub-chapters discuss the main contributors to trends within each IPCC source sector.

2.2.1. Trends in Energy (CRF 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 category is presented in Figure 2.6.

The Energy sector is the major source of GHG emissions in Estonia contributing 67.22% of total emissions in 2021, totalling 10 418.13 kt CO_2 eq. 99.8% of emissions originate from fuel combustion, and only 0.2% from fugitive emissions. Energy-related CO_2 emissions vary mainly concerning the economic trend, the energy supply structure, 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 (closing 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 2019 and 2020 compared to the previous years was mainly in the energy industries, because of the EU ETS emission allowance price increase, lower electricity prices, and warmer winters. In 2021 emissions from Energy sector increased 12.8% compared to 2020, the increase was mainly in the energy industries because of colder winter and higher electricity prices.

Emissions from the Energy sector decreased by 71.2% compared to 1990 (incl. Energy industries – 75.3%; Manufacturing industries and construction – 88.5%; Transport – 5.2%; Other sectors – 65.3%; and Fugitive emissions – 67.7%). The overall progression of GHG emissions in the Energy is presented in Figure 2.6.

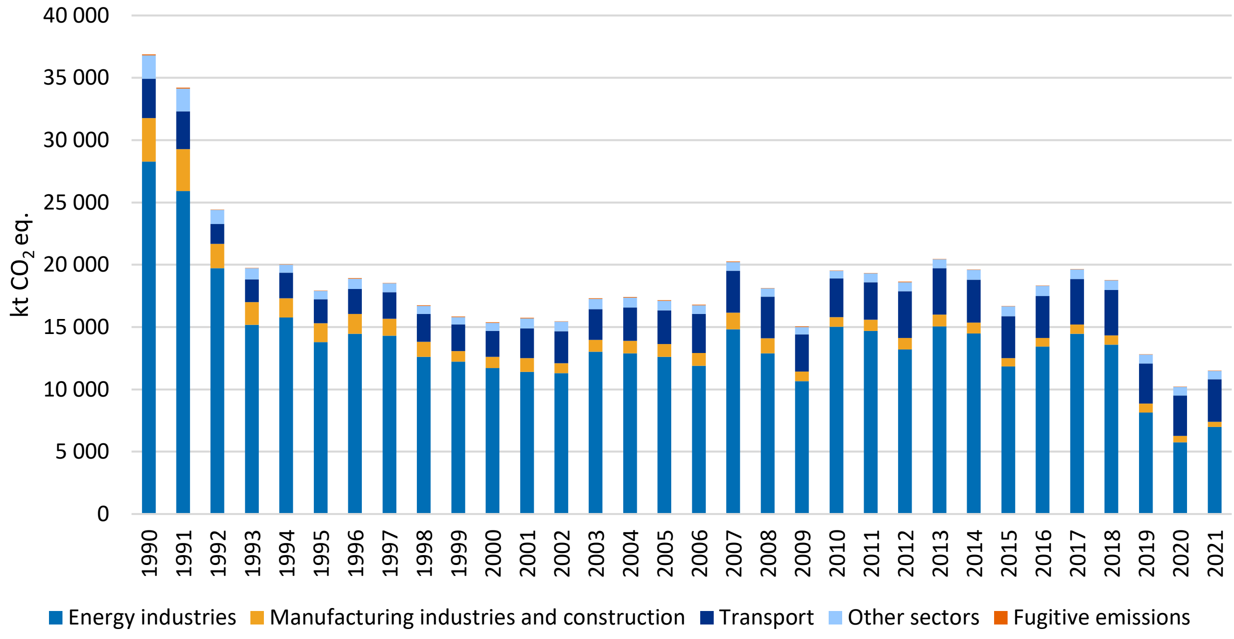


Figure 2.6. Trend in emissions from Energy sector 1990–2021, kt CO_2 eq.

2.2.2. Trends in Industrial processes and product use (CRF 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, NOx, 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 CRF 1.

In 2021 the Industrial processes and product use sector contributed 1.91% of all GHG emissions in Estonia, totalling 295.94 kt CO_2 eq. with indirect CO_2 and 265.33 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 64.27% of total emissions from the sector (with indirect CO_2). Compared to 2020, the emissions from Industrial processes and product use (with indirect CO_2) increased by 2.25% in 2020.

Industrial CO_2 emissions have fluctuated strongly during years 1990–2021.

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. 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. Increase in 2017 emissions was largely caused by 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 Regulation (EU) No 517/2017.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).

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.

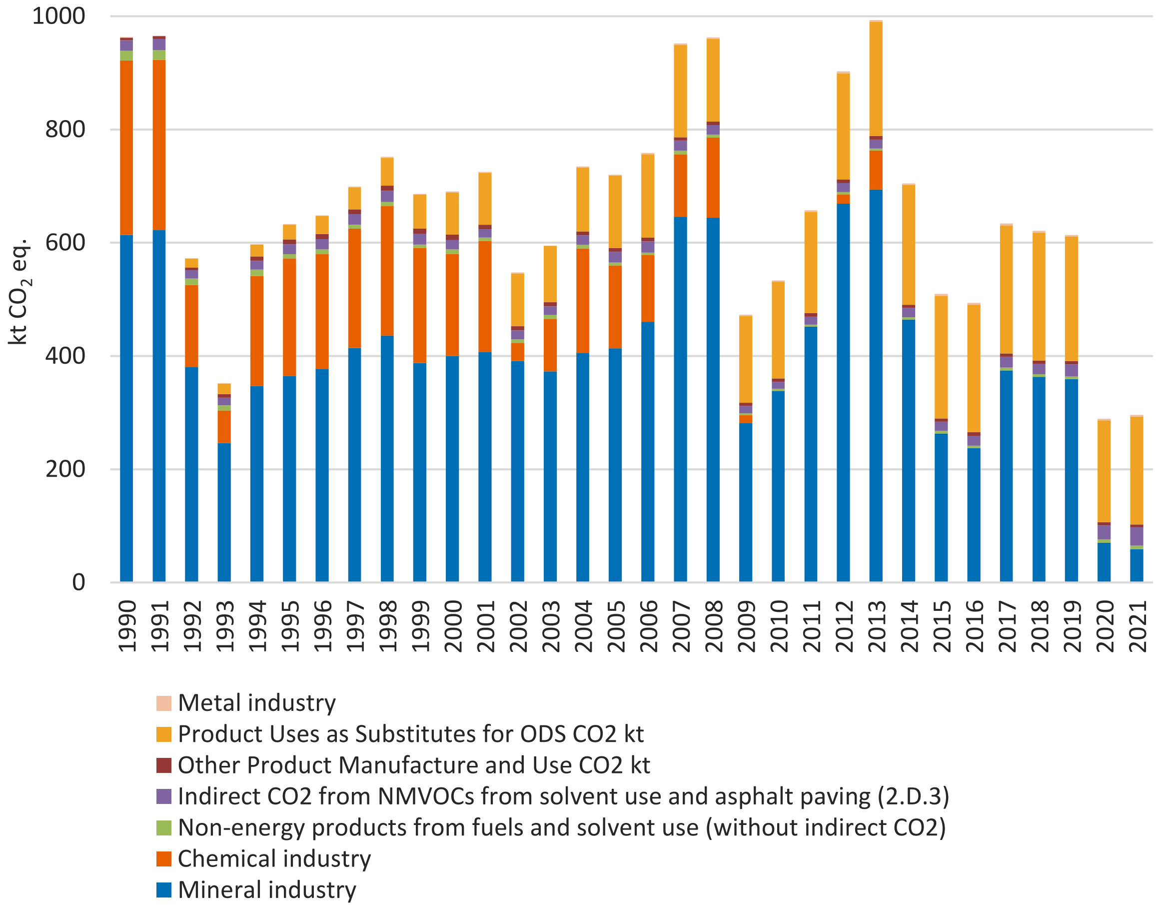


Figure 2.7. Trend in emissions from Industrial processes and product use sector, 1990–2021, kt CO_2 eq.

2.2.3. Trends in Agriculture (CRF 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 1 583.94 kt CO_2 eq. in 2021. The sector contributed about 10.2% to the total CO_2 eq. emissions in Estonia. In 2021, the emissions from Enteric fermentation increased by 0.3% compared to the previous year while the emissions from Manure management decreased by 0.8%. Emissions from Enteric fermentation increased mostly because of the cold winter temperatures that caused animals to use more feed, emissions from Manure management decreased because of the lower livestock population.

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[10]. This led to a rapid decline of agricultural production in Estonia and explains why the GHG emissions from the Agricultural sector have declined by 41.9% in 2021 compared with the base year (1990). In 2002–2008, the most important driving force for 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[11]. 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 all agricultural animals decreased in 2021 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 energy crisis in EU, leading to higher prices for fertilizers, energy and feed.[12] 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 meat, pork, poultry, fish, milk and dairy, cheese, sausages, fruits, and nuts etc. from EU countries to Russia.[13] Consequently, the number of dairy cattle in 2021 fell by 12.5% in comparison with 2014. The number of dairy cattle was record low in 2021 – being only 83,600 heads.[14] The number of swine has fallen by 13.9% in 2021 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 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.[15] 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. However, compared to the previous year, the number of swine has decreased by 2.8%. 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

---

[10] ESTONICA. Encyclopedia about Estonia. Laansalu, A. Crisis in agriculture in the 1990s. [www] http://www.estonica.org/en/The_rural_economy_in_Estonia_until_2001/Crisis_in_agriculture_in_the_1990s/ (20.12.2022).
[11] Estonian Universtity of Life Sciences. (2011). Maaelu arengu aruanne. Tartu: AS Ecoprint, lk 86.
[12] 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/ (23.11.2022)
[13] Maaeluministeerium. Venemaa sanktsioonid Euroopa Liidu toidukaupadele. [www] https://www.agri.ee/maaelu-pollumajandus-toiduturg/pollumajandus-ja-toiduturg/venemaa-sanktsioonid-euroopa-liidu (14.11.2022).
[14] 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 (23.11.2022)
[15] Ministry of Rural Affairs. 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 (14.11.2022)

forced to close down their production.[12] What is more, imported pork is cheaper for the buyer, so people have started to prefer it to domestic pork.[16]

Emissions from Agricultural soils and Enteric fermentation of livestock were the major contributors to the total emissions recorded in the sector – 42.7% and 39.3%, respectively.

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

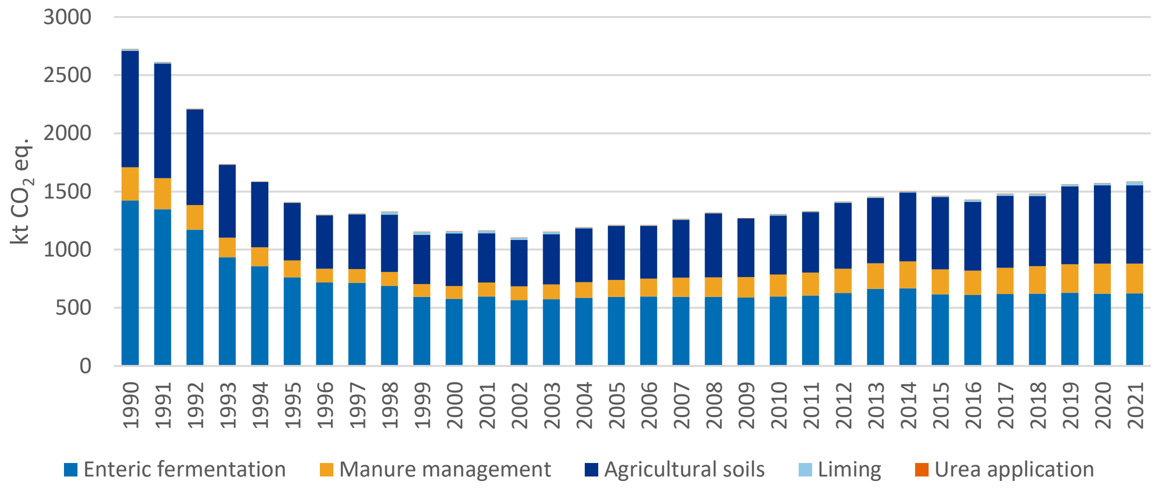


Figure 2.8. Trend in emissions from the Agriculture sector, 1990–2021, kt CO_2 eq.

2.2.4. Trends in Land use, land-use change and forestry (CRF 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. The share of LULUCF sector emissions and removals by each land use category during the time period 1990–2021 is presented in Figure 2.9. In 2021 net emissions from the LULUCF sector equalled 2 882.57 kt CO_2 equivalent, which is 14.9% higher compared to the previous year. In the base year (1990), LULUCF sector acted as C sink with net emissions of -3 695.48 kt CO_2 eq. The LULUCF sector sink is mainly affected by the age structure of forests, management practices in forestry and agriculture, usage of peat soils and horticultural peat, and C sequestration in HWP.

[16] Eesti Põllumajandus-Kaubanduskoda. Kodumaine seakasvatus vajab tarbija toetust – vastasel korral hääbub. [www] https://epkk.ee/kodumaine-seakasvatus-vajab-tarbija-toetust-vastasel-korral-haabub/ (23.11.2022)

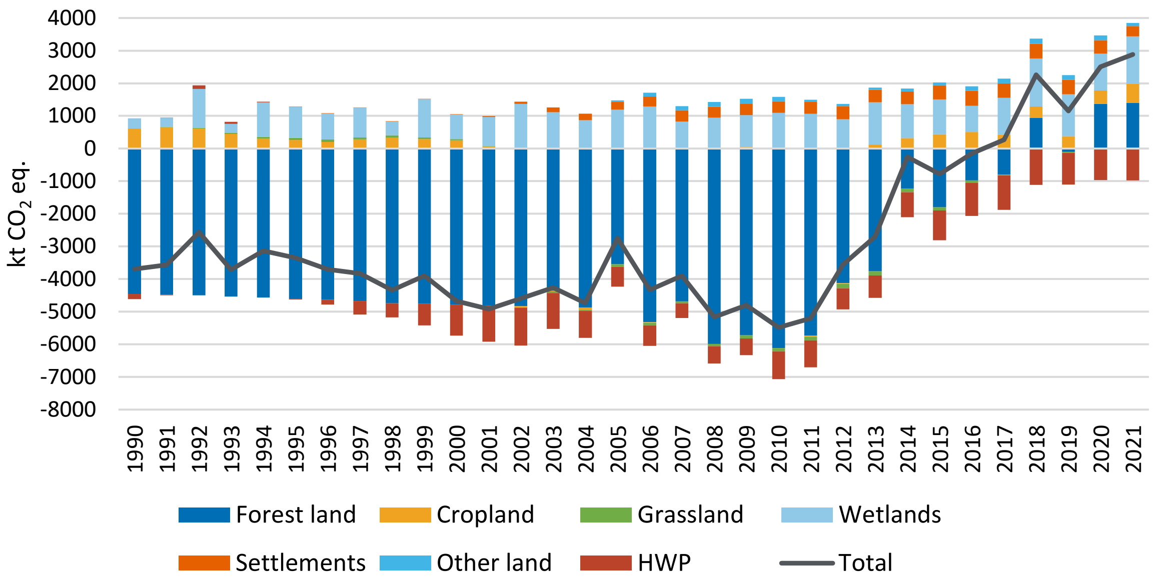


Figure 2.9. Trend in GHG emissions (+) and removals (-) from land use, land-use change and forestry sector 1990–2021, kt CO_2 eq.

In 2021, HWP and Grassland were the only net sink categories and unable to compensate emissions from the other LULUCF categories. Main part of the HWP sink is in the wood panels and sawnwood subcategories; grasslands sequester carbon mainly in the mineral soils following land-use change. The highest net emitters were Wetlands and Forest land categories. GHG emissions from Wetlands came predominately from peat extraction areas and horticultural use of peat.

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 share of young and middle-aged stands led to the growing net annual increment. The felling volume also increased, but the impact of other factors, such as the age structure of forests and increasing forest land area, was more important. Therefore, 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. The annual estimate of average growing stock per hectare is also influenced by variability caused by the NFI sampling design, which is based on the systematic random sampling.

2.2.5. Trends in Waste (CRF 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 waste incineration without energy recovery and open burning of waste, 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.

CO_2 eq. emissions from the Waste sector were 317.16 kt in 2021 2.05% of total GHG emissions in 2021. Total CO_2 eq. emissions from the Waste sector (Table 7.2) in 2021 increased by 0.71% compared to 2020. Compared to the base year of 1990, the amount of CO_2 eq. emissions in 2021 were 21.7% smaller. Compared to the base year, CO_2 eq. emissions from Solid waste disposal (SWD) have decreased by 17.7%, CO_2 eq. emissions from Waste incineration and Open burning of waste by 76.7%, 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 2424.1%.

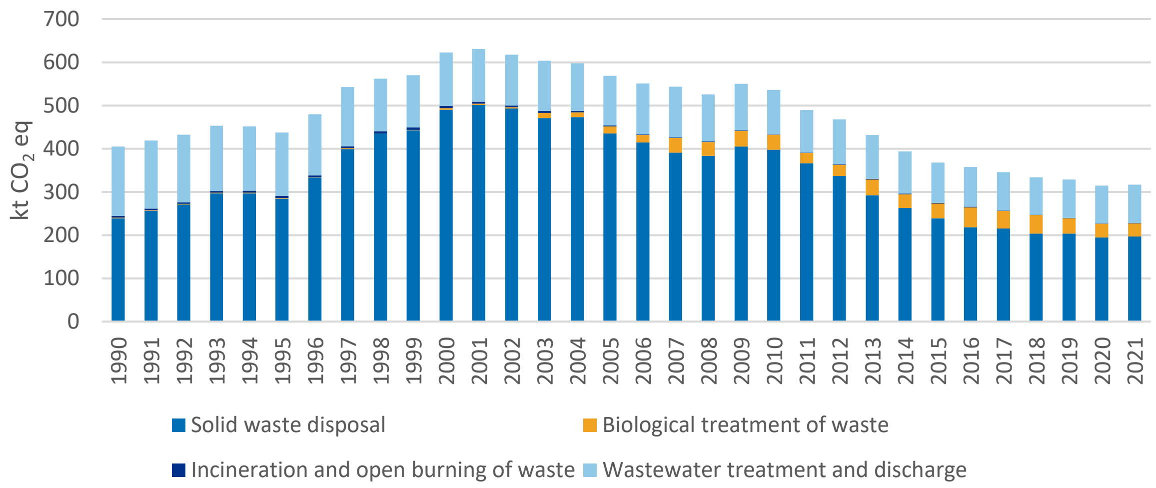


Figure 2.10. Trend in emissions from waste sector by source categories in 1990–2021, kt CO_2 eq.

As seen from Figure 2.10, GHG emissions from the Waste sector are in decreasing trend until 2020.

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 since 2010.

The lowest CO_2 eq. emissions occurred in 2020, which was mainly connected to the decreasing amount of waste deposited in landfills. 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.

3. ENERGY (CRF 1)

3.1. Overview of the sector

The Energy sector is the main source of greenhouse gas emissions in Estonia. In 2021 the Energy sector contributed about 67.2% of total emissions, totalling 10 418.13 kt CO_2 equivalent

Compared to the base year 1990 (36 184.55 kt CO_2 eq.), the emissions have decreased about 71.2%. Most of the Energy sector emissions (99.8%) originate from Fuel combustion and 0.2% from Fugitive emissions. A substantial amount of energy-related emissions are caused by an extensive use of fossil fuels in heat and power production.

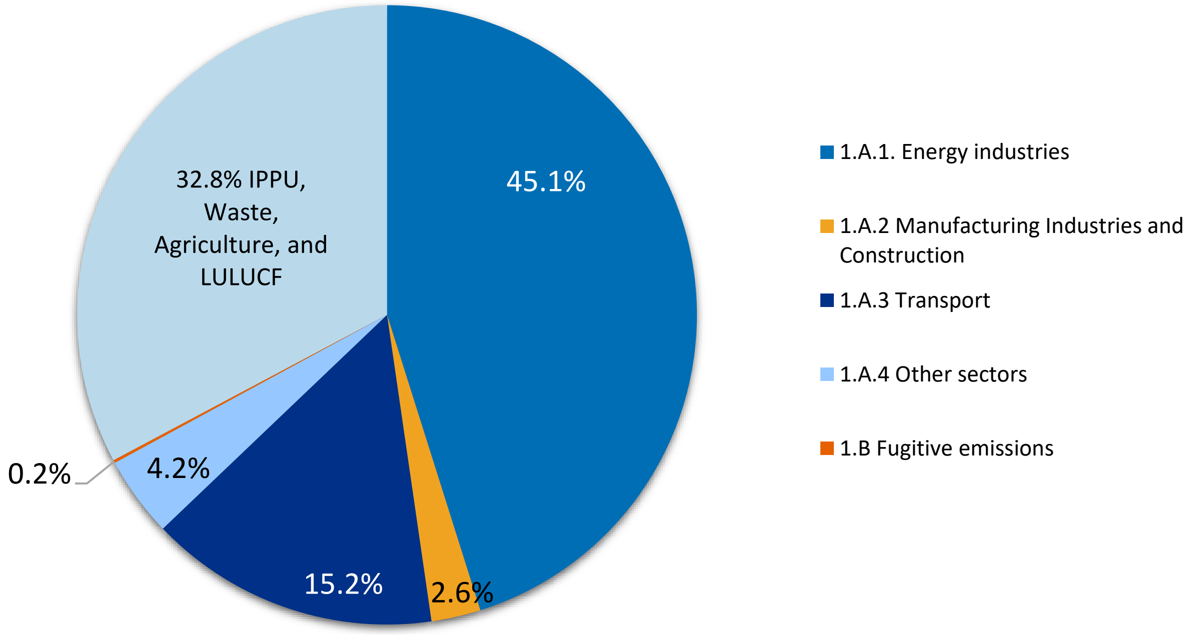


Figure 3.1 Emissions from the Energy sector compared to the total emissions in 2021, %

The share of domestic fuels is large in total energy resources and primary energy balance. This gives strategic independence to electricity supply – the share of imported fuels accounts for approximately 1/4 of total supply, in the European Union (EU) member states average is about 2/3. The share of exported electricity extensively influences the share of oil shale in primary energy balance – the larger the exports of electricity the larger the share of oil shale.

The development of primary energy supply in Estonia is presented in Figure 3.2.

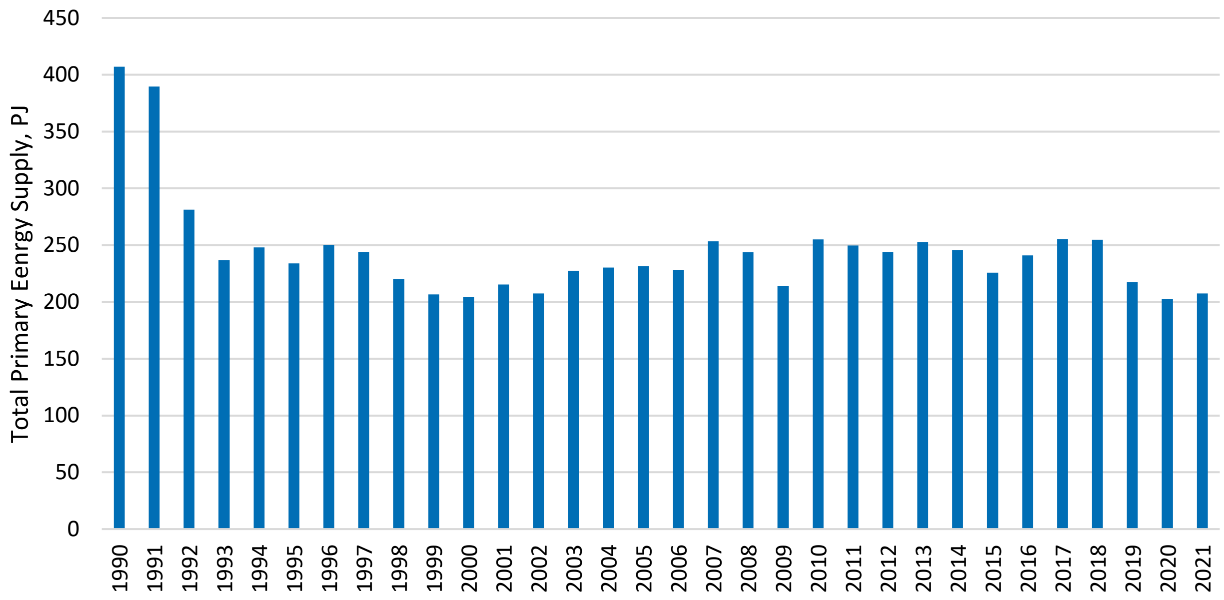


Figure 3.2. Development of total primary energy supply in Estonia in 1990–2021, PJ (Source: Statistics Estonia)

In 2021 the primary energy supply was 207.5 PJ, of which oil shale 53.90%, biomass 19.51%, liquid fossil fuels 16.76%, and natural gas 6.51%. Hydro, wind, and solar power formed 1.58% of total energy supply. Other fuels had smaller shares – coal 0.03%, fossil wastes 0.57%, liquid and gaseous biofuels 1.06%, and peat 0.08%. The primary energy supply increased about 2.4% in 2021 compared to the previous year (see Figure 3.2). Other hydrocarbons contain shale oil, it is domestically produced and fully exported (45 889 TJ was exported in 2021). The main reason for the increase was colder winter temperatures and higher electricity prices.

Figure 3.3 presents the structure of the primary energy supply in 1990 and Figure 3.4. the structure of the primary energy supply in 2021.

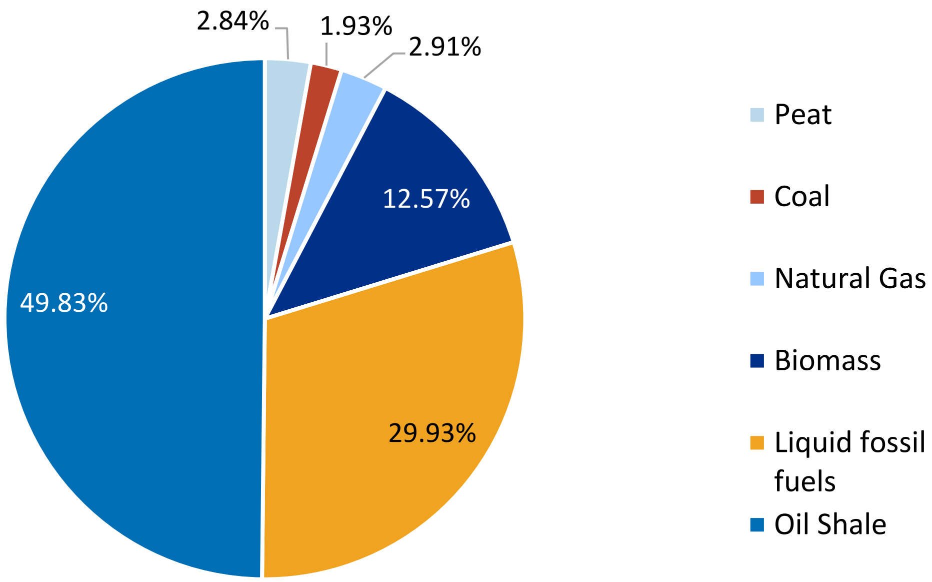


Figure 3.3. Structure of primary energy supply in Estonia in 1990, %

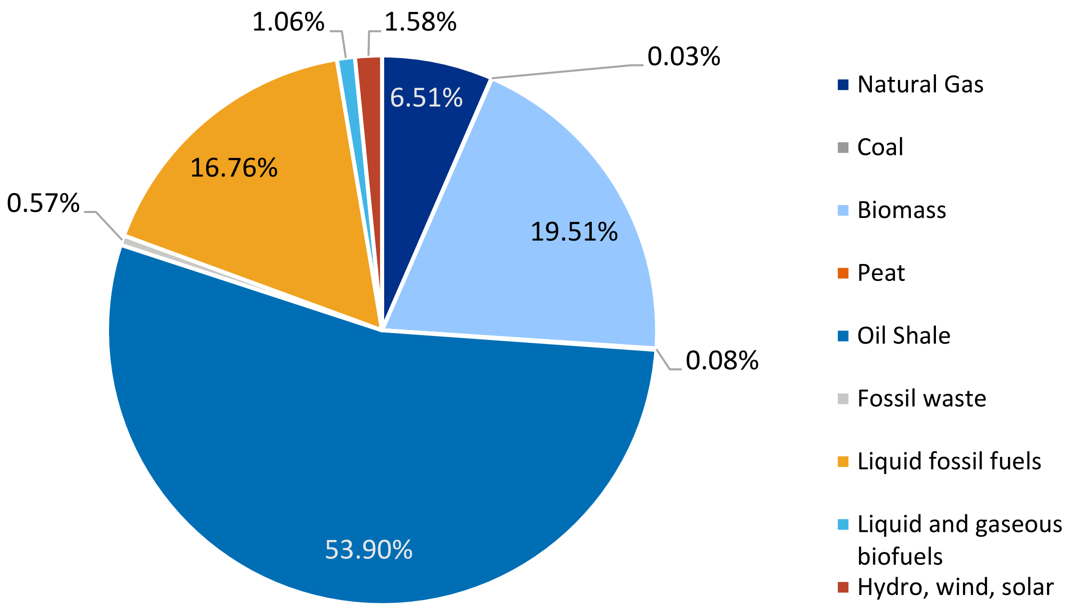


Figure 3.4. Structure of primary energy supply in Estonia in 2021, %

Estonia´s GDP has steadily grown since 2009. In 2020 the GDP fell by 2.9% at constant prices, because of restrictions from COVID-19 pandemic, but was twice lower than EU average. In 2021 GDP increased 8.3% compared to 2020 as the economy began to recover from the COVID-19 crisis[17].

Domestic fuels have a high share in Estonia's energy resources and the primary energy balance, and it is mainly based on oil shale. 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 residential sector (Figure 3.6).

The GHG emission and fuel consumption increased compared to the previous year primarily in the Energy industries, as the colder winter and higher electricity prices. Emissions from the Energy sector by subcategories in 1990–2021 are presented in Figure 3.5.

[17] Statistics Estonia. Estonian economy grew by 5.2% compared to the pre-pandemic level. [www] https://www.stat.ee/en/node/258605 (02.03.2023)

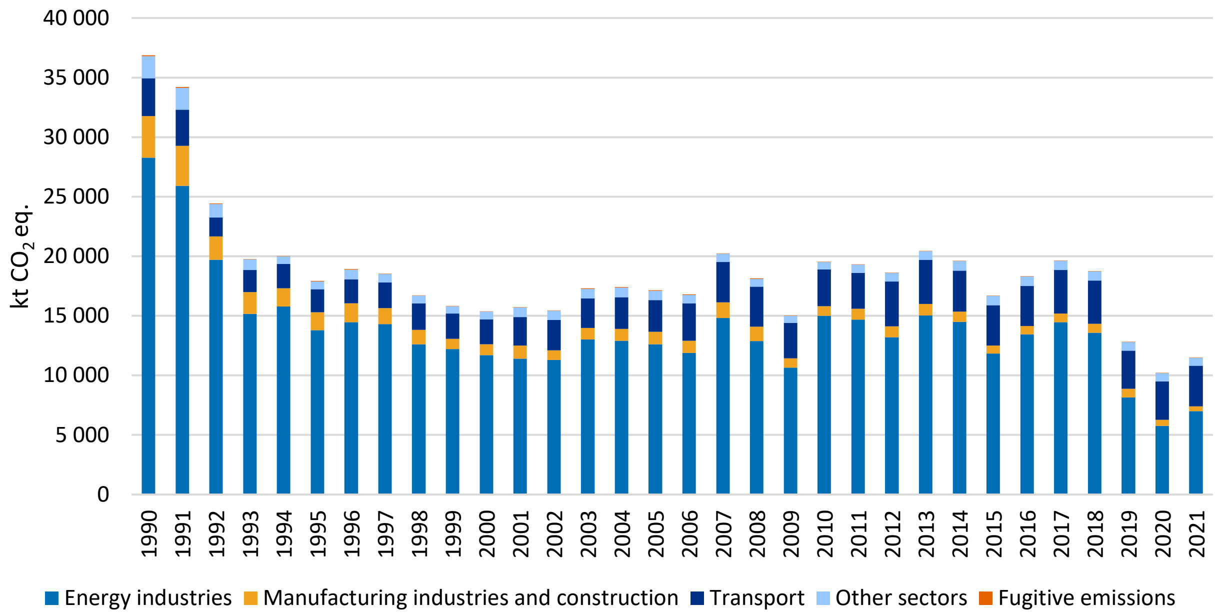


Figure 3.5. Emissions from the Energy sector by subcategory in 1990–2021, kt CO_2 eq.

The trend of fuel consumption in Energy sector in 1990–2021 is presented in Figure 3.6.

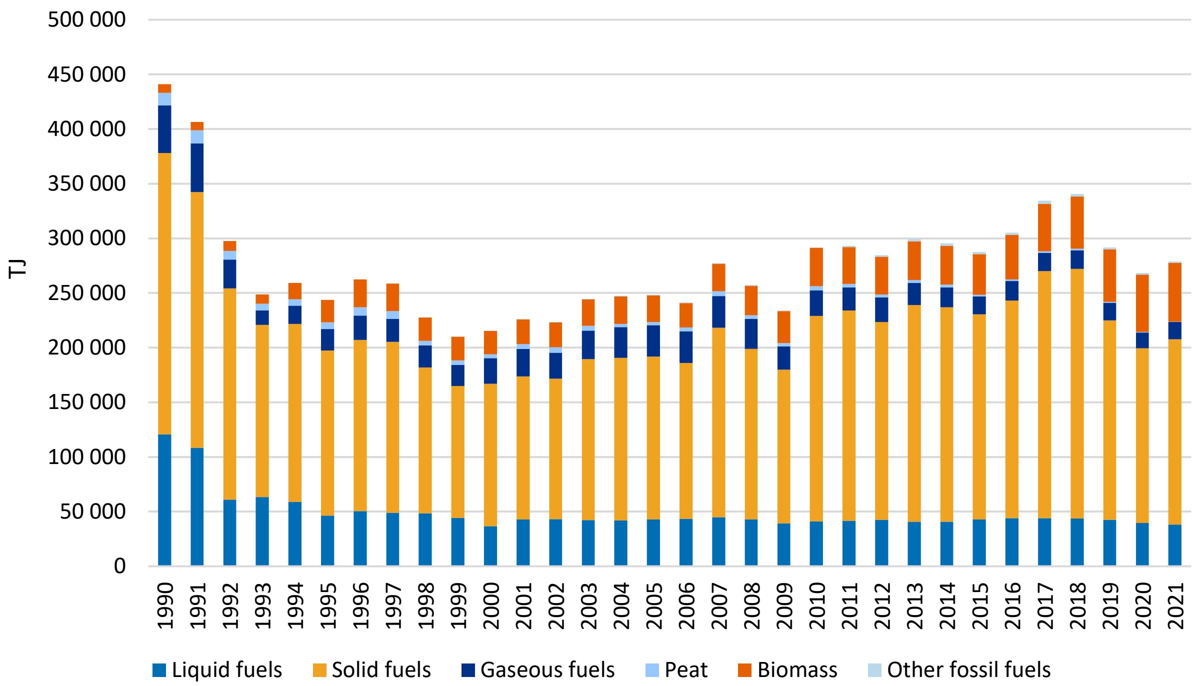


Figure 3.6. Fuel consumption in Energy sector in 1990–2021, TJ

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 and weather conditions. Also, the export of electricity has an essential role as the primal share of electricity in Estonia comes from oil shale. As suggested in the IPCC 2006 Guidelines, the emissions in the Energy sector are divided into Emissions from fuel combustion (CRF 1.A) and Fugitive emissions (CRF 1.B). Emissions from the Energy sector in 1990–2021 by greenhouse gas are presented in Table 3.1.

Table 3.1. Emissions from the Energy sector in 1990, 1995, 2000, 2005, 2010, and 2015–2021 by greenhouse gas, kt CO_2 eq.

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
1 Energy Total, CO_2 eq.	36184.55	17588.23	14981.67	16639.96	18739.76	15635.70	17326.05	18437.69	17594.70	12035.95	9233.15	10418.13
1.A Fuel Combustion Total, kt CO_2 eq.	36112.78	17554.02	14942.62	16593.00	18706.73	15612.77	17300.91	18414.53	17570.42	12013.45	9212.72	10394.98
1.A Fuel Combustion, kt CO_2	35945.86	17456.32	14853.90	16501.64	18608.73	15527.25	17211.90	18319.09	17475.04	11919.18	9118.89	10290.40
1.A Fuel Combustion, CH_4, kt CO_2 eq	106.42	57.30	46.28	40.67	40.63	34.06	35.20	37.35	36.54	36.90	37.40	40.90
1.A Fuel Combustion, N_2O, kt CO_2 eq	60.50	40.40	43.45	50.68	57.38	51.46	53.81	58.09	58.85	57.37	56.44	63.68
1.B Fugitive Emissions, kt CO_2 eq.	71.77	34.21	38.87	46.96	33.03	22.93	25.25	23.16	24.28	22.34	20.43	23.16

3.2. Emission from Fuel combustion (CRF 1.A)

The emissions from Fuel combustion include point sources, transport, and other fuel combustion. Direct (CO_2, CH_4, N_2O) and indirect (CO, NMVOC, NO_x, SO_2) GHGs are reported. Emissions from fuel combustion in the Energy sector are divided into four subcategories as follows:

- CRF 1.A.1 – Energy industries;
- CRF 1.A.2 – Manufacturing industries and construction;
- CRF 1.A.3 – Transport;
- CRF 1.A.4 – Other sectors (Commercial/institutional, Residential, and Agriculture/forestry/fishing sectors), emissions from using military vehicles are included in 1.A.4.a Commercial/institutional

Reported greenhouse gas emissions, used methods, and type of emission factors are listed in Table 3.2.

Table 3.2. Reported emissions, calculation methods, and type of emission factors in Fuel combustion in the Estonian GHG inventory

CRF	Source	Emissions reported	Method	Emission factor
1.A.1	Energy industries	CO_2	T1, T2, T3	D, CS, PS
		CH_4	T1, T2	D, CS
		N_2O	T1, T2	D, CS
1.A.2	Manufacturing industries and construction	CO_2	T1, T2, T3	D, CS, PS
		CH_4	T1, T2, T3	D, CS
		N_2O	T1, T2, T3	D, CS
1.A.3	Transport	CO_2	T1, T2	D, CS
		CH_4	T1, T2, T3	D, CS
		N_2O	T1, T2, T3	D, CS
1.A.4	Other sectors	CO_2	T1, T2	D, CS
		CH_4	T1, T2, T3	D, CS
		N_2O	T1, T2, T3	D, CS

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

Quantitative overview

CO_2 emissions from Fuel combustion (10 290.40 kt) accounted for 98.8% of the Energy sector's total CO_2 eq. emissions and 66.4% of Estonia´s total CO_2 eq. emissions in 2021. The share of CH_4 emissions from Fuel combustion (40.90 kt CO_2 eq.) was relaitively small 0.26 % of total 2021 CO_2 eq. emissions, mainly from incomplete combustion of wood fuels (small combustion). N_2O emissions (63.68kt CO_2 eq.) account for about 0.41% of total 2021 CO_2 eq. and mainly originate from Energy industries and different Transport subsectors. The emissions from Fuel combustion are presented in Table 3.3.

Table 3.3. Emissions from Fuel combustion in Estonia in 1990, 1995, 2000, 2005, 2010, and 2015–2021, kt

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A Fuel Combustion Total, CO_2 eq.	36112.78	17554.02	14942.62	16593.00	18706.73	15612.77	17300.91	18414.53	17570.42	12013.45	9212.72	10394.98
1.A.1 Energy Industries, CO_2 eq.	28284.55	13798.33	11708.30	12611.52	15012.30	11841.10	13441.98	14459.53	13589.85	8150.71	5751.49	6994.68
1.A.2 Manufacturing Industries and Construction, CO_2 eq.	3474.10	1503.74	912.82	1036.64	792.99	658.43	696.61	735.47	741.09	717.91	512.80	398.82
1.A.3 Transport, CO_2 eq.	2480.27	1585.26	1682.50	2166.45	2285.18	2316.08	2363.53	2448.23	2466.16	2415.86	2241.84	2350.65
1.A.4 Other Sectors, CO_2 eq.	1873.87	666.70	639.00	778.40	616.25	797.08	798.78	771.30	773.33	728.97	706.59	650.83

Methods

Emissions from Fuel combustion (CRF 1.A.1 and CRF 1.A.2) are generally calculated by multiplying fuel consumption with either a fuel type-specific emission factor or a technology-specific emission factor. When calculating CO_2 emissions adjustment of the fraction of carbon oxidised is included.

Consumption of solid fuels, liquid fuels, natural gas, peat, and other fossil fuels as well as CO_2, CH_4, and N_2O are presented separately in Annex 2 (A.2.1.2).

Calculations of all emissions from Fuel combustion are done in Excel tables created by the energy sector expert.

Key categories

The key categories in 1990 and 2021 by level and trend (*Tier 1* and *Tier 2*) are presented in Table 1.3.

3.2.1. Comparison of the Sectoral approach and 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 2023 inventory submission, the difference in CO_2 emissions in 2021 between RA and Sectoral approach (SA) was 34.9%. 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 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 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 CRF has to be zero.

Waste consumption and emissions allocation reported in CRF 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

The relevant waste consumption and emissions are also reported under Sectoral approach in Information Item in Biomass and Fossil fuels.

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 CRF 1.D.

In 2021 GHG emissions from international bunkering were 1079.88 kt CO_2 eq., including international navigation 949.70 kt CO_2 eq. and international aviation 130.18 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 2021 emissions from international navigation increased 3.8% compared to 2020.

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 72.7% 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.

Figure 3.7. presents the trend of GHG emissions from International aviation and navigation. It can be seen from the figure that fuel consumption has been increasing in aviation, but fell abruptly in 2020, caused by a decline in international flights. International navigation saw an increase in GHG emissions in 2020 and 2021.

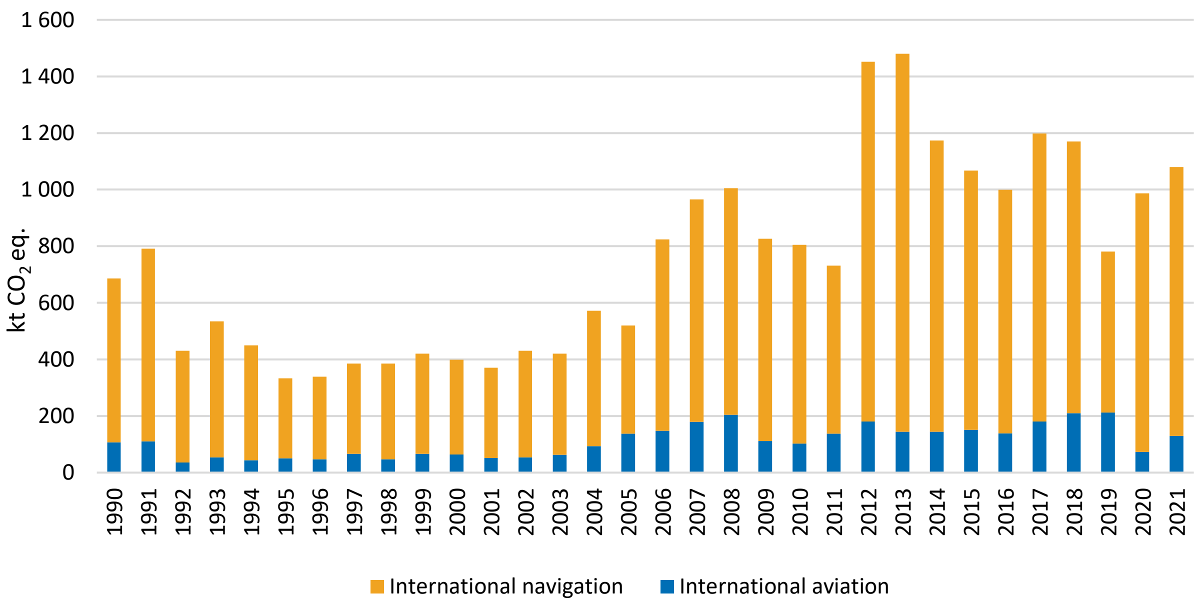


Figure 3.7. Emissions from International bunkers in 1990–2021, kt CO_2 eq.

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.

Category-specific recalculations

Recalculations in 1.D sub-categories are presented in Table 3.4.

Emissions from international navigation were recalculated due to correcting carbon emission factor for light fuel oil in calculations for the whole timeseries.

Table 3.4 Differences between 2023 and 2022 submissions, kt CO_2 eq.

Year	International navigation
1990	1.40
1991	1.69
1992	1.81
1993	2.97
1994	2.64
1995	1.26
1996	1.03
1997	0.94
1998	0.91
1999	1.12
2000	1.21
2001	1.63
2002	1.75
2003	1.52
2004	1.64
2005	1.78
2006	1.77
2007	1.16
2008	0.72
2009	0.63
2010	0.71
2011	0.97
2012	3.17
2013	1.07
2014	1.79
2015	3.66
2016	3.37
2017	4.19
2018	6.36
2019	3.80
2020	5.14

3.2.3. Feedstocks and Non-energy use of fuels

The following fuels are reported under CRF 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 CRF 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 CRF 1.A.2.f Other fuels.

Additional information regarding CRF category 1.AD Feedstocks and non-energy use is presented in Annex 2 (A.2.2.3.).

3.2.4. Energy industries (CRF 1.A.1) and Manufacturing industries and construction (1.A.2)

3.2.4.1. Category description

Energy industries (CRF 1.A.1)

Energy industries (CRF 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 2021 Energy industries (1.A.1) contributed 67.1% of Energy sector emissions, totalling 6994.68 kt CO_2 eq. and 45.1% of total GHG emissions. Compared to the base year 1990, the emissions were 75.3% lower (28 284.55 kt CO_2 eq.). The increase of 21.6% in 2021 in the Energy industries compared to the previous year was mainly because of a colder winter and higher electricity prices.

The emissions from Energy industries by relevant subcategories and gases in 1990–2021 are presented in Table 3.5. Figure 3.8 presents the trend of GHG emissions from Energy industries by relevant subcategories from 1990 to 2021.

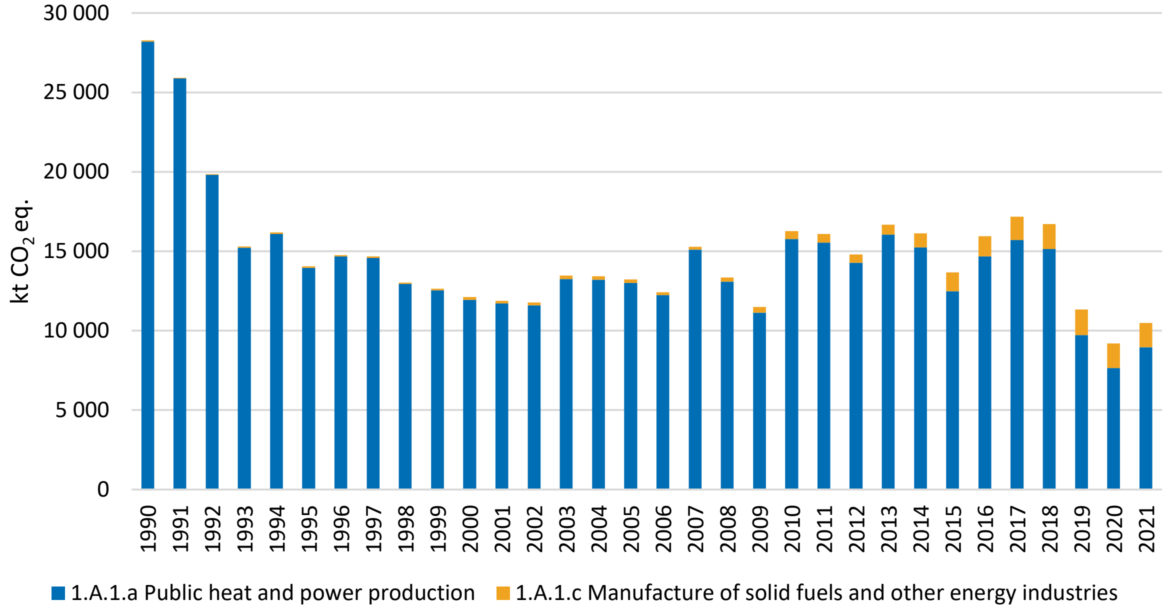


Figure 3.8. Trend of GHG emissions from Energy industries by relevant sub-categories in 1990–2021, kt CO_2 eq.

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 2021 compared to 1990 was 80.7%. 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 close to 20 times compared to 1990 due to extended export of shale oil.

In 2013 a waste incinerator plant was opened in Estonia. These emissions are accounted for in Other fossil fuels in Energy industries sector. In 2021 Iru waste incineration plant emitted 124.26 kt CO_2 eq.

In 2021 the gross electricity production was 7 204 GWh – about 18.5% higher compared to 2020 (6 078 GWh). The electricity export increased from 3 723 GWh in 2020 to 4 703 GWh in 2021 (about 26.3%). The electricity import decreased from 7 367 GWh in 2020 to 7 332 GWh in 2021 (0.48%).

Renewable energy is generated from wind, biomass, solar and small hydroelectric plants in Estonia. While electricity generation in wind parks has increased rapidly the proportion of renewable energy in energy production has intensified. In 2021 the production of electricity from wind energy decreased about 13.2% compared to 2020 the main reason being wind conditions and equipment reliability. The production of solar energy saw an increase of 44.1% in 2021 compared to 2020. 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 2021 the heat production rose around 8.6% compared to 2020 due to colder winter. Roughly 36% of heat was produced in heating plants and power plants produced about 64% of heat.

Estonia imported natural gas, liquid fuels, coal, and solid biofuels in 2021. Natural gas imports increased about 13.2% compared to 2020. Motor gasoline and diesel imports fell about 14.5% compared to the previous year. Coal imports increased about 51.4% compared to 2020.

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

Manufacturing industries and construction (CRF 1.A.2) include emissions from industrial sectors (power plants, boilers, and industrial plants with boilers, and/or other combustion). In 2021 the Manufacturing industries and construction contributed about 3.8% of Energy sector emissions, totalling 398.82 kt CO_2 eq., and about 2.6 % of total GHG emissions.

The structural changes in the economy after regaining independency in 1991 caused the relevant decrease from 1992. Compared to 1990 the emissions have decreased by 88.5% in 2021. Emissions decreased in the Manufacturing industries and construction sector by 22.2% compared to 2020, mainly because of the continuing increase of the EU ETS emission allowance price in 2021, increasing supply of goods in larger countries, and increasing price of raw materials.

According to the structure of CRF tables Manufacturing industries and construction sub-sectors are presented in the following CRF 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 3.6 and Figure 3.9 represent the emissions from Manufacturing industries and construction by relevant subcategories.

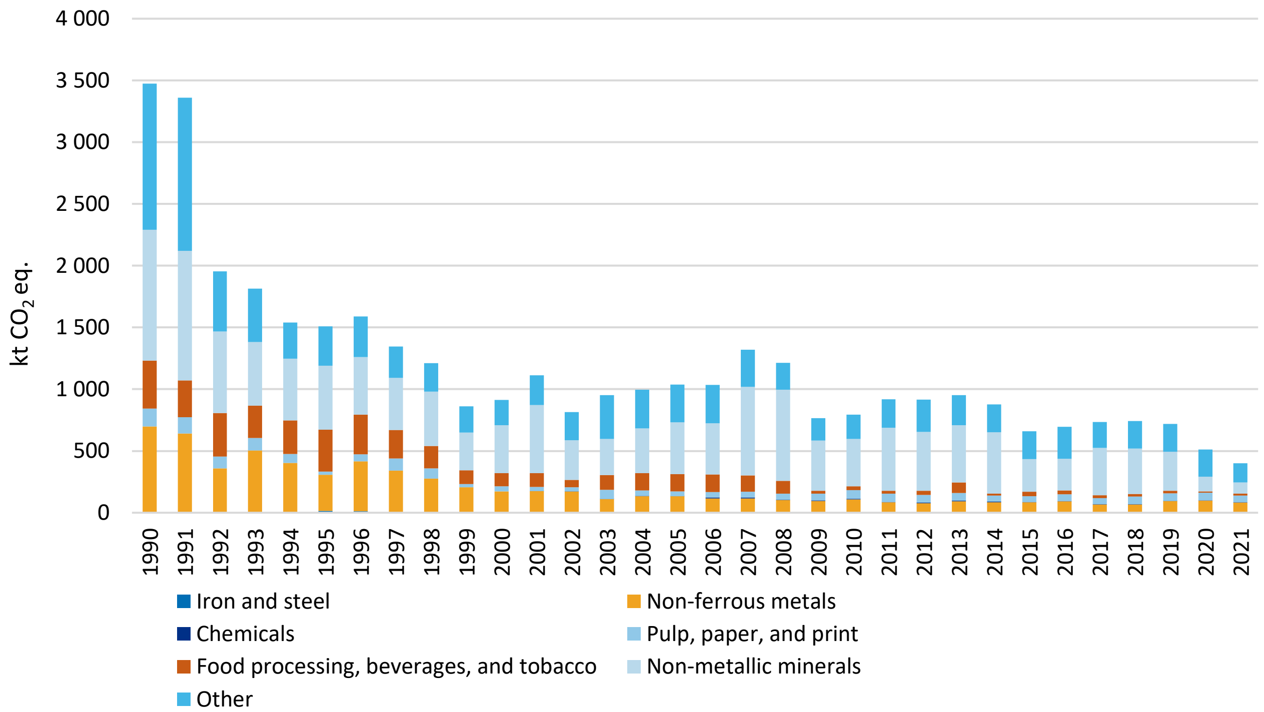


Figure 3.9. Trend of GHG emissions from Manufacturing industries and construction by relevant sub-categories in 1990–2021, kt CO_2 eq.

The **1.A.2.a Iron and steel** CRF 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. The production stabilised 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 2021 the emissions were 0.73 kt CO_2 eq. which is 52.7% increase as the export of goods recovered compared to the previous year.

The trend of GHG emissions in 1.A.2.a Iron and steel in 1990–2021 is presented in Figure 3.10.

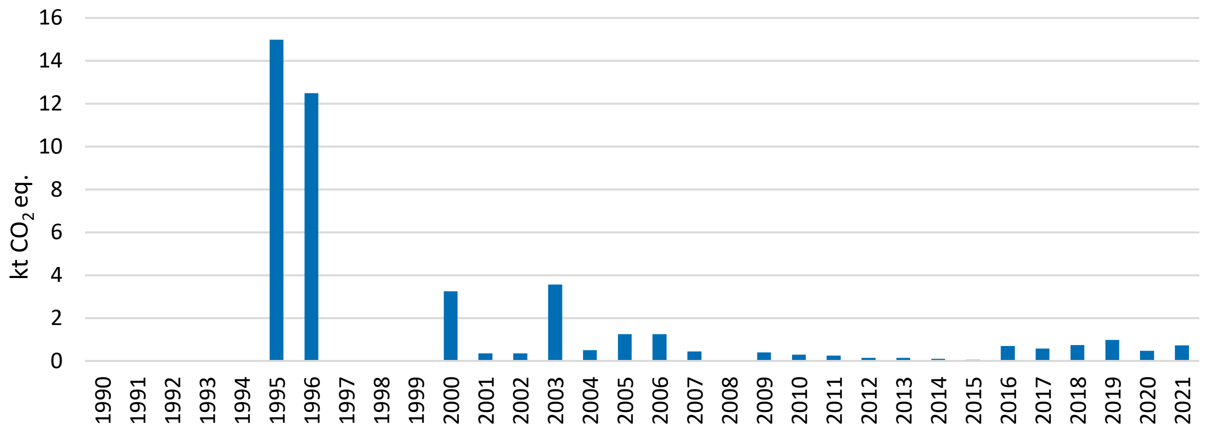


Figure 3.10. Trend of GHG emissions from Iron and steel in 1990–2021, kt CO_2 eq.

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 2021 the emissions from Non-ferrous metals were 0.50 kt CO_2 eq. and decreased 60% compared to 2020 and due to poor availability and growing prices of raw materials. The GHG emission trend matches the trend of fuel consumption in this sub-category.

Figure 3.11. presents the trend of GHG emissions in 1.A.2.b Non-ferrous metals in 1990–2021.

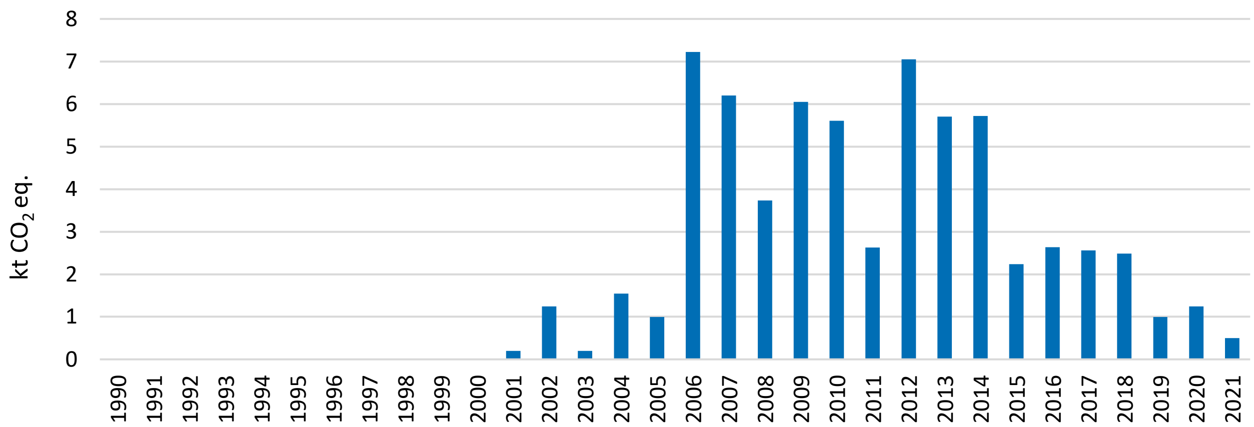


Figure 3.11. Trend of GHG emissions from Non-ferrous metals in 1990–2021, kt CO_2 eq.

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 3.7% of the Manufacturing industries and construction sector GHG emissions in 2021 and were 14.65 kt CO_2 eq and increased 36.1% compared to the previous year due to increasing export

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 3.12. presents the trend of GHG emissions from 1.A.2.c Chemicals in 1990–2021.

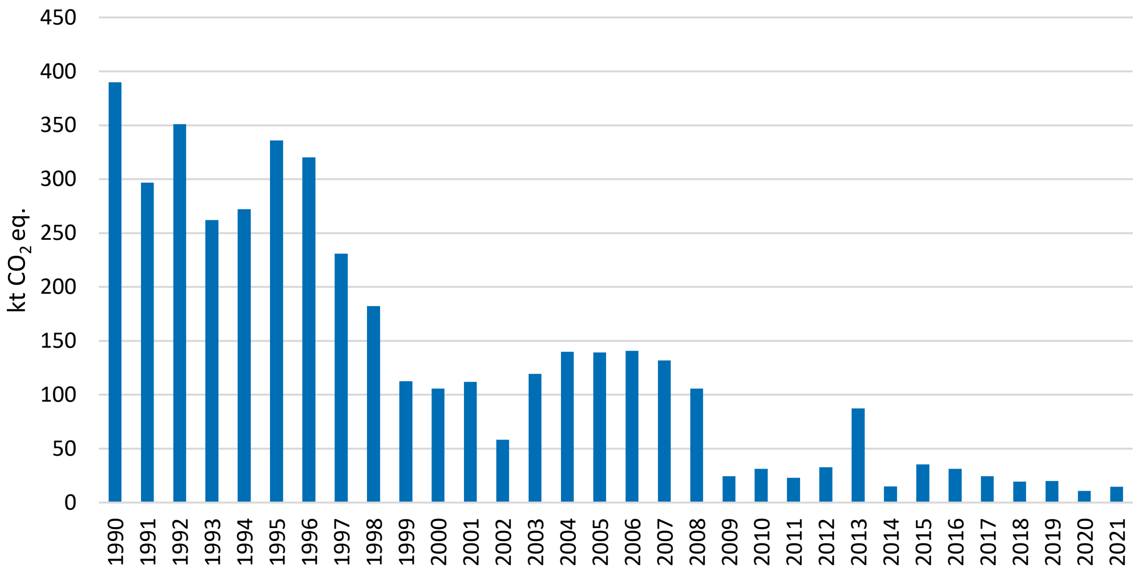


Figure 3.12. Trend of GHG emissions from Chemicals in 1990–2021, kt CO_2 eq.

The CRF sub-category **1.A.2.d Pulp, paper, and print** formed about 14.2% of the Manufacturing industries GHG emissions in 2021 with emissions of 56.4 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. In 2009 the paper production decreased again due to the economic depression, but in 2010 started to rise from the growth of export. The emission decrease in 2011 and 2012 is related to the dropping consumption of natural gas. In 2013 the emissions decreased about 2% compared to 2012. In 2014 the emissions declined about 19%. However, in 2016 a considerable increase in emissions occurred. The emissions raised about 12% compared to the previous year. The relative growth was extensive; however, the absolute growth is quite insignificant compared to the overall emissions of Estonia. The increase is predominantly a result of the increased usage of natural gas. In 2021 GHG emissions decreased 10.5% compared to 2020 as the use of solid biofuels increased and fossil fuels decreased. The above-described factors characterise the GHG emission trend in 1.A.2.d.

The trend of GHG emissions of 1.A.2.d Pulp, paper, and print in 1990–2021 is presented in Figure 3.13.

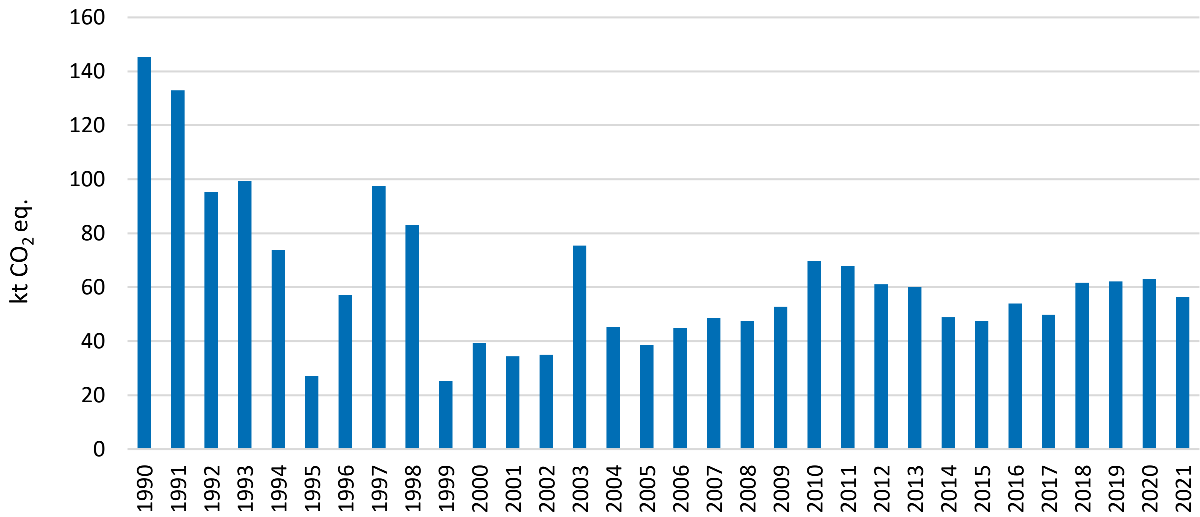


Figure 3.13. Trend of GHG emissions from Pulp, paper and print in 1990–2021, kt CO_2 eq.

The **1.A.2.e Food processing, beverage, and tobacco** CRF sub-category shares about 20.7% of the Manufacturing industries and construction with GHG emissions of 82.4 kt CO_2 eq. in 2021 and decreased 16% compared to the previous year because of decrease in production volume of food products

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. 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 has steadily recovered since the economic crisis. Situation in the foreign market is not affecting this sector that much.

Figure 3.14. describes GHG emissions trend in 1.A.2.e Food processing, beverages, and tobacco in 1990–2021.

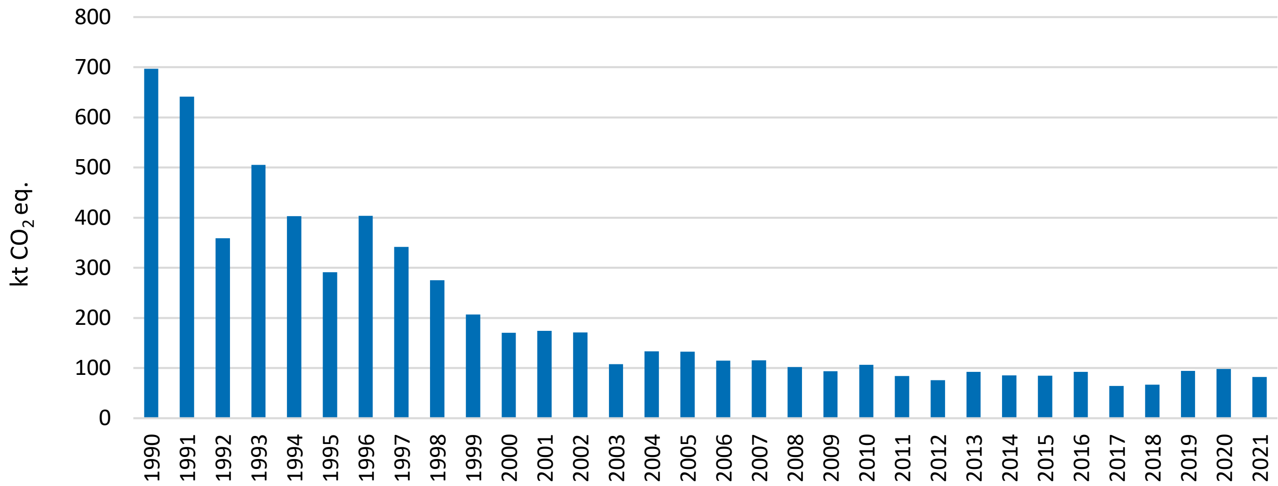


Figure 3.14. Trend of GHG emissions from Food processing, beverages, and tobacco in 1990–2021, kt CO_2 eq.

The **1.A.2.f Non-metallic minerals** CRF category has the is the second largest share in Manufacturing industries and construction with 22.4% and 89.3 kt CO_2 eq. in 2021. The main share of GHG emissions in this sub-category is cement production. Therefore, the trend of GHG emissions follows the trend of fuels used in cement production. In 2015, the emissions decreased about 46.7% compared to 2014 due to an unfavourable cement market. In 2020 emissions decreased about 63% 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 2021 the emissions decreased 23.7% due to a decrease of waste and solid fuel consumption as the EU ETS allowance prices continued to rise.

The trend of GHG emissions in 1.A.2.f Non-metallic minerals in 1990–2021 is presented in Figure 3.15.

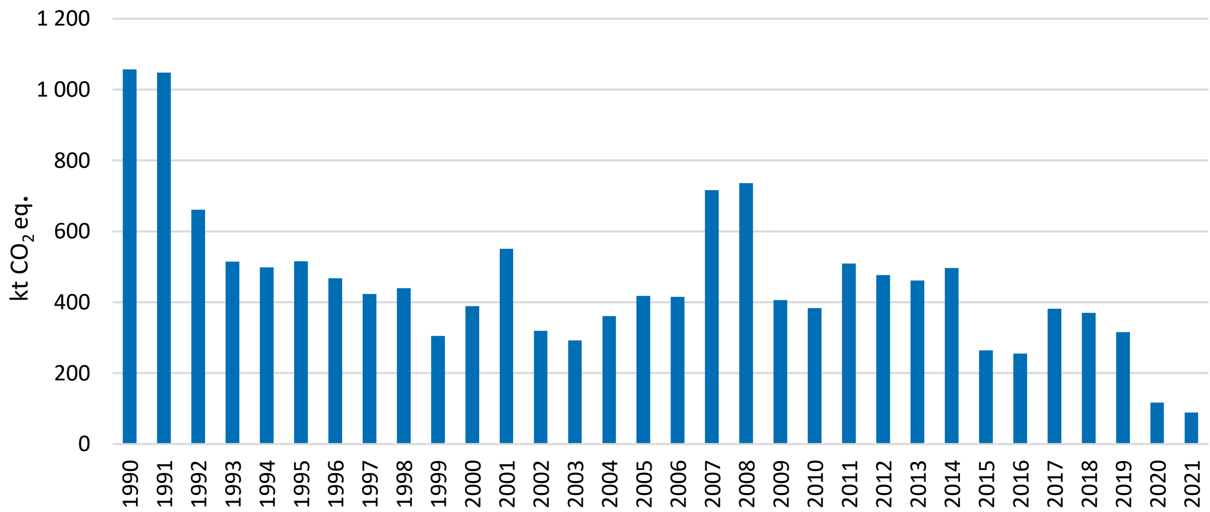


Figure 3.15 Trend of GHG emissions from Non-metallic minerals in 1990–2021, kt CO2 eq.

The **1.A.2.g Other** sub-category has the biggest share in Manufacturing industries and construction sector with close to 39% share in 2021.

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'. 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 15.1% compared to 2010 because of overall economic upturn. The slight increase of emissions in 2016 was caused by the decrease in biomass consumption in Wood and wood products industry sub-sector as there was an introduction of new economical technologies in wood processing or switching to a different fuel. The fuel consumption can be viewed in Figure 3.18. In 2021 emissions decreased 30.3% next to 2020 mostly in the construction industry sector due to decreased production.

Figure 3.16. presents the trend of GHG emissions of 1.A.2.g Other in 1990–2021.

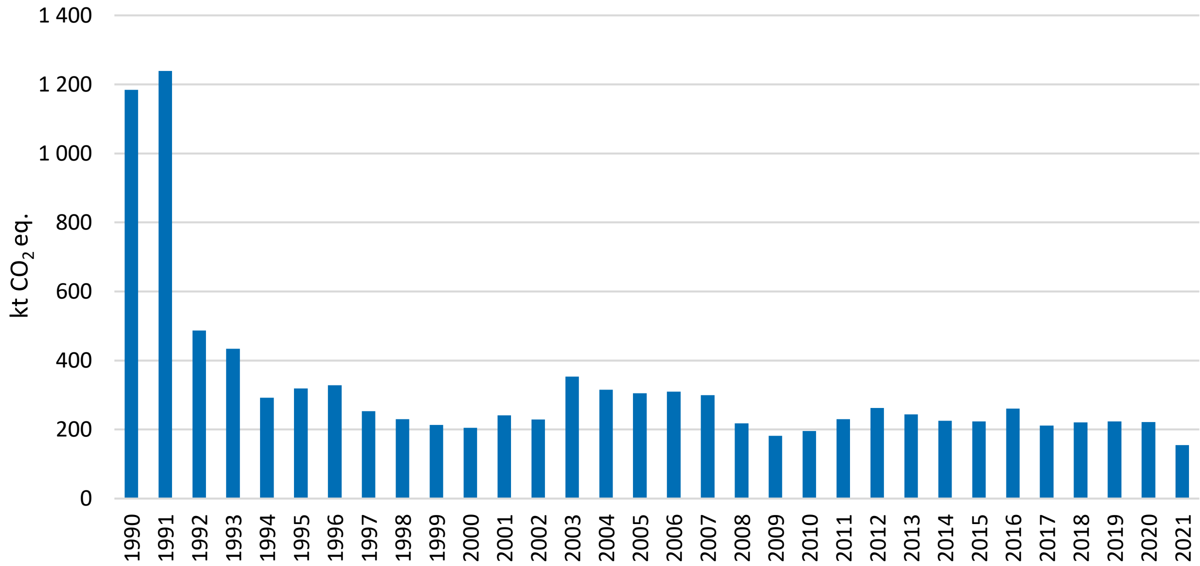


Figure 3.16. Trend of GHG emissions from Other in 1990–2021, kt CO_2 eq.

The values of CO_2 EFs of liquid and solid fuels are fluctuating due to changes in the contribution of different liquid and solid fuels in these fuel groups over time.

The emissions from Energy industries are presented in Table 3.5 and Manufacturing industries and construction are in Table 3.6.

Table 3.5. GHG emissions from Energy industries by relevant subcategories in 1990, 1995, 2000, 2005, 2010, and 2015-2021, kt CO_2 eq.

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A.1 Energy Industries Total, CO_2 eq.	28284.55	13798.33	11708.30	12611.52	15012.30	11841.18	13441.98	14459.53	13589.85	8150.71	5751.49	6994.68
1.A.1.a Public Electricity and Heat Production Total, CO_2 eq.	28205.99	13700.95	11538.33	12383.33	14510.35	10662.56	12173.35	12989.61	12022.96	6538.16	4188.54	5445.05
1.A.1.c Manufacture of Solid Fuels and Other Energy Industries Total, CO_2 eq.	78.56	97.37	169.97	228.19	501.95	1178.62	1268.63	1469.92	1566.89	1612.56	1562.94	1548.63

Table 3.6. GHG emissions from Manufacturing industries and construction by relevant subcategories 1990, 1995, 2000, 2005, 2010, and 2015-2021, kt CO_2 eq.

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A.2 Manufacturing Industries and Construction Total, CO_2 eq.	**3474.10**	**1503.74**	**912.99**	**1036.64**	**793.00**	**658.43**	**696.61**	**735.47**	**741.09**	**717.91**	**512.80**	**398.82**
1.A.2.a Iron and Steel, CO_2 eq.	NO	14.98	3.24	1.24	0.30	0.05	0.70	0.58	0.75	0.97	0.48	0.73
1.A.2.b Non-Ferrous metals, CO_2 eq.	NO	NO	NO	1.00	5.60	2.24	2.64	2.56	2.49	1.00	1.24	0.50
1.A.2.c Chemicals, CO_2 eq.	389.90	335.78	105.79	139.32	31.31	35.31	31.34	24.46	19.34	20.00	10.77	14.65
1.A.2.d Pulp, Paper and Print, CO_2 eq.	145.35	27.24	39.27	38.60	69.82	47.61	54.05	49.87	61.72	62.21	63.03	56.44
1.A.2.e Food Processing, Beverages and Tobacco, CO_2 eq.	697.01	291.27	170.38	132.62	106.57	85.05	92.50	64.62	66.55	94.11	98.11	82.42
1.A.2.f Non-Metallic Minerals, CO_2 eq.	1057.16	515.63	389.16	418.51	384.11	264.82	255.11	381.49	369.91	316.15	117.09	89.33
1.A.2.g Other, CO_2 eq.	1184.69	318.85	205.15	305.35	195.28	223.36	260.28	211.89	220.35	223.47	222.07	154.75

NO – no emissions occurred

3.2.4.2. Methodological issues

Emissions from Fuel combustion in 1.A.1 and 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, shale oil, oil shale semi-coke, oil shale semi-coke gas, generator gas, and peat – *Tier 2* and *Tier 3* approaches are used.

Oil Shale

Oil shale is a primary indigenous fuel in Estonia. 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[18].

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[18].

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[18].

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 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.

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

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.

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

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[19]

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

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'[19] 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 3.9.

Shale Oil

In Estonia shale oil production takes place in three plants: **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 **Eesti Energia Narva Õlitööstus AS** (Estonian Power Narva Oil Industry Ltd.) in Narva.

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.

[19] Riigi Teataja. Välisõhku väljutatava süsinikdioksiidi heite arvutusliku määramise meetodid. [www] https://www.riigiteataja.ee/akt/129122016063?leiaKehtiv (04.03.2023).

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[20]. 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[20] and the rest to the ash hill.

In 2021 78.3 PJ of oil shale was consumed for shale oil production in total and processing of 57.9 PJ of oil shale caused direct CO_2 emissions at the plants (see Table 3.7). This occurs because of a difference in technologies as no CO_2 is emitted directly from gas generator-type plants, however, CO_2 is emitted in solid heat carrier-type plants.

Table 3.7. 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**
1991	1.77	NO	NO	1.77	19.05	5.24	24.29	**26.06**
1992	2.57	NO	NO	2.57	18.22	5.26	23.47	**26.05**
1993	4.20	NO	NO	4.20	20.09	5.44	25.53	**29.73**
1994	4.75	NO	NO	4.75	18.14	5.00	23.14	**27.89**
1995	4.31	NO	NO	4.31	20.14	5.35	25.49	**29.81**
1996	4.58	NO	NO	4.58	21.42	5.37	26.79	**31.38**
1997	5.15	NO	NO	5.15	21.22	5.47	26.69	**31.84**
1998	4.35	NO	NO	4.35	13.14	4.34	17.49	**21.83**
1999	4.14	NO	NO	4.14	9.75	0.47	10.23	**14.37**
2000	5.86	NO	NO	5.86	13.57	5.30	18.87	**24.73**
2001	6.24	NO	NO	6.24	15.38	5.29	20.67	**26.91**
2002	6.74	NO	NO	6.74	16.13	5.52	21.65	**28.38**
2003	7.66	NO	NO	7.66	16.93	5.49	22.42	**30.08**
2004	8.13	NO	NO	8.13	17.63	4.69	22.32	**30.44**
2005	8.87	NO	NO	8.87	17.78	4.21	22.00	**30.86**
2006	8.40	NO	NO	8.40	19.73	4.17	23.90	**32.30**
2007	7.96	NO	NO	7.96	20.72	4.26	24.98	**32.94**
2008	10.85	NO	NO	10.85	19.99	3.87	23.86	**34.70**
2009	13.07	NO	NO	13.07	20.45	4.04	24.49	**37.56**
2010	14.74	2.22	0.20	17.15	21.15	4.10	25.25	**42.40**
2011	13.39	5.48	0.54	19.41	21.28	3.93	25.21	**44.62**
2012	15.13	6.00	0.31	21.44	21.18	3.86	25.04	**46.48**

[20] 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.

Year	Solid Heat Carrier			Total	Gaseous Heat Carrier		Total	Total
	Narva	VKG	Kiviõli	in SHC	VKG	Kiviõli	in gas generators	Oil shale
2013	15.59	6.43	0.18	22.20	21.45	3.96	25.42	**47.61**
2014	18.76	9.37	0.35	28.48	21.35	4.18	25.53	**54.01**
2015	23.86	18.61	0.40	42.88	15.36	4.91	20.27	**63.15**
2016	21.67	23.88	1.50	47.04	5.71	4.85	10.56	**57.61**
2017	26.75	24.45	1.65	52.85	15.54	5.39	20.94	**73.78**
2018	27.26	26.64	1.91	55.81	18.16	5.35	23.50	**79.31**
2019	28.70	28.06	1.82	58.57	19.19	5.01	24.20	**82.78**
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**

NO – no consumption occurred

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 3.8 semi-coke gas and generator gas production data for different shale oil plants is presented.

Table 3.8. 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**
1991	0.39	NO	NO	0.39	2.47	0.37	2.84	**3.23**
1992	0.62	NO	NO	0.62	2.52	0.41	2.94	**3.56**
1993	1.06	NO	NO	1.06	2.65	0.42	3.07	**4.13**
1994	0.91	NO	NO	0.91	2.74	0.41	3.14	**4.05**
1995	0.90	NO	NO	0.90	2.69	0.46	3.15	**4.05**
1996	1.00	NO	NO	1.00	2.91	0.43	3.34	**4.34**
1997	1.05	NO	NO	1.05	2.85	0.42	3.27	**4.32**
1998	0.92	NO	NO	0.92	1.30	0.35	1.66	**2.58**
1999	0.79	NO	NO	0.79	1.20	0.04	1.24	**2.03**
2000	1.04	NO	NO	1.04	1.75	0.43	2.17	**3.21**
2001	1.26	NO	NO	1.26	1.97	0.47	2.44	**3.70**
2002	1.26	NO	NO	1.26	2.15	0.49	2.64	**3.89**
2003	1.32	NO	NO	1.32	2.27	0.48	2.74	**4.06**
2004	1.48	NO	NO	1.48	2.70	0.48	3.18	**4.66**
2005	1.60	NO	NO	1.60	2.46	0.86	3.32	**4.92**
2006	1.48	NO	0.05	1.53	3.08	0.90	3.98	**5.50**
2007	1.40	NO	0.01	1.41	3.41	0.77	4.18	**5.59**
2008	1.83	NO	0.01	1.84	3.32	0.40	3.72	**5.55**
2009	2.19	NO	0.01	2.20	3.37	0.51	3.89	**6.09**
2010	2.66	0.35	0.06	3.06	2.75	0.56	3.31	**6.38**
2011	2.55	0.76	0.06	3.38	2.64	0.68	3.32	**6.69**
2012	2.83	0.89	0.06	3.78	2.74	0.63	3.37	**7.15**
2013	2.73	0.96	0.03	3.71	2.61	0.66	3.27	**6.98**
2014	3.18	1.39	0.06	4.63	2.48	0.71	3.19	**7.81**
2015	4.14	5.23	0.09	9.45	2.52	0.83	3.36	**12.81**

Year	Solid Heat Carrier			Total	Gaseous Heat Carrier		Total	Total
	Narva	VKG	Kiviõli	in SHC	VKG	Kiviõli	in gas generators	Oil shale gas
2016	4.08	4.44	NO	8.52	0.54	0.85	1.39	**9.91**
2017	5.19	3.32	NO	8.51	1.27	0.89	2.16	**10.67**
2018	5.25	5.59	NO	10.84	2.16	1.07	3.23	**14.07**
2019	5.52	5.60	NO	11.12	2.11	1.14	3.25	**14.37**
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**

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 2 (A.2.1.1). GHG emissions from the combustion of different oil shale gases are calculated separately and included into CRF 1.A.1.a Public electricity and heat production under Solid fuels. Consumption of oil shale gases as well as CO_2, CH_4, and N_2O are presented separately in Annex 2 (A.2.1.2).

Waste incineration

Kunda Nordic Tsement AS (Kunda Nordic Cement Ltd.) and **Eesti Energia Iru elektrijaam (**Estonian Power Iru incineration plant**)** use waste in their daily activity.

Kunda Nordic Cement uses waste oils, plastic waste, and other fossil-based solid waste as an alternative fuel source to produce cement, clinker, and splinters. The cement is made in a wet process. Limestone and clay are used for raw material and shale oil is the main fuel source. In 2020 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 two studies conducted at the Iru waste plant in 2015[21] and 2019[22], so the carbon emission factors and waste fractions are plant specific. For the years 2013-2018 the biogenic fraction of waste is 65% and fossil 21%, from 2019 for the local waste the biogenic fraction is 63% and fossil 23%, and for the imported waste the biogenic part of 59% and fossil part of 29% is used. Inert waste is not included in the calculations.

[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.

CO_2 emission factors and other parameters

Carbon emission factors, oxidation factors, and net calorific values used in the emission calculations in 1.A.1 and 1.A.2 are presented below in Table 3.9.

Table 3.9. Carbon emission factors, oxidation factors, and net calorific values in 2021

Fuels	NCV average	Unit	CEF, tC/TJ	Oxidation factor	Source of emission factor
Liquid fuels					
LPG	45.5	GJ/t	17.31	1	CS (Estonia)
Motor gasoline	44	GJ/t	19.14	1	CS (Estonia)
Light fuel oil	42.5	GJ/t	20.17	1	CS (Estonia)
Diesel oil	42.3	GJ/t	19.98	1	CS (Estonia)
Residual fuel oil (heavy fuel oil)	40.15	GJ/t	20.14	1	CS (Estonia)
Solid fuels					
Coal	22.00	GJ/t	25.75	1	CS (Estonia)
Coke oven coke	28.5	GJ/t	29.02	1	CS (Estonia)
Oil shale CFB (fludised bed combustion)	8.16	GJ/t	26.42 – 27.25	1	PS (Estonia)
Oil shale PC (pulverised combustion)	7.47	GJ/t	27.76 – 29.14	1	PS (Estonia)
Milled&sod peat[23]	10.1	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)	56.95	GJ/1000 m^3	18.69	1	PS (Estonia)
Oil shale semi-coke gas (SHC technology, Narva Enefit 280 plant)	47.76	GJ/1000 m^3	19.58	1	PS (Estonia)
Oil shale semi-coke gas (VKG Petroter I plant)	43.12	GJ/1000 m^3	18.78	1	PS (Estonia)
Oil shale semi-coke gas (VKG Petroter II plant)	43.12	GJ/1000 m^3	18.78	1	PS (Estonia)
Oil shale generators gas (VKG Petroter III plant)	43.12	GJ/1000 m^3	18.78	1	PS (Estonia)
Oil shale semi-coke gas (Kiviõli plant)	49.33	GJ/1000 m^3	18.69	1	PS (Estonia)
Oil shale generator gas (Kiviõli plant)	2.73	GJ/1000 m^3	42.10	1	PS (Estonia)
Oil shale generator gas (VKG plant)	2.90	GJ/1000 m^3	47.15	1	PS (Estonia)
Gas gasoline	44	GJ/t	19.09	1	CS (Estonia)
Waste oils (CRF 1.A.2.f)*	25.67	GJ/t	20.18	1	PS, Kunda Nordic Cement
Other fossil based solid waste (MSW) (CRF 1.A.2.f)	17.79	GJ/t	21.82	1	PS, Kunda Nordic Cement
Plastic waste (CRF 1.A.2.f)	21.12	GJ/t	20.45	1	PS, Kunda Nordic Cement
Municipal solid waste (MSW, fossil part) (CRF 1.A.1.a)	10.25	GJ/t	51.72	1	PS, Iru incineration plant
Natural gas	33.6	GJ/1000 m^3	15.07	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 (CRF 1.A.2.f)	16.69	GJ/t	21.82	1	PS, Kunda Nordic Cement
Municipal solid waste (MSW, biogenic part) (CRF 1.A.1.a)	10.25	GJ/t	20.28	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; *biogenic and non-biogenic origin

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

CH_4 and N_2O emission factors for 1.A.1 Energy industries and 1.A.2 Manufacturing industries and construction for different fuels are presented in Table 3.10. 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 3.10. 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[24]
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					
Coal	1	1.5	10	1.5	D, IPCC 2006
Coke oven coke			10	1.5	D, IPCC 2006
Oil shale $_{PC}$[18]	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[24]
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)
Waste oils	–	–	30	4	D, IPCC 2006
Other fossil based waste (MSW)	–	–	30	4	D, IPCC 2006
Plastic waste	–	–	30	4	D, IPCC 2006
Municipal solid waste	0.004*	0.17*	–	–	CS[24]
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

In 1.A.2.g Other emissions from off-road vehicles such as excavators, loaders, and road work machines are also estimated. Activity data of off-road vehicles and emission factors used for estimating GHG emissions can be found in Chapter 3.2.5.4 Off-road vehicles. In Table 3.34 the carbon emission factors of motor fuels used for off-road vehicles are presented, in Table 3.35 CH_4 emission factors and Table 3.36 N_2O emission factors of motor fuels used for off-road transportation are presented.

---

[24]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.

Emission factors of indirect greenhouse gases from Fuel combustion

The NO_x, CO, and NMVOC emission factors used in the Estonian inventory 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 2019 are used[25]. The oil shale direct combustion data is plant-specific, so an average emission factor is provided in the following tables. The emission factors are presented in Table 3.11, Table 3.12, and

Table 3.**13**.

Table 3.11. NO_x emission factors from Fuel combustion (kg/TJ)

	Coal	Natural Gas	Heavy Fuel Oil	Gas Oil	Biomass	Oil Shale	Peat
Energy industries	200	100	250	100	100	79.02*	300
Manufacturing and construction	173	100	513		100	110	300
Other sectors	200	6	51		100	110	300

* – plant-specific

Table 3.12. CO emission factors from Fuel combustion (kg/TJ)

	Coal	Natural Gas	Heavy Fuel Oil	Gas Oil	Biomass	Oil Shale	Peat
Energy industries	100	40	100	100	200	0.88*	100
Manufacturing and construction	931	50	66		700	87	650
Other sectors	5 000	26	57		5 009	5000	5000

* – plant-specific

Table 3.13. NMVOC emission factors from Fuel combustion (kg/TJ)

	Coal	Natural Gas	Heavy Fuel Oil	Gas Oil	Biomass	Oil Shale	Peat
Energy industries	1.5	2.5	3	1.5	48	0*	100
Manufacturing and construction	88.8	2.5	25		48	60	100
Other sectors	600	1.9	0.69		271.58	600	600

***** – plant-specific

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[26] and added to Annex 3 (A.3.2). Some detailed data (i.e. pulverised and fludised bed combustion of oil shale consumption in Narva power plants; shale oil, and semi-coke gas production in Narva oil plant)

[25]EMEP/EEA air pollutant emission inventory guidebook – 2019.
[www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion

[26]Eesti Statistikaameti andmebaas. [www] https://andmed.stat.ee/et (14.03.2023)

is obtained from the energy company Eesti Energia 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 plants.

Municipal solid waste incineration data in 1.A.1.a is plant specific and taken from The Environmental Board database KOTKAS. Other fossil fuels, plastics, and waste oils incinerated in 1.A.2.f Non-metallic minerals subcategory is also plant specific and recieved from Estonian Environment Agency (EstEA) upon request.

Fuel consumption in Energy industries (CRF 1.A.1) and Manufacturing industries and construction (CRF 1.A.2) in 1990–2021 is presented in Figure 3.17, Figure 3.18, Table 3.14, and Table 3.15.

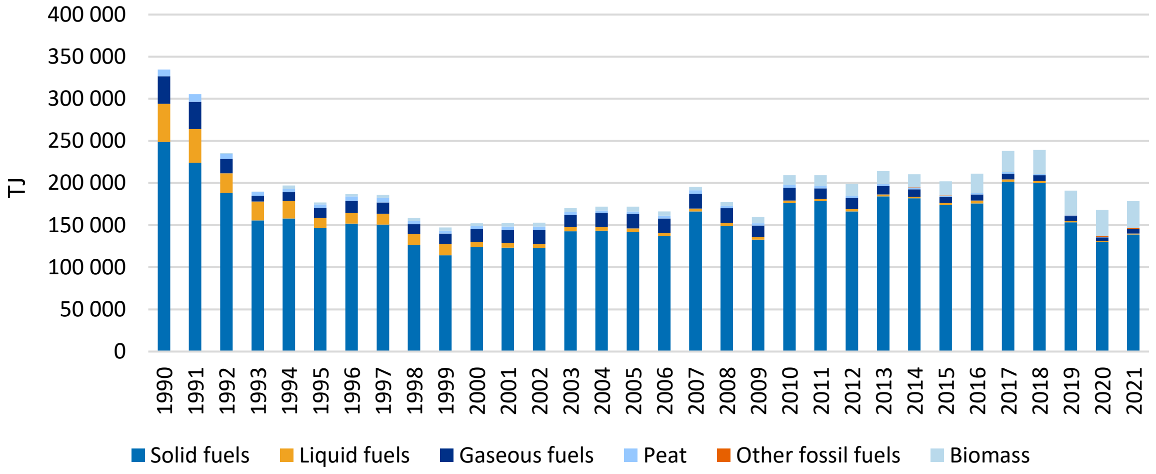


Figure 3.17 Trend of fuel consumption in Energy industries, TJ

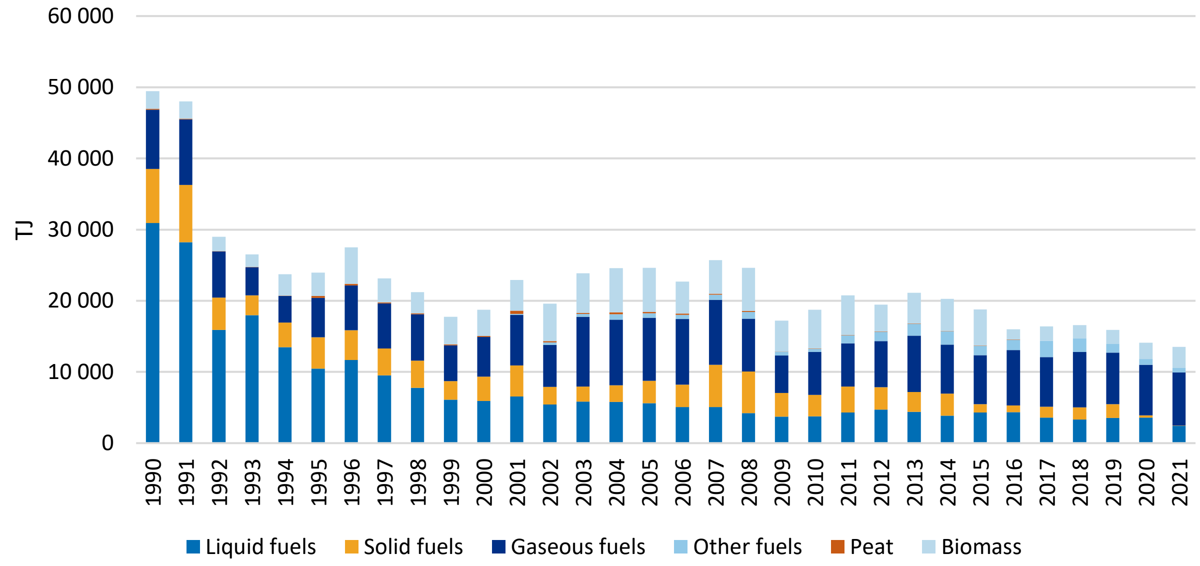


Figure 3.18 Trend of fuel consumption in Manufacturing and construction, TJ

Table 3.14. Fuel consumption in Energy industries in 1990, 1995, 2000, 2005, 2010, and 2015–2021, TJ

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A.1 Energy industries	**330 776**	**172 979**	**149 213**	**166 996**	**202 873**	**189 211**	**201 248**	**227 383**	**225 334**	**176 644**	**154 654**	**165 474**
Liquid fuels	45 263	12 073	5 866	4 342	3 255	2 243	3 060	2 711	2 239	1 390	1 442	817
Solid fuels	244 766	142 405	120 724	136 935	169 785	161 220	166 094	191 028	186 192	139 115	116 103	126 180
Gaseous fuels	32 792	11 927	16 135	17 551	14 882	7 035	7 362	6 924	6 779	5 830	4 303	5 681
Peat	7 956	4 315	2 806	2 509	3 636	1 345	1 366	1 641	1 420	965	641	199
Biomass	0	2 259	3 666	5 642	11 300	16 792	22 705	24 546	28 169	28 766	31 509	31 944
Other fossil fuels[27]	0	0	0	0	0	575	554	532	535	537	657	655

Table 3.15 Fuel consumption in Manufacturing industries and construction in 1990, 1995, 2000, 2005, 2010, and 2015–2021, TJ

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A.2 Manufacturing industries and construction	**45 027**	**22 506**	**15 475**	**19 835**	**15 401**	**13 957**	**10 876**	**11 640**	**11 712**	**11 373**	**9 409**	**8 867**
Liquid fuels	29 085	9 292	3 513	3 751	2 547	2 896	3 240	2 337	2 170	2 672	2 699	1 534
Solid fuels	7 585	4 409	3 253	2 884	2 927	1 174	939	1 523	1 669	1 902	260	7
Gaseous fuels	8 004	5 408	5 099	6 934	4 783	3 948	4 459	3 996	4 564	4 165	3 962	4 130
Peat	90	236	83	148	0	0	0	0	0	0	0	0
Biomass	264	3 161	3 318	5 509	4 678	4 626	802	1 480	1 333	1 414	1 648	2 371
Other fuels[28]	0	0	8	610	467	1 313	1 437	2 304	1 976	1 220	840	645

[27] Municipal solid waste combusted in Iru waste plant, fossil part of waste is included in Other fuels, biogenic part in Biomass
[28] Waste oils, Other fossil based waste, and Plastics combusted in Kunda Nordic Cement

3.2.4.3. Uncertainties and time-series consistency

Uncertainty evaluation of CO_2 emissions has been conducted for liquid, solid, gaseous, and other fuels used in Estonia in 2021. The data availability allows the estimation of uncertainty by a fuel type rather than by a sector in fuel combustion[29].

Incomplete details of source-specific measurement data of activities and emission factors lead to estimating quantitative uncertainty of CO_2 emission by using available estimates and the combination of available measured data;

Data has been taken from Statistics Estonia database.

In the estimation of uncertainty two main components have been considered:

- Uncertainty component for measurement procedure which provides the comparability of results.
- Uncertainty component for dispersion of the input quantity, which in some cases indicate the level of data disaggregation.

  The calculation formula of combined uncertainty in emission u_E is given as Equation 3.2:

Equation 3.2[30]

$$u_e = \sqrt{u_{AD}^2 + u_{EF}^2}$$

Where:

u_e = uncertainty of emissions;
u_{AD} = uncertainty of activity data;
u_{EF} = uncertainty of emission factor.

In gaining expanded uncertainty the coverage factor *k*=2 has been used to provide approximately 95% confidence level of the results (see Equation 3.3):

Equation 3.3[31]

$$U_E = 2 \times u_E$$

Where:

U_E= expanded uncertainty.

The uncertainty of CO_2 emission for fuel combustion in Energy category was evaluated separately for each fuel type. The key points of the evaluation are listed below:

- Liquid Fuels

All liquid fuels, except shale oil and residual fuel oil, are imported to Estonia. Quality requirements for liquid fuels and instrumentation were used in the evaluation of uncertainty of activity data and emission factors.

---

[29] Metrosert AS report: Uncertainty Estimation of CO_2 emission in the Estonian National Greenhouse Gas Inventory, April 2007, Tallinn, Estonia.
[30] IPCC 2006 Guidelines, Volume 1, Chapter 3; Uncertainties, page 3.28, equation 3.1
[31] IPCC 2006 Guidelines, Volume 1, Chapter 3; Uncertainties, page 3.8, Basis for uncertainty analysis

- Solid Fuels

There are two fuel types produced locally: oil shale and peat. The largest contribution to the uncertainty is caused by fluctuation in emission factors of those fuels.

- Gaseous Fuels

The gaseous fuels are imported to Estonia. Quality requirements for gaseous fuels and instrumentation were used in the evaluation of uncertainty of activity data and emission factors.

- Other Fuels

For calculation of uncertainty of CO_2 emission due to other fuels (waste fuels) combustion in the Energy category, Finnish uncertainty factors were used. The contribution to the total uncertainty of fuel combustion is rather small.

The uncertainty factors of carbon emission factors and activity data are presented in Table 3.16. The largest uncertainty contribution 60% is caused by incomplete data of the emission factor of other fuels (waste fuels).

Table 3.16. Estimated relative uncertainties of CO_2 emission due to Fuel combustion in Estonia in 2021[32]

GHG Source and Sink Categories	Gas	Uncertainty of activity data, %	Uncertainty of emission factor, %	Combined relative uncertainty, %
1.A Fuel combustion				
Liquid fuels	CO_2	1.7	1.8	2.5
Solid fuels	CO_2	3.3	38.9*	39.0
Gaseous fuels	CO_2	1.4	3.6	3.9
Other fuels*	CO_2	5	60	60.2

*The uncertainty of the emission factors of the solid fuels category 1.A.1.a is significantly lower – 2.39%.

To estimate the uncertainties of CH_4 and N_2O emissions the IPCC default values for activity data (5% and 10%) and for CH_4 emission factors (25%–150%) were used. For N_2O emission factor uncertainties (50%–125%) IPCC default and some Finnish values were used (see Table 3.17).

Table 3.17. Summary of uncertainty estimates of CH_4 and N_2O emission factors and activity data (95% confidence interval)

Source and Sink	GHG	Activity data uncertainty U_A	Emission factor uncertainty U_E	Reference U_A. U_E
1.A.1 Energy industries				
Liquid, solid, and gaseous fuels	CH_4	5%	50%	**U_A** – IPCC GPG, Table 2.6, p. 2.41 **U_E** – IPCC GPG, Table 2.5, p. 2.41
	N_2O	5%	60%	**U_A –** IPCC GPG, Table 2.6, p. 2.41 **U_E –**Finnish[33]
Biomass	CH_4	5%	60%	**U_A –** IPCC GPG, Table 2.6, p. 2.41 **U_E –** Finnish[33]
	N_2O	5%	60%	**U_A –** IPCC GPG, Table 2.6, p. 2.41 **U_E –** Finnish[33]
1.A.2 Manufacturing industries and constructions				

[32] IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories.
[33] Finnish National Inventory Document 1990–2021.

Source and Sink	GHG	Activity data uncertainty U_A	Emission factor uncertainty U_E	Reference U_A, U_E
Liquid, solid, and gaseous fuels	CH_4	5%	50%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – IPCC GPG, Table 2.5, p. 2.41
	N_2O	5%	60%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]
Biomass	CH_4	5%	60%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]
	N_2O	5%	60%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]
Other fuels	CH_4	5%	60%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]
	N_2O	5%	60%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]

As the Good Practice Guidance does not give CH_4 emission factors uncertainty estimations (U_E) for biomass, and N_2O emission factors (U_E) for biomass and fossil fuels, those factors have been taken from the Finnish 2020 national inventory.

Detailed uncertainty estimations by categories are presented in Annex 1.

3.2.4.4. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.2.3. A complete Quality Assurance (QA) and Quality Control (QC) was carried out for Energy industries and 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.

In the 2023 inventory submission Energy sector CO_2 emissions were compared against the emissions of European Union Emission Trading Scheme (EU ETS) enterprises (for the year 2021. 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 recalculation

Recalculations in 1.A.1 and 1.A.2 sub-categories are presented in Table 3.18.

Emissions were recalculated because of:

- correcting natural gas, peat, and coal consumption data in calculations, updating peat consumption data in 2020 in Joint Questionnaire in 1.A.1.a;
- updating methodology for calculating emissions from waste incineration in 1.A.1.a in 2013-2021;
- updating solid biomass consumption data in 1990-1991 in 1.A.1.a;
- dividing peat into peat briquette and milled&sod peat in calculations in the whole timeseries in 1.A.1.a and 1.A.2 in all sub-categories.
- updating the share of 1-50MW boilers using solid biomass in calculations for CH_4 and N_2O emission factors in 1.A.2.f;
- correcting natural gas CEF for the entire timeseries in calculations in 1.A.2.c.

Table 3.18 Differences between 2023 and 2022 submissions, kt CO_2 eq.

Year	1.A.1.a	1.A.2.c	1.A.2.d	1.A.2.e	1.A.2.f	1.A.2.g
1990	-2.50	-0.61	–	–	-0.13	–
1991	8.88	-1.07	–	–	0.02	–
1992	-1.59	0.01	–	–	-0.12	–
1993	-1.29	-0.27	–	–	0.03	–
1994	-1.34	0.09	–	–	0.03	–
1995	-1.39	-4.15	–	1.24	-0.69	–
1996	-0.43	0.21	0.01	0.83	-0.50	0.25
1997	-3.28	0.70	–	0.41	-0.39	0.17
1998	-3.17	0.64	–	0.33	0.02	0.08
1999	-18.09	0.27	–	0.27	0.05	–
2000	-18.70	-0.21	0.17	–	0.04	0.09
2001	-18.57	0.10	–	0.17	0.06	–
2002	-12.79	-0.30	–	0.16	0.05	–
2003	-15.61	0.12	–	0.08	0.04	–
2004	-14.85	-0.14	–	0.08	0.19	–
2005	-12.78	-0.11	–	0.08	0.11	–
2006	-7.94	-0.13	–	–	0.23	0.01
2007	-24.08	-0.05	–	–	0.25	–
2008	-25.99	-0.06	–	–	0.31	-0.04
2009	-22.83	–	–	–	0.24	–
2010	-25.03	–	–	–	0.55	–
2011	-25.89	–	0.18	–	0.30	–
2012	-20.97	-0.04	–	–	0.18	–

Year	1.A.1.a	1.A.2.c	1.A.2.d	1.A.2.e	1.A.2.f	1.A.2.g
2013	-35.09	-0.16	–	–	0.54	–
2014	-30.80	–	–	–	0.60	–
2015	-20.20	–	–	–	0.49	–
2016	-68.87	–	–	–	0.59	–
2017	-21.83	–	–	–	1.60	–
2018	-47.81	–	–	–	1.06	0.01
2019	-51.22	–	–	–	1.66	–
2020	-94.88	–	–	–	1.61	0.02

– no recalculations occurred

3.2.4.6. Category-specific planned improvements

There are no category-specific improvements planned.

3.2.5. Transport (CRF 1.A.3)

An effective transport system is a significant prerequisite for economic and social development. Transport also has an important social function to satisfy movement needs. In 2021 the number of registered vehicles increased, railway passengers rose, and goods transported by rail reduced. Passengers travelling by sea also increased as well as the number of goods transported.

3.2.5.1. Category description

In 2021 the greenhouse gas emissions from Transport sector amounted for 2350.65 kt CO_2 eq. The share of the Transport sector in the Energy sector was 22.6% and approximately 15.2 % of the total greenhouse gas emissions in 2021. Emissions from Transport include all domestic transport sectors (see Table 3.19):

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

Table 3.19. Reporting categories in the Transport sector

CRF category	Description	Remarks
CRF 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.	Fuel consumption and emissions from off-road vehicles are included in 1.A.2.g Other, 1.A.4.b Households, and 1.A.4.c Agriculture/forestry/fisheries. 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.	Fishing boat emissions are included in the CRF 1.A.4.c Agriculture/forestry/fisheries

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 7.2% 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 4.9% compared to the previous year due to increased diesel use in Road transport and aviation gasoline in Domestic aviation, and lifting the moving restrictions.

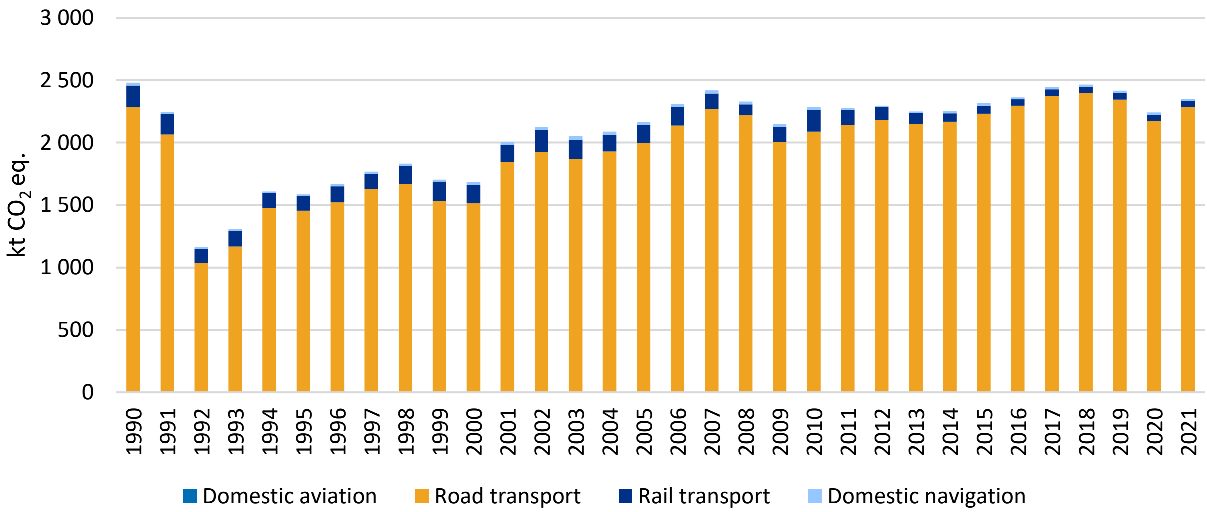


Figure 3.19. Emissions from Transport sector by subcategory in 1990–2021, kt CO_2 eq.

Road transportation is an essential emission source in the Transport sector covering 96.0% of the sector's emissions (see Figure 3.19). The fuel consumption and the emissions from the Transport sector are presented in Table 3.20 and Table 3.21.

Table 3.20. Emissions from the Transport sector by subcategories in 1990, 1995, 2000, 2005, 2010, and 2015–2021, kt CO_2 eq.

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A.3 Transport Total, CO_2 eq.	2480.27	1585.26	1682.50	2166.45	2285.18	2316.08	2363.53	2448.23	2466.16	2415.86	2241.84	2350.65
1.A.3.a Domestic Aviation, CO_2 eq.	5.56	3.26	2.42	4.71	2.80	4.15	3.39	3.58	4.07	3.91	3.59	5.62
1.A.3.b Road Transport, CO_2 eq.	2278.43	1451.57	1510.71	1993.14	2086.08	2228.32	2293.40	2370.85	2391.92	2340.68	2169.16	2279.02
1.A.3.c Rail Transport, CO_2 eq.	174.41	117.90	147.44	143.60	171.26	64.88	51.16	53.35	50.09	54.67	49.07	47.54
1.A.3.d Domestic Navigation, CO_2 eq.	21.87	12.53	21.94	24.99	25.04	18.72	15.58	20.45	20.08	16.59	20.02	18.47

Table 3.21. Fuel consumption in Transport sector in 1990, 1995, 2000, 2005, 2010, and 2015–2021, TJ

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A.3.a Domestic aviation												
Aviation gasoline	78	46	34	66	39	58	47	50	57	55	50	79
1.A.3.b Road transport												
Gasoline	21 567	10 734	12 131	12 522	11 946	9 922	10 487	11 011	11 233	11 266	8 840	8 234
Diesel oil	9 473	8 935	8 487	14 709	16 269	20 046	20 338	20 773	20 991	20 416	20 170	22 281
LPG	9	16	32	62	95	228	256	306	369	440	423	437
CNG	NO	NO	NO	NO	2	116	173	191	172	197	365	275
Biomass*	NO	NO	NO	6.2	314	107	84	45	820	1308	1879	2322
Other fossil fuels*	NO	NO	NO	0.3	6.2	NO	NO	0.3	24	27	37	35
1.A.3.c Railways												
Coal	179	50	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Light fuel oil	1 946	1 396	1 819	1 777	2 115	804	635	660	619	679	607	587
1.A.3.d Domestic navigation												
Diesel oil	296	169	296	338	338	254	212	277	272	226	271	250

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.

3.2.5.2. Domestic aviation

The number of passengers, who passed through international airport in Tallinn and domestic airports in 2021 increased in comparison with 2020. The passenger traffic volume of Estonian airports was over 1.34 million people, which is about 50% more than in 2020. About 1.30 million passengers were transported on international flights and over 42 thousand passengers were transported on domestic flights (27% more than in 2020). In 2021 compared to 2020, cargo and mail services through airports increased 14.9%, amounting to 10 560 tonnes.

At the end of 2021 the Register of Estonian Civil Aircraft included 211 units of aircraft.

The emissions from Domestic aviation (CRF 1.A.3.a) include all domestic aviation transport within Estonian flight regions, generally islands (see 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 0.24% with 5.62 kt CO_2 eq. in 2021. The increase compared with the previous year was on account of an increase in passenger traffic, cargo and mail services, increased LTO cycles, using larger and more powerful turboprop aircraft, and reopening one of the domestic airports for regular flights in 2021. The corresponding emissions were 5.56 kt CO_2 equivalent in 1990.

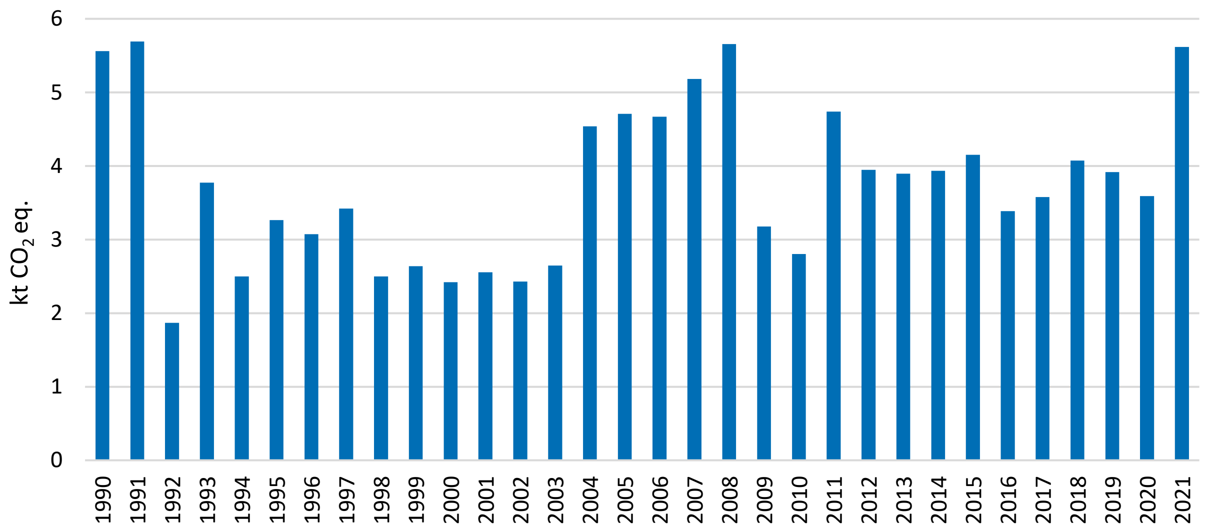


Figure 3.20. GHG emissions from Domestic aviation in 1990–2021, kt CO_2 eq.

Methods

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[34]

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

[34] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.2.

Equation 3.5[35]

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

Equation 3.6[36]

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

Activity data

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 3.7). 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 3.8).

Equation 3.7[37]

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

Equation 3.8[38]

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

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 2019 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 1992–2021. An extrapolation has been made for 1990 and 1991 (Table 3.22).

---

[35] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.3.
[36] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.5.
[37] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.4.
[38] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.5.

Table 3.22. Number of LTO cycles

Year	Domestic LTO	International LTO
1992	2 249	5 247
1993	2 398	5 595
1994	2 366	5 520
1995	3 754	8 760
1996	4 819	11 243
1997	4 516	10 537
1998	4 922	11 484
1999	4 672	10 901
2000	4 778	12 303
2001	4 255	10 408
2002	8 720	15 894
2003	8 025	14 040
2004	6 243	15 868
2005	7 740	17 907
2006	7 219	15 460
2007	7 958	17 078
2008	8 212	20 501
2009	7 598	14 122
2010	7 637	14 855
2011	8 320	17 344
2012	8 692	21 811
2013	7 924	16 672
2014	7 508	16 775
2015	8 097	18 087
2016	6 987	18 292
2017	7 640	20 245
2018	7 372	21 960
2019	8 014	21 391
2020	7 095	8 678
2021	7 676	10 265

Emission factors and other parameters

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 2019 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 2019 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 2021 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[39]	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

Emission factors in kg/tonne of aviation gasoline are converted to kg/TJ using net average calorific value of aviation gasoline. The results for 2021 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

3.2.5.3. Road transport

Road transport (CRF 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 in the CRF category 1.A.4.c Agriculture/forestry/fisheries.

Road transport is the most important emission source in the Transport sector. The emissions from Road transportation of 2 279.02 kt CO_2 eq. in 2021 is about 96.0% of total Transport sector emissions and 21.9% of the Energy sector. In 2021 the GHG emissions of the Road transport sector were about 0.03% 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. In 2013 the emissions decreased about 1.6% as compared to the previous year through an overall decreaseing use of fuels in road transportation. 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 5.1% due to increased use of diesel oil and increased mileage of heavy duty trucks.

[39] EMEP/EEA air pollutant emission inventory guidebook 2019, Table 3-3, p.21 (average fleet).

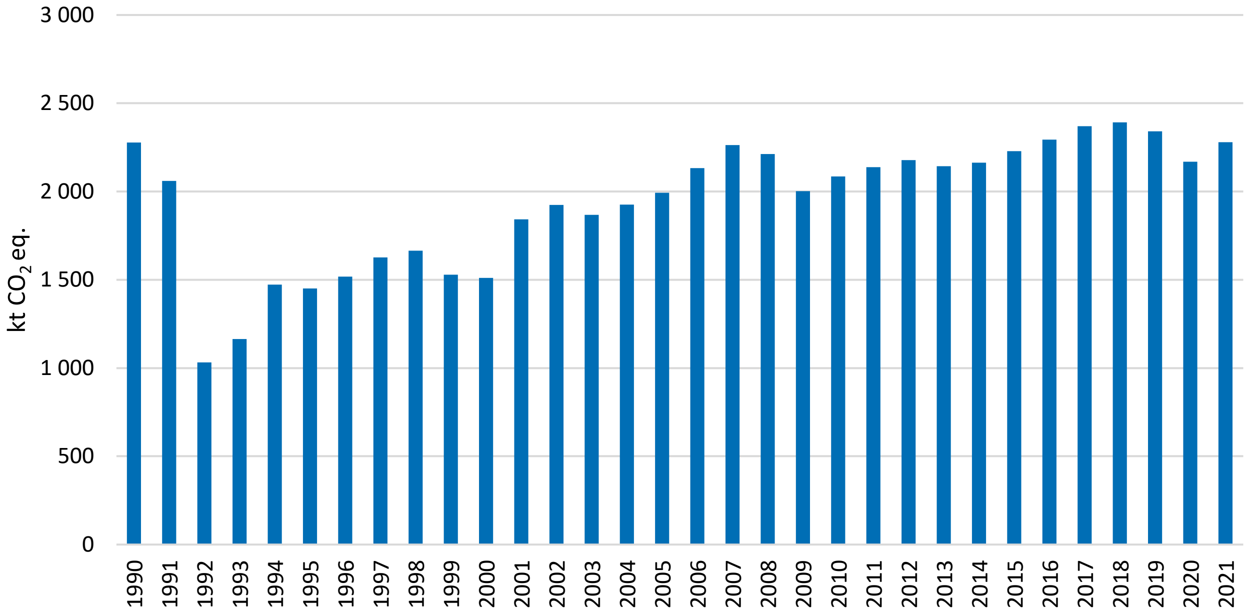


Figure 3.21. Emissions from the Road transport in 1990–2021, kt CO_2 eq.

Methods

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 3.9:

Equation 3.9[40]

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

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).

[40] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.12, equation 3.2.1.

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 2019 sector 1.A.3.b Road transport[41]. 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.

For 2023 submission Estonia also reports the fossil part of biofuels consumption and CH_4 and N_2O emissions in CRF 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. 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 110 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[41] .

The emission equation of *Tier 3* for CH_4 and N_2O is described in the Equation 3.10:

Equation 3.10[42]

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

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).

41 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
42 IPCC 2006 Guidelines, Volume 2, Chaper 3; Mobile Combustion, page 3.15, equation 3.2.5.

Emissions of indirect greenhouse gases from Road transportation

COPERT 5 model is also used for calculation of SO_2, CO, NO_x, and NMVOC emissions road Road transport according to the EMEP/EEA air pollutant emission inventory guidebook 2019 sector 1.A.3.b Road transport methodology.

Activity data

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[43] 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 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 3.25.

Table 3.25. Consumption of bioethanol, biodiesel, and biomethane in Estonia in 2005–2021, TJ

Year	Bioethanol	Biodiesel	Biomethane
2005	NO	6.50	NO
2006	NO	46.93	NO
2007	0.54	21.61	NO
2008	57.67	120.41	NO
2009	3.99	69.73	NO
2010	183.79	136.40	NO
2011	158.84	27.46	NO
2012	150.78	NO	NO
2013	127.97	NO	NO
2014	213.81	0.02	NO
2015	106.99	NO	NO
2016	84.10	NO	NO
2017	39.37	6.33	NO
2018	204.36	526.27	126.00

[43] Riigi Teataja. Liquid fuel act. [www] https://www.riigiteataja.ee/en/eli/ee/502022023001/consolide/current (08.03.2023)

Year	Bioethanol	Biodiesel	Biomethane
2019	308.87	838.00	188.24
2020	259.08	1370.73	285.85
2021	176.16	1735.23	445.11

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 3.26 the number of vehicles and in Table 3.27 road traffic mileage are presented following COPERT 5 model.

Table 3.26. 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**
1991	261	35	50	2	**349**
1992	284	34	49	2	**369**
1993	317	34	49	2	**402**
1994	338	25	35	2	**400**
1995	383	30	42	3	**459**
1996	378	28	38	5	**449**
1997	381	28	37	5	**451**
1998	265	20	36	6	**327**
1999	296	21	31	7	**355**
2000	273	20	29	7	**328**
2001	274	26	31	7	**338**
2002	286	30	30	7	**353**
2003	314	32	30	8	**385**
2004	335	37	30	9	**411**
2005	355	34	26	9	**423**
2006	402	36	29	9	**477**
2007	429	38	29	11	**507**
2008	436	38	27	13	**515**
2009	424	37	27	14	**502**
2010	422	36	27	15	**500**
2011	440	38	27	18	**523**
2012	452	39	27	23	**541**
2013	463	41	28	32	**564**
2014	479	44	28	29	**580**
2015	537	42	29	31	**639**
2016	564	59	31	37	**691**
2017	585	63	31	39	**717**
2018	583	67	29	38	**716**
2019	628	74	32	42	**775**
2020	625	76	31	44	**777**
2021	635	80	31	45	**791**

Table 3.27. 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
1991	5721	671	1200	5	7598
1992	2352	352	793	5	3503
1993	2733	383	845	5	3966
1994	4170	416	833	5	5424
1995	3877	444	836	8	5165
1996	4101	487	837	11	5435
1997	4392	552	917	13	5872
1998	4161	477	1075	15	5728
1999	4017	509	896	16	5438
2000	4134	503	893	16	5546
2001	5301	726	1004	16	7048
2002	5203	868	1045	17	7133
2003	5246	821	933	20	7020
2004	5448	954	934	24	7360
2005	5822	954	892	29	7697
2006	6481	948	935	43	8406
2007	7008	974	955	54	8991
2008	6871	961	989	65	8886
2009	6574	724	813	55	8165
2010	6446	753	967	54	8219
2011	6490	800	1036	50	8376
2012	6620	846	1029	59	8554
2013	6665	842	955	69	8532
2014	6891	874	927	67	8759
2015	7388	814	915	65	9181
2016	7676	1007	852	76	9611
2017	7986	1093	846	77	10003
2018	8354	1236	824	81	10494
2019	8495	1252	796	65	10608
2020	8122	1252	719	53	10146
2021	8086	1395	906	82	10469

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.

Emission factors and other parameters

Liquid fossil fuels

CO_2 emission factors of gasoline, LPG, and diesel oil for Road transport are presented in Table 3.28. 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 3.28. 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
1991	19.50	38.85	2.40	20.01	7.31	2.46	17.72	19.03	0.00
1992	19.50	35.84	2.19	20.01	7.42	2.52	17.72	19.03	0.00
1993	19.50	36.17	2.30	20.01	7.45	2.34	17.72	18.99	0.56
1994	19.50	38.68	2.63	20.00	7.35	2.22	17.72	19.13	1.09
1995	19.51	39.21	2.90	20.02	7.46	2.34	17.83	19.38	2.09
1996	19.49	38.78	3.01	20.01	7.37	2.45	17.83	19.42	3.02
1997	19.52	37.76	2.96	20.01	7.21	2.42	17.79	19.26	3.32
1998	19.60	37.81	2.93	20.01	7.46	2.56	17.77	19.14	3.24
1999	19.55	35.97	3.03	20.01	7.30	2.31	17.75	18.90	3.44
2000	19.27	32.11	3.46	20.01	7.16	2.18	17.72	18.65	3.63
2001	19.34	31.00	3.70	19.97	6.84	1.88	17.75	18.53	3.11
2002	19.71	28.32	3.76	19.96	6.64	1.81	17.76	18.17	3.34
2003	19.79	25.81	3.64	19.97	6.44	1.62	17.76	18.11	3.31
2004	19.79	23.30	3.68	19.95	6.20	1.65	17.75	18.04	3.33
2005	19.27	22.89	3.51	19.95	6.05	1.59	17.75	17.89	3.47
2006	19.03	21.19	2.50	19.94	5.35	1.65	17.73	17.56	3.55
2007	19.06	19.30	2.31	19.94	4.66	1.73	17.62	17.29	3.62
2008	19.19	16.83	2.14	19.95	4.53	1.80	17.52	17.15	3.60
2009	19.40	15.99	2.06	19.91	3.89	1.83	17.56	16.94	3.64
2010	19.77	14.71	1.91	19.89	3.61	1.87	17.47	16.65	3.65
2011	19.78	13.77	1.82	19.92	3.34	1.97	17.29	16.36	3.72
2012	19.61	12.70	1.67	19.96	2.84	2.12	17.59	17.03	2.67
2013	19.80	12.01	1.51	19.94	2.46	2.27	17.30	14.72	3.33
2014	19.88	10.66	1.31	19.95	2.17	2.37	17.31	13.80	3.00
2015	19.85	11.10	1.34	19.92	1.89	2.49	17.30	13.38	2.90
2016	19.82	10.76	1.23	19.89	1.61	2.58	17.41	12.93	2.68
2017	19.81	10.02	1.06	19.94	1.40	2.65	17.24	12.69	2.47
2018	19.37	9.43	0.93	19.96	1.16	2.73	17.36	13.25	2.68
2019	19.09	9.40	0.92	19.87	1.12	2.72	17.73	11.22	1.88
2020	19.22	9.24	0.88	19.94	0.92	2.77	17.39	10.53	1.31
2021	19.14	9.31	0.71	19.98	0.78	2.85	17.31	10.50	1.11

The amounts of fuels imported in 2021 are presented in Table 3.29.

Table 3.29. Imported fuel amounts in 2021 by country

Country	Gasoline, kg	Diesel, kg	LPG, kg
Austria	–	–	187651
Belarus	–	7175848	–
Belgium	–	530809	31
Czechia	–	–	2903
Cyprus	–	–	2364968
Denmark	–	–	228
Finland	60277527	149224646	896934
France	–	–	764
Germany	–	1918906	6530
Greece	–	–	525
Ireland	–	–	2558
Italy	–	–	6425
Latvia	286224	15895360	4659935
Lithuania	232802628	400828831	203350
Netherlands	–	2271424	790
Poland	–	384096	181223
Russia	83390946	166002014	6429139
Sweden	141458	18964826	2874396
United Kingdom	–	2	7

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 2021 by country are presented in Table 3.30.

Table 3.30. Carbon emission factors used in the calculation of the country-specific CO_2 emission factor for liquid fuels in Road transport, tC/TJ

Country	Gasoline	Diesel	LPG
Austria	–	–	17.20
Belarus	–	20.10	–
Belgium	–	20.20	17.20
Czechia	–	–	17.97
Cyprus	–	–	17.20
Denmark	–	–	17.67
Finland	19.50	20.00	17.70
France	–	–	17.21
Germany	–	20.19	18.09
Greece	–	–	17.20
Ireland	–	–	17.37

Country	Gasoline	Diesel	LPG
Italy	–	–	17.20
Latvia	18.91	20.40	17.13
Lithuania	19.13	19.85	18.22
Netherlands	–	19.78	18.19
Poland	–	19.76	17.04
Russia	18.90	20.21	17.21
Sweden	19.64	20.25	17.75
United Kingdom	–	20.20	17.42

* 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 2019[45]. 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[44] (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 were calculated using the weighted average method for the years 2010-2020 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 2019 guidebook[45], 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[46] of the Minister of Economic Affairs and Infrastructure biomethane used in transport must meet the quality requirements of

---

[44]Handbook Emission Factors for Transport. [www] https://www.hbefa.net/e/index.html (10.09.2021).
[45]EMEP/EEA air pollutant emission inventory guidebook 1.A.3.b.i-iv Road Transport 2019: 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 (10.09.2021).
[46]Riigi Teataja. Gaasituru toimimise võrgueeskiri. [www] https://www.riigiteataja.ee/akt/129122020033?leiaKehtiv (10.03.2022).

natural gas. Table 3.31 presents the CEF-s, CH_4 and N_2O emission factors for CNG and biomethane.

Table 3.31. 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

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 CRF 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 2019, Chapter 1.A.3.b Road transport[45].

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[47]. 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 2019 Guidebook[48].

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[49].

HVO is also considered 100% bio-origin. For the HVO the average carbon content of 84.8[50]% and calorific value of 44[50] MJ/kg.

In 2021 the fossil CO_2, CH_4, and N_2O emissions from transportation biofuels totalled 4.36 kt CO_2 eq., constituting 0.03% of Estonia's total GHG emissions.

3.2.5.4. Off-road vehicles

Off-road vehicles are used in industry, agriculture, forestry, and for household purposes (see Table 3.32).

Table 3.32 Reporting categories of off-road vehicles sources

CRF category	Description	Remarks
1.A.2.g Other	Excavators, loaders, road work machines	Fuel conusmption and emissions are included in 1.A.2.g Other
1.A.4.b Residential	Other miscellaenous equipment (e.g. ATV-s, forklifts, cranes, etc.)	Fuel conusmption and emissions are included in 1.A.4.b Residential
1.A.4.c Agriculture/forestry/fisheries	Tractors, harvesters, forestry machines	Fuel conusmption and emissions are included in 1.A.4.c Agriculture/forestry/fisheries

In 2021 emissions from off-road vehicles accounted for 203.41 kt CO_2 eq., which is a 0.8% decrease compared to the previous year. Emissions off-road mobile equipment in 1990-2021 are shown in Figure 3.22. The overall GHG consumption trend follows the fuel consumption trend. The biggest share in emissions is in 1.A.4.c since most of the fuel is consumed in tractors in agriculture. 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 with the growth of the economy. The trend of GHG emissions matches the trend of fuel consumption.

[47] Note on fossil carbon content in biofuels. Ioannis Sempos, 2019
[48] EMEP/EEA 2019 Guidebook, Part B, 1. Energy, 1.A Combustion, 1.A.3.b.i-iv Road Transport, Table 3-29
[49] 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.
[50] 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

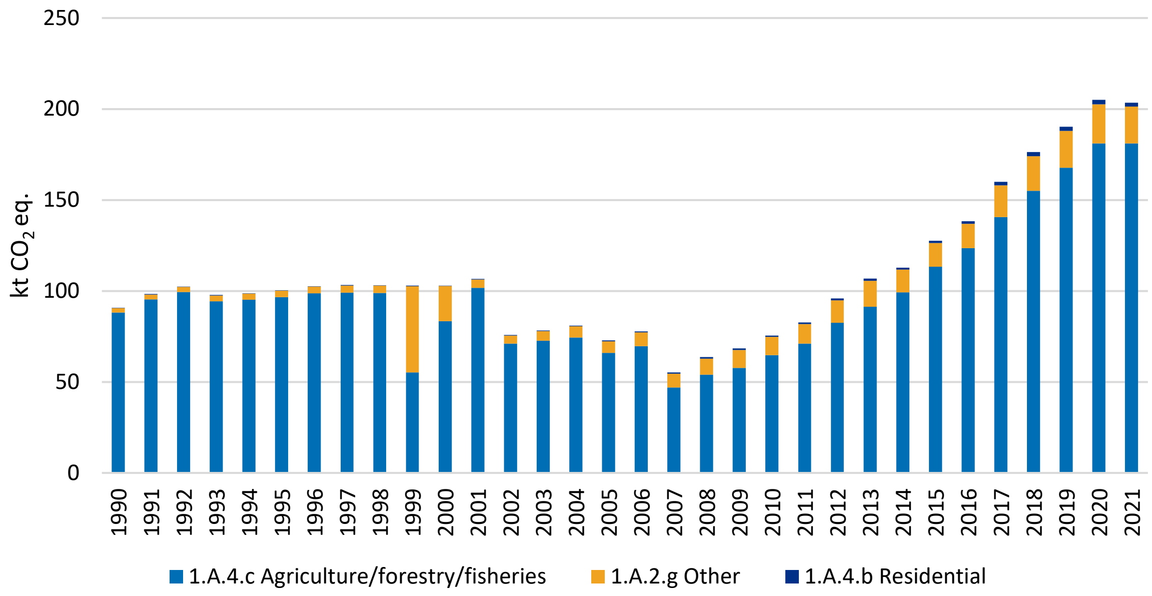


Figure 3.22 Emissions from off-road vehicles in Estonia in 1990-2021, kt CO_2 eq.

Diesel oil and gasoline is used for off-road equipment. The fuel consumption trend can be seen in Figure 3.23. Most of the diesel oil is used in Agriculture/forestry/fisheries sector in tractors and gasoline is only consumed in tractors in Agriculture/forestry/fisheries sector.

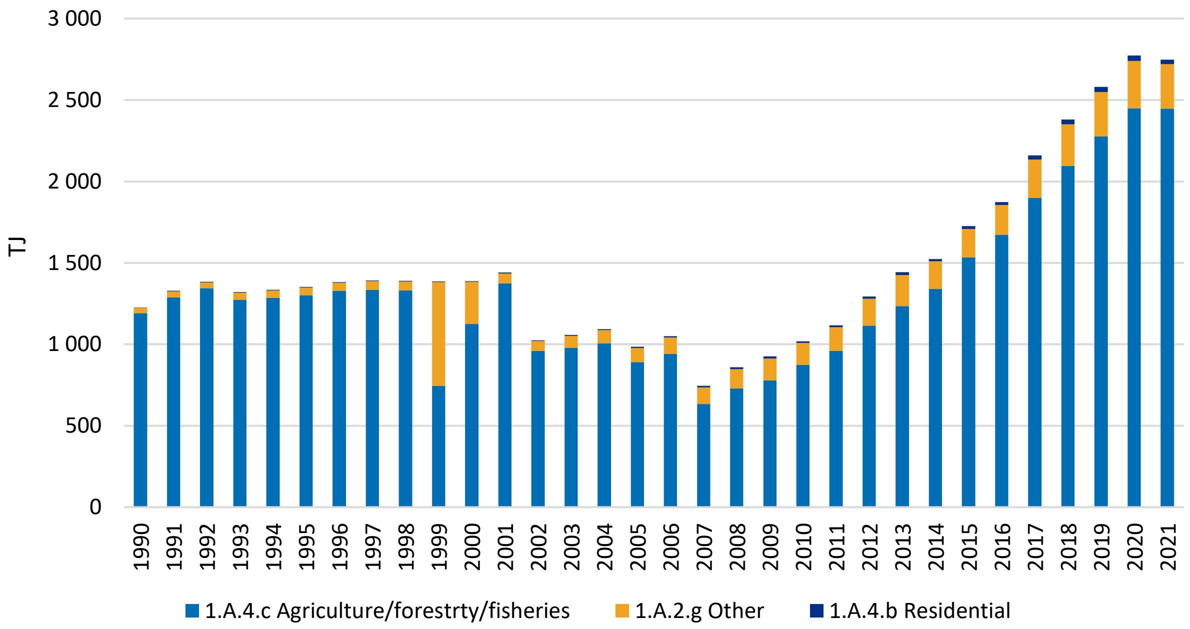


Figure 3.23 Fuel consumption of off-road vehicles in Estonia in 1990-2021

Methods

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 2019 1.A.4 Non road mobile machinery *Tier 3* methodology[51] 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

The number of vehicles is obtained from different sources. The data for the years 2010-2021 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 1990-2020, 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 2010-2021. In Figure 3.24 number of vehicles by vehicle type is presented[52].

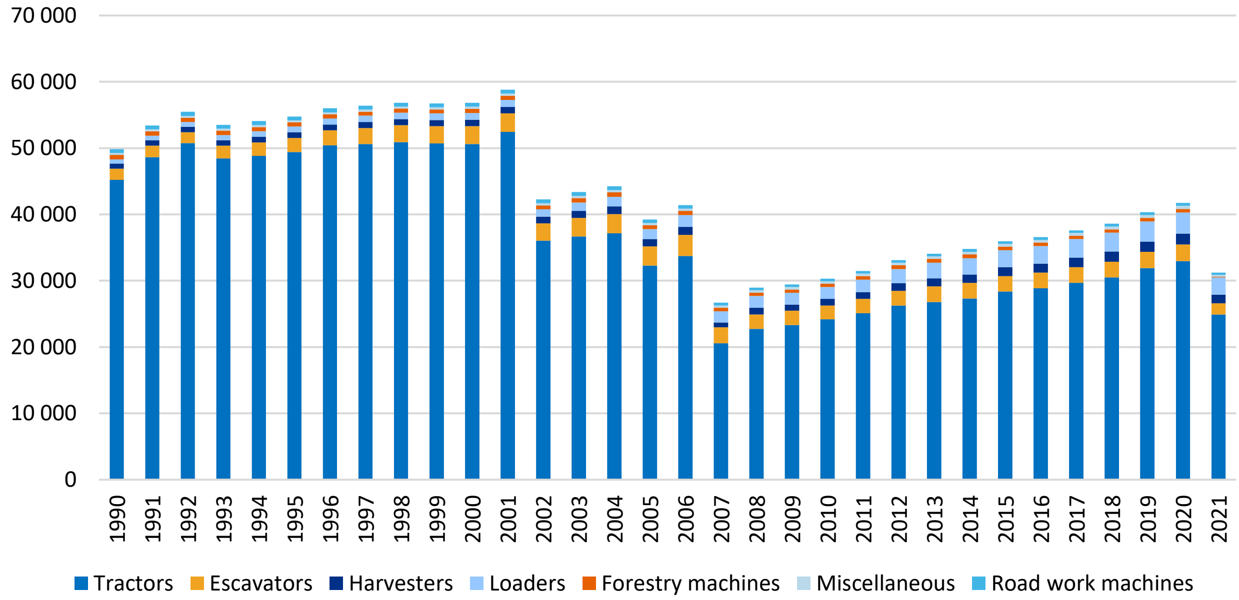


Figure 3.24 Number of off-road vehicles in 1990-2021

[51] 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

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

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 3.33 the consumption of fuels in off-road vehicles is presented.

Table 3.33 Consumption of fuels from off-road vehicles, TJ

Year	Diesel	Gasoline
1990	1201	26
1991	1301	27
1992	1356	28
1993	1294	27
1994	1308	27
1995	1325	27
1996	1355	27
1997	1364	27
1998	1362	27
1999	1360	27
2000	1361	27
2001	1413	27
2002	1005	20
2003	1037	20
2004	1073	20
2005	967	18
2006	1031	19
2007	731	14
2008	843	15
2009	909	16
2010	1001	18
2011	1099	18
2012	1276	17
2013	1424	18
2014	1507	16
2015	1709	17
2016	1856	17
2017	2137	23
2018	2347	34
2019	2529	51
2020	2706	67
2021	2666	82

Emission factors and other parameters

Carbon emission factors for gasoline and diesel oil for off-road vehicles are presented in Table 3.34. 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 3.34. Carbon emission factors for fuels used for off-road vehicles, tC/TJ

Year	Gasoline	Diesel
	CEF	CEF
1990	19.50	20.01
1991	19.50	20.01

Year	Gasoline	Diesel
	CEF	CEF
1992	19.50	20.01
1993	19.50	20.01
1994	19.50	20.00
1995	19.51	20.02
1996	19.49	20.01
1997	19.52	20.01
1998	19.60	20.01
1999	19.55	20.01
2000	19.27	20.01
2001	19.34	19.97
2002	19.71	19.96
2003	19.79	19.97
2004	19.79	19.95
2005	19.27	19.95
2006	19.03	19.94
2007	19.06	19.94
2008	19.19	19.95
2009	19.40	19.91
2010	19.77	19.89
2011	19.78	19.92
2012	19.61	19.96
2013	19.80	19.94
2014	19.88	19.95
2015	19.85	19.92
2016	19.82	19.89
2017	19.81	19.94
2018	19.37	19.96
2019	19.09	19.87
2020	19.22	19.94
2021	19.14	19.98

CH_4 emission factors by vehicle type used in calculations are presented in Table 3.35 and N_2O emission factors in Table 3.36.

Table 3.35 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
1991	14.7	28.6	4.2	4.3	2.2	3.4	3.2	3.7	3.2
1992	14.6	28.4	4.2	4.2	2.2	3.4	3.2	3.7	3.1
1993	14.5	28.1	4.2	3.9	2.2	3.4	3.2	3.6	3.1
1994	14.4	27.9	4.2	3.9	2.2	3.4	3.2	3.6	3.1
1995	14.3	27.7	4.2	3.8	2.2	3.4	3.2	3.6	3.1
1996	14.2	27.5	4.2	3.7	2.2	3.4	3.2	3.5	3.0
1997	14.0	27.3	4.2	3.7	2.2	3.4	3.2	3.5	3.0
1998	13.8	27.2	4.2	3.7	2.2	3.4	3.2	3.4	3.0
1999	13.7	27.0	4.2	3.7	2.2	3.4	3.2	3.4	3.0
2000	13.5	26.8	4.2	3.6	2.2	3.4	3.2	3.4	2.9
2001	13.4	26.1	4.2	3.5	2.2	3.4	3.1	3.4	2.9
2002	13.3	25.6	4.2	3.4	2.1	3.3	3.0	3.4	2.9

Year	Gasoline		Diesel						
	Tractors	Other	Tractors	Excavators	Harvesters	Loaders	Forestry	Other	Road work
2003	13.2	25.1	4.1	3.1	1.9	2.9	2.7	2.8	2.8
2004	13.1	24.7	4.1	2.9	1.8	2.6	2.5	2.5	2.7
2005	13.0	24.4	4.0	2.8	1.6	2.4	2.1	2.2	2.6
2006	12.7	24.1	3.9	2.7	1.5	2.3	2.0	2.0	2.5
2007	12.3	23.9	3.4	2.2	1.0	1.8	1.5	1.7	2.1
2008	12.1	23.7	3.3	1.8	1.0	1.6	1.3	1.4	1.8
2009	11.9	23.5	3.1	1.6	0.8	1.3	1.1	1.3	1.7
2010	11.7	24.6	2.9	1.4	0.8	1.1	1.1	6.5	1.6
2011	11.7	24.6	2.7	1.4	0.8	1.1	1.1	6.1	1.6
2012	11.7	24.7	2.5	1.3	0.7	1.0	1.0	5.3	1.5
2013	11.7	24.7	2.3	1.2	0.6	0.9	0.9	5.1	1.5
2014	11.7	24.4	2.1	1.2	0.6	0.9	1.0	3.0	1.4
2015	11.7	24.4	1.9	1.1	0.5	0.9	1.0	2.7	1.4
2016	11.7	24.4	1.8	1.1	0.5	0.9	0.9	2.5	1.3
2017	11.7	24.8	1.6	1.0	0.4	0.8	0.9	3.0	1.3
2018	11.7	24.6	1.5	1.0	0.4	0.8	0.8	3.0	1.3
2019	10.9	24.6	1.4	1.0	0.4	0.8	0.8	3.1	1.2
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

Table 3.36 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
1991	1.3	1.1	3.0	2.9	3.2	3.1	3.1	3.0	3.1
1992	1.3	1.1	3.0	3.0	3.2	3.1	3.1	3.0	3.1
1993	1.3	1.1	3.0	3.0	3.2	3.1	3.1	3.0	3.1
1994	1.3	1.1	3.0	3.0	3.2	3.1	3.1	3.1	3.1
1995	1.3	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
1996	1.3	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
1997	1.3	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
1998	1.3	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
1999	1.3	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
2000	1.3	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
2001	1.3	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
2002	1.3	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
2003	1.4	1.1	3.0	3.1	3.2	3.1	3.1	3.1	3.1
2004	1.4	1.1	3.0	3.1	3.2	3.1	3.2	3.1	3.1
2005	1.4	1.1	3.0	3.2	3.2	3.1	3.2	3.2	3.1
2006	1.4	1.1	3.0	3.2	3.3	3.1	3.2	3.2	3.2
2007	1.4	1.1	3.1	3.2	3.3	3.2	3.2	3.2	3.2
2008	1.4	1.1	3.1	3.2	3.3	3.2	3.2	3.2	3.2
2009	1.4	1.1	3.1	3.2	3.3	3.2	3.3	3.2	3.2
2010	1.4	1.3	3.1	3.2	3.3	3.2	3.3	2.8	3.2
2011	1.4	1.3	3.1	3.2	3.3	3.2	3.3	2.9	3.2
2012	1.4	1.3	3.1	3.2	3.3	3.2	3.3	2.9	3.2
2013	1.4	1.3	3.2	3.2	3.3	3.2	3.3	2.9	3.2
2014	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.1	3.2

Year	Gasoline		Diesel						
	Tractors	Other	Tractors	Excavators	Harvesters	Loaders	Forestry	Other	Road work
2015	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.1	3.2
2016	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.1	3.2
2017	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.1	3.2
2018	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.1	3.2
2019	1.4	1.3	3.2	3.2	3.3	3.2	3.3	3.1	3.2
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

Emissions of indirect greenhouse gases from Off-road vehicles

In 2021 Estonia developed NO_x, CO, and NMVOC emission are estimates using EMEP/EEA air pollutant inventory guidebook 2019 1.A.4 Non road mobile machinery *Tier 3* methodology as for CH_4 and N_2O. Emissions are estimated for gasoline and diesel separately and for each vehicle type[52].

3.2.5.5. Railway

New trains started to run on Estonian railways in 2013 after several years of railway reconstructions. There were 188 locomotives, 18 electric railcars, 32 diesel railcars, 199 passenger wagons, and 22 574 freight wagons registered according to Statistics Estonia at the end of 2021. All non-electric locomotives use diesel oil in Estonia. From 1990 to 1998 also coal-burning locomotives were used in Estonia.

Rail transport enterprises carried 23.3 million tonnes of goods in 2021. 9.5 million tonnes of transit goods were delivered by rail, of which 1.8 million tonnes were refined oil products and over 7.3 million tonnes were chemical products.

Railway transportation in Estonia has a small share of emissions in the Transport sector. The emissions were 47.54 kt CO_2 eq. in 2021 with the share of 2.0% 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.

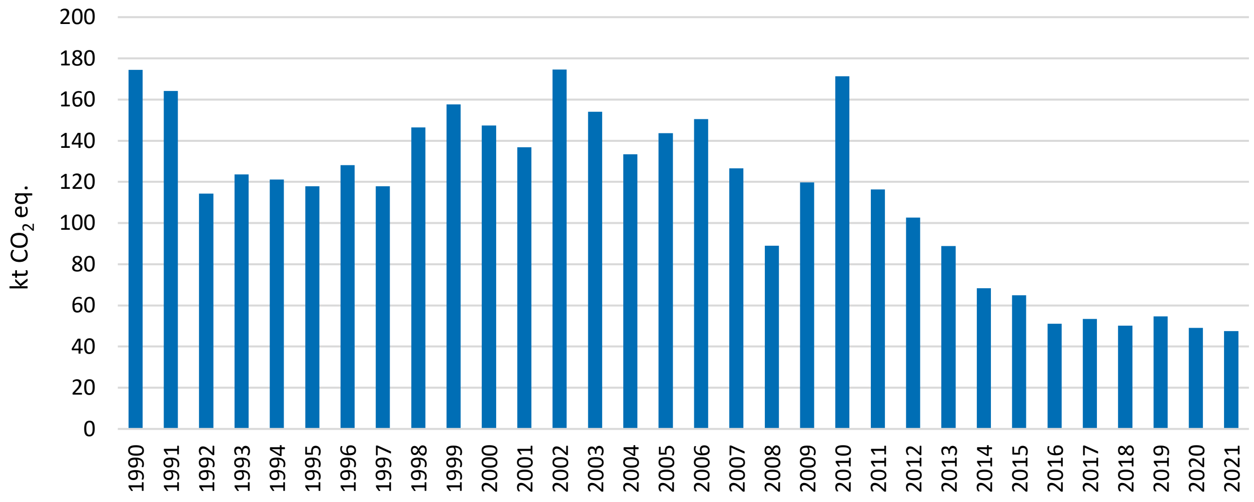


Figure 3.25. Emissions from Railways in 1990–2021, kt CO_2 eq.

In general, the CO_2 emissions trend matches the fuel consumption trend in the Rail transport sector (Figure 3.25). 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. The freight turnover was at the same level as it was ten years ago. The rail passenger traffic disruption in 2008 was caused by a major reconstruction of railways. In 2009 the volume of transit goods increased by 8% compared to 2008 and in 2010 by 11% compared to 2009. A decrease in cargo turnover induced a rise in goods sent abroad and received by rail – in 2011 20% more goods were sent and 40% more goods were received next to 2010. In 2012 almost 8% fewer goods were carried by rail transport enterprises than in 2011. In 2013 the emissions decreased about 13.4% in contrast to 2012 due to the decrease in cargo turnover. In 2014 emissions decreased close to 23.1% compared to 2013. This was caused by a sharp decrease in transporting goods by rail. The emissions in 2020 were 7.6% lower compared to the previous year, because of a decrease in freight cargo and passenger transportation. In 2021 the emissions from Rail transport decreased 3.1%.

Methods

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.

Activity data

The activity data on fuel consumption used in Railways is obtained from Joint Questionnaire dataset managed by Statistics Estonia and is presented in Table 3.21.

Emission factors and other parameters

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 2019, and SO_2 EF is country-specific (expert estimation). Emission factors are presented in Table 3.37.

Table 3.37. Emission factors used in the calculation of emissions from Railways

Fuel	GHG	EF	Source
Diesel Oil	CO_2	19.98 tC/TJ	CS
	CH_4	4.15 kg/TJ	IPCC 2006, Vol.2, Chapter 3, Table 3.4.1
	N_2O	28.6 kg/TJ	IPCC 2006, Vol.2, Chapter 3, Table 3.4.1
	NOx	52.4 kg/t	EMEP/EEA Guidebook 2019
	CO	10.7 kg/t	EMEP/EEA Guidebook 2019
	NMVOC	4.65 kg/t	EMEP/EEA Guidebook 2019
	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 2019
	CO	931 kg/TJ	EMEP/EEA Guidebook 2019
	NMVOC	88.8 kg/TJ	EMEP/EEA Guidebook 2019
	SO_2	1 028 kg/TJ	CS

CS – country-specific

3.2.5.6. Domestic navigation

Estonian Transport Administration manages Ship Register that listed 109 seagoing ships (gross weight 100 tons or more) and 30 inland ships at the end of 2021. 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 18.47 kt CO_2 eq. in 2021 (0.8% of Transport sector emissions). The decrease comparing to the previous year was due to a decrease in diesel oil consumption. 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 3.26. The fuel consumption data for 2002, and 2006-2008 has been corrected because one of the water transport companies had previously reported the fuel use in international waters under domestic fuel use. Therefore, the GHG emissions have been recalculated for these years.

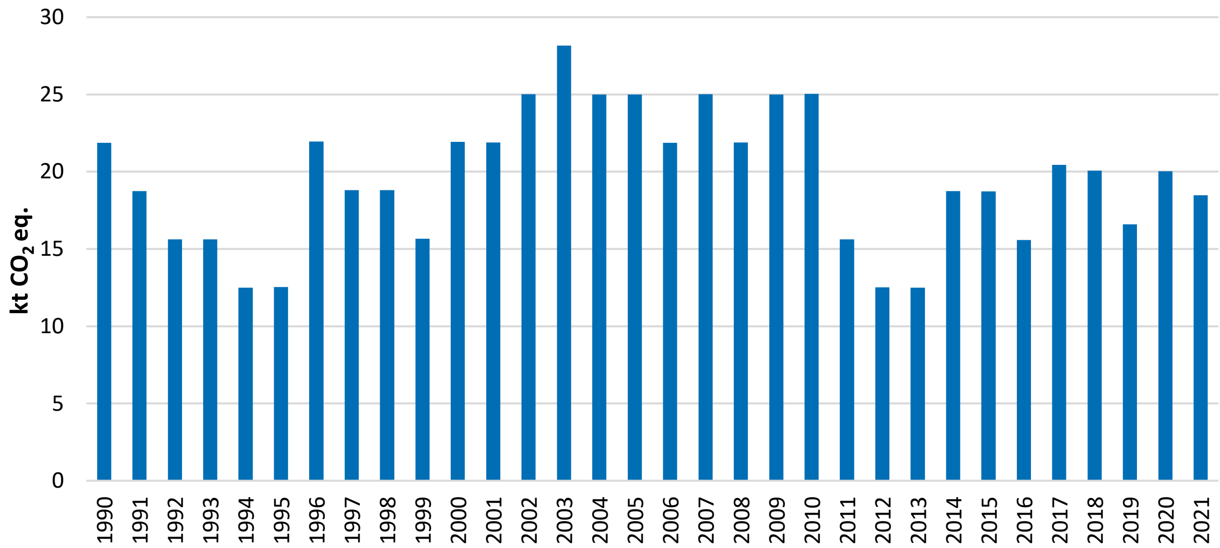


Figure 3.26. Emissions from Domestic navigation in 1990–2021, kt CO_2 eq.

Methods

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.

Activity data

The activity data on fuel consumption used in Domestic navigation is gained from the Statistics Estonia and presented in Table 3.21.

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.

Emission factors and other parameters

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 and coal and for diesel for NO_x, CO, and NMVOC are taken from the IPCC 2006 guidelines. NO_x, CO, and NMVOC EFs for coal are taken from the EMEP/EEA Guidebook 2019[25], SO_2 EF is country-specific. All emission factors are presented in Table 3.38.

Table 3.38. Emission factors used in the calculation of emissions from Domestic navigation

Fuel	GHG	EF	Source
Diesel Oil	CO_2	19.98 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 2019
	CO	573.9 kg/t	EMEP/EEA Guidebook 2019
	NMVOC	181.5 kg/t	EMEP/EEA Guidebook 2019
	SO_2	141.2 kg/TJ	CS

CS – country-specific

3.2.5.7. Uncertainties and time-series consistencies

Uncertainty evaluation of CO_2 emissions has been conducted for liquid, solid, gaseous, and other fuels used in Estonia in 2021. The data availability allows the estimation of uncertainty by a fuel type rather than by a sector in fuel combustion[29].

The estimated relative uncertainites of CO_2 emissions due to fuel combustion are presented in Table 3.16 in Chapter 3.2.4.3.

To estimate the uncertainties of CH_4 and N_2O emissions in the Transport sector the IPCC default values for activity data (5% and 10%) and for CH_4 emission factors (25%–150%) were used. For N_2O emission factor uncertainties (50%–125%) IPCC default and some Finnish values were used (see Table 3.39).

Table 3.39. Summary of uncertainty estimates of CH_4 and N_2O emission factors and activity data (95% confidence interval)

Source and Sink	GHG	Activity data uncertainty U_A	Emission factor uncertainty U_E	Reference U_A, U_E
Liquid and solid fuels	CH_4	5%	40%	IPCC GPG, p. 2.49
	N_2O	5%	50%	IPCC GPG, p. 2.49
Biomass	CH_4	5%	100%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]
	N_2O	5%	150%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]

3.2.5.8. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.2.3. A complete Quality Assurance (QA) and Quality Control (QC) was carried out 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[26] 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.

3.2.5.9. Category-specific recalculations

Recalculations in 1.A.3 sub-categories are presented in the Table 3.40.

Emissions were recalculated because of:

- Correcting a minor error in fuel consumption data in calculations in 1.A.3.a in 1990;
- correcting light fuel oil consumption data in Joint Questionnaire in 2019 and 2020 in 1.A.3.c Rail that was previously accounted for in 1.A.4.a Commercial/institutional in companies owning railways as not their main activity;
- correcting light fuel oil consumption data in Joint Questionnaire for one of the water transport companies that had previously also reported the light fuel use in international waters in 2002, and 2006-2008 in 1.A.3.d Domestic Navigation;
- using updated version of COPERT 5 model, and including CH_4 and N_2O emission calculations, and updated carbon fossil part of biofuels in CO_2 calculations in 2005-2021.

Table 3.40 Differences between 2023 and 2022 submissions, kt CO_2 eq.

Year	1.A.3.a	1.A.3.b	1.A.3.c	1.A.3.d
1990	-0.003	–	–	–
1991	–	–	–	–
1992	–	–	–	–
1993	–	–	–	–
1994	–	–	–	–
1995	–	–	–	–
1996	–	–	–	–
1997	–	–	–	–
1998	–	–	–	–
1999	–	–	–	–
2000	–	–	–	–
2001	–	–	–	–
2002	–	–	–	-9.38
2003	–	–	–	–
2004	–	–	–	–

Year	1.A.3.a	1.A.3.b	1.A.3.c	1.A.3.d
2005	–	-0.01	–	–
2006	–	-0.05	–	-12.50
2007	–	-0.02	–	-28.14
2008	–	-0.12	–	-40.66
2009	–	-0.07	–	–
2010	–	-0.14	–	–
2011	–	-0.03	–	–
2012	–	–	–	–
2013	–	–	–	–
2014	–	–	–	–
2015	–	–	–	–
2016	–	–	–	–
2017	–	-0.03	–	–
2018	–	0.25	–	–
2019	–	-1.12	17.49	–
2020	–	-3.07	14.71	–

– - no differences in recalculations

3.2.5.10. Category-specific planned improvements

There are no category-specific improvements planned.

3.2.6. Other sectors (CRF 1.A.4)

3.2.6.1. Category description

Sub-categories of CRF 1.A.4 includes emissions from the small combustion of fuels:

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

These sectors cover mainly fuels used in heating commercial, institutional, and agriculture buildings, off-road vehicles in residential and agriculture sector, and fishing boats.

In 2021 emissions in CRF 1.A.4 Other sectors were 650.83 kt CO_2 eq., about 6.3% of the Energy sector's emissions and 4.2% of total GHG emissions in Estonia. Corresponding emissions in 1990 were 1873.87 kt CO_2 equivalent (see Figure 3.27 and Table 3.42).

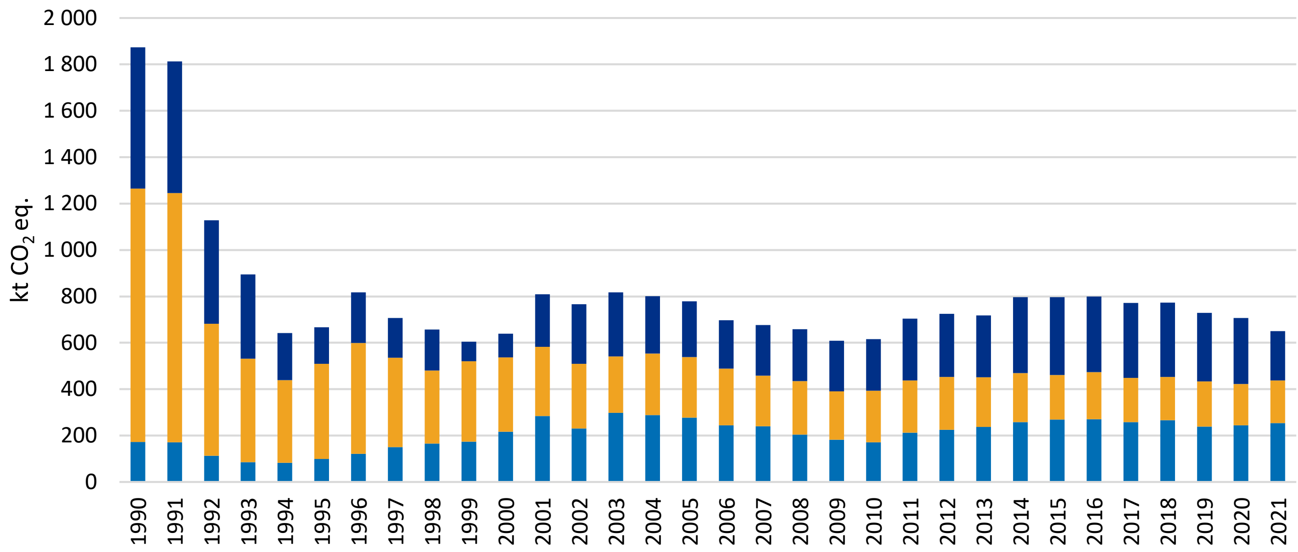


Figure 3.27. Trend of GHG emissions from Other sectors, kt CO_2 eq.

GHG emissions from CRF **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.

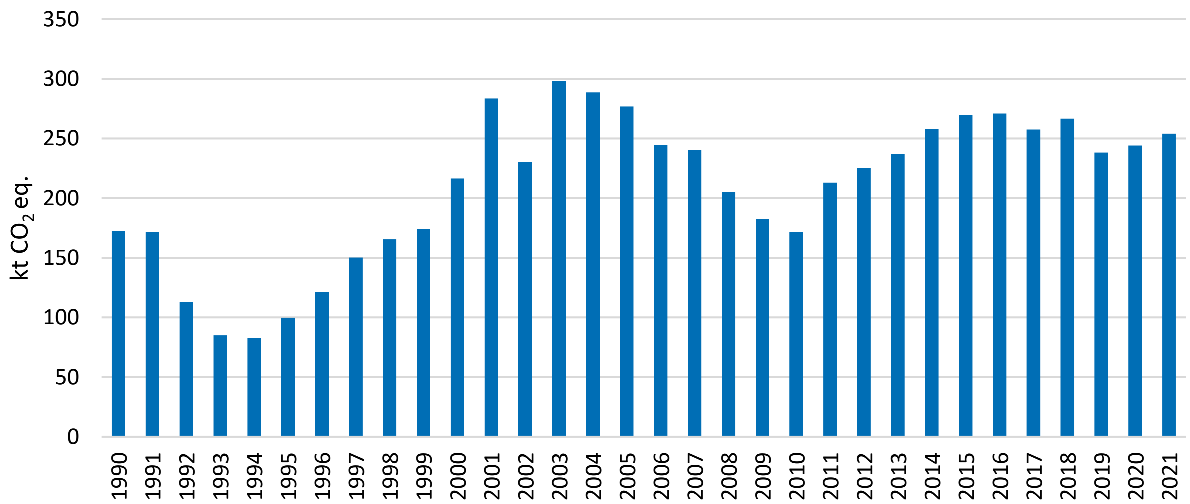


Figure 3.28. Trend of GHG emissions from Commercial and institutional sector, kt CO_2 eq.

The decreasing trend of GHG emissions in Commercial/institutional at the beginning of the 90s (from 1993 up to 2000) reflects the general economic development trend after regaining independence in 1991. 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 the downwards trend in GHG emissions (see Figure 3.28). Since 2011 the GHG emissions have increased with the growth of the economy. In 2020 the GHG emissions increased 2.4% compared to 2019 following a growing natural gas consumption. In 2021 the

GHG emissions increased 4.1% being 253.94 kt CO_2 eq. as natural gas consumption grew and solid biomass consumption decreased compared to the previous year.

The category **1.A.4.b Residential** sub-sector includes GHG emissions from fuel combustion in households and other miscellaneous mobile equipment. 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 houses, weather conditions, etc (see 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 2021 more than three times in comparison with 1990/1991 (see Figure 3.29). In 2021 the emissions in Residential sector were 183.05 kt CO_2 eq. which is about 2.8% increase compared to the previous year.

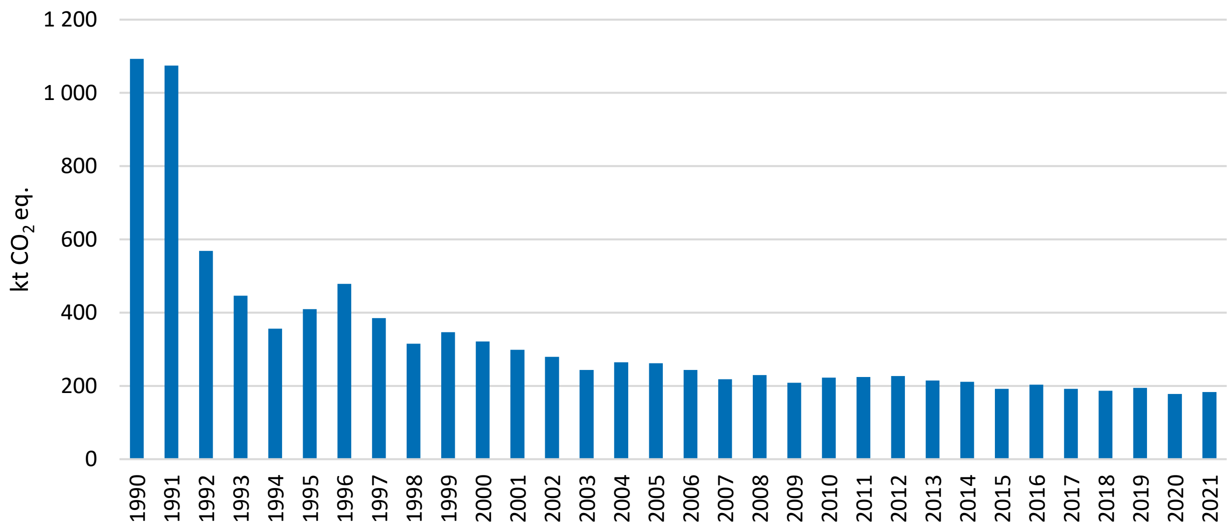


Figure 3.29. Trend of GHG emissions from Residential sector, kt CO_2 eq.

Under category **1.A.4.c Agriculture/forestry/fisheries** GHG emissions from stationary and mobile fuel combustion in agriculture, fishing, and hunting are reported. Mobile sources include tractors, harvesters, and forestry machines. 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 the 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 (see 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 19% compared to the previous year. This was related to an increase in diesel consumption. In 2016 emissions fell 3.3% compared to the previous year mainly due to the falling consumption of light fuel oil 15.4%%. The same trend continued in 2020 when the GHG emissions decreased 3.9% compared to 2019. In 2021 emissions decreased about 24.8% compared to previous year as production in agriculture sector decreased (decrease in farm animals, and large-scale price increase of production inputs).

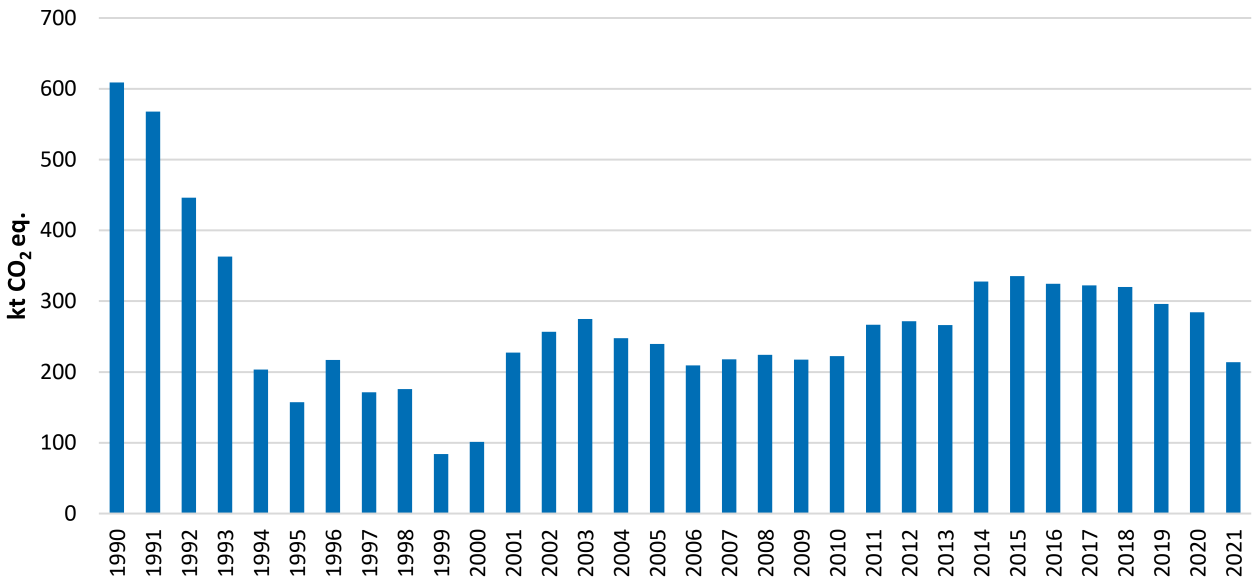


Figure 3.30. Trend of GHG emissions from Agriculture/forestry/fisheries sector, kt CO_2 eq.

The CO_2 EFs of liquid and solid fuels are fluctuating by reason of changes in the shares of different liquid and solid fuels over time.

3.2.6.2. Methodological issues

Methods

Emissions from sub-categories of CRF 1.A.4 are calculated using the IPCC 2006 methodology.

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[26] and added to Annex 3 (A.3.2).

The fuel consumption data by main fuel groups is presented in Table 3.43 and Figure 3.31.

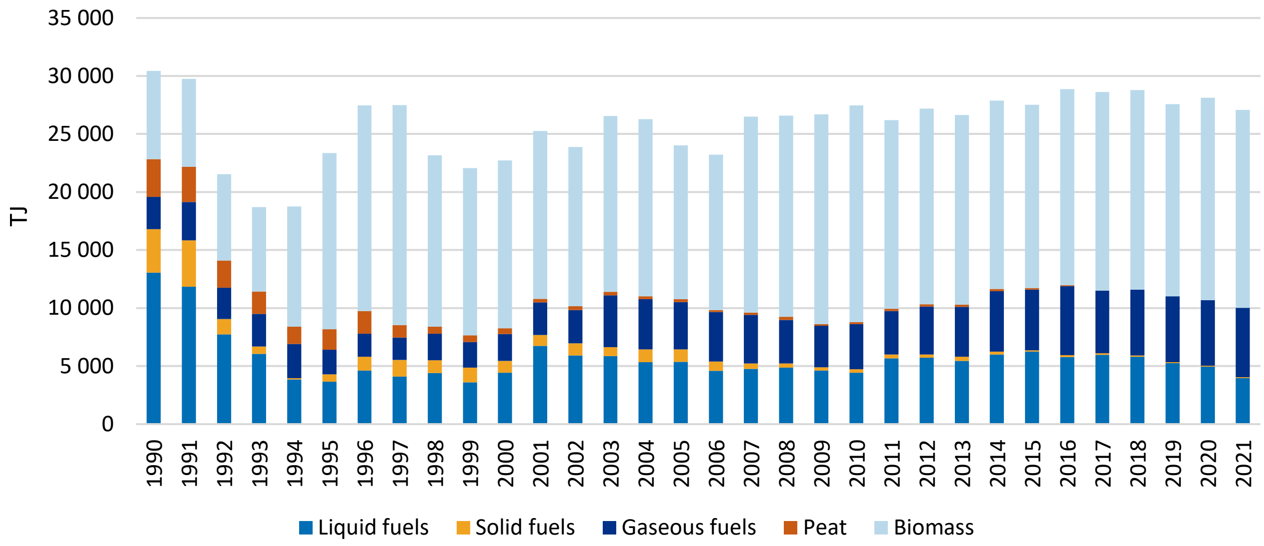


Figure 3.31. Fuel consumption in CRF 1.A.4 Other sectors, TJ

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 (see Figure 3.32).

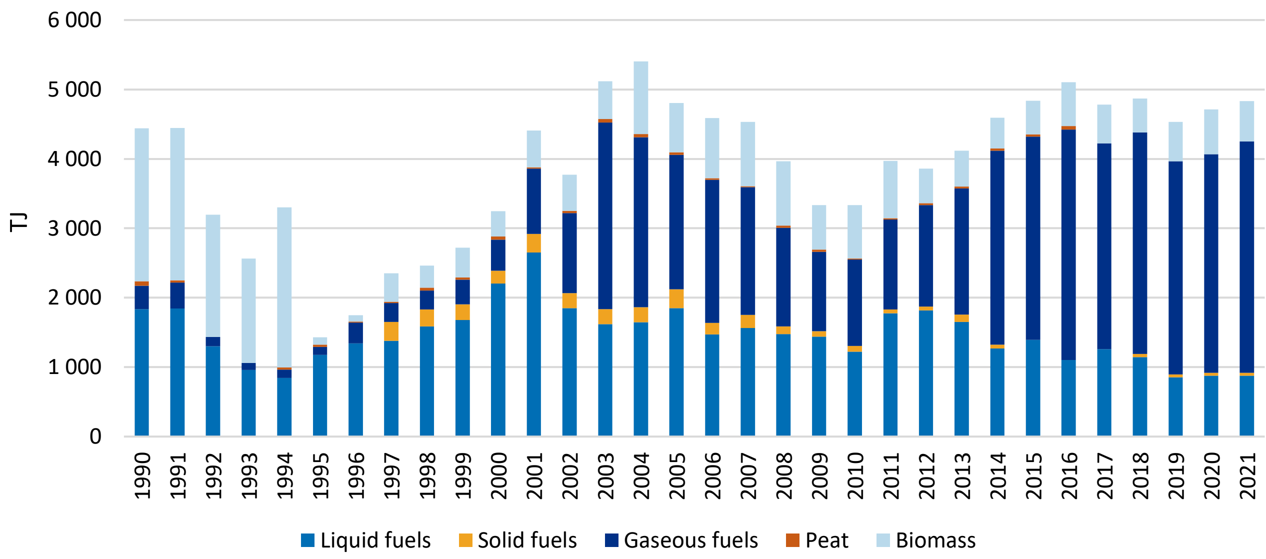


Figure 3.32. Fuel consumption in Commercial/institutional sector, TJ

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.

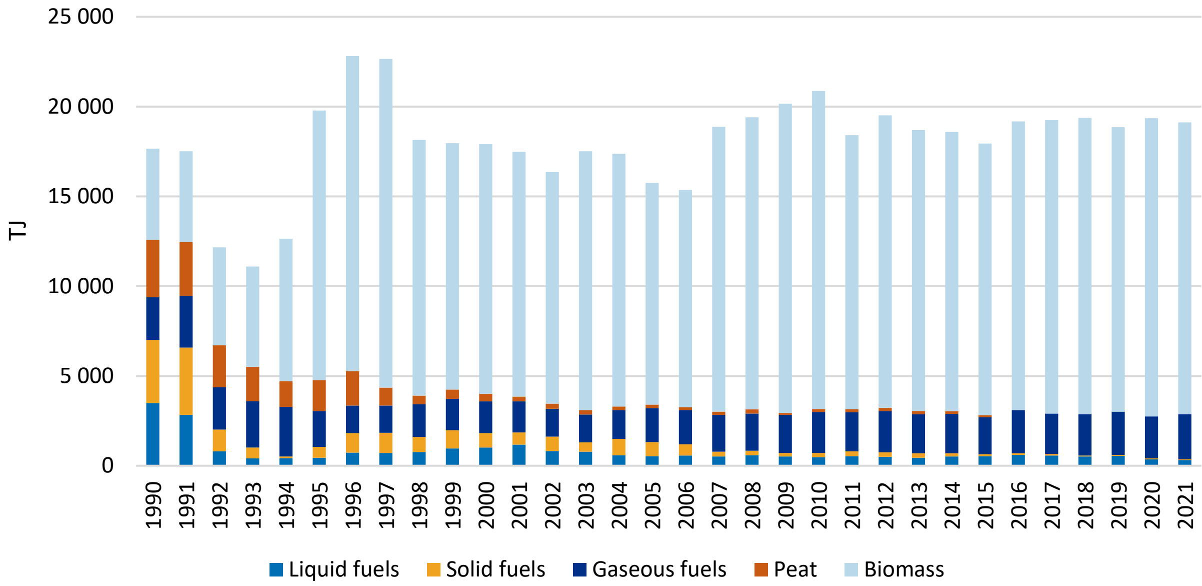


Figure 3.33. Fuel consumption in Residential sector, TJ

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 73%, 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 19% next to 2013. In 2019 fuel consumption decreased by 8.7% and in 2020 2.8% compared to the respective previous year mainly because of decreased use of diesel oil. In 2021 fuel consumption decreased about 23.1% because of decreased production in Agriculture sector.

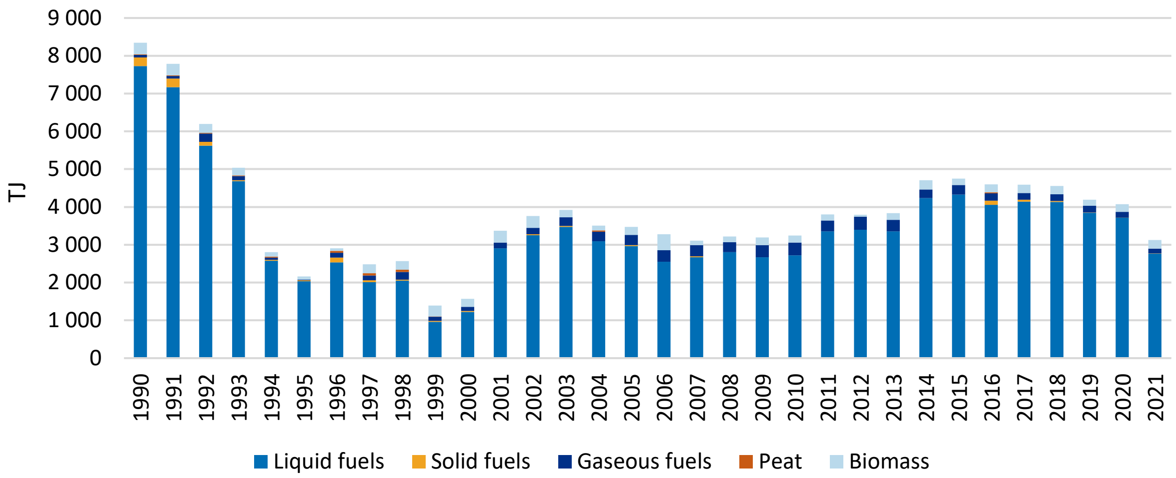


Figure 3.34. Fuel consumption in Agriculture/forestry/fisheries sector, TJ

Consumption of solid fuels, liquid fuels, natural gas, peat, and other fossil fuels as well as CO_2, CH_4, and N_2O are presented separately in Annex 2 (A.2.1.2).

Emission factors and other parameters

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 3.41). In 2022 NIR submission Chapter 3.2.6.4 was described a category specific planned improvement about an ongoing project (2020-2023) on developing country-specific factors for heating appliances in households in 1.A.4.b Residential sector. In 2023 the project was finalised, and Estonia developed country-specific CH_4 and N_2O emissions factors for solid biomass in 1.A.4.b Residential sector.

Table 3.41. 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.A.4.c	0.003	0.12	CS[24]
	1.A.4.b	5	0.1	IPCC 2006
Biogases	1.A.4.a, 1.A.4.c	0.003	0.12	CS[24]
Light fuel oil, residual fuel oil	1.A.4.a, 1.A.4.c	0.003	0.17	CS[24]
	1.A.4.b	10	0.6	IPCC 2006
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, 1.A.4.c	1.72	2.45	CS[24]
	1.A.4.b	300	1.4	IPCC 2006

Fuel	Sector	CH_4	N_2O	Source
Solid biomass	1.A.4.a	0.29	0.21	CS[24]
	1.A.4.b	1.72	2.45	CS[24]
	1.A.4.c	30.07	1.13	CS[24]

CS – country-specific

Table 3.42. Emissions from Other sectors by relevant subcategories in 1990, 1995, 2000, 2005, 2010, and 2015-2021, kt CO_2 eq.

Sector	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A.4 Other sectors total, CO_2 eq.	**1873.87**	**666.70**	**639.00**	**778.40**	**616.25**	**797.08**	**798.78**	**771.30**	**773.33**	**728.97**	**706.59**	**650.83**
1.A.4.a Commercial/ institutional, CO_2 eq.	172.35	99.87	216.42	276.96	171.34	269.54	270.84	257.40	266.73	238.17	243.97	253.94
1.A.4.b Residential, CO_2 eq.	1092.72	409.62	321.22	262.05	222.36	192.16	203.32	191.72	186.70	194.89	178.15	183.05
1.A.4.c Agriculture/ forestry/ fisheries, CO_2 eq.	608.80	157.21	101.37	239.39	222.55	335.38	324.63	322.18	319.89	295.90	284.48	213.83

Table 3.43. Fuel consumption in Other sectors in 1990, 1995, 2000, 2005, 2010, and 2015-2021, TJ

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
1.A.4 Other Sectors Total	**30449**	**23368**	**22729**	**24018**	**27454**	**27532**	**28885**	**28623**	**28789**	**27579**	**28135**	**27076**
Liquid fuels	13049	3666	4436	5354	4433	6251	5768	5970	5801	5248	4954	3962
Solid fuels	3749	624	1014	1086	299	109	190	132	110	103	89	80
Gaseous fuels	2786	2121	2322	4089	3885	5248	5937	5400	5671	5662	5649	5981
Peat	3264	1753	487	227	160	137	71	0	0	0	0	0
Biomass	7601	15203	14470	13263	18677	15787	16918	17122	17207	16567	17444	17053

In 1.A.4.b Residential emissions from other miscellaneous equipment and in 1.A.4.c Agriculture/forestry/fisheries emissions from off-road agricultural and forestry transport are also estimated. Activity data of off-road vehicles and emission factors used for estimating GHG emissions can be found in Chapter 3.2.5.4 Off-road vehicles. In Table 3.34 the carbon emission factors of motor fuels used for off-road vehicles are presented, in Table 3.35 CH_4 emission factors and Table 3.36 N_2O emission factors of motor fuels used for off-road transportation are presented.

3.2.6.3. Uncertainties and time-series consistencies

Uncertainty evaluation of CO_2 emissions has been conducted for liquid, solid, gaseous, and other fuels used in Estonia in 2021. The data availability allows the estimation of uncertainty by a fuel type rather than by a sector in fuel combustion[29].

The estimated relative uncertainites of CO_2 emissions due to fuel combustion are presented in Table 3.16 in Chapter 3.2.4.3.

To estimate the uncertainties of CH_4 and N_2O emissions in the Transport sector the IPCC default values for activity data (5% and 10%) and for CH_4 emission factors (25%–150%) were used. For N_2O emission factor uncertainties (50%–125%) IPCC default and some Finnish values were used (**Table 3.44**).

Table 3.44. Summary of uncertainty estimates of CH_4 and N_2O emission factors and activity data (95% confidence interval)

Source and Sink	GHG	Activity data uncertainty U_A	Emission factor uncertainty U_E	Reference U_A, U_E
Liquid, solid, and gaseous fuels	CH_4	5%	50%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – IPCC GPG, Table 2.5, p. 2.41
Solid and gaseous fuels	N_2O	5%	50%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]
Liquid fuels	N_2O	5%	75%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]
Biomass	CH_4	10%	150%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]
	N_2O	10%	150%	U_A – IPCC GPG, Table 2.6, p. 2.41 U_E – Finnish[33]

3.2.6.4. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.2.3. 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.

3.2.6.5. Category-specific recalculations

Recalculations in 1.A.4 sub-categories are presented in Table 3.44.

Emissions were recalculated because of:

- dividing peat into milled&sod peat and peat briquette for the whole timeseries in all 1.A.4 subsectors;
- correcting the default emission factor values for diesel oil and gasoline for CH_4 and N_2O in 1.A.4.b Residential sector;
- using country-specific CH_4 and N_2O emission factors for biomass instead of default values;
- correcting light fuel oil consumption on mobile and stationary sectors as it was double counted in 1.A.4.b Residential sector.

Table 3.45. Differences between 2023 and 2022 submissions, kt CO_2 eq.

Year	1.A.4.a	1.A.4.b	1.A.4.c
1990	–	-40.27	–
1991	–	-39.99	–
1992	–	-43.20	–
1993	–	-43.66	–
1994	–	-62.70	0.08
1995	–	-118.82	–
1996	–	-139.11	0.42
1997	0.17	-145.60	0.51

Year	1.A.4.a	1.A.4.b	1.A.4.c
1998	0.25	-113.63	0.51
1999	0.17	-109.70	0.09
2000	0.26	-111.63	–
2001	0.17	-110.18	–
2002	9.57	-104.38	–
2003	0.16	-117.07	–
2004	0.24	-114.97	–
2005	0.17	-101.26	–
2006	12.67	-100.72	–
2007	28.33	-130.52	–
2008	–	-134.87	–
2009	–	-142.17	–
2010	–	-147.72	–
2011	–	-127.86	–
2012	–	-136.90	–
2013	–	-132.01	–
2014	–	-130.30	–
2015	–	-128.22	–
2016	0.18	-135.12	0.20
2017	–	-138.09	0.02
2018	–	-139.82	0.03
2019	-16.21	-135.51	0.02
2020	-13.58	-143.85	0.02

3.2.6.6. Category-specific planned improvements

There are no category-specific improvements planned.

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

3.3.1. Solid Fuels (CRF 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 2).

3.3.2. Oil and Natural Gas (CRF 1.B.2)

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.

CO_2 and CH_4 emissions from operations with natural gas are reported in following sub-sectors in CRF 1.B.2 Oil and Natural gas sector:

- 1.B.2.b.i Venting;
- 1.B.2.b.iii 4 Transmission and storage
- 1.B.2.b.iii 5 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 3.45.

Table 3.46. Reported emissions, calculation methods, and type of emission factors

CRF	Source	Emissions	Method	Emission factor
1.B.2.b.i	Venting	CO_2	T1	D
		CH_4		
1.B.2.b.iii 4	Transmission and storage	CO_2	T1	D
		CH_4		
1.B.2.b.iii 5	Distribution	CO_2	T1	D
		CH_4		

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

3.3.2.1. Category description

Estonia reports CO_2 and CH_4 emissions from natural gas venting, transmission, and distribution. Natural gas is 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 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.

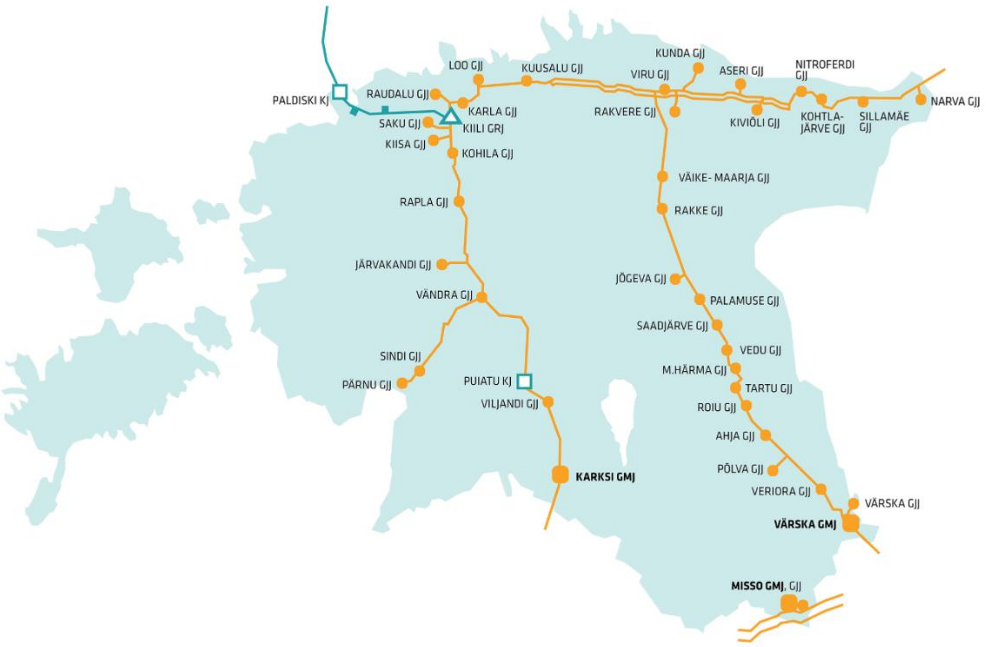


Figure 3.35. Natural gas distribution network in Estonia

In 2021 fugitive emissions from oil and natural gas were 23.16 kt CO_2 eq, of which CO_2 is 0.03 kt and CH_4 23.13 kt CO_2 eq. It is about 0.22% of the Energy sector's emissions and 0.15 % of total GHG emissions in Estonia. Corresponding emissions were 71.77 kt CO_2 eq. in 1990.

3.3.2.2. Methodological issues

The calculation of CH_4 emissions from oil and gas activities is presented in Equation 3.11:

Equation 3.11[53]

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

Where:

Emissions =	CH_4 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 CRF 1.B.2 is taken from the Joint Questionnaire dataset made by Statistics Estonia.

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

Emission factors and other parameters

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). All calculations of fugitive emissions are done in Excel tables created by the energy sector expert.

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. Quantitative overview

Table 3.46 shows CO_2 and CH_4 emissions from natural gas venting, Table 3.47 from natural gas transmission, Table 3.48 from natural gas distribution, and Table 3.49 presents total fugitive emissions.

Table 3.47. CO_2 and CH_4 emissions from natural gas venting in 1990, 1995, 2000, 2005, 2010, and 2015-2021

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Natural Gas Venting CO_2, kt	0.005	0.003	0.003	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Natural Gas Venting CH_4, kt	0.32	0.15	0.18	0.21	0.15	0.10	0.12	0.10	0.11	0.11	0.09	0.10
Natural Gas Venting Total, kt CO_2 eq.	9.01	4.30	4.88	5.90	4.15	2.88	3.16	2.91	3.05	2.83	2.57	2.91

Table 3.48. CO_2 and CH_4 emissions from natural gas transmission in 1990, 1995, 2000, 2005, 2010, and 2015-2021

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Natural gas transmission CO_2, kt	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.001
Natural gas transmission CH_4, kt	0.29	0.14	0.16	0.19	0.14	0.09	0.10	0.09	0.10	0.09	0.08	0.09
Natural gas transmission total, kt CO_2 eq.	8.22	3.92	4.45	5.38	3.78	2.63	2.88	2.65	2.78	2.58	2.34	2.65

Table 3.49. CO_2 and CH_4 emissions from natural gas distribution in 1990, 1995, 2000, 2005, 2010, and 2015-2021

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Natural gas distribution CO_2, kt	0.09	0.04	0.05	0.06	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Natural gas distribution CH_4, kt	1.94	0.93	1.05	1.27	0.89	0.62	0.68	0.63	0.66	0.61	0.55	0.63

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Natural gas distribution total, kt CO_2 eq.	54.54	25.99	29.54	35.68	25.10	17.42	19.11	17.60	18.45	17.10	15.52	17.60

Table 3.50. Total fugitive emissions in 1990, 1995, 2000, 2005, 2010, and 2015-2021, kt CO_2 eq

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Natural gas venting, transmission, and distribution total, kt CO_2 eq.	71.77	34.21	38.87	46.96	33.03	22.93	25.15	23.16	24.28	22.34	20.43	23.16

3.3.2.4. Uncertainties and time-series consistency

2006 IPCC *Tier 1* method is used to estimate the uncertainties in this category.

Uncertainties of activity data (± 10%) and emission factors (± 25%) are taken from the IPCC Good Practice Guidance.

3.3.2.5. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.2.3. A complete Quality Assurance (QA) and Quality Control (QC) was carried out for 1.B.2 Fugitive emissions 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.

3.3.2.6. Category-specific recalculations

Recalculations in 1.A.4 sub-categories are presented in Table 3.50.

Recalculations occurred because of correcting natural gas consumption data in 1.A.1.a Public electricity and power production calculations for the entire timeseries and this affected the total activity data of natural gas.

Table 3.51 Differences between 2023 and 2022 submissions, kt CO_2 eq.

Year	1.B.2.b.i	1.B.2.b.iii 4	1.B.2.b.iii 5
1990	-0.01	-0.010	-0.06
1991	-0.02	-0.017	-0.11
1992	-0.005	-0.005	-0.03
1993	-0.004	-0.004	-0.02
1994	-0.004	-0.004	-0.03
1995	-0.004	-0.004	-0.03
1996	-0.006	-0.006	-0.04
1997	-0.009	-0.008	-0.05
1998	-0.009	-0.008	-0.05
1999	-0.06	-0.05	-0.35
2000	-0.06	-0.06	-0.39
2001	-0.06	-0.05	-0.36
2002	-0.04	-0.04	-0.25
2003	-0.06	-0.05	-0.36

Year	1.B.2.b.i	1.B.2.b.iii 4	1.B.2.b.iii 5
2004	-0.05	-0.04	-0.29
2005	-0.05	-0.04	-0.28
2006	-0.04	-0.03	-0.21
2007	-0.08	-0.07	-0.49
2008	-0.08	-0.08	-0.50
2009	-0.08	-0.07	-0.47
2010	-0.08	-0.08	-0.51
2011	-0.08	-0.08	-0.50
2012	-0.07	-0.06	-0.40
2013	-0.06	-0.05	-0.35
2014	-0.05	-0.04	-0.28
2015	-0.04	-0.03	-0.23
2016	-0.19	-0.18	-1.18
2017	-0.03	-0.03	-0.20
2018	-0.12	-0.11	-0.71
2019	-0.12	-0.11	-0.74
2020	-0.07	-0.06	-0.39

3.3.2.7. Category-specific planned improvements

There are no category-specific improvements planned.

3.4 CO_2 transport and storage (CRF 1.C)

Up to 2021 no CO_2 transport and storage has been used in Estonia.

4. INDUSTRIAL PROCESSES AND PRODUCT USE

4.1. Overview of the sector

Greenhouse gas emissions from the Industrial processes and product use sector contributed 1.91% to the total anthropogenic greenhouse gas emissions in 2021 (Figure 4.1), totalling 295.94 kt CO_2 eq. with indirect CO_2 and 265.33 kt CO_2 eq. without indirect CO_2. Indirect CO_2 emissions in the sector is 30.61 kt CO_2 eq.

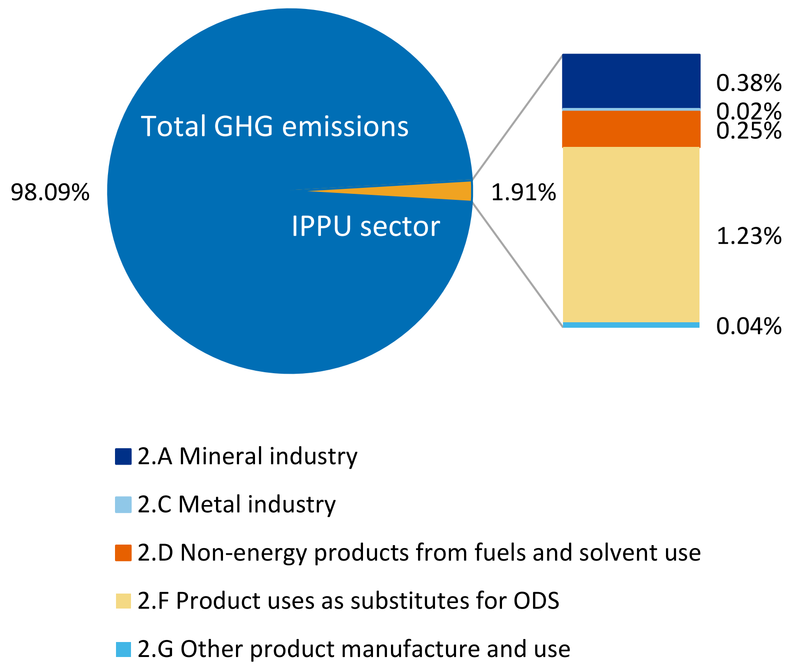


Figure 4.1. Emissions from Industrial processes and product use compared with total emissions in 2021, %

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

- Mineral industry (CRF 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 (CRF 2.B) – CO_2 emissions from ammonia production;
- Metal industry (CRF 2.C) including CO_2 emissions from secondary lead production (aggregated with CO_2 emissions from soda ash used by rare and rare earth metal industry);
- Non-energy products from fuels and solvent use (CRF 2.D) including CO_2 emissions from use of 1) lubricants and 2) paraffin waxes and 3) urea-based catalysts for motor vehicles, NMVOC emissions from solvent use and road paving with asphalt;
- Product uses as substitutes for ODS (CRF 2.F) including HFC emissions from refrigeration and air conditioning, foam blowing agents, fire protection and aerosols.

- Other product manufacture and use (CRF 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 (CRF 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 CRF 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 1990–2021

	Method applied/EF used				
GHG SOURCE AND SINK CATEGORIES	**CO_2**	**HFCs**	**N_2O**	**SF_6**	**Indirect CO_2**
2.A.1 Cement production	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/D		

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

Compared to 2020, the emissions from the Industrial processes and product use sector (with indirect CO2) increased by 2.30% in 2021.

Regarding chemical industry (2.B) – ammonia production has completely ceased since 2014 and the company has announced that it has sold all its 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 also the 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. 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. The decrease in 2020 was caused by the closure of clinker production in the only cement plant in Estonia in March 2020.

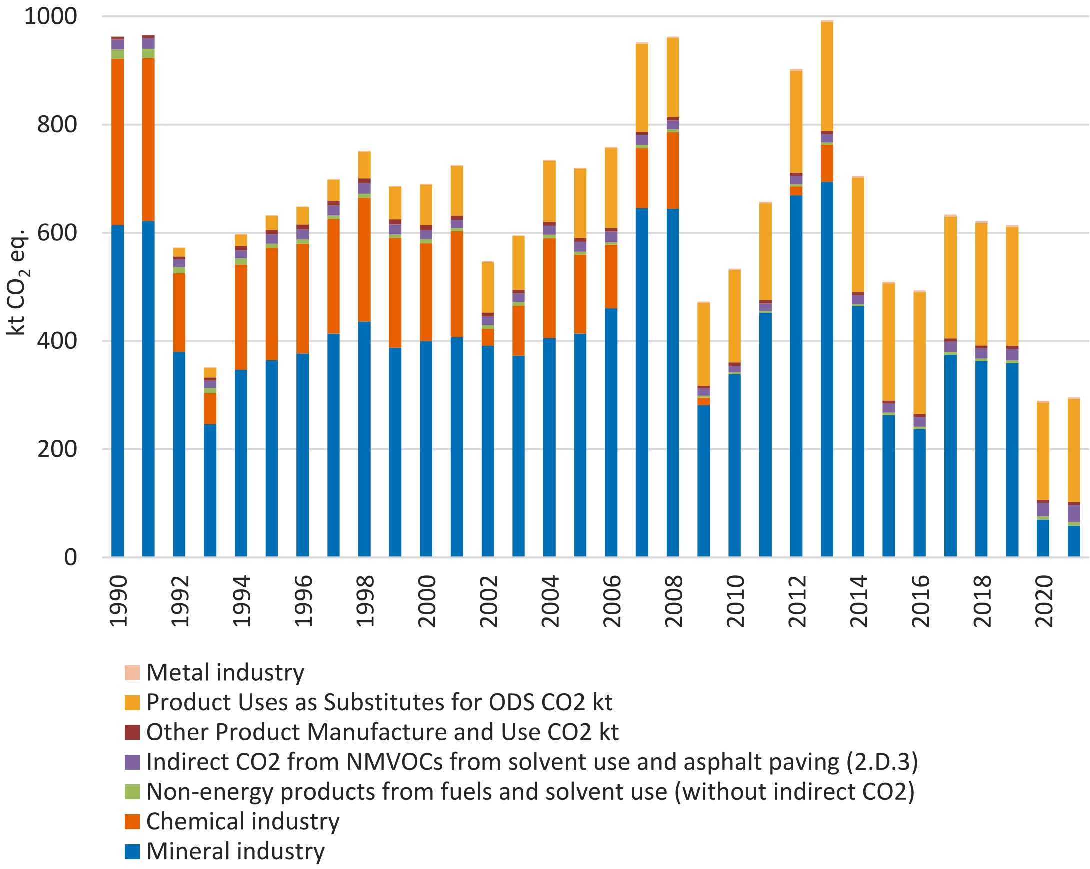


Figure 4.2. Emissions from Industrial processes and product use in 1990–2021 (with indirect CO_2), kt CO_2 eq.

Table 4.2. Trends in the greenhouse gas emissions from Industrial processes and product use in 1990–2021, kt CO_2 equivalent

*The use of HFC-s started in 1992 in Estonia

	1990	1995	2000	2005	2010	2015	2019	2020	2021
CO_2									
Mineral industry	614.0	364.4	399.9	413.6	338.5	262.8	359.2	70.3	58.8
Chemical industry	307.7	207.8	180.8	146.4	NO	NO	NO	NO	NO
Metal industry	0.8	0.7	1.6	1.5	2.5	3.0	3.3	2.9	3.0
Non-energy products from fuels and solvent use (without indirect CO_2)	17.4	7.5	7.4	5.1	4.2	5.5	5.7	6.6	7.8
Indirect CO_2 from solvent use and road paving with asphalt	18.4	17.4	16.5	18.5	11.3	15.8	20.4	23.8	30.6
N_2O									
Other product manufacture and use	4.9	5.4	7.2	6.0	4.5	3.4	2.8	2.8	2.4
HFCs	NO*	26.5	74.7	128.2	170.7	216.4	219.7	179.9	190.2
PFCs	NO**	NO	NO	NO	NO	NO	NO	NO	NO
SF_6, t	NO***	3.2	2.7	1.1	1.9	2.4	2.9	3.0	3.1
Total (with indirect CO_2)	**963.1**	**632.8**	**690.7**	**720.3**	**533.6**	**509.4**	**614.0**	**289.3**	295.9
Total (without indirect CO_2)	**944.7**	**615.4**	**674.2**	**701.8**	**522.3**	**493.6**	**593.6.6**	**265.5**	265.3

**The use of PFC-s took place in 2006-2008 in Estonia

***The use of SF_6 started in 1991 in Estonia

Key categories

The key categories in 1990 and 2021 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3.

4.2. Mineral industry (CRF 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;
  - Other (2.A.4.d) – use of limestone for flue gas desulphurisation at power plant until 2017;
  - 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.

CO_2 emissions from the Mineral industry have fluctuated since 1990 (Table 4.3 and Figure 4.3), decreased in 1993, 2009–2010,2015–2016 and 2020. 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, as used wet process was causing high CO_2 emissions and as the CO_2 quota prices started to rise, cement production using wet process technology was economically not 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 desulphurization (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. Instead of limestone, they used oil shale with higher calcium carbonate content in 2018 –2021 emissions from it are accounted under the Energy sector.

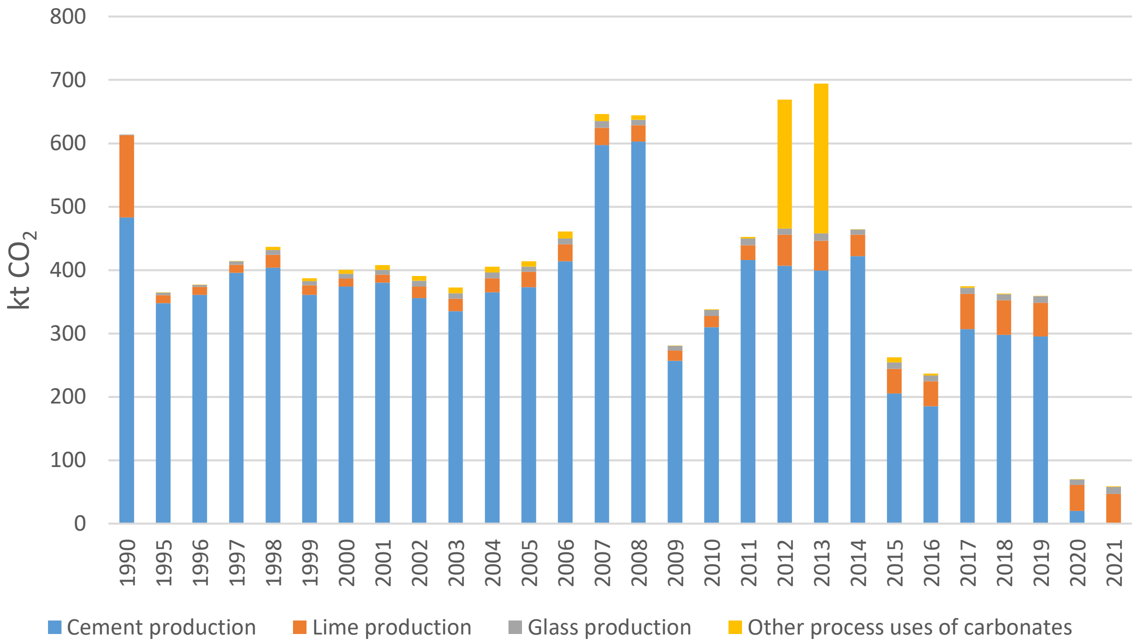


Figure 4.3. CO_2 emissions from Mineral industry in 1990–2021, kt

Table 4.3. CO_2 emissions from Mineral industry in 1990–2021, kt

	1990	1995	2000	2005	2010	2015	2019	2020	2021
2.A.1 Cement production	483.0	347.9	373.7	372.9	310.4	205.6	295.5	20.1	NO
2.A.2 Lime production	129.7	12.4	12.8	24.1	17.7	38.7	52.8	40.7	46.8
2.A.3 Glass production	1.2	4.0	7.4	8.1	9.7	10.0	10.4	9.0	11.0
2.A.4.a Ceramics	NA	0.05	6.0	8.5	0.7	1.0	0.5	0.5	1.0
2.A.4.b Soda ash use	IE[54]	IE	IE	IE	IE	IE	IE	IE	IE
2.A.4.d Other - Use of limestone for flue gas desulphurisation	NO	NO	NO	NO	NO	7.6	NO	NO	NO
Total	**614.0**	**364.4**	**399.9**	**413.6**	**338.5**	**262.8**	**359.2**	**70.3**	**58.8**

[54] All emissions previously reported under 2.A.4.b are now included into emissions reported under 2.C.5

4.2.1. Cement production (CRF 2.A.1)

4.2.1.1. Source category description

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, 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 CO_2 quota prices rose rapidly in 2019 and in 2020, therefore clinker production was ceased.

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 are also reported in the CRF and are calculated by the plant and reported to the Estonian Environmental Decisions Information System (KOTKAS[55]).

4.2.1.2. Methodological issues

Methods

Emissions from the cement production were calculated using a method compliant with the *Tier 2* method (Equation 4.1) from the IPCC 2006 Guidelines[56].

Equation 4.1

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

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[57] 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[58]).

Emission factors

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 plant.

[55] https://kotkas.envir.ee/, (22.02.2023)
[56] IPCC 2006 Guidelines, Volume 3, Chapter 2: Mineral Industry, page 2.9, equation 2.2.
[57] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018R2066 (22.04.2023)
[58] http://apki.net/wp-content/uploads/2013/05/WBCSD-CO2-Energy-Accounting-Reporting-Standard-for-The-Cement-Industry.pdf, (22.02.2023)

Activity data

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 CKD correction factor calculation done by the plant is compliant with the *Tier 2* method from the IPCC 2006 Guidelines[59].

The plant has stated that each year the CKD correction factor differs 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[60] and European Commission's best available techniques (BAT) reference document[61] to reduce 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, emission factors and CO_2 emissions for clinker production in 1990–2021

2.A.1 Cement production	1990	1995	2000	2005	2010	2015	2019	2020	2021
Clinker production, kt	790.3	571.3	619.5	635.4	536.7	356.3	503.6	35.0	NO
$EF_{clinker}$, t/t	0.549	0.547	0.538	0.547	0.549	0.558	0.556	0.555	NO
CKD correction factor	1.113	1.113	1.121	1.073	1.054	1.034	1.055	1.037	NO
CO_2 emissions kt	483.0	347.9	373.7	372.9	310.4	205.6	295.5	20.1	NO

4.2.1.3. Uncertainties and time-series consistency

The uncertainties of activity data and emission factors of clinker as well kiln dust production were provided by the plant operators. The uncertainty of activity data in 2020 was 0.024%, the uncertainty of the emission factor was 1.245%. The overall uncertainty was 1.25%.

For overall uncertainty of EF uncertainties of EF-s of clinker and kiln dust were combined by addition[62]. EF-s of both materials were based on chemical analysis of CaO, MgO and free lime. During the 2020 submissions´ centralized review, the review team noted (question I.1) that the influence from possible errors in the chemical analysis on the final uncertainty value was not explained in the NIR. In response to the ERT question during the review, Estonia clarified that the uncertainty of EF is combined (by addition) from the uncertainty of EF of clinker and that of kiln dust and that uncertainties of EFs of both materials consist of uncertainties of chemical analyses of CaO, MgO. For the overall emission uncertainty, the uncertainties of EF and AD are combined by multiplication. The uncertainty of AD is the uncertainty of weighing clinker and kiln dust and does not include chemical analysis. During the 2021 review, TERT asked for

[59] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.13, equation 2.5.
[60] https://www.riigiteataja.ee/en/eli/ee/510012019010/consolide/current, (22.02.2023)
[61] https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/CLM_Published_def_0.pdf, (22.02.2023)
[62] IPCC 2006 Guidelines, Volume 1, Chapter 3, page 3.28, equation 3.2

additional information how uncertainty is calculated[63]. As a response, the plant provided information that they are using World Business Council for Sustainable Development methodology for calculations and provided methodology approval documentation signed by the Minister of the Environment.

During the period of 1990-2020 Estonia had only one plant producing clinker and cement and this plant was also part of the European Union Emissions Trading System (EU ETS). Under the EU ETS, businesses must monitor and report their emissions for each calendar year and have their emission reports checked by an accredited verifier.

The uncertainties of the quantities presented by the company's GHG emissions report are calculated based on the formula, which is provided in the guidelines for the implementation of the Commission Regulation (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council – Guidance on Uncertainty Assessment (MRR Guidance document No. 4).

The uncertainty of the activity data of clinker and kiln dust is calculated by using activity data reported by the company and the uncertainty of the scale used to weigh raw materials in the factory. The activity data used in the calculations is the same that is reported in the EU ETS report. The uncertainty of the calibrated scale used to weigh the amounts of the raw mixtures is 0.025.

The uncertainty of the emission factor:

The value of the emission factor of clinker has been calculated according to the measurements of CaO, MgO and free lime content in the clinker made in the laboratory and the calculations of the value of the specific emission factor Calc B2 using the WBCSD CSI version 3.1 methodology with a plant specific clinker uncertainty of 0.007 tCO2/t provided by the company.

The value of the emission factor of kiln dust has been calculated according to the annual weighted average measurements of the CaO, MgO and free lime content carried out in the laboratory, and based on the mentioned results, the emission coefficient calculations made with the WBCSD CSI version 3.1 methodology with a plant specific clinker uncertainty of 0.007 tCO2/t provided by the company. The emission factors of clinker and kiln dust vary from year to year as they are calculated each year taking into account the content of CaO, MgO and free lime.

The overall emission uncertainty:

The overall emission uncertainty is calculated using the uncertainty of the scale used to weigh raw materials (0.0025) and the uncertainty of the emission factor. Possible errors in the chemical analysis affect the final uncertainty values, as the uncertainty of the emission factor (where EFs of clinker and kiln dust already contain possible errors of chemical analyses of CaO, MgO and free lime) is included in the calculation of the overall uncertainty.

The calculation explanations above were given by the company. The Ministry of the Environment has also approved the use of the calculation method with an approval document.

4.2.1.4. Category-specific QA/QC and verification

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.

[63] FCCC/ARR/2020/EST/I.1

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[55]).

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 were that the emissions in the EU ETS reports were rounded to the nearest ton (according to the Regulation (EU) 2018/2066 the emissions have to be submitted with the accuracy of 1 ton).

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

4.2.1.5. Category-specific recalculations

No category-specific recalculations have been done.

4.2.1.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.2.2. Lime production (CRF 2.A.2)

4.2.2.1. Source category description

CO_2 emissions from lime production are due to calcination of calcium and magnesium carbonates at high temperatures. In Estonia there are currently three lime production plants, out of which the smallest contributes ca 0.02% of the total lime production, the second largest around 46% and the biggest attributes to 54% of the total production in 2021.

4.2.2.2. Methodological issues

Methods

Emissions from lime production are calculated by multiplying emission factor with activity data. Activity data is mainly collected directly from the industry, but in the earlier years (1990–1996) industrial statistics have also been used. Two lime plants provide their emission factors which they use for their emission reports to EU ETS. The emission factor for historical plants in 1990–1996 are based on the IPCC's default emission factors.

The methods for calculating emissions from lime production are consistent with the Tier 2 level method (Equation 4.2) from the IPCC 2006 Guidelines[64].

Equation 4.2

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

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;

[64] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.21, equation 2.6.

$CF_{lkd,i}$ = 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.

Emission factors

Four different emission factors were used to calculate emissions from lime production. 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 also industrial statistics was used to calculate emissions from plants closed during 1990-1996. For the years 1990-1996 we used production data from Statistics Estonia and the IPCC default 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 managed to get 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 from which we have received company-based data have stayed the same throughout the time series. Two bigger plants that must submit their EU ETS reports are calculating 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[65] 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. In the 2010 submission of the NIR in chapter 4.2.2.5. Source-specific recalculations on page 130 it is stated: "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 is stated on page 357 in chapter 10.1. The same EFs have been used also for later years.

The emission factors were used to calculate emissions from lime production:

1. For historical lime plants in 1990–1996 the IPCC default value for lime emission factor 0.7665 was used.

2. One of the bigger plant 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 0.7857t 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.

3. 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.

4. The smallest lime plant has been estimating their emission factor since 1994.

---

[65] https://www.riigiteataja.ee/akt/108032019006?leiaKehtiv, (22.02.2023)

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

The operator of the biggest 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[66]) 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[67]. This complies with the fact that in their annual waste report the plant reports no mineral waste. The environmental permit and e-mail from the plant operators can be provided to reviewers on request.

The operator of the second biggest plant confirms that almost all of kiln dust arises from crushing the burnt lime after the lime is weighed. CO_2 emissions are calculated on the basis 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 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.

According to the IPCC 2006 Guidelines (Equation 4.3)[68]:

Equation 4.3

$$EF_{lime} = 0.85 \times EF_{high\ calcium\ lime} + 0.15 \times EF_{dolomitic\ lime}$$

$EF_{lime} = 0.85 \times 0.75 + 0.15 \times 0.86 = 0.7665$. This value is applied to those companies that were closed before 1996, as no better data is available.

Activity data

Activity data (Table 4.5) for lime production is collected mainly directly from the 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 (1997–2020).

The production in 2020 decreased because of decreased consumption. Main reason for the decreased consumption was the price increase of lime mainly due to CO_2 quota price increase. In 2021 the production rose a little, but not back to the level of the years 2017-2019.

Data on lime production as well as emission factors between 1990–2021 are available in Table 4.5.

Table 4.5. Activity data, emission factors and CO_2 emissions for lime production in 1990–2021

2.A.2 Lime	1990	1995	2000	2005	2010	2014	2015	2016	2017	2019	2020	2021
Lime production, kt	185.0	16.8	19.9	37.2	26.9	48.8	54.5	55.4	78.0	73.1	54.8	63.8
IEF_{lime}, t/t	0.70	0.74	0.64	0.65	0.66	0.70	0.71	0.71	0.71	0.72	0.74	0.73

[66] Database of Estonian environmental permits, https://kotkas.envir.ee/permits/public_view?search=1&owner_name=&permit_nr=20971&permit_status=ISSUED&search_location=&issue_date_end=&valid_start_date_end=&valid_start_date_start=&represented_id=&issue_date_start=&permit_id=101135, (22.02.2023).
[67] https://eippcb.jrc.ec.europa.eu/reference, (22.02.2023).
[68] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.22, equation 2.8.

2.A.2 Lime	1990	1995	2000	2005	2010	2014	2015	2016	2017	2019	2020	2021
CO_2 emissions kt	129.7	12.4	12.8	24.1	17.7	34.1	38.7	39.3	55.4	52.8	40.7	46.8

4.2.2.3. Uncertainties and time-series consistency

The uncertainty of tonnes of produced lime is 0.18%. This is combined uncertainty of two largest lime producer´s output.

The default value of EF uncertainty 2%, is used for lime production[69].

The percentage of CaO and MgO in the lime differs from year to year because of differences in the quality of raw material. The EFs of CaO and MgO are calculated based of the ratio of molecular weight of CO2 to CaO/MgO. 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. In the 2010 submission of the NIR in chapter 4.2.2.5. Source-specific recalculations on page 130 it is stated: "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 is stated on page 357 in chapter 10.1. The same EFs have been used also for later years.

4.2.2.4. Category-specific QA/QC and verification

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 completeness of the category was checked from the Estonian Environmental Decisions Information System (KOTKAS[55]), 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 from plants submitting EU ETS reports have been compared with EU ETS data in the period of 2005-2021. 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 have to be submitted with the accuracy of 1 ton) but the emissions in the GHG inventory are not rounded.

4.2.2.5. Category-specific recalculations

No category-specific recalculations have been done.

4.2.2.6. Category-specific planned improvements

There are no planned category-specific improvements.

[69] IPCC 2006 Guidelines,Volume 3, Chapter 2, Table 2.5.

4.2.3. Glass production (CRF 2.A.3)

4.2.3.1. Source category description

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.

4.2.3.2. Methodological issues

Methods

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[70] is used (Equation 4.4).

According to the Tier 1 method:

Equation 4.4

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

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[71] is used (Equation 4.5).

Equation 4.5

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

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.

Activity data (1993–2021) was collected directly from glass producing company.

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

---

[70] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.28, equation 2.10.
[71] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.28, equation 2.12.

Emission factors

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 2006–2021. 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[72] and are based on stoichiometric ratios. The emission factor for limestone is then (Equation 4.6):

Equation 4.6

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

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[73]. 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.

Activity Data

The consumption of limestone, sodium carbonate and coke has been used as activity data when calculating emissions from container glass production. Activity data was collected directly from the glass producing plant (Table 4.6).

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 taken into account and national level data on the mass of flat glass produced was multiplied by 0.20 × (1 – 0.50) = 0.10 tonnes CO_2/tonnes glass produced.

Data on glass production as well as emission factors between 1990–2021 are available in Table 4.6.

Table 4.6. Activity data and emission factors and emissions from container and glass production in 1990–2021

2.A.3 Glass	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
Container glass production, kt	NO	27.9	59.1	62.1	81.6	88.0	86.7	76.7	76.9
Limestone consumption, kt	NO	3.86	8.99	8.64	11.17	11.35	11.98	10.50	12.85
IEF, t/t	NA	0.434	0.434	0.434	0.441	0.44	0.44	0.44	0.44
Sodium carbonate consumption, kt	NO	2.90	8.10	10.20	11.25	11.91	12.13	10.55	12.92
$EF_{default}$, t/t	NA	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415
Coke consumption, t	NO	9.89	34.85	36.33	18.78	22.85	27.27	24.51	26.86
IEF, t/t	NA	3.667	3.667	3.667	3.667	3.192	3.190	3.190	3.190

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

2.A.3 Glass	1990	1995	2000	2005	2010	2015	2019	2020	2021
Flat glass production, kt	12.3	11.2	NO	NO	NO	NO	NO	NO	NO
$EF_{default}$ x (1 - CR), t/t	0.1	0.1	NA	NA	NA	NA	NA	NA	NA
CO_2 emissions kt	1.2	4.0	7.4	8.1	9.7	10.0	10.4	9.0	11.0

4.2.3.3. Uncertainties and time-series consistency

The plant estimated the activity data uncertainty to be at ±0.32%. Uncertainty of the emission factor is estimated at ±1% as suggested in IPCC 2006 Guidelines[74].

4.2.3.4. Category-specific QA/QC and verification

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 completeness of the category was checked from the Estonian Air Pollution Sources Information System and no other glass production plants were found. The environmental report of the glass plant from Estonian Environmental Decisions Information System (KOTKAS[55]) was compared to the GHG inventory data and no discrepancies were found.

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 2023 submission were compared with respective data from EU ETS. The amounts of limestone, soda ash and coke were identical in ETS and GHG inventory.

4.2.3.5. Category-specific recalculations

No category-specific recalculations have been done.

4.2.3.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.2.4. Other process uses of carbonates (CRF 2.A.4)

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

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

4.2.4.1. Ceramics (CRF 2.A.4.a)

Subcategory 2.A.4.a Ceramics consists of

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

[74] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.31.

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.

The emissions from different ceramic products are aggregated in the CRF. 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).

4.2.4.1.1. Bricks and roof tiles production

Source category description

Historically in Estonia there have been multiple plants that have produced either bricks or roof tiles or both. In the last 13 years there has been only one big producer. The output has been fluctuating a lot because of variance in export demand.

Methodological issues

Methods

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[75]. In the case of the large production plant, from the years 2001-2020 the emissions arose only from limestone filler. Since 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 4.7):

Equation 4.7

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

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 4.8):

Equation 4.8

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

Where:

CO_2 emissions = emissions of CO_2 from other process uses of carbonates, tonnes;
M_{ls} = mass of limestone consumed, tonnes;
M_d = mass of dolomite consumed, tonnes;

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

EF_{ls} or EF_d = emission factor for limestone or dolomite calcinations, tonnes CO_2/tonne carbonate.

Emission factors

Emission factors for calculating emissions from limestone and dolomite use are based on the IPCC default factors[76]. 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, the emission factor 0.47732 t of CO_2 per tonne of dolomite is used.

Activity data

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 2001-2020. 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 2021. 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 have 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%[77] 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[78].

For the years 1992–2021 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.

Data on ceramics production as well as emission factors between 1990–2021 are available in Table 4.7 and as it can be seen from there that IPCC default EF-s for calcium carbonate (0.43971) and dolomite (0.47732) are used and the proportion of these substances in raw

[76] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.
[77] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34
[78] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.36.

material is actually small – it is on the row "High-calcium limestone consumption for all ceramics (limestone filler + 85% of carbonate component of some type of clay), kt.

Table 4.7. Activity data, emission factors and emissions from bricks and tiles and lightweight gravel production in 1990–2021

	1990	1995	2000	2005	2010	2015	2019	2020	2021
2.A.4.a Ceramics									
Production of ceramics, kt including:	251.1	28.8	119.6	184.6	38.3	33.4	35.0	36.9	36.2
Production of bricks and tiles, kt	251.1	28.8	32.7	69.0	38.3	33.4	35.0	36.9	36.2
Emissions from bricks and roof tile production, kt	NA	0.051	0.014	0.653	0.705	0.952	0.527	0.509	1.031
EF of bricks and roof tiles, t CO_2/t products	NA	0.002	$4 \cdot 10^{-4}$	0.008	0.018	0.028	0.015	0.014	0.028
Production of lightweight gravel, kt	NO	NO	86.9	115.6	NO	NO	NO	NO	NO
Emissions from lightweight gravel production, kt	NO	NO	6.0	7.9	NO	NO	NO	NO	NO
EF of lightweight gravel, t/t	NO	NO	0.069	0.068	NO	NO	NO	NO	NO
High-calcium limestone consumption for all ceramics (limestone filler + 85% of carbonate component of some type of clay), kt	NO	0.10	9.48	14.13	1.60	2.16	1.20	1.16	1.28
$EF_{default}$ t/t ($CaCO_3$)	$EF_{default}$ t/t ($CaCO_3$) 0.43971 was used for all years								
Dolomite consumption (15% of carbonate component of some type of clay), kt	NO	0.017	3.804	4.835	0.001	0.0004	0.0003	0.0002	0.0001
$EF_{default}$ t/t ($CaMg(CO_3)_2$)	$EF_{default}$ t/t ($CaMg(CO_3)_2$) 0.47732 was used for all years								

Uncertainties and time-series consistency

The largest producer estimated the total uncertainty to be about 2%. The uncertainty of activity data is estimated at ±0.1% (by the supplier of limestone filler) and consists of uncertainty of limestone weighing.

Uncertainty of the emission factor was estimated at ±2%, which consists mainly of the uncertainty of chemical analysis for carbonate content.

The total uncertainty is ±2%. The effect of uncertainties of small producers' emissions on the total uncertainty is minimal because its emissions are 0.1% of the total emissions.

Category-specific QA/QC and verification

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.

For completeness check, the Estonian Environmental Decisions Information System (KOTKAS[55]) 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%.

Category-specific recalculations

No category-specific recalculations were done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.2.4.1.2. Lightweight gravel production

Source category description

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 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.

Methodological issues

Methods

Emissions from lightweight gravel production were calculated using the Tier 1 methodology from the IPCC 2006 Guidelines (Equation 4.9)[79]. According to the Tier 1 method:

Equation 4.9

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

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.

Emission factors

Emission factors for calculating emissions from limestone and dolomite use are based on the IPCC default factors[80]. 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.

Activity data

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 the 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 for clays. It was assumed that 85% of the carbonates consumed are limestone and 15% are dolomite[81].

[79] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34, equation 2.14.
[80] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.
[81] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.36.

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

Uncertainties and time-series consistency

IPCC Tier 1 method was used in estimating the uncertainties of this category.

The emission factor uncertainty was estimated at ±5%. The emission factor is the stoichiometric ratio reflecting the amount of CO_2 released upon calcinations of the carbonate.

The uncertainty of activity data is estimated at ±10%. The uncertainty of activity data took into account the uncertainty associated with weighing and proportioning the carbonates in clay and the uncertainty associated with the assumption of a default breakdown of limestone and dolomite of 85%/15%.

Category-specific QA/QC and verification

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.

For completeness check the Estonian Environmental Decisions Information System (KOTKAS[55]) was checked and no other plants that have emitted CO_2 from ceramic products were found.

The activity data could not have been compared with the data from Statistics Estonia, because Statistics Estonia cannot provide separate data on lightweight gravel production for confidentiality reasons.

Category-specific recalculations

No source-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.2.4.2. Other – Limestone use for flue gas desulphurisation (CRF 2.A.4.d)

4.2.4.2.1. Source category description

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 2021 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 fuelling the emissions arising from it are accounted under the Energy sector.

4.2.4.2.2. Methodological issues

Methods

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[82].

Emission factors

Calculation methods for emission factors are adapted from verified EU-ETS reports from three power plants and modified in 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[83]. 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")[84].

Activity data

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 CRF Reporter.

4.2.4.2.3. Uncertainties and time-series consistency

The uncertainty of activity data was estimated by the plants at ±0.1%.

---

[82] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.36.
[83] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.
[84] https://www.riigiteataja.ee/akt/108032019006?leiaKehtiv, (22.02.2023)

The uncertainty of the emission factor depends on the accuracy of chemical analysis. The emission factor uncertainty in 2017 was estimated to be ±2% which is in the middle of the range of default values (1–3%) suggested by the IPCC 2006 Guidelines[85].

4.2.4.2.4. Category-specific QA/QC and verification

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 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 CRF were compared with emissions reported to EU ETS. The emissions reported in the CRF were 8.6% higher than those reported for EU ETS in 2017. The differences are caused by the conformation of different emission factor calculation methods of different companies (more information in paragraph 4.2.4.2.2 Emissions factors).

4.2.4.2.5. Category-specific recalculations

No category-specific recalculations were done.

4.2.4.2.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.3. Chemical industry (CRF 2.B)

4.3.1. Ammonia production (CRF 2.B.1)

4.3.1.1. Source category description

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 2014–2021, no NH_3 production took place at this plant. The plant operator has announced that it has sold all of 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. 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 stabilized 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 the production and in emissions was in 2009. In 2009, the plant temporarily stopped production at the beginning of February. In 2010–2011, there was no production of ammonia

[85] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.39.

in Estonia. The plant restarted ammonia production at the beginning of December in 2012 and production continued until September 2013.

4.3.1.2. Methodological issues

Estonia was accounting 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 under the Agriculture sector, 3.H. Urea application together with imported urea that was used as fertilizer.
2. In current submission, 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 under subsector 2.D.3 Other.

Methods

Estonia uses method Tier 3 in calculating CO_2 emissions from ammonia production (Equation 4.10)[86].

According to the Tier 3 method:

Equation 4.10

$$CO_2\ emissions = \sum_i (TFR_i \times CCF_i \times COF_i \times 44/12) - R_{CO2}$$

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.

Emission factors

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

[86] IPCC 2006 Guidelines, Volume 3, Chapter 3, page 3.13.

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.

Activity data

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, emission factors and CO_2 emissions from ammonia production in 1990–2021 are in Table 4.8.

Table 4.8. Activity data (and its differences to statistical data), emission factors and CO_2 emissions from ammonia production in 1990–2021

2.B.1	1990	1995	2000	2005	2010–2011	2012	2013	2014–2021
Ammonia production, kt	294.0	201.3	176.8	212.6	NO	17.2	120.9	NO
Amount of natural gas used as feedstock, million m^3	227	148	124	146	NO	13	83	NO
Amount of natural gas used as feedstock, TJ	7 657	4 978	4 166	4 915	NO	448	2789	NO
Difference between natural gas feedstock AD (TJ) to statistical data, %	0.0	0.0	0.0	0.0	NO	0.0	0.0	NO
Carbon content of natural gas, t C/TJ	15.1	15.5	15.2	15.0	NO	14.8	15.1	NO
$EF_{ammonia}$, t/t (recovered amounts subtracted)	1.4	1.4	1.3	1.3	NO	1.4	1.3	NO
CO_2 captured in produced urea subtracted from emissions, kt	116.4	74.7	50.7	124.8	NO	7.6	85.8	NO
CO_2 emission from ammonia production, kt (recovered amounts not included)	307.7	207.8	180.8	146.4	NO	16.6	68.6	NO

4.3.1.3. Uncertainties and time-series consistency

The uncertainty of activity data was provided by the plant, and it was ±1% in 2013. The uncertainty of emission factor was determined mainly by the carbon content of natural gas and uncertainty of weighing carbamide of which carbon is subtracted from emissions. For carbon content uncertainty the same uncertainty value for natural gas carbon content as in the Energy sector – ±3.6% – was used. Uncertainty of weighing carbamide was 2% according to the plant operator. The carbon oxidation coefficient has negligible uncertainty. The uncertainty of EF is $\sqrt{(3.6^2+2^2)}$= 4.1%. Total uncertainty was $\sqrt{(1^2+4.1^2)}$ = 4.2% in 2013.

4.3.1.4. Category-specific QA/QC and verification

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.

In 2014-2021, the plant had no obligation to submit its EU ETS report because no production took place during these years.

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 asked to provide background data sources that inform estimates of natural gas used as fuel in ammonia plants[87]. Background data is provided by the plant operator and the before mentioned data sources used for quality control EU ETS and Estonian Air Pollution Sources Information System.

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[88]. 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 4.8. For 1990–2003 and 2005–2013 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.

4.3.1.5. Category-specific recalculations

No category-specific recalculations have been done.

4.3.1.6. Category-specific planned improvements

There are no planned category-specific improvements.

[87] ARR2016/ Table 5. I.8 IPPU
[88] ARR2016/ Table 5. I.9 IPPU

4.4. Metal industry (CRF 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 and rare earth metals and compounds industry.

In CRF CO_2 emissions from both categories are aggregated and reported under 2.C.5 – Lead production. Most emissions arise from lead production.

In CRF, 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 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 CRF for the years 1990–2002.

The reason why emissions from soda ash used in rare 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 and rare earth metals and compounds industry is described separately in following subparagraphs.

4.4.1. Lead production (CRF 2.C.5)

4.4.1.1. Source category description

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 desulphurization 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 neutralized with Na_2CO_3.

4.4.1.2. Methodological issues

The lead battery recycling plant was launched in autumn 2003 and therefore emissions were small in the first year.

Emissions arise from: 1) neutralization of sulphuric acid with soda ash and; 2) reduction-oxidation reaction between coal and lead carbonate in the smelting process. In 2021 emissions from the category 2.C were 3.00 kt CO_2.

Methods

Estonia uses the *Tier 3*[89] 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 taking into account the following:

1. Emissions from soda ash reaction with sulphuric acid in neutralization process are calculated by multiplying the stoichiometric ratio of CO2/Na2CO3 with the amount of used carbonates (Equation 4.11)[90]. 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.

The summarized reaction can be described by the following equation:

Equation 4.11

$$PbSO_4 + Na_2CO_3 + C = Pb + CO + CO_2 + Na_2SO_4$$

Emission factors

The emission factor of soda ash is 0.41492[91]. The emission factor of anthracite is carbon content multiplied with EF of the carbon – 44/12.

Activity data

The quantity of soda ash used for sulphuric acid neutralization as well as the quantity and carbon content of anthracite used as a reducing agent are provided by the plant. Table 4.9 presents the quantities of consumed anthracite in lead production and aggregated quantities of soda ash and ammonium bicarbonate used in lead and rare and rare earth metals production. Aggregation is because of confidentiality reasons.

Table 4.9. 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**	**1995**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
Anthracite use kt	NO	NO	NO	0.309	0.657	0.624	0.764	0.668	0.676
Soda ash and ammonium bicarbonate use, kt	1.87	1.56	3.74	1.48	1.26	2.88	2.52	2.26	2.44

4.4.1.3. Uncertainties and time-series consistency

The uncertainty of activity data is default value for *Tier 3* method ±5%[92]. Uncertainty of emission factor is also 5% – the default value for *Tier 3*.

[89] IPCC 2006 Guidelines, Volume 3, Chapter 4, page 4.73
[90] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.35
[91] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1
[92] IPCC 2006 Guidelines, Volume 3, Chapter 4, page 4.76, table 4.23

4.4.1.4. Category-specific QA/QC and verification

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[55]). No differences were found.

4.4.1.5. Category-specific recalculations

No recalculations have been done.

4.4.1.6. Category-specific planned improvements

No category-specific improvements are under active consideration at the moment.

4.4.2. Emissions from rare and rare earth metals and compounds industry (reported under CRF category 2.C.5 Lead production aggregated with emissions from lead production)

4.4.2.1. Source category description

Separation and production of rare 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.

4.4.2.2. Methodological issues

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) neutralization of residual solutions and gases in rare metals production. In addition, there are emissions arising from calcination of rare earth metal carbonates to oxides.

Methods

Estonia uses the *Tier 3* method of category 2.A.5 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[91]) 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

$$La_2(CO_3)_3 = La_2O_3 + 3CO_2$$

Emission factors

The emission factor of soda ash is 0.41492[91]. 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.

Activity data

The quantities of soda ash used by the plant in 1998, 2002-2021 (in 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.

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[93], Äripäev, 1998[94]).

4.4.2.3. Uncertainties and time-series consistency

The uncertainty of the emission factor for this category estimated at ±5%. The emission factor is the stoichiometric ratio reflecting the amount of CO_2 released upon decomposition of the carbonate.

The uncertainty of activity data is estimated at ±3% as suggested in the 2006 IPCC Guidelines[95]. The overall uncertainty of category 2.C.5 is 5.83%.

4.4.2.4. Category-specific QA/QC and verification

The quantities of consumed soda ash and volumes of REE compounds were checked from the Estonian Environmental Decisions Information System (KOTKAS[55]). No significant differences were found.

4.4.2.5. Category-specific recalculations

No category-specific recalculations have been done.

---

[93] Äripäev, 1995 https://www.aripaev.ee/uudised/1995/12/03/silmet-otsib-uusi-partnereid, (22.02.2023).
[94] Äripäev, 1998 https://www.aripaev.ee/uudised/1998/11/19/silmet-ootab-kasumit, (22.02.2023).
[95] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.39, section 2.5.2.2.

4.4.2.6. Category-specific planned improvements

No improvements are planned at the moment.

4.5. Non-energy products from fuels and solvent use (CRF 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 4.4.

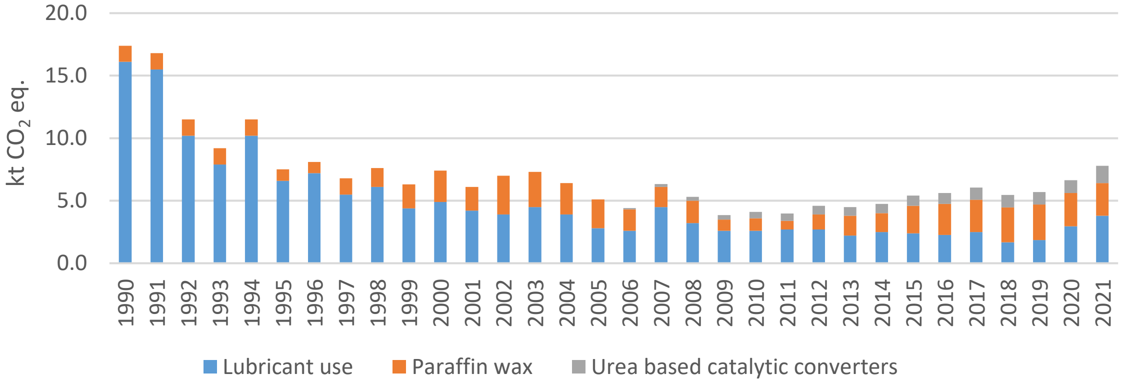


Figure 4.4. CO_2 emissions from non-energy products from fuels and solvent use in 1990–2021, kt

Table 4.10. Activity data, emission factors and emissions concerning lubricants, paraffin waxes and urea based catalytic converters for motor vehicles

	1990	1995	2000	2005	2010	2014	2015	2019	2020	2021
2.D.1 Lubricant use, kt	27.3	11.2	8.4	4.8	4.5	4.3	4.1	3.1	5.0	6.5
Lubricant use, TJ	1 098	449	336	191	180	172	165	126	202	262
CO_2 emission, kt	16.1	6.6	4.9	2.8	2.6	2.5	2.4	1.9	3.0	3.8
$EF_{lubricants}$, t/t	0.5896 for all years									
2.D.2 Paraffin wax use, kt	2.2	1.6	4.2	3.8	1.8	2.5	3.8	4.8	4.5	4.4
Paraffin wax use, TJ	88	63	167	154	71	100	153	194	182	179
CO_2 emission, kt	1.3	0.9	2.5	2.3	1.0	1.5	2.2	2.8	2.7	2.6
$EF_{paraffin\ waxes}$, t/t	0.5896 for all years									
2.D.3 Urea based catalysts for motor vehicles, kt	NO	NO	NO	NO	2.1	3.1	3.4	4.3	4.2	5.8
CO_2 emission, kt	NO	NO	NO	NO	0.5	0.7	0.8	1.0	1.0	1.4
$EF_{catalytic\ converters}$, t/t	0.2383 for all years									

	1990	1995	2000	2005	2010	2014	2015	2019	2020	2021
Sum of CO_2 emissions from 2.D.1-2.D.3, kt (excl. indirect CO_2)	17.4	7.5	7.4	5.1	4.1	4.7	5.5	5.7	6.7	7.8

4.5.1. Lubricant use (CRF 2.D.1)

4.5.1.1. Source category description

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.

4.5.1.2. Methodological issues

Method

Emissions from lubricants were calculated using the Tier 1 method according to the IPCC 2006 Guidelines (Equation 4.14)[96]. 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[97].

Equation 4.14

$$CO_2\ emissions = \sum (LC \times CC_{lubricant} \times ODU_{lubricant}) \times 44/12$$

Where:

CO_2 emissions = CO₂ 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.

In 2021 the apparent consumption of lubricants was 6.53 kt and the CO_2 emission from this category (2.D.1) was 3.85 kt.

Activity Data

Data on production of lubricants in 1990–2021 was provided by Statistics Estonia. No production of motor and industrial oils was present in Estonia during 1990–2021 according to Statistics Estonia and the Eurostat database[98].

The apparent consumption of lubricants was calculated with the formula: import minus export, as no lubricant production occurred.

[96] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.7, equation 5.2.
[97] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.9, section 5.2.2.2.
[98] https://ec.europa.eu/eurostat/web/main/data/database, (22.02.2023)

The quantities in tonnes were converted into TJ using the default net calorific value – 40.2 TJ/kt in line with the IPCC 2006 Guidelines[99].

Activity data on lubricants are presented in Table 4.10.

Emission factors

According to Tier 1 the weighted average ODU factor 0.2 for lubricants is used[100].

The default carbon content for lubricants 20.0 t C/TJ was applied[101].

4.5.1.3. Uncertainties and time-series consistency

Statistics Estonia estimated the uncertainty of activity data (international trade) to be 5%, which is the same value as suggested in the IPCC 2006 Guidelines (section 5.2.3.2). For ODU, the default uncertainty of 50% was used. For carbon content, the coefficient the default uncertainty of ±3% was used.

4.5.1.4. Category-specific QA/QC and verification

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.

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. Import numbers declined steadily from 1990 to 2006, which has made the biggest impact on the overall trend. The amount of lubricants used show that less lubricants are needed on the market. 2020 and 2021 data shows increase in usage of lubricants and therefore rise in CO_2 emissions.

4.5.1.5. Category-specific recalculations

No category-specific recalculations have been done.

4.5.1.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.5.2. Paraffin wax use (CRF 2.D.2)

4.5.2.1. Source category description

The category includes such products as candles, petroleum jelly, paraffin waxes and other waxes, including ozokerite. Most of the CO_2 emissions in this category derive when the waxes

[99] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.18, table 1.2.
[100] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.9, table 5.2.
[101] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.21, table 1.3.

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.

4.5.2.2. Methodological issues

Method

Emissions from paraffin waxes were calculated using the *Tier 1* method according to the IPCC 2006 Guidelines (Equation 4.15)[102], 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[102]

$$CO_2\ emissions\ =\ PW\ \times\ CC_{wax}\ \times\ ODU_{wax}\ \times\ 44/12$$

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.

In 2021, the apparent consumption of paraffin waxes (including candles) was 4.44 kt and the CO_2 emission from this category (2.D.2) was 2.62 kt.

Activity data

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 2006–2021 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 basically 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 1995–2021 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 tonnes were converted into TJ using the default net calorific value – 40.2 TJ/kt[103].

Activity data on paraffin waxes are presented in Table 4.10.

102 IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.11, equation 5.4.
103 IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.18, table 1.2.

Emission factors

Default oxidation factor (ODU) of 0.2 and carbon content 20.0 t C/TJ were applied according to the IPCC 2006 Guidelines[104].

4.5.2.3. Uncertainties and time-series consistency

Uncertainty of activity data on paraffin wax consumption is estimated to be ca 20% for the years 2007–2021[105]. For earlier years, the uncertainty of activity data is estimated to be 50% because the emissions were calculated on estimates.

For carbon content coefficient the default uncertainty of ± 5% was used.

The applied default ODU factor 0.2 has an uncertainty of about 100%.

4.5.2.4. Category-specific QA/QC and verification

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.

All possible CN 8-digit codes for paraffin waxes were checked from Eurostat to make sure that all of them were included.

4.5.2.5. Category-specific recalculations

No category-specific recalculations were done.

4.5.2.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.5.3. Other (CRF 2.D.3)

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.

4.5.3.1. Other – Urea based catalysts for motor vehicles

4.5.3.1.1. Source category description

Directive 2005/55/EC of the European Parliament and of the Council introduced Euro IV maximum limit of NOx 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

[104] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.21, table 1.3.
[105] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.13 section 5.3.3.2.

registered after 1st September 2015 have to 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[106]. 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[107].

Summary reaction of urea in SCR systems (Equation 4.16):

Equation 4.16

$$4NO + 2(NH_2)_2CO + O_2 = 4N_2 + 4H_2O + 2CO_2$$

4.5.3.1.2. Methodological issues

The *Tier 2* method from the IPCC 2006 Guidelines was used[108].

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.

For average consumption of DEF per fuel consumption, the IPCC 2006 Guidelines suggest a default value 1–3% of diesel fuel consumption.

The emission factor consists of the concentration of urea in it (purity) and stoichiometric coefficient of conversion of C in urea into CO_2.

In 2021, the consumption of urea-based DEF (AdBlue) was 5.79 kt and the CO_2 emission from this category (2.D.3) was 1.38 kt. The main reason for having a higher emission compared to 2020, is the growing number of new (Euro 6 complying) passenger cars, light commercial vehicles and trucks and buses.

Methods

According to the *Tier 2* methodology:

Equation 4.17

$$Emission = Activity \times 12/60 \times Purity \times 44/12$$

Where:

12/60 = stoichiometric coefficient of carbon in urea;
44/12 = stoichiometric coefficient of conversion of carbon to CO_2.

---

[106] EAA air pollutant inventory emission guidebook 2019, page 61 (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, (22.02.2023)
[107] 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, (22.02.2023).
[108] IPCC 2006 Guidelines, Volume 2, Chapter 3 page 3.12.

Emission factors

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.

Activity data

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, from 2015 light vehicles have also been accounted.

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%.

4.5.3.1.3. Uncertainties and time-series consistency

1. Uncertainty of activity data consists of:

   - uncertainty of diesel fuel consumption, which is 1.7% according to a country-specific study[109] done by the Estonian Central Office of Metrology;

   - uncertainty of consumption of DEF per diesel fuel unit. The default average consumption of DEF per fuel consumption is 1–3%[110]. Assuming that the average value is somewhere in the higher end of this range as told by Estonian fuel wholesalers, the uncertainty is estimated to be about 30%.

The combined uncertainty of activity data is $\sqrt{(1.7^2+30^2)}$=30%

2. Uncertainty of emission factor depends mainly on uncertainty of urea concentration in DEF. It is assumed that the concentration range matches the quality standard for aqueous ISO 22241-1:2006 Diesel engines –NO_x reduction agent AUS32 –Part 1: Quality requirements which suggests that concentration is 32.5 ± 0.7%. Therefore, the emission factor is 0.7%.

The total uncertainty of emissions from catalysts for motor vehicles is therefore: $\sqrt{(0.7^2+30^2)}$=30%.

4.5.3.1.4. Category-specific QA/QC and verification

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.8

[109] AS Metrosert (Estonian Central Office of Metrology) (2007). Uncertainty estimation of CO_2 emission in Estonian national greenhouse gas inventory in 2004. Report.
[110] IPCC 2006 Guidelines, Volume 2, Chapter 3, page 3.12.

4.5.3.1.5. Category-specific recalculations

Emissions have been recalculated for the years 2017-2020 due to updated COPERT 5 data on the consumption diesel and therefore urea-based DEF (AdBlue). The recalculations are in the Table 4.11.

Table 4.11. Recalculations of the emissions and the consumed amount of urea-based Diesel Exhaust Fluid (DEF) (AdBlue) in 2017-2020

Year	2023 submission; Consumption of urea-based DEF (AdBlue) kt	2023 submission; Emission from of urea-based DEF (AdBlue) kt CO_2	2022 submission; Consumption of urea-based DEF (AdBlue) kt	2022 submission; Emission from of urea-based DEF (AdBlue) kt CO_2
2017	4.09308	0.97552	4.14840	0.98870
2018	4.39657	1.04785	4.82286	1.14945
2019	4.34029	1.03443	4.57299	1.08990
2020	4.17394	0.99479	4.74672	1.13130

4.5.3.1.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.5.3.2. Solvent use

4.5.3.2.1. Source category description

The use of solvents and products containing solvents result 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 15^{th} of March.

In CRF 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 4.12).

The NMVOC and indirect CO_2 emissions from solvents by the EMEP/EEA Air pollutant emission inventory NRF code are shown in Table 4.12. 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) 38.1%; 2) 39.8%; 3) 27.4% and 4) 4.7%, respectively, in 2021 (Table 4.13).

Table 4.1212. Reported emissions from Solvent use in 2021

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

Emissions from the Solvent use category have increased in recent years due to economic growth and larger consumption. A large increase in NMVOC emissions has been in paint application (industrial and domestic) and in 2021 also in other domestic solvent use. 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. The increase in 2020 year´s domestic solvent use is caused by increased consumption of desinfection fluids (COVID-19) and antifreezes (this could be because of increased consumption of solar cells[98]). Emission factors of domestic solvent use (other than paints) have not been decreased in time series because according EMEP/EEA Air Pollutant Inventory Guidebook 2019[143] 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 in 2020 were 34.2% larger because emissions from domestic solvent use and coating applications (e.g paint) have increased.

The fluctuation of total NMVOC emissions during the period 1990–2021 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 seeFigure 4.5).

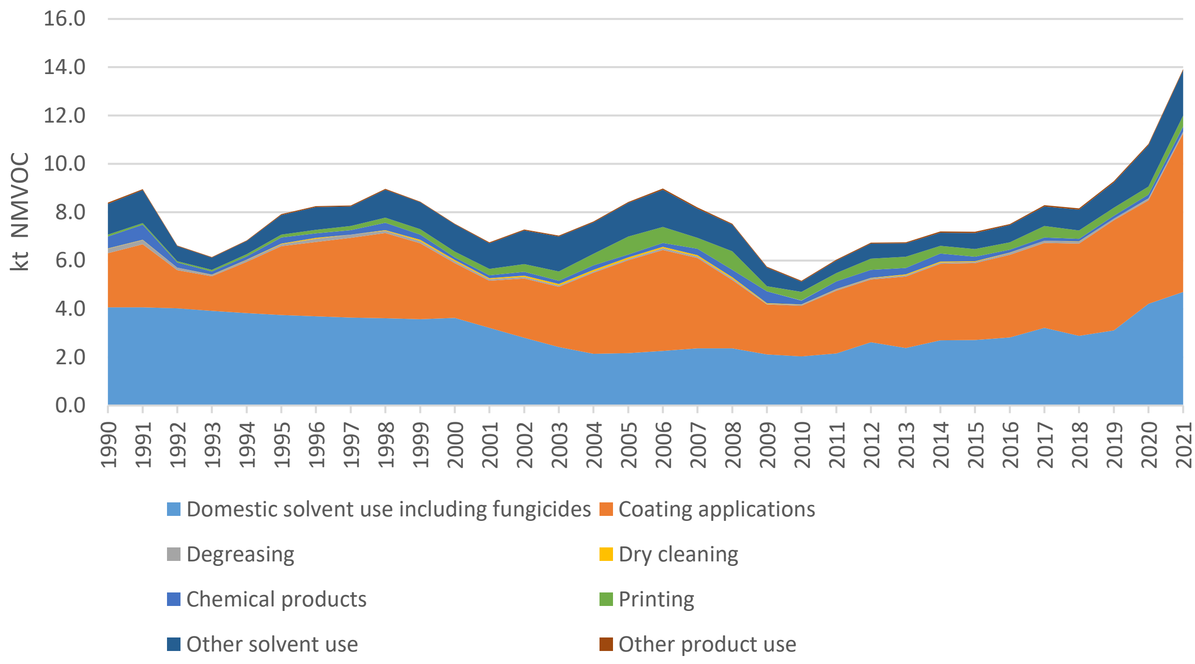


Figure 4.5. Total NMVOC emissions from Solvent use in 1990–2021, kt

Table 4.13. Emissions from Solvent use and Road paving with asphalt in 1990–2021, kt

Emissions from Solvent use and Road paving with asphalt, kt		**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
2D3a	NMVOC emissions from Domestic solvent use (e.g., fungicides), kt	4.07	3.75	3.63	2.17	2. 03	2.71	3.11	4.22	4.70
2D3d	NMVOC emissions from Coating applications (e.g., paint), kt	2.24	2.85	2.26	3.84	2.09	3.18	4.56	4.28	6.56
2D3e	NMVOC emissions from Degreasing, kt	0.18	0.08	0.08	0.05	0.05	0.06	0.07	0.07	0.08
2D3f	NMVOC emissions from Dry cleaning, kt	0.01	0.02	0.05	0.06	0.01	0.03	0.01	0.01	0.01
2D3g	NMVOC emissions from Chemical products, manufacture, and processing, kt	0.50	0.25	0.11	0.13	0.16	0.18	0.11	0.17	0.21
2D3h	NMVOC emissions from Printing, kt	0.08	0.13	0.25	0.74	0.35	0.32	0.34	0.33	0.45
2D3i	NMVOC emissions from Other solvent use, kt	1.26	0.81	1.11	1.38	0.42	0.66	1.04	1.71	1.87
2G	NMVOC emissions from Other product use (e.g. tobacco), kt	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total NMVOC from solvent use, kt		**8.36**	**7.90**	**7.50**	**8.39**	**5.13**	**7.15**	**9.24**	**10.78**	**13.89**
Indirect CO_2 emissions from NMVOCs from Solvent use, kt		**18.40**	**17.37**	**16.50**	**18.46**	**11.29**	**15.74**	**20.33**	**23.71**	**30.55**
NMVOC emissions from Road paving with asphalt, kt		**0.03**	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**	**0.03**

Emissions from Solvent use and Road paving with asphalt, kt	1990	1995	2000	2005	2010	2015	2019	2020	2021
Indirect CO_2 emissions from NMVOCs from Road paving with asphalt, kt	**0.05**	**0.01**	**0.02**	**0.03**	**0.03**	**0.04**	**0.04**	**0.05**	**0.04**
Total indirect CO_2 emissions from Solvent use and Road paving with ashphalt, kt	**18.45**	**17.39**	**16.52**	**18.50**	**11.32**	**15.80**	**20.40**	**23.79**	**30.61**

4.5.3.2.2. Methodological issues

The compiling of NMVOC emission data from the Solvent use category is performed by the Estonian Environment Agency. An inventory of air pollutants is 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 2019.

Indirect CO_2 emissions from Solvent use were calculated using methodology from the IPCC 2006 Guidelines (Equation 4.18)[111]. According to the method:

Equation 4.18

$$CO_2\ emissions\ =\ Emissions_{NMVOC}\ \times\ \%\ carbon\ in\ NMVOCs\ by\ mass\ \times\ 44/12$$

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.

4.5.3.2.3. Uncertainties and time-series consistency

As Estonia has developed a detailed inventory for these sources, the uncertainty of activity data is estimated to be the default value of 25% (as suggested in the IPCC 2006 Guidelines[112]).

Uncertainties of indirect CO_2 from Solvent use were estimated based on the uncertainties of respective NMVOC emissions. For CO_2 emission factor uncertainty, the default value of 10% was used. The uncertainty of emission factor considered the fact that the default fossil carbon content fraction of NMVOC is 60% by mass and can vary between 50–70%.

4.5.3.2.4. Category-specific QA/QC and verification

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 the 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.

---

[111] IPCC 2006 Guidelines, Volume 1, Chapter 7, page 7.6, box 7.2.
[112] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.17, section 5.5.4.

4.5.3.2.5. Category-specific recalculations

NMVOC emissions and indirect CO_2 from them have been recalculated for the years 2014-2020. Recalculations of 2014-2020 emissions were done because of Estonian Environment Agency's correction of activity data.

Table 4.14. Recalculations of 2014-2020 emissions of NMVOCs from solvent use

Year	Difference in NMVOC emissions from 2D3h Printing industry, 2023 - 2022 submission, kt	Difference in NMVOC emissions from 2D3d Paint application, 2023 - 2022 submission, kt	Difference in indirect CO_2 emissions in 2023 submission, kt
2014	-0.13011	-	-0.286242
2015	-0.1501	-	-0.33022
2016	-0.16886	-	-0.371492
2017	-0.19394	-	-0.426668
2018	-0.23867	-	-0.525074
2019	-0.18767	0.011041	-0.3885838
2020	-0.19826	-0.00156	-0.439604

4.5.3.2.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.5.3.3. Road paving with asphalt

4.5.3.3.1. Source category description

In this source category NMVOC emissions from road paving with asphalt are reported. The NMVOC emissions are calculated at the Estonian Environment Agency.

NMVOC emission from the road paving with asphalt: 0.03 kt in 2021.

Indirect CO_2 emissions from road paving with asphalt: 0.045 kt.

NMVOC and indirect CO_2 emissions in 1990–2021 are shown in Table 4.13.

4.5.3.3.2. Methodological issues

Methods

NMVOC emissions from road paving with asphalt were calculated using the *Tier 1* default approach from the renewed EMEP/EEA Guidebook 2019 (Equation 4.19).

According to the *Tier 1* method:

Equation 4.19

$$E_{pollutant} = AR_{production} \times EF_{pollutant}$$

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 4.19).

Activity data

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 Asphalt Pavement Association for the years 1990–2021.

Emission factors

Default NMVOC factors are taken from EMEP/EEA Guidebook 2019. 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%.

4.5.3.3.3. Uncertainties and time-series consistency

The uncertainty of activity data (production of hot asphalt mix) is estimated at ±10%. The uncertainty of NMVOC emission factor for total hot asphalt mix (batch and drum hot mix) production is estimated at ±100% as suggested in the IPCC 2006 Guidelines[113].

The uncertainty of the average carbon content of NMVOCs is 10%. The combined emission factor of indirect CO_2 is $\sqrt{(100^2+10^2)}=100\%$.

4.5.3.3.4. Category-specific QA/QC and verification

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.

4.5.3.3.5. Category-specific recalculations

There are no category-specific recalculations.

4.5.3.3.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.6. Product uses as substitutes for ODS (CRF 2.F)

In 2021 greenhouse gas emissions under the category CRF 2.F Product uses as substitutes for ODS amounted to 190.21 kt CO_2 equivalent, which was about 1.23% of the total greenhouse gas emissions in Estonia.

Under this category, Estonia reports HFC emissions from refrigeration and air-conditioning equipment (CRF 2.F.1), HFC emissions from foam blowing agents (CRF 2.F.2), HFC emissions from fire protection (CRF 2.F.3) and HFC emissions from aerosols (CRF 2.F.4).

[113] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.16, section 5.4.4.

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 Regulation (EU) No 517/2014[114]). In addition, wholesalers have bought more HFC-s from other EU countries. An exemption is the high-GWP R-404A which sale has been decreasing in recent years but in 2021 there was an increase. 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 have increased rapidly since 1993, especially HFC emissions from refrigeration and air-conditioning equipment, which is the major source of halocarbons in Estonia (Figure 4.6).

As it can be seen from Figure 4.6, the increase of HFC emissions have halted three times – in 2008, 2015 and 2017-2020. In 2021 there was an increase in HFC emissions – 5.4 % compared to 2020 due to decommissioning 15 year old equipment that contained high amount of HFCs.

In 2008, one-component polyurethane foams with R-134a were banned by Regulation (EU) No 842/2006[115] and large foam producers in Estonia replaced propellant R-134a with R-152a, which has a significantly lower GWP, thus emissions decreased sharply. This has been elaborated in chapter 4.6.2.3 "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 2015 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 third halt in emissions growth in 2017-2020 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.

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 4.6.1.1.2.

[114] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014R0517&from=en (22.02.2023)
[115] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32006R0842&from=EN (22.02.2023)

Concerning industrial refrigeration, the Regulation (EU) No 517/2014 does not impose such strict bans on HFC-s like for commercial refrigeration equipment. That is the main reason why decrease of R-404A stock and emissions are slower than in commercial refrigeration.

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 22%.

HFC emissions from the A/C and HP sector do not decrease yet but use of lower GWP refrigerant R-32 is slowly increasing.

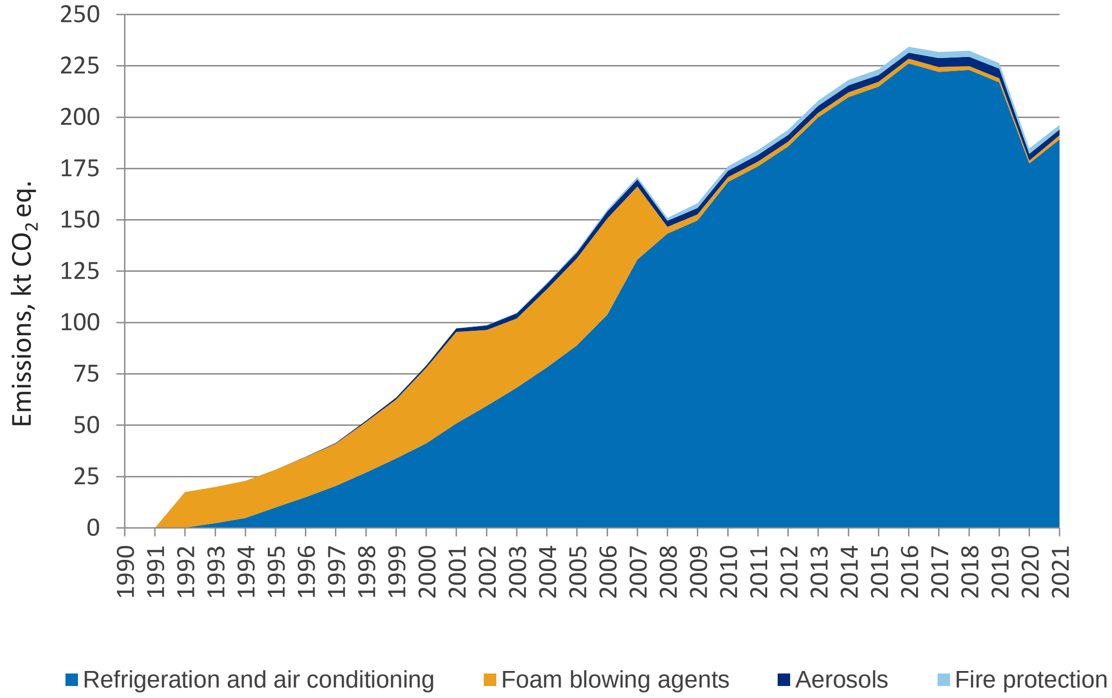


Figure 4.6. Actual emissions of HFCs by subcategory in 1990–2021, kt CO_2 equivalent

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). Quality control of activity data, emission factors and data on measured emissions was made by the experts of the Estonian Environmental Research Centre.

4.6.1. Refrigeration and air conditioning (CRF 2.F.1)

Refrigeration and air-conditioning (RAC) are responsible for about 96.4% of the Estonian F-gas emissions (183.27 kt CO_2 eq. in 2020). 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).

4.6.1.1. Commercial refrigeration (CRF 2.F.1.a)

4.6.1.1.1. Source category description

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 centralized 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 2021 HFC stock (mostly used in supermarket systems), R-134a – about 9% mainly used in vending machines, small shops and restaurants) and R-407F – 5% (substitute for R-404A). Little new equipment with R-404A was installed in 2021 since supermarket chains are aware of the bans on equipment with R-404A stipulated in Regulation (EU) No 517/2014.

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 of beverages and other goods (stand-alone equipment) was estimated at ca 15 000 units.

4.6.1.1.2. Methodological issues

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 data was collected from a national database of F-gas equipment set up according to Regulation 517/2014 (FOKA database). Refilling data was voluntarily supplied by service companies because in the FOKA database was incomplete data on refilling. The 2021 stock data (70.50 t of HFC) had to be completed by the estimation of the stock by supplementary 4.56 t which makes a total sum of 75.05 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 country-specific emission rate EF_{op} is calculated higher (15%), see below).

The total amount of HFC refrigerants was 75.05 t for the 2021 stock of supermarkets and small shops (reported and estimated) and includes non-HFC components of refrigerant blends, e.g., R-448A, R-449A. This amount is ca 3 tonnes higherr than in the previous submission for the year 2020. 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 4 300 possible clients (with on average three devices with a refrigerant charge of 350 g/device), resulting in about 4.52 t of HFC- and HC-refrigerants. Estonian experts estimated that R-404A constituted 30% (1.35 t) and R-134a 33% (1.47 t) in this subcategory. The share of other HFC refrigerants (R-422A, R-422D, R-452A) is ca 4%. The rest of the stock (1.51 t) is consisting 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 2.40 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).

The amount of R-134a, R-404A and R-407C filled in new equipment in 2006 was decommissioned according to 15 years lifetime in 2021. Emissions: Refilling data was provided by service companies as in the national database of F-gas equipment (FOKA) the data was incomplete. Complete activity data was provided by 14 service companies, 9 companies provided refilling data. These 14 companies cover most of the market. The R-404A from decommissioned equipment was collected and re-used for servicing the remaining equipment.

The actual refilling rate 11.7% is used as operating emission factor. This is lower as 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 are leaking less. Another reason could be that according to the 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.

An EF_{op} of 11.7% is applied to supermarkets and small shops and it covers both emissions from operating and servicing the equipment. The equipment of restaurants still has an EF_{op} 15% as in previous years because the service ban does not affect them. The vending machines in Estonia are relatively leak-proof. In this sector, the emission rate (EF_{op}) is estimated at 1.5%/year. These emission factors are in the range of the IPCC 2006 Guidelines (10–35% for medium and large commercial refrigeration and 1–15% for stand-alone commercial refrigeration)[116].

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[117].

The EF_{disp} (disposal loss factor) is estimated at a value of 50%. This disposal emission factor is based on the IPCC 2006 Guidelines estimates of recovery efficiency as well as estimates from Estonian service companies. 50% of the refrigerant is recovered from disposed of equipment and subsequently either recycled or destructed.

The method used is *Tier 2a* with country-specific determination of EF as described in the IPCC 2006 Guidelines:

- Country-specific EF_{manu} (filling): 0.5%;
- Country-specific operating emission factor EF_{op}: 11.7% (vending machines: 1.5%);
- Country-specific disposal emission factor EF_{disp}: 50%.

In 2021 the total quantity of HFCs filled into new commercial refrigeration equipment was 0.50 t (without non-HFC components). The manufacturing emissions from this filling were 0.003 t. The HFC stock amounted to 80.42t (67.87of R-404A, 6.97 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 9.20 t R-404A (7.96 t) and HFC-134a (0.62 t), constituted the largest part of them.

The amount of R-404A, R-134a and R-407C filled in new equipment in 2006 was decommissioned according to 15 years lifetime in 2021.

In 2021, the amount of HFC refrigerant remaining in products at decommissioning amounted to 5.12 t of R-404A, 0.63 t of R-134a and a small amount of other refrigerants – 5.76 t of HFCs total. The emissions from disposal were in total 2.88 t (2.56 t of R-404A, 0.31 t of R-134a and small amount of other refrigerants).

Total HFC emissions from commercial refrigeration in 2021 amounted to 12.09 t (43.89 kt CO_2 eq.).

4.6.1.1.3. Uncertainties and time-series consistency

The uncertainty of the three-activity data ‘Filled in new manufactured products’, ‘HFC stock in operating systems’ and ‘Remained in products at decommissioning’ is estimated at ± 8.9% (0.10) which is less than in the previous submission. The reviews of the 2020 and 2022 submissions gave recommendation to improve accuracy and completeness of data collected for

[116] Information about the development of the PLF for commercial refrigeration was included as the recommendation of the UNFCCC review team.
[117] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

2.F.1 subsector (I.7, 2020) in commercial refrigeration subsector. The uncertainty of activity data results mainly from estimations in the determination of the total HFC stock. The collected activity data was more complete than in 2020 and therefore the estimated stock was smaller. The estimated stock comprises mainly from difference of the number of supermarkets present and the number of those which HFC amount is known. The amount HFC-s in unknown small shops also contributes to activity data uncertainty. Low-GWP refrigerants were reported by 9 of 16 service companies.

The activity data was collected partly from the FOKA registry (registry for equipment containing F-gases and ozone depleting substances) and partly by questionnaires sent to service companies per e-mails. Data on refilling was collected by questionnaires sent to service companies per e-mails because data from the FOKA database was incomplete.

The uncertainty of the EF is not improved in comparison with previous submission. Activity data of clients of 14 service companies was used, only 9 of them gave refilling data and the refilling data of the rest contributed to the uncertainty. The uncertainty of EF is 41.1%.

The combination of the uncertainty of activity data 8.9% with the respective emission factor (± 41.1%) results in the UN of manufacturing, operating and disposal HFC emissions of ± ~42.0%.

4.6.1.1.4. Category-specific QA/QC and verification

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.

4.6.1.1.5. Category-specific recalculations

No recalculations have been done.

4.6.1.1.6. Category-specific planned improvements

There are no planned category-specific improvements. Estonia has improved AD completeness of the commercial refrigeration sector for the year 2019–2021 by thoroughly interviewing the service companies. The database for F-gas equipment and their service was overhauled in 2021, but still needs some improvements, as now the usage of the database by the service companies is low. Inventory team has forwarded this observation to the Estonian Environment Board and the Ministry of the Environment who are responsible for the development of FOKA. The discussions and development of the system are ongoing.

4.6.1.2. Domestic refrigeration (CRF 2.F.1.b)

4.6.1.2.1. Source category description

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 before mentioned types of refrigerants.

4.6.1.2.2. Methodological issues

According to Statistics Estonia, there were about 626 500 households in Estonia in 2021. The number of domestic refrigerators was estimated at 621 488 and the number of newly imported fridges/freezers at 68 695 (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 2021 which in turn is estimated via lifetime. The average lifetime of fridges/freezers was estimated to be 9 years in 2021. 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 year. In the waste refrigerant removed from the fridges in 2019-2021 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. Controversially the proportion of HFC-134A containing fridges in disposed equipment it is estimated by producer responsibility organization to have been 26% in 2021. The reason could be that the actual lifetime of HFC-134A containing fridges is longer than 15 years.

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[118].

The number of refrigerators decommissioned per annum can be calculated (based on 9 years average lifetime) at 61 421 out of which 44 061 were collected by recycling companies and sent for treatment to foreign countries. The remaining 17 360 are disposed of without refrigerant recovery. EES Ringlus assumed that (i) *ca* 26% of the non-collected refrigerators contain R-134A, and (ii) in each of them 94% of the original 150-gram charge is left (6% already emitted), (iii) the disposal HFC-134A emissions are 0.64 t ($EF_{disposal}$ = 100%).

The method used is *Tier 2a* with country-specific EF as described in the IPCC 2006 Guidelines:

- Country-specific average refrigerant charge per unit: 150 g R-134A;
- Country-specific operating emission factor: 0.4%.

The total 2021 amount of R-134A emissions in this subcategory was 0.64 t (stock emissions: 0.006 t, end-of-life emissions: 0.64 t) representing 0.84 kt CO_2 equivalent.

4.6.1.2.3. Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts according to approach 1 of the IPCC 2006 Guidelines.

[118] IPCC 2006 Guidelines, Volume 3, Chapter 7, table 7.9, page 7.52.

The data are based on direct information from industry, so that the UN of the activity data on the number of units (stock, annual importation, annual decommissioning) is estimated to be (± 20%). The UN of the emission factor is assessed at ± ~10%, so that the combined UN of the emissions (operating and disposal) is estimated to be ± 22%.

4.6.1.2.4. Category-specific QA/QC and verification

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.

4.6.1.2.5. Category-specific recalculations

No recalculations have been done.

4.6.1.2.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.3. Industrial refrigeration (CRF 2.F.1.c)

4.6.1.3.1. Source category description

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 most important industrial sector. The output of food industry has stayed at the same level in the last years. 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 80.1% of the stock. HFC-134a makes up 7.9% of the stock. Other HFC refrigerants (R-407C, R-410A, R-407F, R-448A etc.) are of minor importance. 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 sector.

4.6.1.3.2. Methodological issues

Information on potential HFC users in the food and other industries was compiled in cooperation with experts from refrigeration service providers/companies specialized in industrial application. Activity data was provided by 14 service companies who cover most of the market and for 2 companies data from FOKA database and previous years' data was used. Basic data about the Estonian food industry can be found in the statistics of the Agriculture and

Food Board (PTA[119]) as companies handling foodstuff shall be approved by the PTA and the data is available online.

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 22.41% or 18.9 t of the total HFC stock of 84.38 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 2006 was decommissioned in 2021.

Emissions: Activity data (stock, new installations in 2021, refilling data) was provided by service companies and collected via the national database of F-gas equipment (FOKA) set up according to Regulation (EU) No 517/2014 and additional survey (for collecting data that was missing from FOKA database).

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 8.9% which is lower than the prior value of 15%. 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).

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[120] estimates of recovery efficiency and estimates from service companies. 50% of HFC containing refrigerants are recovered.

The method used *Tier 2a* with a country-specific EF as described in the IPCC 2006 Guidelines:

- Country-specific EF_{manu} (filling): 0.5%;
- Country-specific operating emission factor EF_{op}: 9.1%;
- Country-specific disposal emission factor EF_{disp}: 50%.

The total quantity of HFCs filled into new industrial refrigeration equipment in 2021 amounted to 0.27 t (0.25 t of R-448A, 0.06 t of R-134a, 0.09 R-404A). The manufacturing emissions from filling were 0.001 t of HFCs (0.003 kt CO_2 eq.).

The HFC stock amounted to 83.3 t (6.57t of R-134a, 66.73 t of R-404A, 1.28 t of R-407C, 1.67t of R-407F, 1.36 t of R-410A, 0.76 t of R-448A and small volumes of R-452A, R-422A, R-422D, R-417A). The emissions from stock totalled 7.58 t of HFCs (26.86 kt CO_2 eq.) .

[119] https://jvis.agri.ee/jvis/avalik.html#/toitKaitlemisettevotedparing, (20.02.2023)
[120] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

The amount of refrigerants left in products at decommissioning amounted to 5.0 t (0.20 t of R-134a, 4.52 t of R-404A, 0.03 t of R-407C). The disposal emissions totalled 2.50 t of HFCs (9.84 kt CO_2 eq.).

In 2021, total HFC emissions from industrial refrigeration amounted to 10.08 t (36.71 kt CO_2 eq.).

4.6.1.3.3. Uncertainties and time-series consistency

Emissions uncertainty (UN) was assessed by the Öko-Recherche experts. The combination of the individual uncertainties follows approach 1 of the IPCC 2006 Guidelines.

The uncertainty of the three-activity data ‘Filled in newly manufactured products’, ‘HFC stock in operating systems’ and ‘Remained in products at decommissioning’ is estimated ± 9.1% The uncertainty results from estimations in the determination of the total HFC stock. The UNFCCC reviews of the 2020 (I.7,2020) and 2022 observation gave recommendation to improve accuracy and completeness of data collected for 2.F.1 subsector in industrial refrigeration subsector.

The activity data was collected partly from the FOKA registry and partly by questionnaires sent to service companies per e-mails. Data on refilling was collected by questionnaires sent to service companies per e-mails.

Activity data from 14 service companies was used and 6 of them provided refilling data. The refilling data of the rest contributed to the uncertainty. The uncertainty of EF is 17.7%. The combination of this value with the UN of the respective emission factor (± 9.1%) results in the UN of emissions of ± 19.9%.

4.6.1.3.4. Category-specific QA/QC and verification

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.

4.6.1.3.5. Category-specific recalculations

No recalculations have been done.

4.6.1.3.6. Category-specific planned improvements

There are no planned category-specific improvements. Estonia has improved AD completeness of the industrial refrigeration sector for the year 2019–2021 by thoroughly interviewing the service companies. The database for F-gas equipment and their service was overhauled in 2021 but still needs some improvements, as at the moments the usage of the database by the service companies is low. Inventory team has forwarded this observation to the Estonian Environment Board and the Ministry of the Environment who are responsible for the development of FOKA. The discussions and development of the system are ongoing.

4.6.1.4. Transport refrigeration (CRF 2.F.1.d)

4.6.1.4.1. Refrigerated vehicles

Source category description

As of 31.12.2021, 1 080 refrigerated vans and trucks and 1 720 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 case of vans and smaller trucks, and the blend R-404A in bigger trucks and trailers.

Methodological issues

The Estonian Transport Administration provided a list of all vehicles registered at the end of 2021, 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.

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[121]. These emissions are equated to the CRF emission category 'emissions from manufacturing'. The annual losses from the operating systems (emissions from stocks) including service emissions on refilling amount to average 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.

The method used for calculation is the Tier 2 method with country-specific determination of EF provided in the IPCC 2006 Guidelines.

- 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%;

[121] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

- Country-specific disposal emission factor: 30%.

The total 2021 quantity of HFCs filled in the equipment of newly registered refrigerated vehicles in Estonia amounted 61.3 kg of R-452A and 0.9 kg of R-134A. The 'manufacturing' emissions of these first fills were 0.61 kg of R-452A and 0.009 kg of R-134A. The HFC stock in refrigerated vehicles amounted to 0.49 t of R-134A, 19.25 t of R-404A and 2.61 t of R-452A. The emissions from stock were 0.15 t of R-134A 5.77 t of R-404A and 0.78 t of R-452A. The amount of refrigerant left in products at decommissioning from 2011 (10 years old refrigerated vehicles) amounted to 0.77 t of R-404A and 0.05 t of R-134A. The disposal emissions were 0.001 t of R-134A and 0.23 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 6.72 t 25.41 kt CO_2 eq in 2021.

Uncertainties and time-series consistency

The emissions uncertainty was assessed by the Öko-Recherche experts. The combination of the individual uncertainties follows approach 1 of the 2006 IPCC Guidelines.

The uncertainty of the two activity data 'First fill of new equipment' and 'HFC stock in operating vehicles' is estimated ± 8.5%, which is the combination of the individual uncertainty of a) total registrations (new or operating) by weight categories in 2018 (± 1%), b) refrigerant charges (± 6%) and c) refrigerant split into R-134a, R-404A and R-452A (± 6%).

The combination of the uncertainty of new fill or of stock (± 8.5%) with the uncertainty of the respective emission factors (± 5%) results in the uncertainty of both manufacturing and operating HFC emissions of ± 10%.

Category-specific QA/QC and verification

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.

Category-specific recalculations

No recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.4.2. Reefer containers

Source category description

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 0.078% in 2021, thus Estonian reefer containers constituted 0.078% of the world HFC stock and HFC emissions of the worldwide reefer container fleet in the same year.

Methodological issues

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[122];
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 emissions of R-134A and R-404A are calculated by means of emission factors. The operating emission factor is 10%[123]. 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[124]. 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.

The method used is *Tier 2a* with international default EF, as described in the IPCC 2006 Guidelines:

In 2021 the HFC stock in reefer containers amounted to 5.65 t of R-134A and 1.10 t of R-404A. The 2021 HFC stock emissions from reefer containers attributable to Estonia were 0.57 t of R-134A and 0.11 t of R-404A. In 2021, the emissions from decommissioning of reefer containers attributable to Estonia were 0.13 t of R-134A and 0.02 t of R-404A.

The lifetime for reefer containers is according to experts about 14 years.

Total HFC emissions from reefer containers amounted to 0.83 t 1.43 kt CO_2 eq in 2021.

Uncertainties and time-series consistency

The emissions uncertainty was assessed by the Öko-Recherche experts. The combination of the individual uncertainties follows approach 1 of the 2006 IPCC Guidelines.

The uncertainty of the basic activity data 'worldwide HFC stock' is the same as in the German inventory: ± 8.4%, which is the combination of the individual uncertainty of a) number of units (± 3%), b) HFC-charges (± 5%), c) HFC-split (± 6%).

The uncertainty of the Estonia share in world trade is estimated at ± 3%, and the uncertainty of the operating emission factor ± 5%. The combined uncertainty of the HFC emissions (both 134a and 404A) can be calculated ± 10%.

[122] https://www.worldcargonews.com/in-depth/in-depth/lessors-maintain-a-positive-mood (20.02.2023)
[123] 2002 report of the refrigeration, air conditioning and heat pump technical options committee (RTOC)https://wedocs.unep.org/handle/20.500.11822/7796, (02.02.2023)
[124] IPCC 2006 Guidelines, Volume 3, Chapter 7.5.2.2 "Choice of emission factors" and 7.5.2.3 "Choice of activity data"

Category-specific QA/QC and verification

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.

Category-specific recalculations

The stock and emissions for the years 2011-2020 have been recalculated. Decommissioned reefer containers were not subtracted from average stock. In 2015 -2020 the percentage of Estonian reefer container units percentage was corrected (little different each year, not constant through years). New F-gas HFC-513A was added to the reefer containers calculations 2018-2020.

Table 4.15. Recalculations of average stock of reefers, and operating emissions

	2022 submission							2023 submission							
	Stock end of year, HFC-404A, t	Av.stock end of year, HFC-134A, t	Av.stock , HFC-134A, t	Operating emissions, HFC-134A, t	Av. Stock Estonia, HFC-134A,	Operating emissions Estonia,HFC- 134A	Op. emissions Estonia, HFC-134A, CO2 eq-t	Stock end of year, HFC-404A, t	Av.stock end of year, HFC-134A, t	Av.stock , HFC-134A, t	Operating emissions, HFC-134A, t	Av. Stock Estonia, HFC-134A, t	Operating emissions Estonia, HFC-134A, t	Op. emissions Estonia, HFC-134A, CO2 eq-t	Difference in op. emissions, HFC-134A, CO_2 eq. t
2011	917	4774	4534	453	3.52	0.35	0.46	897	4774	4534	453	4.40	0.44	0.57	0.11
2012	1043	5256	5015	501	3.90	0.39	0.51	1030	5130	4952	495	4.80	0.48	0.62	0.11
2013	1130	5515	5386	539	4.19	0.42	0.55	1109	5303	5217	522	5.06	0.51	0.66	0.11
2014	1225	5808	5662	566	4.40	0.44	0.57	1193	5501	5402	540	5.24	0.52	0.68	0.11
2015	1337	6222	6015	602	5.01	0.50	0.65	1281	5816	5658	566	4.71	0.71	0.92	0.27
2016	1406	6324	6273	627	5.80	0.58	0.75	1298	5867	5841	584	5.50	0.54	0.70	-0.05
2017	1508	6593	6459	646	5.49	0.55	0.72	1330	6072	5969	597	5.07	0.51	0.66	-0.06
2018	1629	6940	6766	677	5.26	0.53	0.69	1342	6358	6215	621	4.83	0.48	0.62	-0.07
2019	1745	7202	7071	707	5.72	0.57	0.74	1343	6541	6449	645	5.22	0.52	0.68	-0.06
2020	1875	7529	7365	737	7.16	0.72	0.94	1349	6762	6651	665	6.46	0.65	0.85	-0.09

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.5. Mobile air-conditioning (CRF 2.F.1.e)

4.6.1.5.1. Passenger cars

Source category description

In 2021, there were 634 039passenger cars in the traffic register kept by Estonian Transport Administration. 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%.

Methodological issues

The Estonian Transport Administration provided a list of all passenger cars registered at the end of 2021, subdivided into production years (dating back to 1994 and beyond). In 2021 no cars with HFC-134a were registered in accordance with the EU directive 2006/40/EC (MAC Directive).

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 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).

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)[125], where the authors claim the data published in it to be representative of all EU countries.

Different types of vehicles have different product life factor (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.[126]

The method used for calculations is the Tier 2 according to the IPCC 2006 Guidelines[127] with Europe-specific determination of EF:

- 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.

The total HFC-134a stock in passenger car MACs in Estonia amounted to 66.19 t in the year 2021. The HFC-134a emissions from the Estonian passenger car fleet in 2021 totalled 6.62 t (10%) (8.60 kt CO_2 eq.).

The amount of HFC-134a in the passenger cars MACs disposed in 2021 was estimated at 5.09 t (8.60 kt CO_2 eq). Disposal emissions from the Estonian passenger car fleet in 2021 totalled 2.55 t (EF=50%), the CO_2 equivalent of which was 3.31 kt.

Total MAC HFC emissions from passenger cars in 2021 amounted to 9.16 t (11.91kt CO_2 eq.).

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts. For the combination of individual uncertainties approach 1 of the IPCC 2006 Guidelines was applied.

The UN of the basic activity data 'HFC stock' is estimated ± 8.5%, which is the combination of the individual UN of a) total registrations in 2017 (± 1%), b) MAC quotas (± 6%), c) refrigerant charges (± 6%) – with most quotas and charges being taken from Germany.

The combination of the UN of the stock (± 8.5%) with the UN of the operating emission factors (± 5%) results in the UN of the HFC emissions of ± 10%.

[125] 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.

[126] 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.

[127] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

Category-specific QA/QC and verification

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 the Industrial processes and product use sector according to the IPCC Tier 1 method.

Category-specific recalculations

No recalculations have been made.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.5.2. Trucks

Source category description

In 2021, there were about 140 108 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), about 44% of which are newer than 12 years (their approximate lifetime).

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 of these younger vehicles with air-conditioners is relatively high – 79–100% of new trucks depending on the category. 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.

Methodological issues

The Estonian Transport Administration provided a list of all trucks registered at the end of 2021, 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 were available.

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, 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 method used is the *Tier 2a* with Europe-specific determination of EF, as described in the IPCC 2006 Guidelines:

- 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)[128]: 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[129].
- 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[130] estimates of recovery efficiency and estimates from service companies.

In 2021, the total R-134a stock in truck MACs in Estonia amounted to 23.94 t and R-134a emissions from the Estonian truck fleet totalled 2.93 t (3.81 kt CO_2 eq.).

The amount of R-134a in the truck MACs disposed of in Estonia in 2021 was estimated at 1.84 t. Disposal emissions from the Estonian truck fleet in 2021 totalled 0.92 t (EF=50%), the CO_2 equivalent of which is 1.20 1.28 kt.

Total MAC HFC emissions from trucks in 2021 amounted to 3.85 t (5.01 kt CO_2 eq.).

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts. For the combination of individual uncertainties approach 1 of the IPCC 2006 Guidelines was applied.

The UN of the basic activity data 'HFC stock' is estimated at ± 8.5%, which is the combination of the individual UN of a) total registrations by weight categories in 2020 (± 1%), b) MAC quotas (± 6%), c) refrigerant charges (± 6%) – with quotas and charges being taken from Germany.

The combination of the UN of the stock (± 8.5%) with the UN of the operating emission factors (± 5%) results in the UN of the HFC emissions of ± 10%.

Category-specific QA/QC and verification

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 IPCC *Tier 1* method.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

---

[128] 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).
[129] IPCC 2006 Good Practice Guidance and Uncertainty Management, Chapter 3, table 3.23, page 3.110.
[130] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

4.6.1.5.3. Buses

Source category description

In 2021, 5 327 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. 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 metres long refrigerant pipes but also due to vibration.

Methodological issues

The Estonian Transport Administration provided a list of all buses registered at the end of 2021 (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.

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.

Method according to the IPCC 2006 Guidelines[131]: *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.
- Disposal emission factor 50% is based on the IPCC 2006 Guidelines estimates of recovery efficiency and estimates from service companies.

The total R-134A stock in bus MACs in Estonia amounted to 18.64 t in the year 2021. The operating emissions from the Estonian bus fleet in 2021 totalled 2.73 t of R-134a, the CO_2 equivalent of which was about 3.55kt.

The amount of HFC-134a in the bus MACs disposed of in 2021 was estimated at 1.16 t. Disposal emissions from the Estonian bus fleet in 2021 totalled 0.58 t (EF=50%), the CO_2 equivalent of which is 0.76 kt.

Total MAC HFC emissions from buses in 2021 amounted to 3.31 t (4.31 kt CO_2 eq.).

[131] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts. For the combination of individual uncertainties approach 1 of the IPCC 2006 Guidelines was applied.

The UN of the basic activity data 'HFC stock' is estimated at ± 8.7%, which is the combination of the individual UN of a) total registrations in 2017 (± 1%), b) bus split (± 5%), c) MAC quota (± 5%), d) refrigerant charge (± 5%).

The combination of the UN of the stock (± 8.7%) with the UN of the operating emission factor (± 5%) results in the UN of the HFC emissions of ± 10%.

Category-specific QA/QC and verification

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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.5.4. Ships

Source category description

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.

Methodological issues

Ships under the Estonian flag with GT 100 or more and fishing vessels >18 m is listed in the Estonian Ship Register (Estonian Maritime Authority). 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 a national database. The data on the type of refrigerant, charge and refilling in 2021 were provided directly by the ship owners. The estimation of the stock emissions is based on the average refilling rate.

According to the Estonian Maritime Administration, tugboats >100 GT have no air-conditioning devices.

The method used is *Tier 2a* with country-specific determination of EF, as described in the IPCC 2006 Guidelines:

- Country-specific HFC refrigerant blend stock: total 14.39 t, thereof 5.13 t of R-134a, 3.08 t of R-407F, 0.05 t of R-507A, 1.73 t of R-407C, 0.64 t of R-404A, 0.10 t of R-434A, 0.76

t R-438A, 0.03 t of R-427A, 0.08 t of R-417A. The stock is 8% larger than in 2020 as one new ship was added under the Estonian flag at the very end of 2020 with 400 kg of R-438A.

- Country-specific stock emissions (refills) totalled 4.5 t, which is 32% of the stock. EF of 30% (average of previous years) is used for emission calculation, which is in accordance with the IPCC Good Practice Guidance.
- Country-specific decommissioning emissions factor: 50%. Disposal emission factor 50% is estimated based on data from waste collecting companies. In 2021 there was no decommissioning.

In 2021, the total MAC HFC emissions from ships amounted to 4.54 t (7.69 kt CO_2 eq.).

Uncertainties and time-series consistency

The data on refills are reliable and complete. Consequently, the uncertainty of the HFC emissions is estimated at ± 5%.

Category-specific QA/QC and verification

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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.5.5. Railcars

Source category description

In 2021, there were 171 railcars and engines in the Estonian fleet equipped with a working air conditioner. The number of railcars has decreased by 7% compared to 2020 due to the decline in freight transportation which has led to taking some of the railcars out of service.

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.

Methodological issues

The Estonian Technical Regulatory Authority was contacted to establish the size of the countrywide railcar fleet. For obtaining MAC data in Estonian railcars local rail operators involved in passenger transport were interviewed in 2021. 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.

The method used is *Tier 2a* with country-specific determination of EF as described in the IPCC 2006 Guidelines.

- Country-specific average refrigerant charges: 30 kg/year of R-134a for cars of international trains, 11.09 kg for standard cars and 0.68 kg/year 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 0.1% for all railcars in 2021, which is in accordance with the IPCC Good Practice Guidance[132].

The total HFC-134a stock in railcar MACs in Estonia amounted to 1.37 t in 2021.

Total MAC HFC emissions from railcars in 2021 amounted to 1.39 kg (0.002 kt CO_2 eq.).

Uncertainties and time-series consistency

The emissions uncertainty was assessed by the Öko-Recherche experts or the combination of individual uncertainties approach 1 of the IPCC 2006 Guidelines was applied.

The uncertainty of the basic activity data 'HFC stock' is estimated at ± 3%, which is the combination of the individual uncertainty of a) number of operating vehicles with air conditioning in 2021 (± 0%), and b) refrigerant charges (± 3%).

The combination of the uncertainty of the stock (± 3%) with the uncertainty of the operating emission factors (± 5%) results in the uncertainty of the HFC emissions of ± 5.8%.

Category-specific QA/QC and verification

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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.5.6. Wheel tractors and mobile machinery

Source category description

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 machineries (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.

In 2021, there were 34 552 wheel-tractors and 9046 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 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.

[132] IPCC 2006 Good Practice Guidance, Chapter 3, page 3.110, table 3.23.

Methodological issues

The Estonian Transport Administration provided a list of all wheel tractors and mobile machinery registered at the end of 2021. Official data about air-conditioning of the vehicles were not available.

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.

The method used is *Tier 2a* with country-specific determination of EF, as described in the IPCC 2006 Guidelines.

- 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.

In 2021, the total HFC-134a stock in tractor and mobile machinery MACs in Estonia amounted to 18.69 t. The HFC-134a emissions from the entire Estonian fleet totalled 3.94 t , the CO_2 equivalent of which is about 5.12 kt.

The amount of HFC-134a in the tractor/mobile machinery MACs disposed of in 2021 was estimated at 1.59 t. Disposal emissions from the respective Estonian fleet totalled 0.32 t (EF=20%), the CO_2 equivalent of which is 0.41 kt.

In 2021, the total MAC HFC emissions from wheel tractors and mobile machinery amounted to 4.26 t (5.53 kt CO_2 eq.).

Uncertainties and time-series consistency

The emissions uncertainty was assessed by the Öko-Recherche experts. For the combination of individual uncertainties, approach 1 of the IPCC 2006 Guidelines was applied.

The uncertainty of the basic activity data 'HFC stock' is estimated ± 14.5% for every vehicle type, which is the combination of the individual uncertainty of a) total registrations by vehicle types in 2017 (± 3%), b) MAC quotas (± 10%), c) refrigerant charges (± 10%).

The combination of the uncertainty of the stock (± 14.5%) with the uncertainty of the operating emission factors (± 10%) results in the uncertainty of the HFC emissions of ± 17.6%.

Category-specific QA/QC and verification

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.

Category-specific recalculations

Recalculations have been done considering changes in number of tractors and decommissioning 13 years old tractors.

Table 4.16. Recalculations due to changes of the HFC amount in operating systems and remained in products at decommissioning

	2022 Submission				2023 submission				
Year	**In operating systems, t**	**Remained in products at decommissioning, t**	**Total emissions, t**	**Total emissions, kt CO_2 eq**	**In operating systems, t**	**Remained in products at decommissioning, t**	**Total emissions, t**	**Total emissions, kt CO_2 eq**	**Difference in total emissions, CO_2 eq. t**
2010	11.444	0.880	2.592	3.370	11.297	0.869	2.559	3.327	-0.043
2011	12.304	0.946	2.785	3.621	11.960	0.920	2.708	3.520	-0.101
2012	13.302	1.023	3.014	3.918	12.786	0.983	2.898	3.768	-0.15
2013	14.048	1.081	3.217	4.182	13.900	1.069	3.154	4.100	-0.082
2014	14.741	1.134	3.345	4.349	14.593	1.122	3.312	4.305	-0.044
2015	15.427	1.187	3.502	4.553	14.973	1.152	3.400	4.420	-0.133
2016	15.623	1.202	5.193	6.751	15.623	1.202	3.547	4.611	-2.14
2017	15.020	1.155	3.405	4.427	16.885	1.299	3.828	4.976	0.549
2018	15.706	1.208	3.555	4.622	17.105	1.316	3.873	5.034	0.412
2019	17.702	1.362	4.004	5.205	17.702	1.362	4.004	5.205	0
2020	16.365	1.455	3.738	4.859	17.819	1.371	4.029	5.238	0.379

4.6.1.5.7. Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.6. Stationary air-conditioning (CRF 2.F.1.f)

4.6.1.6.1. Heat pumps

Source category description

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 2021, no heat pumps were manufactured and filled with refrigerant in Estonia.

Methodological issues

Estonian Heat Pump Association provided expert report on heat pumps in Estonia in 2021. The inventory compiler complemented it with data from importers of air-to-air heat pumps which was missing from the expert report. 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 2021, the stock of installed heat pumps in Estonia amounted to approximately 180 114 systems (17 975 ground, 12 899 water, 114 730 air and 1079 other heat pumps) out of which 18 639 were installed in 2021. Air heat pumps have become a very popular substitution to 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.

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[133] and the IPCC Good Practice Guidance[134]. 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.

The method used for calculations is the *Tier 2a* method with country-specific determination of EF as described in the IPCC 2006 Guidelines:

- Country-specific EF_{manu}: 2%;
- Country-specific EF_{op}: 2.5%;
- Country-specific EF_{disp}: 30%.

In 2021, no heat pumps were manufactured and filled with refrigerant in Estonia. In 2021, operating stock amounted to 38.11 t of R-407C (ground and other HP), 141.01t of R-410A and 44.65 t of R-32 (air HP). Respective operating emissions totalled 0.57 t of R-407C, 3.53 t of R-410A and 1.12 t of R-32. The amount of refrigerant in HP at decommissioning was 1.5 t of R-407C and 4.0 t of R-410A. Disposal emissions in 2021 totalled 0.45 t of R-407C and 1.20 t of R-410A.

Total HFC emissions from heat pumps in 2021 amounted to 7.24t (12.12 kt CO_2 eq.).

Uncertainties and time-series consistency

The Öko-Recherche experts assessed the uncertainty of emissions pursuant to approach 1 of the IPCC 2006 Guidelines. The data on heat pumps are deemed precise because the relevant associations, companies and experts for heat pumps and refrigeration systems in Estonia provided them.

The uncertainty of the three-activity data ‘Filled in newly manufactured products’, ‘HFC stock in operating systems’ and ‘Remained in products at decommissioning’ is estimated at ± 9%. The emission factors are estimated ± 5%. The combination of the uncertainty of the three-activity data with the uncertainty of the emission factors results in the uncertainty of the HFC emissions of ± 10.3%.

[133] IPCC 2006 Guidelines, Volume 3, chapter 7, page 7.52, table 7.9.
[134] IPCC Good Practice Guidance 2000, Chapter 3, page 3.106, table 3.22.

Category-specific QA/QC and verification

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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned improvements.

4.6.1.6.2. Stationery and room air-conditioning

Source category description

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) have to 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.

Methodological issues

2021 year´s data 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 2021 equipment stock, refrigerant charges by weight and HFC types and EF for domestic manufacturing and operating stock.

As mentioned in the heat pump section, the topic of data on heat pumps, as well as stationary and room air conditioning systems was discussed together with the Estonian Heat Pump Association to avoid double-counting.

The numbers of operating systems are the following: 2 076 chillers, 6 645 ventilation systems and 32 505 split systems. 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 Guidelines[135]. 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.

[135] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

The method used for calculations is the *Tier 2a* method with country-specific determination of EF as described in the IPCC 2006 Guidelines:

- 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%.

Manufacturing emissions in 2021 were: 0.006 t of R-134a, 0.0.02 t of R-32 and 0.004 t of R-125.

The operating stock in 2021 amounted to 157.15 t of R-134a, 70.42 t of R-32 and 64.64 t of R-125 and operating emissions were: 3.61 t of R-134a, 4.22 t of R-32 and 4.16 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 2021 were: 2.27 t of R-134a, 0.90 t of HFC-32 and 0.95 t of HFC-125.

Total HFC emissions from stationary and room air-conditioning in 2021 amounted to 16.11 t (27.32 kt CO_2 eq).

Uncertainties and time-series consistency

The Öko-Recherche experts assessed the uncertainty of emissions pursuant to approach 1 of the IPCC 2006 Guidelines. The relevant associations, companies and experts in Estonia very roughly estimated the data on stationary A/C systems, especially data on emission factors of split systems and chillers.

The uncertainty of the activity data HFC consumption and stock is estimated at ± 15%. The uncertainty of the ventilation emission factors is ± 10%. The EF for chillers and split systems are more uncertain (± 26%); they are supposed to be too low. The combination of the uncertainty of stock/consumption with the uncertainty of the (given) emission factors result in the uncertainty of the HFC emissions of ± 30% (chillers, splits), and ± 18% (ventilation systems).

Category-specific QA/QC and verification

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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

Estonia continues to seek more complete and consistent statistical data on heat pump stock and average refrigerant charges.

4.6.2. Foam blowing agents (CRF 2.F.2)

4.6.2.1. Closed cells (CRF 2.F.2.a)

4.6.2.1.1. PU insulation panels

Source category description

In 2021, 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.

Methodological issues

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%[136].

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[137] and the IPCC Good Practice Guidance.

The method used for calculations is the *Tier 2a* method with country-specific determination of EF as described in the IPCC 2006 Guidelines:

- Country-specific EF_{op}: 0.5%.

The 2021 Estonian HFC-134a bank in PU insulation panels amounted to 14.26 tons, the annual use-phase emissions were 0.07 tons (0.09 kt CO_2 eq.).

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts. For the combination of individual uncertainties approach 1 of the IPCC 2006 Guidelines was applied.

[136] 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.
[137] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.37, table 7.7.

The UN of the basic activity data 'HFC stock' is estimated at ± >10% because it is based on both official statistical data and expert judgment.

The combination of the UN of the stock (± >10%) with the UN of the operating emission factor (± 10%) results in the UN of the HFC emissions of ± 14%.

Category-specific QA/QC and verification

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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.2.1.2. Spray and injection PU foam

Source category description

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. In the meantime, companies 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.

Methodological issues

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. As a consequence, in the 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.

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[138]. The product life factor (EF_{op}) is according to chemical suppliers 1%.

The method used for calculations is the *Tier 2a* method with country-specific determination of EF as described in the IPCC 2006 Guidelines:

- Country-specific EF_{manu}: 20%;
- Country-specific EF_{op}: 1%.

In 2021 the stock constituted of 9.34 t of HFC-365mfc, 0.72 t of HFC-227ea and 0.03 t of HFC-134a. Stock emissions were: 93.35 kg HFC-365mfc, 7.15 kg HFC-227ea and 0.28 kg HFC-134a.

Total HFC emissions from Spray and injection PU foam in 2021 amounted to 0.75 t (0.74 kt CO_2 eq).

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts. The UN of the basic activity data 'HFC consumption' is estimated at ± >10% because it is based on sales data and expert judgment. The combination of the UN of the consumption (± >10%) with the UN of the manufacturing emission factor (FYL) of ± 10% results in the UN of the HFC emissions of ± 14%.

Category-specific QA/QC and verification

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.

The companies which insulate buildings with PU spray and injection foam were asked if they used HFCs. No company used HFCs in their product, but air or water instead.

Category-specific recalculations

Emissions of the years 2015-2020 have been recalculated because new data on HFC-containing spray foam sold in Estonia was obtained from two companies. Amounts of HFC-365mfc and HFC-227ea and emissions are in the Table 4.17.

Table 4.17. Recalculation of amounts of HFC-s containing in spray foams sold in Estonia in 2015-2020 and emissions from them.

	2015	2016	2017	2018	2019	2020
HFC-365mfc in new products, 2022 submission, t	-		0.0539	0.0543	0.054	-
HFC-365mfc in new products, 2023 submission, t	0.542	0.761	1.821	1.291	1.781	2.394
HFC-227ea in new products, 2022 submission, t	-	-	0.002	0.002	0.002	-
HFC-227ea in new products, 2023 submission, t	0.041	0.057	0.137	0.097	0.134	0.180
HFC-365mfc in stocks, 2022 submission, t	0.258	0.255	0.296	0.293	0.290	0.287
HFC-365mfc in stocks, 2023 submission, t	0.691	1.293	2.737	3.742	5.129	6.993
HFC-227ea in stock, 2022 submission, t	0.033	0.032	0.033	0.034	0.035	0.035
HFC-227ea in stock, 2023 submission, t	0.065	0.110	0.219	0.294	0.399	0.539

[138] 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).

	2015	2016	2017	2018	2019	2020
Emissions from closed cell foams, CO_2 eq. kt, 2022 submission	0.169	0.168	0.177	0.177	0.176	0.165
Emissions from closed cell foams, CO_2 eq. kt, 2023 submission	0.288	0.340	0.58	0.476	0.593	0.741

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.2.1.3. XPS insulation foam

Source category description

The 2021 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.

Methodological issues

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 Guidances, 0.75%.

The method used for calculations is the *Tier 2a* method with country-specific determination of EF as described in the IPCC 2006 Guidelines:

- Country-specific EF_{op}: 0.66%;
- 2021 HFC-134a bank: 7.85 t;
- 2021 use-phase emissions: 0.05 t (0.66%) (0.07 kt CO_2 eq.).

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts.

No official statistical data on the XPS board consumption in Estonia is available. Thus, the annual sales and the current stock of XPS foam with HFC-134a had to be calculated with sector experts. The UN of the activity data 'HFC stock' is estimated at ± 20%. The uncertainty of the emission factor is estimated at 10% so that the UN of the annual use-phase emissions is ± 22.36%.

Category-specific QA/QC and verification

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 IPPU sector according to IPCC *Tier 1* method.

Environmental permits database and air pollution point sources database were checked for XPS producers. No XPS production plants were found.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.2.2. Open cells (CRF 2.F.2.b)

4.6.2.3. One component PU foam

Source category description

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 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.

Methodological issues

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.

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 CRF 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 CRF table, 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%).

The method used for calculations is the *Tier 2a* method with country-specific determination of EF as described in the IPCC 2006 Guidelines:

- Country-specific EF_{manu}: 0.52% (HFC-152a);
- Country-specific EF_{op}: 100%;
- Manufacturing emissions: 1.71 t of R-152a (0.19 kt CO_2 eq.);
- Stock = use-phase emissions: 7.70 t of HFC-152a (1.06 kt CO_2 eq.).

Total HFC emissions from One component PU foams in 2021 amounted to 9.41 t (1.30 t CO_2 eq.).

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts. As the domestic and foreign manufacturers provided all the relevant data, the data uncertainty is estimated low. The uncertainty of the annual HFC consumption and – consequently – use-phase emissions by the quantity and HFC type is ± 15%. The same value applies to manufacturing emissions.

Source-specific QA/QC and verification

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.

Emissions of HFC-152a from OCF manufacturing were cross-checked against reports from Estonian Environmental Decisions Information System KOTKAS and no significant differences were found.

For completeness check, the Estonian database of environmental permits and KOTKAS[55] were checked for other foam producers. No other foam producers which would use HFCs were found.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.2.3.1. PU integral skin foam

Source category description

In Estonia, the PU Integral Skin Foam production started in 2004 with HFC-365mfc. Beforehand, ozone-depleting HCFC-141b was used, which it 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 2010–2021, PU Integral Skin Foam was neither manufactured nor used in Estonia, thus no emissions were occurring.

Methodological issues

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. The EF_{manu} is likewise in accordance with the IPCC 2006 Guidelines[139]. The IPCC Good Practice Guidance default emission factor is 95%, which is lower than the country-specific emission factor.

Method according to IPCC 2006 Guidelines: *Tier 2a* with country-specific determination of EF.

- Country-specific EF_{manu}: 100%.

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts. The UN of the activity and emissions data ‘HFC consumption’ is estimated at only ± 3% because it is based on information of the only user.

Category-specific QA/QC and verification

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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.3. Fire protection (CRF 2.F.3)

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.

4.6.3.1. Source category description

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

---

[139] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.33.

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 damages. 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.

4.6.3.2. Methodological issues

Data on the amount of the three mentioned HFC-based fluids for fire protection in the 2021 stock was acquired from the database set up according to article 6 of the Regulation No 517/2014 and missing data collected from service companies. The first HFC installation dates to 2000.

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. 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%.

In Estonia, the total 2021 quantity of F-gases in installed firefighting systems amounted to 31.18 t (23.28 t of R-227ea, 1.97 t of R-23 and 6.44 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%: 0.039 t of R-23, 0.01 t of R-125, 0.11 t of R-134a and 0.465 t of R-227ea.

Total HFC emissions from Fire protection in 2021 amounted to 0.62 t (5.25 kt CO_2 eq.).

4.6.3.3. Uncertainties and time-series consistency

The estimation for emissions uncertainty (UN) was provided by the Öko-Recherche experts according to approach 1 of the IPCC 2006 Guidelines. The data are based on direct information from industry, so that the UN of the data on the different HFC stocks can be estimated comparably low (± 10%). The UN of the emission factor is assessed ± ~10%, so that the combined UN of the emissions is estimated ± 14%.

Category-specific QA/QC and verification

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.

4.6.3.4. Category-specific recalculations

Quantity of HFC-23 in stock 2020 has been recalculated because one service company did not report all the equipment. This equipment was not newly installed. The recalculation is in Table 4.18.

Table 4.18. Recalculations of fire protection F-gases and emissions in 2020

Year	HFC-23 stock in 2022 submission t	HFC-23 stock in 2023 submission t	Emissions from stock (2%) in 2022 submission, t	Emission from stocks (2%) in 2023 submission, t	Difference in stock emissions, t	Difference in stock emissions, CO_2 eq. kt
2020	2.88	3.28	0.06	0.07	0.12	0.40

4.6.3.5. Category-specific planned improvements

There are no planned category-specific improvements.

4.6.4. Aerosols (CRF 2.F.4)

4.6.4.1. Metered dose inhalers (CRF 2.F.4.a)

4.6.4.1.1. Source category description

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.

4.6.4.1.2. Methodological issues

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 2021). Use-phase emissions: The number of MDIs for both anti-asthma and natural medicines sold to the domestic market in 2021 (production + import - export) is the stock of the year 2021. 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 2021 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.

Method according to IPCC 2006 Guidelines: *Tier 2a* with country-specific EF.

- Country-specific EF_{manu}: 3%;
- Country-specific EF_{op}: 100%;
- Natural medicines: In 2021 the amount of HFC-134a used in domestic production was 0.81 t, of which 3% were manufacturing emissions (0.02 t or 0.03 CO_2 eq. kt). 100% of the products (0.81 t of HFC) was sold to the domestic market, resulting in use-phase emissions of the same amount (1.05 kt CO_2 eq).

- Anti-Asthma MDIs: The 2021 domestic market was 1.13 t of HFC-134a with the same quantities of emissions. The emissions of CO_2 eq. are 1.47 kt. There were no HFC-227ea containing MDI-s on Estonian market in 2021.
- Total HFC emissions from Metered-dose inhalers in 2021 amounted to 1.94 t (2.52 kt CO_2 eq.).

4.6.4.1.3. Uncertainties and time-series consistency

The emissions uncertainty was assessed by the Öko-Recherche experts according to approach 1 of the IPCC 2006 Guidelines.

The data are based on direct information from manufacturers and from trade departments in industry, so that the activity data on domestic production and domestic market are deemed highly reliable. Consequently, the uncertainty of the emissions (manufacturing and use-phase) is estimated at ± 10%.

4.6.4.1.4. Category-specific QA/QC and verification

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.

4.6.4.1.5. Category-specific recalculations

There was a calculation error in the amount HFC-134a in operating system and therefore also in total emission of HFC-134a in Metered-dose inhalers in 2019 (Table 4.19).

Table 4.19 Recalculations of HFC 134a in operating system and the total emissions of HFC 134a in Metered-dose inhalers in 2019.

Year	2022 submission; HFC 134a in operating system, t	2023 submission; HFC 134a in operating system, t	2022 submission; HFC 134a in operating system, CO_2 eq. t	2022 submission; total emissions of HFC 134a in metered-dose inhalers, t	2023 submission; total emissions of HFC 134a in metered-dose inhalers, t	2023 submission; HFC 134a in operating system, CO_2 eq. t	Difference in 2022 and 2023 submissions, CO2 eq. kt
2019	2.061	2.112	2.746	2.092	2.143	2.786	0.04

4.6.4.1.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.6.4.2. Technical aerosols (CRF 2.F.4.b)

4.6.4.2.1. Source category description

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 of technical aerosols containing HFC-s with GWP value of 150 or more on the EU market has been banned since 2018.

4.6.4.2.2. Methodological issues

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.

Method according to IPCC 2006 Guidelines: *Tier 2a* with country-specific EF.

- Country-specific EF_{op}: 100%;
- Country-specific charge of aerosol cans: 12.9 g.

4.6.4.2.3. Uncertainties and time-series consistency

The uncertainty of emissions was assessed by the Öko-Recherche experts according to approach 1 of the IPCC 2006 Guidelines.

The data are based on direct information from industry, so that the uncertainty of the activity data on the number of units and on charges can be estimated low (± 10%). The same uncertainty value applies to the emissions because the emission factor is 100%.

4.6.4.2.4. Category-specific QA/QC and verification

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 the Industrial processes and product use sector according to the IPCC *Tier 1* method.

4.6.4.2.5. Category-specific recalculations

No category-specific recalculations have been done.

4.6.4.2.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.7. Other product manufacture and use (CRF 2.G)

This category includes:

- SF_6 emissions from Electrical equipment (CRF 2.G.1);
- SF_6 emissions from Accelerators (CRF 2.G.2b), historical SF_6 and PFC emissions from Sport shoes and Car tires (CRF 2.G.2.d);
- N_2O emissions from Medical applications (CRF 2.G.3.a) and from Propellant for pressure and aerosol products (CRF 2.G.3.b).

Emissions from category Other product manufacture and use are shown in Figure 4.7.

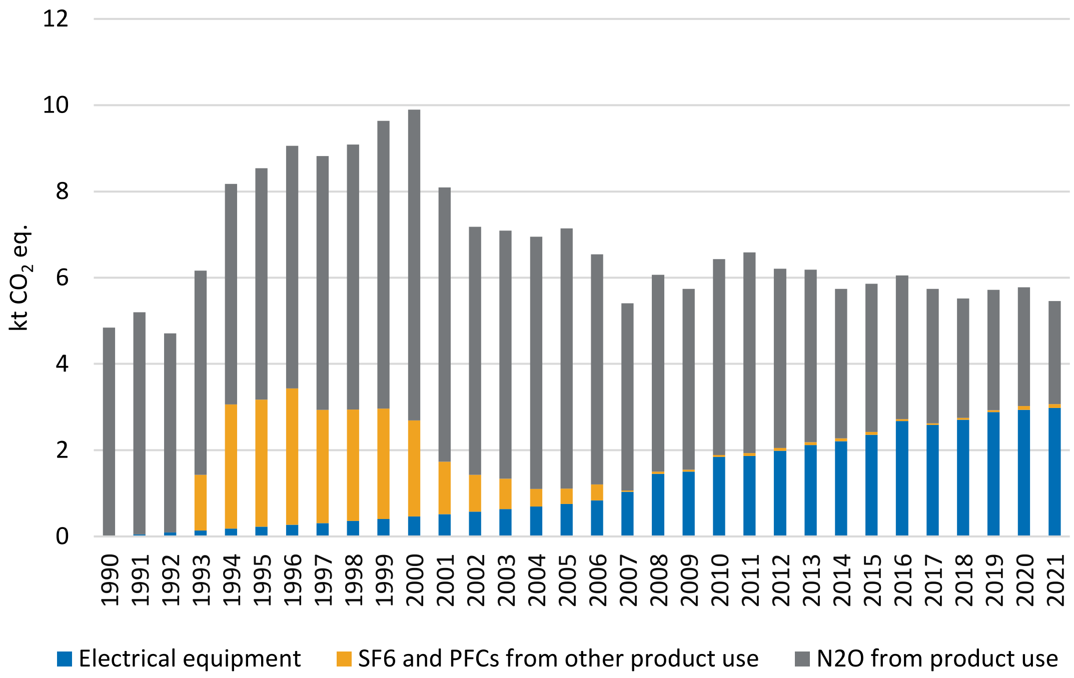


Figure 4.7. Emissions from Other product manufacture and use in Estonia in 1990–2021, kt CO_2 eq.

4.7.1. Electrical equipment (CRF 2.G.1)

4.7.1.1. Source category description

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) operate 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.

4.7.1.2. Methodological issues

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 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.

The method used for calculations is *Tier 3*, as described in the IPCC 2006 Guidelines:

- 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[140].

In 2021, total stock in operating systems amounted to 31.96 t of SF_6. Manufacturing emissions amounted to 0.17 t. Total emissions from stock were 0.13 t. 44.6kg of SF_6 was disposed and emissions from it were 0.89 kg in 2021.

Total emissions from switchgear in 2021 were 0.13 t of SF_6 which is 2981.6 t (or 2.98 kt) CO_2 equivalent.

4.7.1.3. Uncertainties and time-series consistency

Öko-Recherche experts assessed the emissions uncertainty (UN) pursuant to approach 1 of the IPCC 2006 Guidelines. As the activity data are based on direct information from industry, their UN is estimated low: ± 3%. The UN of the default emission factors is ± 10% (IPCC 2006 GL, Tier 3). The combined UN of the emissions is ± ~10.4%.

4.7.1.4. Category-specific QA/QC and verification

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 the Industrial processes and product use sector according to the IPCC *Tier 1* method.

4.7.1.5. Category-specific recalculations

There was a calculation error made in the year 2020 calculations. The recalculations are in Table 4.20.

Table 4.20. Recalculations of SF_6 in operating system (medium- and highvoltage) equipment, emissions in stock and total emissions in 2020.

Year	SF_6 in operating system, t	SF_6 in operating system, t	Emissions from stock, t 2022	Emissions from stock, t 2023	SF_6 total emissions, t 2022	SF_6 total emissions t. 2023	Total SF_6 emissions CO_2 eq. kt	Total SF_6 emissions CO_2 eq. kt	Difference in 2022 and
2020	30.98	31.004	0.123	0.124	0.124	0.125	2.914	2.938	0.024

[140] 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 (15.12.2021)

4.7.1.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.7.2. SF_6 and PFCs from Other product use (CRF 2.G.2)

4.7.2.1. Accelerators (CRF 2.G.2.b)

4.7.2.1.1. Source category description

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.

4.7.2.1.2. Methodological issues

Data on charge and use-phase losses were directly submitted from the medical operators. One operator calculated the emission rate of all equipment at most 5% a year. The other operator reported that their emission rate was 10%.

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 case of switchgear.

The 2021 stock of SF_6 totalled 39.8 kg, with 2021 operating emissions of 3.77 kg. There were no emissions from disposal, as no equipment was decommissioned in 2021.

Emissions from accelerators totalled 3.77 kg (or 0.089 kt) CO_2 equivalent in 2021.

4.7.2.1.3. Uncertainties and time-series consistency

The data are based on the estimation of the operators. The emissions uncertainty is estimated at ± 30%.

4.7.2.1.4. Category-specific QA/QC and verification

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 the Industrial processes and product use sector according to the IPCC *Tier 1* method.

4.7.2.1.5. Category-specific recalculations

There was a calculation error in the annual stock of SF_6 in the year 2020 therefore the emission has been recalculated. The recalculation is in the Table 4.21.

Table 4.21 Recalculations of SF_6 annual stock in 2020.

Year	2022 submission; Annual stock of SF6, t	2022 submission; Emissions from SF_6 stock, t	2023 submission; Annual stock of SF_6, t	2023 submission; Emissions from SF_6 stock, t	Difference in 2022 and 2023 submission, t	Difference in 2022 and 2023 submission, CO_2 eq. kt
2020	0.0366	0.00371	0.0398	0.00377	0.00006	0.0015

4.7.2.2. Category-specific planned improvements

There are no planned category-specific improvements.

4.7.2.3. Adiabatic properties: Shoes and Tires (CRF 2.G.2.d)

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.

4.7.2.3.1. Sport shoes

Source category description

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 is of such shoes is calculated at three years. 100% of the F-gases in these soles is considered to have emitted to the atmosphere at the end-of-life of the shoes.

Methodological issues

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.

The method follows the IPCC 2006 Guidelines (Emissions in year t = Sales in year t-3).

- EF_{disp}: 100% (IPCC GL).

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts according to approach 1 of the IPCC 2006 Guidelines.

The data are based on direct information from industry, so that the UN of the activity data ‘sales in year 2005’ and ‘emissions in 2008’ can be estimated comparably low (± 10%).

Category-specific QA/QC and verification

The data for this category 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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.7.2.3.2. Car tires

Source category description

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[141] or one year after importation.

Methodological issues

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.

Uncertainties and time-series consistency

The emissions uncertainty (UN) was assessed by the Öko-Recherche experts according to approach 1 of the IPCC 2006 Guidelines. The activity data are rated reliable, and uncertainty estimated comparably low (± 10%).

[141] IPCC 2006 Guidelines, Volume 3, Chapter 8, page 8.31.

Category-specific QA/QC and verification

The data for this category 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.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.7.3. N_2O from product uses (CRF 2.G.3)

4.7.3.1. Medical applications (CRF 2.G.3.a)

4.7.3.1.1. Source category description

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.

4.7.3.1.2. Methodological issues

N_2O emissions from N_2O used in medical and other applications are estimated taking into account the amount of N_2O sold to the Estonian market. Activity data was collected directly from the companies importing N_2O for medical use and other applications to Estonia from 1992 to 2021. 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. According to the IPCC 2006 Guidelines[142], 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.

The amount of medical N_2O sold and emitted in Estonia in 2021 was 7.16 t (1.90 kt CO_2 eq.). The amount of N_2O sold and emitted was 16% smaller than in 2020 because of disruptions to scheduled treatments in the hospital caused by the COVID-19 pandemic.

4.7.3.1.3. Uncertainty and times-series consistency

IPCC Tier 1 method was used in estimating the uncertainties of this category.

The data are based on direct information from companies importing N_2O to Estonia and selling it to the Estonian market so that the uncertainty of activity data is estimated low: ± 5%. The uncertainty of the emission factor is assumed to be extremely small and is estimated at ± 2%.

4.7.3.1.4. Source-specific QA/QC and verification

The data for this category was collected by the expert of the Estonian Environmental Research Centre. 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.

---

[142] IPCC 2006 Guidelines, Volume 3, Chapter 8, page 8.36.

4.7.3.1.5. Category-specific recalculations

There was a calculation error in the amount of N_2O sold by one of the companies in 2019. The recalculation of N_2O emissions is in the Table 4.22.

Table 4.22. Recalculations of N_2O sold to the Estonian market in 2019.

Year	2022 submission; Annual stock of N_2O kt	2023 submission; Annual stock of N_2O kt	2022 submission; Emissions of N_2O kt CO_2	2023 submission; Emissions of N_2O kt CO_2	Difference between 2022 and 2023 submission, N_2O kt CO_2
2019	0.00792	0.00798	2.0988	2.1147	0.0159

4.7.3.1.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.7.3.2. Propellant for pressure and aerosol products (CRF 2.G.3.b)

4.7.3.2.1. Source category description

Under this source category, Estonia reports N_2O emissions from aerosol cans.

4.7.3.2.2. Methodological issues

N_2O containing technical aerosol cans are not produced in Estonia but were imported and sold to the Estonian market from 2007–2021. The total quantity of N_2O supplied to the Estonian market was asked from the distributors of N_2O products. In 2021, 280 aerosol cans containing N_2O were sold to the Estonian market.

For 2020 years´ ESD review the review team noted that Estonia had reported zero N_2O emissions from aerosol cans in 2018. The review recommended to estimate the emissions, either since country-specific data or average t N2O/capita factor from Member States that report country-specific data using amount of gas as activity data.

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 2005-2020. 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.

From interviews with supermarket chains, it was learned that only 2% 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.

The amount of N_2O used as propellant in aerosol cans in Estonia in 2021 was 0.0019 kt (0.49 kt CO_2 eq).

4.7.3.2.3. Uncertainty and times-series consistency

IPCC Tier 1 method was used in estimating the uncertainties of this category.

The data is mainly based on international trade statistics which uncertainty is estimated ± 5%. When combining this with the uncertainty N_2O content of the whipped cream cans – maximally 4% then the overall uncertainty of activity data is 6.4%. The uncertainty of the emission factor is assumed to be extremely small and is estimated at ± 2%.

4.7.3.2.4. Source-specific QA/QC and verification

The data for this category was collected by the expert of the Estonian Environmental Research Centre. 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.

4.7.3.2.5. Category-specific recalculations

No recalculations were made.

4.7.3.2.6. Category-specific planned improvements

There are no planned category-specific improvements.

4.8. Other production (CRF 2.H)

4.8.1. Category description

This source category includes the NMVOC emissions from the Pulp and paper (CRF 2.H.1) and Food industries (CRF 2.H.2). In addition, NO_x, CO and SO_2 emissions from the Pulp and 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 CRF 1.

4.8.2. Methodological issues

For 15th April 2023 submission 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. Incomplete time series before the year 2006 is complemented with interpolated data (calculated on production volumes).

The NMVOC emissions from food industry are calculated as diffuse sources based on statistical data and using the EMEP/EEA Guidebook 2019.[143]

Activity data for the years 1990–1994 is obtained from the annual proceeding of Statistics Estonia ‘Industry’ and for the years 1995–2021 from the electronic database on the website of Statistics Estonia.

---

[143] EMEP/EEA air pollutant emission inventory guidebook 2019. [www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019 (22.02.2023).

4.8.3. Category-specific QA/QC and verification

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.

4.8.4. Category-specific recalculations

No category-specific recalculations have been done.

4.8.5. Category-specific planned improvements

There are no planned category-specific improvements.

5. AGRICULTURE (CRF 3)

5.1. Description and quantitative overview

5.1.1. Overview of the sector

The total GHG emissions reported in the Agricultural sector for Estonia were 1 583.94 kt CO_2 eq. in 2021. The sector contributed about 10.2% to the total CO_2 eq. emissions in Estonia. In 2021, the emissions from Enteric fermentation increased by 0.3% compared to the previous year while the emissions from Manure management decreased by 0.8%. Emissions from Enteric fermentation increased mostly because of the cold winter temperatures that caused animals to use more feed, emissions from Manure management decreased because of the lower livestock population in most animal categories.

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).

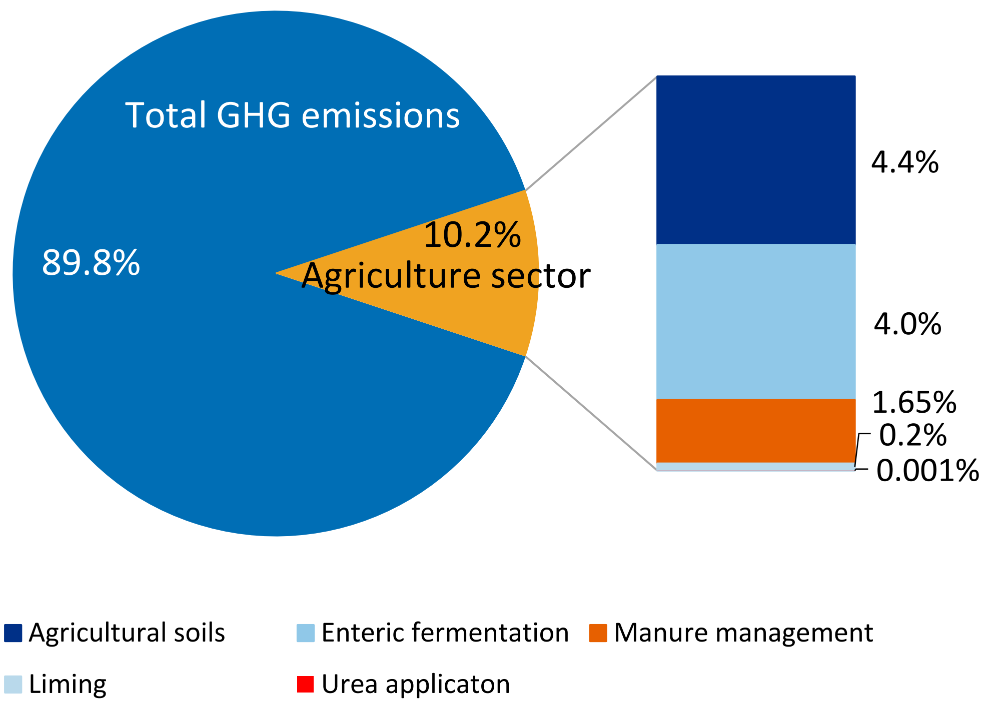


Figure 5.1. Emissions from the Agriculture sector compared to the total CO_2 eq. emissions in 2021, %

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.[10] 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%[10].

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[11]. The positive impact on the agricultural production manifested itself 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 41.8% in 2021 compared with the base year (i.e. 1990), mostly due to a decrease in the livestock population and 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 all agricultural animals decreased in 2021 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 energy crisis in EU, leading to higher prices for fertilizers, energy and feed.[12] In accordance with the observation by 2022 ERT, we have provided further information regarding fluctuations in livestock populations starting from 2014. 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 meat, pork, poultry, fish, milk and dairy, cheese, sausages, fruits, and nuts etc. from EU countries to Russia.[13] Consequently, the number of dairy cattle in 2021 fell by 12.5% in comparison with 2014. The number of dairy cattle was record low in 2021 – being only 83.6 thousand heads.[14] The number of swine has fallen by 13.9% in 2021 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 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.[15] 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. However, compared to the previous year, the number of swine has decreased by 2.8% in 2021. 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.[12] What is more, imported pork is cheaper for the buyer, so people have started to prefer it to domestic pork.[16]

Table 5.1. Estonia's agricultural GHG emissions by sources in 1990–2021, kt

Year	Enteric fermen -tation	Manure management		Agricultural soils	Liming	Urea application	Total GHG emissions			Total CO₂ eq. emissions
	CH_4	CH_4	N_2O[144]	N_2O[145]	CO_2	CO_2	CH_4	N_2O	CO_2	CO_2 eq.
1990	50.74	6.64	0.38	3.79	12.11	1.00	57.38	4.17	13.11	2 723.70
1995	27.17	3.35	0.20	1.86	3.59	0.64	30.52	2.06	4.23	1 405.61
2000	20.66	2.45	0.16	1.70	19.41	0.43	23.10	1.86	19.85	1 158.69
2005	21.22	3.45	0.18	1.75	7.22	1.41	24.67	1.93	8.63	1 212.06
2010	21.32	4.74	0.21	1.91	9.37	0.01	26.07	2.17	9.37	1 302.23
2015	22.03	5.41	0.23	2.35	9.04	0.03	27.44	2.58	9.07	1 459.91
2016	21.76	5.41	0.23	2.23	14	0.03	27.17	2.46	14.03	1 426.11
2017	22.07	5.89	0.23	2.33	16.3	0.10	27.97	2.56	16.4	1 478.63
2018	22.15	6.21	0.24	2.28	19.27	0.13	28.36	2.52	19.41	1 480.33
2019	22.45	6.50	0.24	2.52	15.46	0.13	28.95	2.77	15.6	1 559.55

[144] N_2O emissions include Indirect N_2O emissions from the Manure management category.
[145] N_2O emissions include Indirect N_2O emissions from the Agricultural soils category.

Year	Enteric fermen -tation	Manure management		Agricultural soils	Liming	Urea application	Total GHG emissions			Total CO₂ eq. emissions
	CH_4	CH_4	N_2O[144]	N_2O[145]	CO_2	CO_2	CH_4	N_2O	CO_2	CO_2 eq.
2020	22.20	6.80	0.25	2.55	15.73	0.13	29.00	2.80	15.86	1 569.74
2021	22.26	6.72	0.25	2.55	28.45	0.13	28.97	2.81	28.62	1 583.94

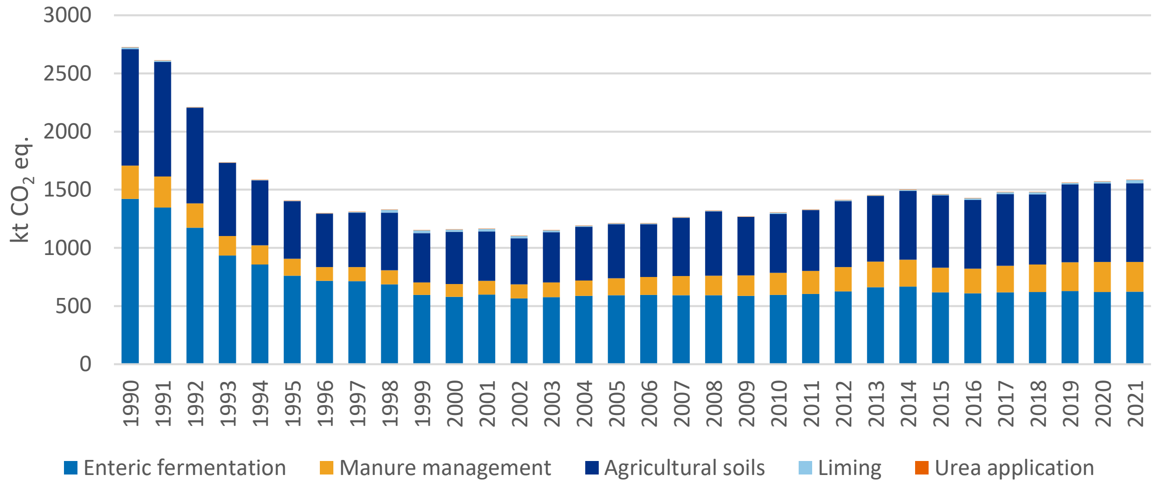


Figure 5.2. Trends in emissions by categories in Estonia in 1990–2021, kt CO_2 eq.

The following is a short overview of the results in the nitrogen balance in Estonia in 2021. The total amount of nitrogen excreted with manure was 24 573 tonnes in 2021. The total nitrogen that volatilized from manure management as NH_3 and NO_3 was 4 195 tonnes. The total nitrogen from nitrogen leaching and run-off from manure management was 49 tonnes. 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 46 767 tonnes and from crop residues 29 806 tonnes. Nitrogen in other sources, which were accounted in the Agriculture sector, was noticeably lower than 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 8 892 tonnes. The total nitrogen from nitrogen leaching and run-off from agricultural soils were 29 294 tonnes 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 cattle, swine, sheep, goats, fur-bearing animals and horses;
- CH_4 emissions from manure management of cattle, swine, sheep, goats, poultry, fur-bearing animals, rabbits and horses;

- N_2O emissions from manure management of cattle, swine, sheep, goats, poultry, fur-bearing animals, rabbits and horses;
- Indirect N_2O emissions from manure management;
- N_2O emissions from organic N fertilizers;
- N_2O emissions from organic soils cultivation;
- 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.2.5 Indirect N_2O emissions			T2/CS
3.D.1.1 Inorganic N fertilizers			T1/D
3.D.1.2. Organic N fertilizers			T1/D
3.D.1.3 Urine and dung deposited by grazing animals			T1/D
3.D.1.4 Crop residues			T1/D
3.D.1.5 Mineralization/immobilization associated with loss/gain of soil organic matter			T1/D
3.D.1.6 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

Key categories

The key categories in 1990 and 2021 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3.

References – sources of 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 (CRF tables, NIR).
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.jkkeskus.ee/jkk/en.html	- 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
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

5.1.2. Livestock characterization

Livestock population decreased in 2021 in comparison with the base year (Figure 5.3): the number of dairy cattle decreased by 70.2%, i.e. from 280.7 thousand heads to 83.7 thousand heads (Figure 5.3, Figure 5.5), the number of non-dairy cattle decreased from 477.1 thousand heads in 1990 to 167.1 thousand heads in 2021 (Figure 5.3, Figure 5.6). The total number of swine decreased by 64.2%, i.e. from 859.9 thousand heads in 1990 to 308 thousand heads in 2021 (Figure 5.3, Figure 5.7). The number of horses decreased from 8.6 thousand heads in 1990 to 5.4 thousand heads in 2021 – by 37%. The number of sheep decreased by 52.9% – from 158.5 thousand heads in 1990 to 74.7 thousand heads in 2021 (Figure 5.3). However, the population of goats increased from 2.1 thousand heads to 4.9 thousand from 1990 to 2021 (Figure 5.3). The poultry population decreased 52.2% by 2021 compared to the base year – from 5 597.2 thousand heads in 1990 to 2 674.9 thousand heads in 2021 (Figure 5.4).

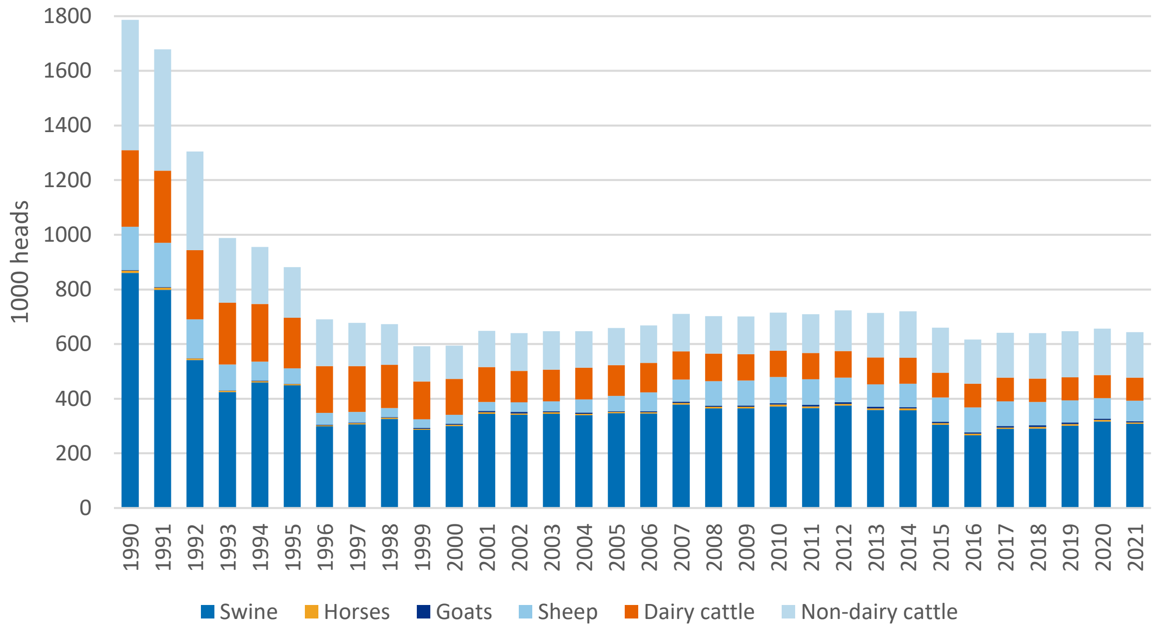


Figure 5.3. Population of livestock in Estonia in 1990–2021 (December 31st), 1000 heads

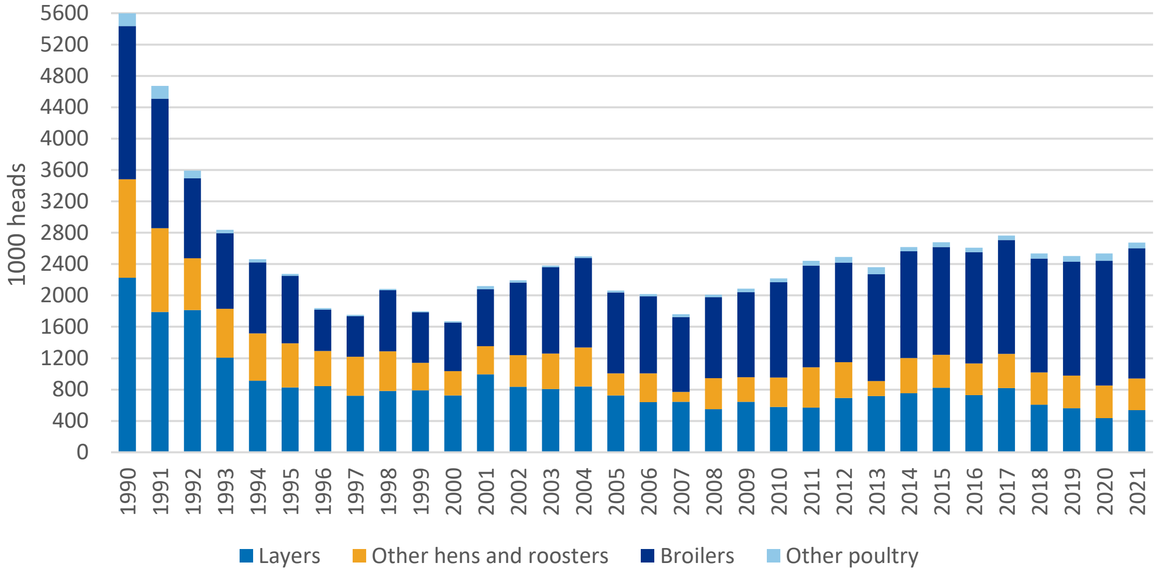


Figure 5.4 Population of poultry in Estonia in 1990–2021, 1000 heads

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 5.6. The number of non-dairy cattle reported in the CRF tables (Figure 5.6, Annex A.2.2_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 aggregate 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.

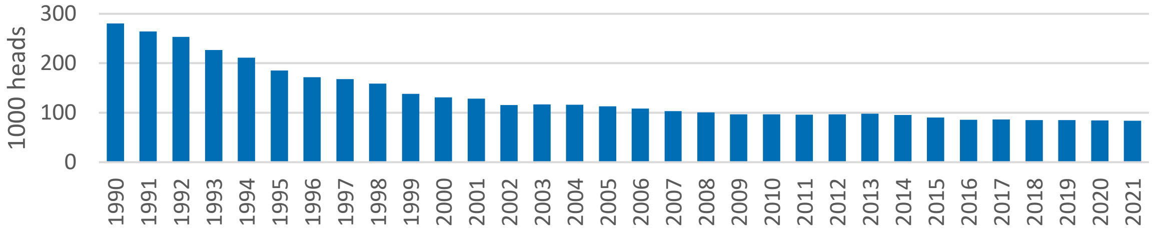


Figure 5.5. Population of dairy cattle in Estonia in 1990–2021 (December 31st), 1000 heads

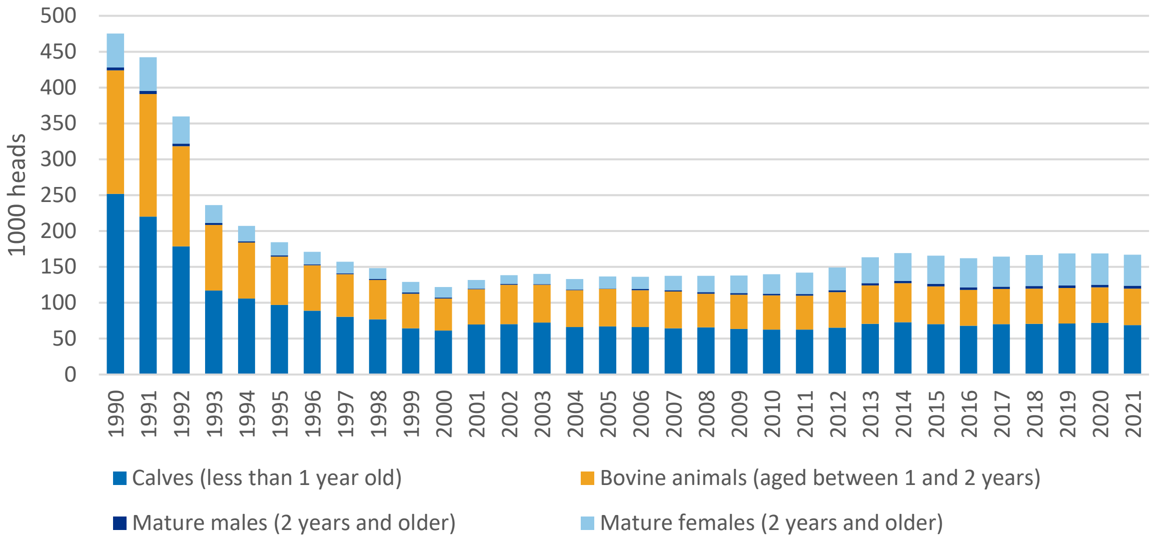


Figure 5.6. Population of non-dairy cattle in Estonia in 1990–2021 (December 31st), 1000

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 5.7, Annex A.2.2_I.2).

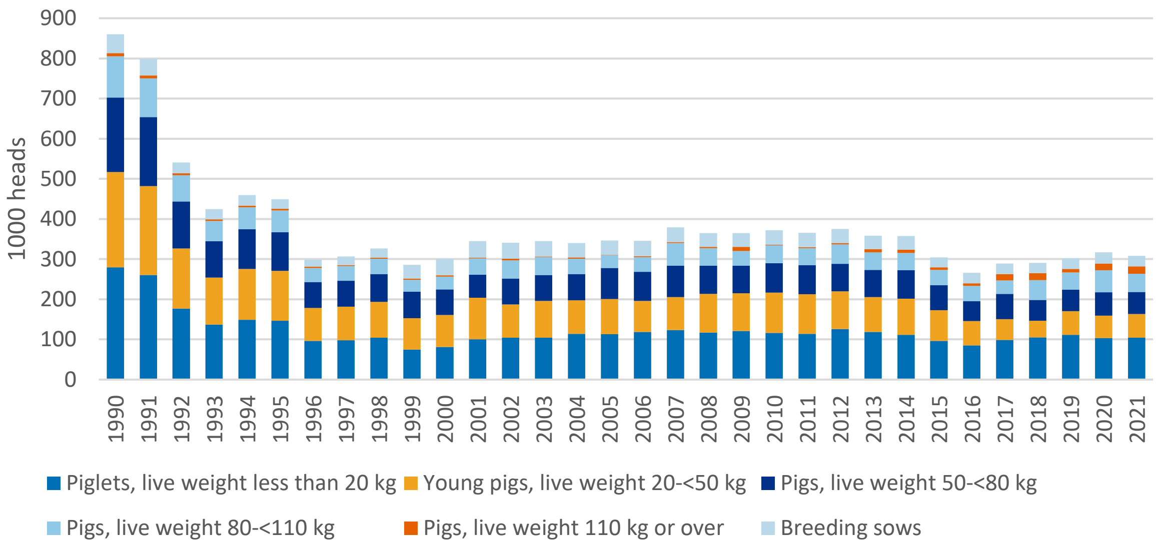


Figure 5.7. Population of swine in Estonia in 1990–2021 (December 31st), 1000 heads

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.[146]. 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 no. 88 of 6/09/2010, according to which the cages of fur animals had to be increased in size by 2017[147]. Nowadays, a major share of the production of Estonian fur farming is exported[148]. Fur animal population is in a strong decreasing trend with only 363 animals remaining in the farms in 2021, since fur farming will be banned in Estonia by 2026.

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 5.4). 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.

Seasonal births or slaughters 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[149]. In the Estonian GHG inventory, the annual average population Equation 5.1 has been used in estimates of the annual average of livestock population for broiler chickens, fur animals killed for fur and broiler rabbits.

Equation 5.1

$$AAP = Days\_alive \times \frac{NAPA}{365}$$

Where:

AAP = annual average population;
NAPA= number of animals produced annually.

[146] Saveli, O. (2004). Fur farming of Estonia. Animal Breeding in Estonia. Tartu: Paar OÜ.
[147] Riigi Teataja. Nõuded karuslooma pidamise ja selleks ettenähtud ruumi või ehitise kohta. [www] https://www.riigiteataja.ee/akt/13356899?leiaKehtiv (20.12.2021).
[148] ESTONICA. Encyclopedia about Estonia. Laansalu, A. Livestock farming. [www] http://www.estonica.org/en/The_rural_economy_in_Estonia_until_2001/Livestock_farming/ (20.12.2021).
[149] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, p 10.8.

The annual average livestock populations reported in the CRF tables, and their trends are provided in Table 5.4.

Table 5.4. The number of livestock population in Estonia in 1992–2021, in accordance with SE (as of 31 December) and FAO datasets, 1000 heads[150]

Year	Cattle		Pigs		Sheep		Goats		Horses		Poultry	
	SE	FAO	SE	FAO	SE	FAO	SE	FAO	SE/AR IB	FAO	SE	FAO
1992	613.1	708.3	541.1	798.6	123.1	141.9	1.1	NR	6.6	7.8	3 418.1	5 704
1995	369.8	419.5	448.8	459.8	48.2	61.5	1.7	NR	4.6	5	2 911.3	3 178
2000	252.8	267.3	300.2	285.7	29	28.2	3.2	2.7	4.2	3.9	2 366.4	2 462
2005	249.5	249.8	346.5	340.1	49.6	38.8	2.8	2.9	4.8	5.1	1 878.7	2 183
2010	236.3	234.7	371.7	365.1	78.6	76.5	4.1	3.9	6.8	5.4	2 046.4	1 793
2015	256.2	264.7	304.5	357.9	85.9	85.2	5	4.6	6.3	6.3	2 161.8	2 315
2016	248.2	248.2	265.9	265.9	85.5	85.5	5.1	5.1	5.7	5.7	2 112.0	2 084
2017	250.9	250.9	289.1	289.1	80.8	80.8	5.1	5.1	5.7	5.7	2 252.7	2 223
2018	251.9	251.9	290.4	290.4	73.1	73.1	5.2	5.2	5.7	5.7	2 125.7	2 059
2019	254.0	254.0	301.6	301.6	70.8	70.8	4.7	4.7	5.5	NA	2 150.9	2 080
2020	253.3	253.3	316.8	316.6	68.1	NA	4.5	NA	5.6	NA	2 148.8	2 055
2021	250.8	250.8	308	308	65.6	NA	4.3	NA	5.4	NA	2 105.1	2 032

NR – data is not reported by the FAO, NA – data was not available during the inventory compilation

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 is adjusted according to the calculated annual average population of 2007–2021. The data used in the calculations of the average yearly population of sheep and goats are presented in Annex A.2.2_I.5.

The annual average population for a year t was calculated with Equation 5.2 by using the chronological mean of censuses, as follows:

Equation 5.2

$$NoA = (NoA_{March} + NoA_{June} + NoA_{Sep} + NoA_{Dec})/4$$

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].

[150] Statistics Estonia. Livestock and poltry by county (quarters) [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__loomakasvatussaaduste-tootmine/PM09 (22.12.2022); FAO. FAOSTAT data. Crops and livestock products. [www] https://www.fao.org/faostat/en/#data/QCL (02.01.2023).

Poultry

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[151] which was also used in the estimation of the average annual population using the Equation 5.1. The data used in the calculations of the average yearly poultry population are presented in Annex A.2.2_I.6.

Fur animals

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[152]. 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 colour-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[153]. The average fertility rate for Ltd. Balti Kasrusnahk in 2005 was 3.8/litter[154]. 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.2.2_I.8.

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. These data primarily represent 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); and in 2021 another one was carried out. The mentioned surveys have covered only the number of breeding females in compliance with the EU regulation 2018/1091[155] or the respective earlier regulations.

---

[151] Tikk, H., Tikk, V., Piirsalu, M., Hämmal, J. (2007). Linnukasvatus I. Tartu: OÜ Tartumaa Trükikoda, lk 32.
[152] Piirsalu, P. Minkide värvusmutandid ja nende kasvatamine. [www] http://www.eau.ee/~alo/karusloomad/mingid/?Minkide_sigimine/Poegimine (15.01.2022).
[153] Fur Institute of Canada. Fox farming. [www] https://fur.ca/fur-farming/fox-farming/ (15.01.2022).
[154] Piirsalu, P. Hõbe- ja sinirebaste värvusmutandid ja nende kasvatamine. [www] http://www.eau.ee/~alo/karusloomad/rebased/?Rebased (15.01.2022).
[155] 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 (10.01.2022).

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[156]. 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.

5.1.3. NMVOC and NO_x emissions

NMVOC emission from Manure management and NO_x emission originating from Agricultural soils have been reported in the CRF (Table 5.5). The emissions are in compliance with the data submitted under the Convention on Long-Range Transboundary Air Pollution in the Estonian Informative Inventory Report 1990–2021, compiled by the EstEA. In the Agriculture sector, NO_x emission from Agricultural soils and NMVOC emissions from Manure management decreased by 41.5% and 53.3%, 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 2019. 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 1990–2021 submitted under the Convention on Long-Range Transboundary Air Pollution[157].

Table 5.5. NMVOC and NO_x emissions originating from the Agriculture sector in 1990–2021, kt

Year	NO_x	NMVOC
1990	4.75	9.89
1995	1.72	4.85
2000	1.63	3.30
2005	1.62	4.04
2010	2.01	3.90
2015	2.38	4.51
2016	2.38	4.30
2017	2.42	4.67
2018	2.42	4.58
2019	2.48	4.27
2020	2.58	4.43
2021	2.78	4.62

5.2. Enteric fermentation (CRF 3.A)

5.2.1. Category description

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

[156] Home page of Härma Küülikud. Küülikute hooldamisest ja pidamisest. [www] http://www.rabbitfarm.planet.ee/kasulikinfo.html (24.01.2022).
[157] Estonian Environment Agency. Estonian Informative Inventory Report 1990–2019, Ch. 5 Agriculture (NFR 3).

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 2021 (Table 5.12). 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 2015–2021 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 2021, being only 83.6 thousand heads. The growth in CH_4 emissions from enteric fermentation in the recent years is the result of increased milk production per cow and the growing number of beef cattle. The CO_2 eq. emissions from enteric fermentation of Estonian livestock made up 39% of the total CO_2 eq. emissions from the Agricultural sector in 2021. CH_4 emissions from enteric fermentation in 2021 were 56% lower than the emissions of the base year due to the decrease in the number of the livestock population (Table 5.6, Figure 5.8).

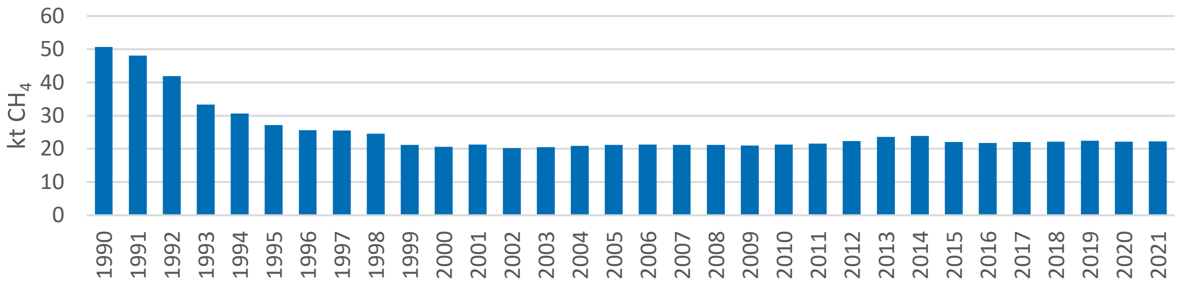


Figure 5.8. Enteric fermentation CH_4 emissions from Estonian livestock in 1990–2021, kt

Table 5.6. CH_4 emissions from Enteric fermentation by animal type in 1990–2021 in Estonia, kt

Year	Cattle	Swine	Sheep	Goats	Horses	Poultry	Rabbits	Fur animals	Total CH_4, kt
1990	48.39	0.89	1.29	0.01	0.15	NE	NE	0.02	50.74
1995	26.16	0.46	0.44	0.01	0.08	NE	NE	0.01	27.17
2000	19.95	0.34	0.27	0.02	0.08	NE	NE	0.01	20.16
2005	20.30	0.37	0.44	0.02	0.09	NE	NE	0.01	20.66
2010	20.00	0.40	0.77	0.02	0.12	NE	NE	0.01	21.22
2015	20.85	0.33	0.71	0.03	0.11	NE	NE	0.01	22.03
2016	20.60	0.29	0.73	0.03	0.10	NE	NE	0.01	21.76
2017	20.90	0.32	0.72	0.03	0.10	NE	NE	0.01	22.07
2018	21.00	0.33	0.69	0.03	0.10	NE	NE	0.004	22.15
2019	21.36	0.32	0.65	0.03	0.10	NE	NE	0.0004	22.45
2020	21.11	0.36	0.60	0.02	0.10	NE	NE	0.0003	22.20
2021	21.19	0.34	0.60	0.02	0.10	NE	NE	0.00004	22.26

5.2.2. Enteric fermentation of cattle

5.2.2.1. Methodology, data availability, data sources and emission factors

The *Tier 2* method of IPCC 2006 (Equation 5.3–Equation 5.12) 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). In the 2013 submission, two key recalculations were performed: namely, the population of calves (less than 1 year old) was split into two groups: calves aged 0–6 months and calves aged 6–12 months. Methane emissions from enteric fermentation were 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 CRF Reporter was changed: CH_4 emissions from enteric fermentation of bovine animals were 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 (on the basis of 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 5.3)

Equation 5.3[158]

$$NE_{mj} = C_{f\,j} \times (weight_j)^{0.75}$$

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 5.4[159]

$$Cf\ (in\ cold) = Cf_i + 0.0048 \times (20 - ℃)$$

Where:

Cf = coefficient for calculating NE_m (Table 5.7);
℃ = mean daily temperature during the winter season.

[158] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.15, equation 10.3.
[159] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.13, equation 10.2.

Table 5.7. C_f coefficient[160]

Animal category	C_{fi}
Cattle (non-lactating)	0.322
Cattle (lactating)	0.386
Cattle (bulls)	0.37

Net energy for activity for animals (Equation 5.5)

Equation 5.5[161]

$$NE_{aj} = C_a \times NE_{mj}$$

Where:

NE_{aj} = net energy intake by *j* category of cattle, MJ/head/day;
C_a = coefficient corresponding to animals' feeding situation (Table 5.8);
NE_m = net energy required for maintenance by *j* category of cattle (Equation 5.3).

Table 5.8. Activity coefficients corresponding to animals' feeding situation[162]

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

Net energy for growing – net energy needed for growth (live weight gain) (Equation 5.6). 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 5.6[163]

$$NE_g = 22.02 \times (\frac{BW}{C \times MW})^{0.75} \times WG^{1.097}$$

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;
C= a coefficient with a value of 0.8 for females, 1.0 for castrates and 1.2 for bulls;

160 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.16, table 10.4.
161 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.16, equation 10.4.
162 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.17, table 10.5.
163 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.17, equation 10.6.

MW = the mature live body weight of an adult female in moderate body condition, kg.

Net energy for lactation – energy for lactation

Equation 5.7[164]

$$Ne_{li} = kg\_of\_milk/day_i \times (1.47 + 0.40 \times Fat_i)$$

Where:

NE_{li} = net energy for lactation by dairy cattle, MJ/head/day;
Fat = fat content of milk, %.

Net energy for pregnancy

Equation 5.8[165]

$$NE_{pregnancy} = C_{pregnancy} \times NE_m$$

Where:

$NE_{pregnancy}$ = net energy required for pregnancy, MJ/head/day;
$C_{pregnancy}$= pregnancy coefficient = 0.1[(166)];
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 5.9[167]

$$REM = 1.123 - \left(4.092 \times 10^{-3} \times DE_{ji}\%\right) + \left(1.126 \times 10^{-5} \times \left(DE_{ji}\%\right)^2\right) - 25.4/DE_{ji}\%$$

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 5.10[168]

$$REG = 1.164 - \left(5.160 \times 10^{-3} \times DE_{ji}\%\right) + \left(1.308 \times 10^{-5} \times \left(DE_{ji}\%\right)^2\right) - 37.4/DE_{ji}\%$$

164 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.18, equation 10.8.
165 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, equation 10.13.
166 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, table 10.7.
167 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, equation 10.14.
168 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.21, equation 10.15.

Where:

REG = ratio of net energy available for growth in a diet to digestible energy consumed for *j* category of cattle.

Gross energy for cattle

Equation 5.11[169]

$$GE = \frac{(NE_{mji} + NE_{feedji} + NE_{l} + NE_{workji} + NE_{pregnancyj}) \times (\frac{100}{DE_{ji}\%})}{(NE/DE)_{ji} + (NE_{gji}/\{NE_{g}/DE\}_{ji})}$$

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[170], 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 5.12 [171]

$$EF = [GE \times Y_m \times (365 days/yr)]/[55.65 MJ/CH_4 kg]$$

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.2.2_III.1);

Milk production per day, kg/day – a source of data is SE (Annexes A.2.2_II.1-2);

Fat content of milk, % – data were obtained from EARC (Annexes A.2.2_II.3-4);

---

[169] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.21, equation 10.16.

[170] Net energy for work was not calculated.

[171] 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.2.2_II.5);

Feed digestibility, % – data were obtained from Kaasik, A. report, 2020;

Methane conversion rate, Y_m % (Table 5.9) – the values of Ym of mature dairy and non-dairy cattle and bovine animals were obtained from the 2006 IPCC Guidelines.

Table 5.9. Methane conversion rate, %[172]

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[173], which stipulate markedly lower methane emissions. Additionally, the consumption of milk (only) assumes zero methane emissions from the rumen[174]. 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[175]. 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 CRF 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 5.10.

Table 5.10. CH_4 EF of Enteric fermentation of non-dairy cattle in 2021, kg CH_4/head/year

Livestock category of non-dairy cattle	Emission factor, kg CH_4/head/year
Mature males (2 years and over)	75.6
Mature females (2 years and over)	88.6
Bovine animals (aged between 1 and 2 years)	62.9
Calves (6–12 months)	18.8

172 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.30, table 10.12.
173 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 (24.01.2022).
174 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.30.
175 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
Calves (0–6 months)	3.3

The values of CH_4 EF have increased in the period of 1990–2021, mainly due to the increased milk production per cow (Table 5.11**).**

Figure 5.9 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 5.11.

Table 5.11. Weight, milk yield per cow and fat content of milk, gross energy intake and enteric fermentation CH_4 EFs for dairy cattle in 1990–2021 (Annexes A.2.2_II.1–4, A.2.2_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
1995	559.2	4.08	3 588	236	101
2000	574.1	4.29	4 660	267	114
2005	588.7	4.21	5 886	300	128
2010	604.0	4.11	7 021	329	140
2015	619.5	3.98	8 442	341	145
2016	622.6	4.00	8 878	352	150
2017	625.9	3.94	9 159	358	153
2018	629.3	3.91	9 287	360	154
2019	632.6	3.89	9 633	368	157
2020	635.9	3.89	9 943	367	156
2021	636.3	3.9	9 966	367	157
IPCC default					
EE[176]	550[177]		2 555[177]		99[178]
WE	600		5 986		117

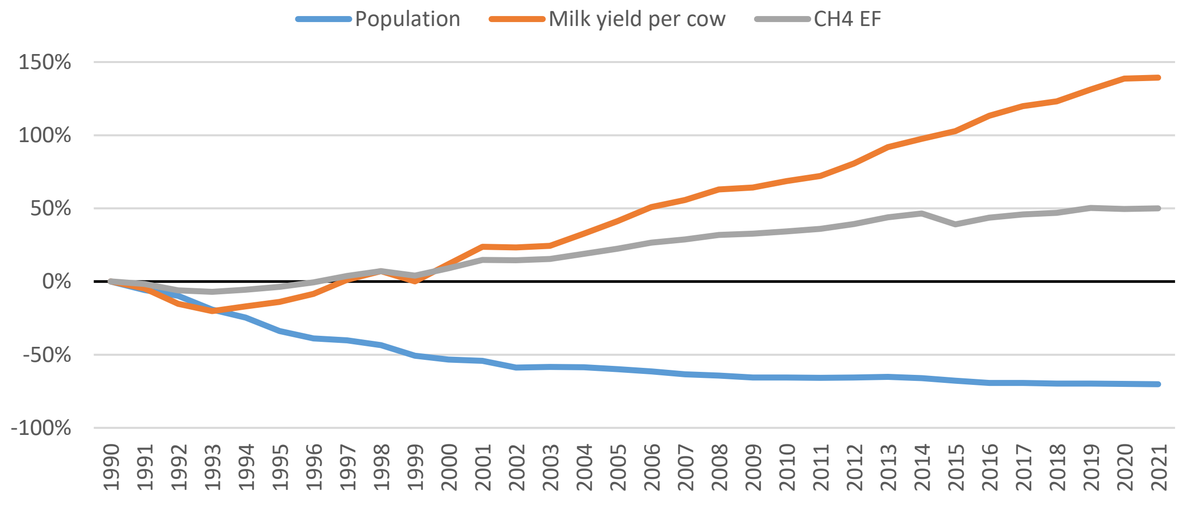


Figure 5.9. Changes in dairy cattle population, milk yield per cow and CH_4 EF in the period of 1990–2021 in relation to the base year (1990), %

[176] EE – Eastern Europe, WE – Western Europe.
[177] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.72, table 10A.1.
[178] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.29, table 10.11.

5.2.2.2. Quantitative overview – CH_4 emissions from enteric fermentation of cattle in 2021

Total CH_4 emissions from cattle enteric fermentation were 21.19 kt in 2021. Dairy cattle livestock was the main contributor to CH_4 emissions from cattle enteric fermentation in Estonia in 2021 (Table 5.12). The number of dairy cows, which has been decreasing in Estonia over the last 20 years, was 95.5–96.7 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 2021, so the number of dairy cattle in 2021 fell by 12.5% in comparison with 2014, consequently. In fact, the number of dairy cattle was record low in 2021 – being only 83,600 heads.

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 Europe.[179] CH_4 emissions from cattle enteric fermentation decreased by 56.2% in 2021 compared with the base year.

Table 5.12. CH_4 emissions from Enteric fermentation of cattle in 1990–2021 in Estonia, kt

Year	Cattle[180]			Total, CH_4, kt
	Dairy cattle	Other mature cattle	Growing cattle	
1990	29.32	4.88	14.18	48.39
1995	18.65	1.94	5.57	26.16
2000	14.93	1.47	3.55	19.95
2005	14.43	1.60	4.26	20.30
2010	13.54	2.68	3.78	20.00
2015	13.17	3.77	3.91	20.85
2016	12.93	3.92	3.76	20.60
2017	13.17	4.00	3.73	20.90
2018	13.09	4.17	3.74	21.00
2019	13.34	4.25	3.76	21.36
2020	13.17	4.10	3.84	21.11
2021	13.11	4.15	3.94	21.19

5.2.3. Enteric fermentation of swine

5.2.3.1. Methodology, data availability, data sources and emission factors

The *Tier 2* method (Equation 5.13–Equation 5.16) 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. Methane conversion factors in Table 5.13 were

[179] Postimees. Maa elu. Eestis on Euroopa suurima piimaanniga lehmad. [www] https://maaelu.postimees.ee/7500032/eestis-on-euroopa-suurima-piimaanniga-lehmad (15.11.22)
[180] 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.

taken from the 2006 IPCC Guidelines; ratios of feed digestibility were obtained from a study by A. Kaasik[181].

Gross energy intake by swine

Equation 5.13[182]

$$GE_j = ME_j/(DE_j - Ym - UE)$$

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[183];
UE = urinary energy excretion, 2% for swine[184].

Equation 5.14[185]

$$ME_j = 2.0 \times w_j^{0.63}$$

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 5.15[186]

$$CH_4 Emission = EF_j \times population_j/(10^6 kg/Gg)$$

Where:

CH_4 Emission$_j$ = methane emissions from Enteric fermentation from *j* category of swine, kt CH_4/year.

Equation 5.16[187]

$$EF = [GE \times Y_m \times (365 days/yr)]/[55.65 MJ/CH_4 kg]$$

[181] Kaasik, A. Report of the projekt „Kariloomade söödaplaanide uuring 1990–2020“.
[182] 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.
[183] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.35, table A-4.
[184] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, p 10.42.
[185] 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..
[186] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, p 10.28, equation 10.19.
[187] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.31, equation 10.21.

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.

Table 5.13 demonstrates CH_4 emission factors for each category of swine and the IPCC default EF for swine recommended for developed countries.

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**[188]
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	

5.2.3.2. Quantitative overview – CH_4 emissions from enteric fermentation of swine in 2021

The total CH_4 emissions from swine enteric fermentation were 0.34 kt in 2021. The emissions decreased by 61.2% since the base year (Figure 5.10). 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 13.9% in 2021 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 lead to lower number of swine population in the country.[15] 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. However, compared to the previous year, the number of swine has decreased by 2.8%. 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.[12] What is more, imported pork is cheaper for the buyer, so people have started to prefer it to domestic pork.[16]

[188] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, table 10.10.

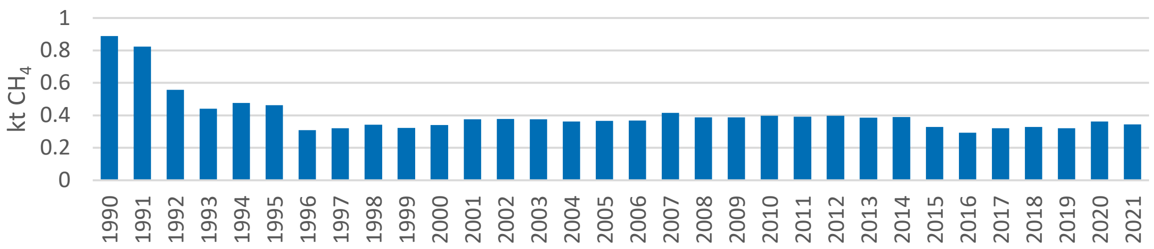


Figure 5.10. CH_4 emissions from Enteric fermentation of swine in 1990–2021 in Estonia, kt

5.2.4. Enteric fermentation of other livestock

5.2.4.1. Methodology, data availability, data sources and emission factors

The *Tier 1* of IPCC 2006 (Equation 5.17) was used to estimate CH_4 emissions from Enteric fermentation of other livestock.

Equation 5.17[189]

$$CH_4 Emission = EF_j \times population_j / (10^6 kg/Gg)$$

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.

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[190]

Livestock category	Emission factor, kg CH_4/head/year
Sheep	8
Goats	5
Horses	18
Poultry	Not estimated
Fur animals	0.1[191]
Rabbits	Not estimated

[189] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, equation 10.19.
[190] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, table 10.10 (developed countries).
[191] 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.

5.2.4.2. Quantitative overview – CH_4 emissions from enteric fermentation of other livestock categories in 2021

The total CH_4 emissions from Enteric fermentation of other livestock were 0.72 kt in 2021. CH_4 emissions have declined by 49.4% in 2021 compared with the base year due to a decrease in the number of other livestock population (Figure 5.11. C).

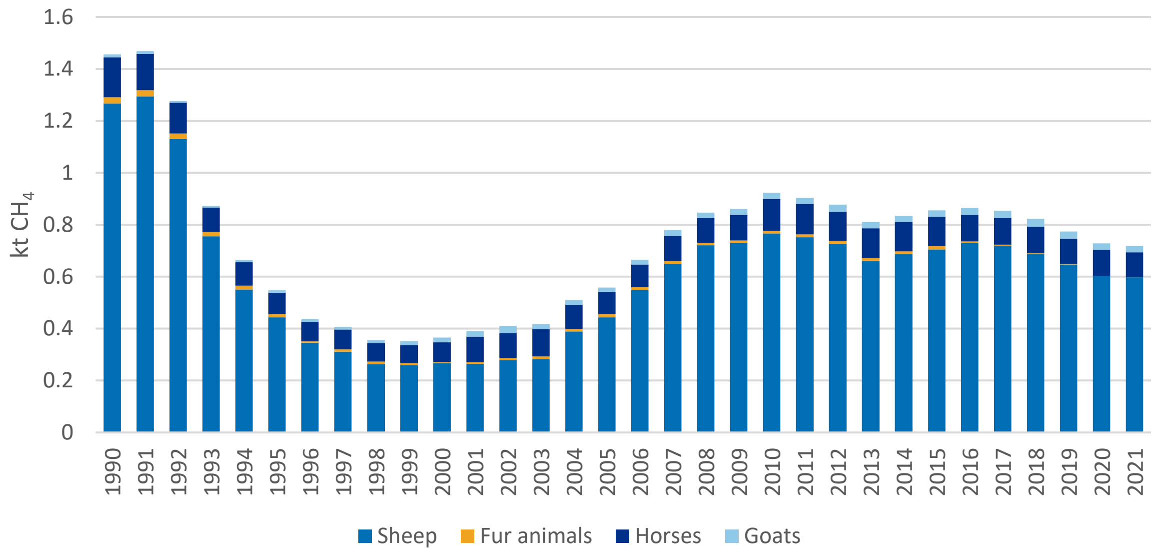


Figure 5.11. CH_4 emissions from Enteric fermentation of other livestock categories in 1990–2021, kt

5.2.5. Uncertainties and time series consistency

The estimation of CH_4 emissions from Enteric fermentation of cattle and swine was carried out based on the *Tier 2* approach with Estonian activity data and default factors obtained from the IPCC Guidelines. The *Tier 1* method was used to estimate CH_4 emissions from other livestock: goats, horses, sheep, and fur animals.

Since the 2019 submission, country-specific uncertainty rates of activity data have been implemented for cattle, swine, and sheep calculations. The data for calculating their uncertainties were obtained from Statistics Estonia. The data of uncertainties of other livestock were obtained from the study of Rypdal and Winiwarter (2001), where uncertainties of activity data (livestock population) are presented for a few countries: Austria (±10%), Norway (±5–10%), the Netherlands (<±5%), USA (±2%). The experiences of Austria were used to calculate uncertainties in emissions from Enteric fermentation of livestock (Table **5.15**). The uncertainty in CH_4 emission factors for livestock categories (cattle, swine, sheep, goats, horses, fur animals) is reported to be ±40%[192].

Despite that the *Tier 2* method is used in calculating emissions from cattle and swine, the default uncertainty rate was taken as ±20% due to the lack of uncertainty analysis performed to estimate uncertainty rates of each parameter (Table **5.15**).

Table 5.15. Estimated values of uncertainties used in the Agriculture sector

[192] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.33.

Input	Uncertainty	References
Activity data		
Estonia’s dairy cattle population	± 0.72%	Statistics Estonia
Estonia’s non-dairy cattle population	± 1.11%	Statistics Estonia
Estonia’s swine population	± 0.49%	Statistics Estonia
Estonia’s sheep population	± 6.53%	Statistics Estonia
Estonia’s other livestock population (goats, horses, poultry, and fur animals)	± 10%	Rypdal and Winiwarter, 2001
Emission factors		
Enteric fermentation (CH_4) (cattle, swine, sheep, goats, horses, fur animals)	± 40%	IPCC, 2006. Agriculture. pp. 10.33

5.2.6. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for Estonian GHG inventory at the national level are presented in Chapter 1.2.3.

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[193]. The activities are carried out every year during the inventory. The QC check list is used during the inventory.

5.2.7. Category-specific recalculations

Pregnancy rate, milk yield etc to mature female cattle
Pregnancy rate and milk yield, fat and protein content of milk etc. were added for mature female cattle in addition to dairy cows. This is due to the fact that mature females are also suckler cows, are pregnant for some time of the year and produce milk. This was not considered in the previous submissions.
This correction is based on the QA conducted by A. Kaasik in 2020.[194] Pregnancy rate of 80% and milk yield as of 3000 kg/year were applied to mature female cattle for the whole timeseries.

This has a relatively large impact on Estonian Agriculture sector's emissions for the whole timeseries, as it increases the emissions between 30-60 kt CO_2 eq for all years in the timeseries.

Number of horses in 2019-2021

The number for horse population was updated in 2023 submission for the years 2019-2020, because Statistics Estonia stopped collecting horse population data in 2019. We have switched to Agricultural Registers and Information Board (ARIB) Equine database. The ARIB Equine database, provides the current numbers of horse population and does not provide historical overviews. We are extracting the number of horses as of 31.12.2022 (for keeping the consistency with other animal groups) and made an interpolation for the years 2019-2021 for keeping the time series consistency with the SA database. The comparison of updated numbers of horses is shown in Table 5.16.

[193] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.33-10.34.
[194] Kaasik, A., docent at the Chair of Animal Nutrition, Estonian University of Life Sciences. Quality assurance control report for Estonia’s national GHG inventory and inventory report 2021, Agriculture subsector 3.A – Enteric fermentation. (2020)

Table 5.16. Comparison of horse population and emissions from enteric fermentation by horses in 2019-2020 between 2022 and 2023 submissions, head

	Activity data		GHG emissions in CO_2 eq., kt	
Submission	**2019**	**2020**	**2019**	**2020**
2022 submission	5700	5700	2.9	2.9
2023 submission	5525	5369	2.8	2.7

Rounding activity data

Livestock numbers were rounded to an integer in 2023 submission for the whole time series for the following animal groups: sheep, goats, calves aged 0-6 months and 6-12 months, laying hens, other hens and roosters, broilers, swine, rabbits, fur animals.

Average weight for dairy cattle and growing cattle were rounded to two decimal points, and digestibility of feed for growing cattle was rounded to one decimal point for the 2023 submission.

Correcting average winter temperature for 2020

The average winter temperature (average for December, January and February) was corrected due to correcting the error in activity data for the year 2020. The average winter temperature used in 2022 submission was -2.67 degrees Celsius, it has been corrected to be +1.8 degrees Celsius.

CH_4 emissions from enteric fermentations in 1990-2020 were recalculated due to following: adding the pregnancy rate, milk yield etc. for mature female cattle, updating the number of horses, rounding the activity data and correcting the average winter temperature for 2020.

A comparison of the changed values of the amounts of CH_4 emissions due to the recalculations between 2023 and 2022 submissions are shown in Table 5.17.

Table 5.17. CH_4 emissions in 2023 and 2022 submissions from enteric fermentation, kt

Enteric fermentation	1990	1995	2000	2005	2010	2015	2019	2020
2022 submission	49.11	26.53	20.16	20.68	20.45	20.80	21.07	20.94
2023 submission	50.74	27.17	20.66	21.22	21.32	22.03	22.45	22.20

5.2.8. Category-specific planned improvements

There are no category-specific planned improvements.

5.3. Manure management (CRF 3.B)

5.3.1. 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[195].

[195] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.35.

CH_4 emissions from Manure management formed 11.87% of the total agricultural emissions in Estonia in 2021.

The largest contributor to the CH_4 emissions in manure management in 2021 was the cattle subcategory. The total CH_4 emissions from livestock manure management were 6.72 kt in Estonia in 2021, the emissions have decreased by 1.1% in 2021 in comparison with the base year (Table 5.18, Figure 5.12). 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.

Table 5.18. CH_4 emissions from Manure management in 1990–2021 in Estonia, kt

Year	Cattle	Swine	Sheep	Goats	Horses	Poultry	Fur animals	Rabbits	Total
1990	2.14	4.14	0.03	0.0003	0.013	0.15	0.16	0.007	6.64
1995	1.18	2.00	0.01	0.0003	0.007	0.06	0.09	0.006	3.35
2000	0.90	1.45	0.01	0.0005	0.007	0.04	0.03	0.005	2.45
2005	1.71	1.57	0.01	0.0004	0.007	0.05	0.09	0.007	3.45
2010	2.86	1.72	0.02	0.0006	0.011	0.06	0.07	0.003	4.74
2015	3.54	1.69	0.02	0.0007	0.01	0.07	0.08	0.002	5.41
2016	3.76	1.52	0.02	0.0007	0.009	0.07	0.03	0.002	5.41
2017	4.09	1.67	0.02	0.0007	0.009	0.07	0.04	0.002	5.89
2018	4.37	1.72	0.02	0.0008	0.009	0.06	0.03	0.002	6.21
2019	4.72	1.69	0.02	0.0007	0.009	0.06	0.003	0.002	6.50
2020	4.78	1.93	0.01	0.0006	0.009	0.06	0.002	0.002	6.80
2021	4.80	1.82	0.01	0.0006	0.008	0.07	0.0002	0.002	6.72

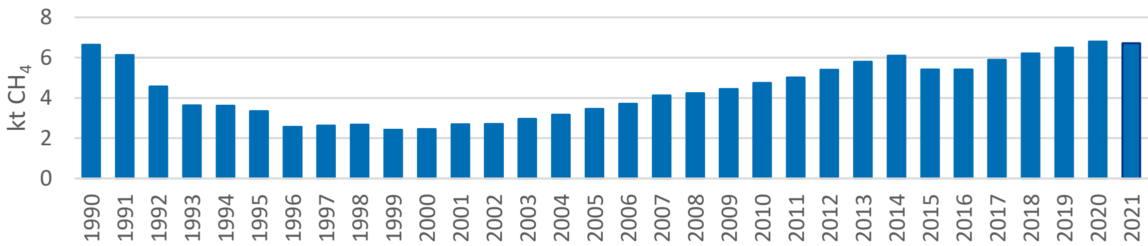


Figure 5.12. CH_4 emissions from Estonian livestock manure management in 1990–2021, kt

5.3.1.1. Cattle manure management

5.3.1.1.1. Methodology, data availability, data sources and emission factors

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[196]

$$CH_4\_Emission_j = EF_j \times Population_j / (10^6 kg/Gg)$$

[196] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.37, equation 10.22.

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[197]

$$EF_j = VS_j \times {}^{365\ days}/_{yr} \times B_{oj} \times 0.67\ {}^{kg}/_{m^3} \times \sum_{nK} MCF_{nK} \times MS\%_{jK}$$

Where:

EF_j = annual methane emission factor for *j* category of cattle kg;
VS_j = volatile solid excreted for *j* category of cattle, kg;
Bo_j = maximum CH_4 producing capacity for manure produced by *j* category of cattle, kg of VS (Table 5.19);
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[198]

$$VS = [GE \times (1 - (DE\%)/100) + (UE \times GE)][((1 - ASH)/18.45)]$$

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.

Table 5.19. Parameters used in the estimates

Cattle category	**Digestibility of feed, %**[199]	**Bo** [200]
		m^3 CH_4/kg VS
Mature cattle[201]		
Dairy	70.2	0.24

[197] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.41, equation 10.23.
[198] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.42, equation 10.24.
[199] Kaasik, A. (2020) Report of the project "Kariloomade söödaplaanide uuring 1990–2020", pages 18-19.
[200] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.77–10.78, table 10A-4.
[201] 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 cattlefor Eastern European countries).

Cattle category	Digestibility of feed, %[199]	Bo [200] m^3 CH_4/kg VS
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

The module on MMS (Annex A.2.2_IV) and CH_4 EFs employed in the estimations are presented in Table 5.20. 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 5.20. MMS usage, methane conversion factors (MCFs) and manure management emission factors for dairy cattle in 2021 in Estonia

	MMS, %			Emission factor, %
	Liquid/slurry	Solid storage	Pasture/range	kg CH_4/head/yr
Estonian average[202]	89.7	6.4	1.8	34.3
MCFs [203],%	10	2	1	

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 loose-housing system the 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[204], the share of slurry stored in pit storage below the dairy cows is zero. In addition, the Estonian document on best available techniques (BAT)[205] 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

[202] Kaasik, A. Eesti lauda- ja sõnnikukäitlustehnoloogiate ning sõnniku laotamise tehnoloogia uuring, [www] https://www.klab.ee/wp-content/uploads/2021/09/Laudatehnoloogiad_final.pdf (22.12.2021)
[203] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.45, table 10.17.
[204] KOTKAS, [www] https://kotkas.envir.ee/ (07.12.2021).
[205] 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 (16.12.2021).

Estonia, using BATs is obligatory for operators owning Air or Integrated Pollution Prevention and Control (IPPC) permit according to the Ambient air protection act[206].

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[207].

Implied CH_4 EFs have increased since 1990 due to changes in the technology of dairy cattle housing (Figure 5.13). 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.2.2_IV).

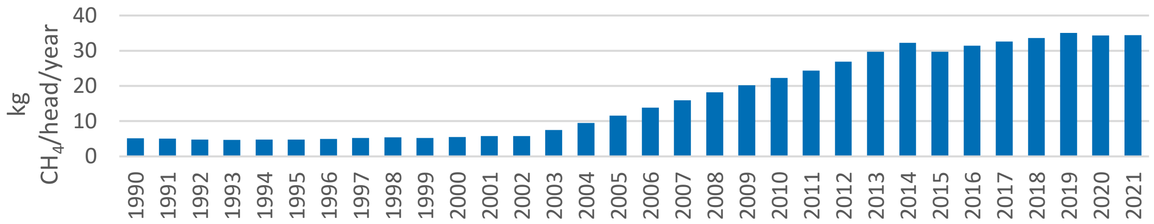


Figure 5.13. Implied CH_4 emission factor for dairy-cattle MMS in 1990–2021, kg CH_4/head/year

In 1990–2003, a share of mature non-dairy cattle manure stored in solid storage MMS constituted about 68% and manure from pasture about 32%. Since 2003, the MMSs of mature non-dairy cattle have made a shift from solid MMS towards liquid MMS and deep litter MMS[202]. Hence, in 2021, share of mature non-dairy cattle manure was the following: 4.3% solid storage, 14.3% manure from pasture, 41% liquid and 40.4% deep litter MMS fraction. In 2021, CH_4 EFs applied in the estimations of mature non-dairy cattle were the following: mature males – 19.34 kg CH_4/head/year and mature females – 19.51 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 5.21. (See also Annex A.2.2_IV).

Table 5.21. MMS usage, methane conversion factors and manure management emission factors for growing cattle in 2021 in Estonia

	MMS, %[202]				EFs, kg CH_4/head/year		
	Liquid/ slurry	**Solid storage**	**Deep litter**	**Pasture/ range**	**Bovine animals**	**Calves (6–12 months old)**	**Calves (0–6 months old)**
Estonian average	14.8	0.1	68.0	17.2	15.3	4.8	1.8

CH_4 IEFs for growing cattle have increased since 2003 due to the decreased proportion of solid manure and the more widespread use of liquid manure and deep litter systems (Figure 5.14).

[206] Riigi Teataja. Atmosfääriõhu kaitse seadus. [www] https://www.riigiteataja.ee/akt/A%C3%95KS (14.02.2023).
[207] Kaasik, A., Möls, M. Loomakasvatusest eralduvate saasteainete heitkoguste inventuurimetoodikate täiendamine ja heite vähendamistehnoloogiate kaardistamine. [www] https://envir.ee/media/5276/download (10.01.2022).

The change has been caused by shifts in the housing technology – from tie-stall housing to loose-housing system.

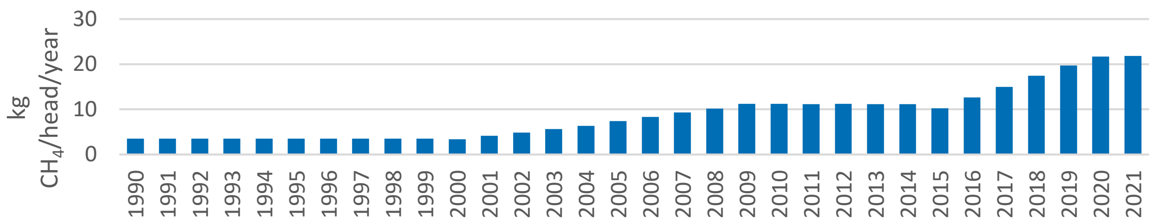


Figure 5.14. Implied CH_4 emission factor for growing cattle MMS in 1990–2021, kg CH_4/head/year

5.3.1.1.2. Quantitative overview – CH_4 emissions from cattle manure management in 2021

The total CH_4 emissions from cattle manure management were 4.80 kt in Estonia in 2021, the emissions increased by 124% by 2021 in comparison with the base year (Table 5.22). 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 5.22. CH_4 emissions from cattle manure management in 1990–2021 in Estonia, kt

Year	Dairy cattle	Other mature cattle	Growing cattle	Total emissions
1990	1.43	0.18	0.54	2.14
1995	0.89	0.07	0.21	1.18
2000	0.72	0.05	0.13	0.90
2005	1.31	0.06	0.34	1.71
2010	2.15	0.23	0.48	2.86
2015	2.70	0.39	0.46	3.54
2016	2.71	0.50	0.55	3.76
2017	2.82	0.61	0.66	4.09
2018	2.86	0.74	0.77	4.37
2019	2.98	0.86	0.88	4.72
2020	2.89	0.91	0.98	4.78
2021	2.88	0.92	1.00	4.80

5.3.1.2. Swine manure management

5.3.1.2.1. Methodology, data availability, data sources and emission factors

Methane production from the manure management of swine by subcategories was estimated based on the algorithm described in Chapter 5.2.3.1.

Methane conversion factors and the use of different systems of manure management for swine manure storage are presented in Table 5.23.

The dataset used to develop the country-specific module on MMS in Estonia is described in Annex A.2.2_IV and the results are presented in Table 5.24. MCF related to each type of MMS and CH_4 EFs are reported in the same table.

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.

Emission estimations submitted by Estonia concerning anaerobic digestion of manure are currently not estimated. However, with an ongoing project (2020-2023) Estonia is developing a methodology to estimate GHG emissions from the production of biomethane from agricultural (and waste) sources and developing country-specific emission factors for biomethane production. Emissions from biogas use will be reported under Energy sector.

Implied CH_4 emission factors for swine MMS have slightly changed in the period of 1990–2021 due to changes in the structure of the swine population. 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. The IEFs started growing since 2014 and 2015 due to the outbreak of African swine fever in the region in 2015 that enhanced biosecurity requirements for pigsties, both of which changed the structure of swine weight-groups again – the numbers of swine in the youngest groups fell. The values of IEFs are reported in Figure 5.15.

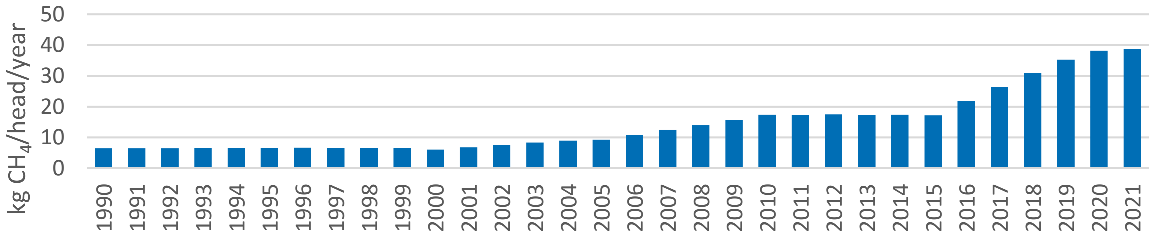


Figure 5.15. Implied CH_4 emission factor for swine MMS in 1990–2021, kg CH_4/head/year

Table 5.23. Parameters used in the estimates

Swine category	Feed digestibility, %[181]	VS, kg/h/d	Bo, m^3 CH_4/kg VS[208]	MCF, %[209]
Piglets, live weight less than 20 kg	83	0.11	0.45	0.6
Young pigs, live weight 20–<50 kg	83	0.24	0.45	0.6
Fattening pigs				
live weight 50–<80 kg	80	0.42	0.45	0.6
live weight 80–<110 kg	80	0.53	0.45	0.6
live weight 110 kg or more	80	0.58	0.45	0.6
Breeding pigs, live weight 50 kg or more	80	0.32	0.45	0.6

[208] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.80-10.81, tables 10A-7 and 10A-8.
[209] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.35, table A-4.

Table 5.24. MMS usage, methane conversion factor and Manure management emission factors for swine in 2021 in Estonia

			Estonian average[202]	**MCFs**[210]**, %**
MMS, %		Liquid/ slurry	96.12	17
		Solid storage	0.54	2
		Deep litter	3.31	17
Emission factor, kg CH4/head/year	Piglets, live weight less than 20 kg		2	-
	Young pigs, live weight 20–<50 kg		4.41	-
	Fattening pigs…	...live weight 50–<80 kg	7.84	-
		...live weight 80–<110 kg	9.95	-
		…live weight 110 kg or more	10.92	-
	Breeding pigs, live weight 50 kg or more		10.31	-

5.3.1.2.2. Quantitative overview – CH_4 emissions from swine manure management in 2021

The total CH_4 emissions from swine manure management were 1.82 kt in Estonia in 2021 (Figure 5.16). The emissions decreased by 55.9% in 2021 compared with the base year due to the decrease in the number of the swine population.

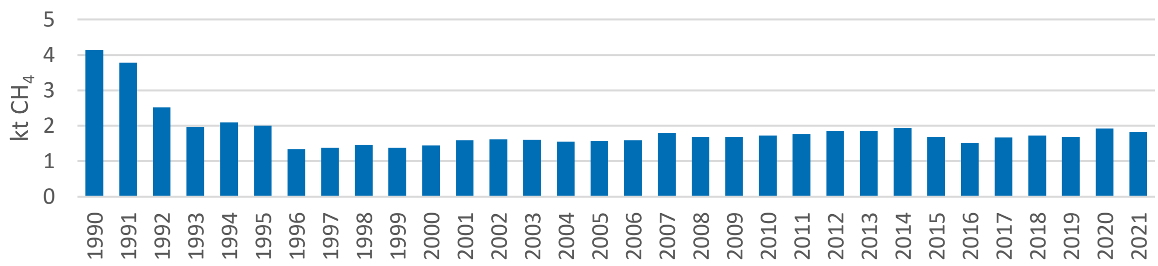


Figure 5.16. CH_4 emissions from swine MMSs in 1990–2021 in Estonia, kt

5.3.1.3. Other livestock manure management

5.3.1.3.1. Methodology, data availability, data sources and emission factors

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.

The module on MMS for sheep, goats and horse livestock categories was developed based on the animals' grazing period (Annex A.2.2_IV). Animal wastes generated by livestock categories are stored in 'solid MMS' (Table 5.25).

[210] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.45, table 10.17.

Table 5.25. MMS usage and methane emission factors from Manure management of other livestock categories[211]

Livestock category	MMS, %		Emission factor[212], kg CH_4/head/year
	Solid storage	Pasture/range/yards	
Sheep	50.68	49.32	0.19
Goats	50.68	49.32	0.13
Horses	58.9	41.1	1.56
Poultry	99.41	0.59	
Broilers			0.02
Layers and other chickens			0.03
Other Poultry			0.055
Fur animals	100	-	
Foxes and raccoons			0.68
Minks			0.68
Rabbits	100	-	0.08

5.3.1.3.2. Quantitative overview – CH_4 emissions from manure management of other livestock categories in 2021

The total CH_4 emission from the MMS of other livestock categories was 0.09 kt in Estonia in 2021 (Figure 5.17). The emission declined by 74.9% in 2021 compared with the base year due to the decrease in the number of other livestock population. The emissions in 2021 have increased compared to the previous year. Although there was a decline in most animal categories population, the small increase in emissions from other livestock was mainly caused by a small increase in poultry population.

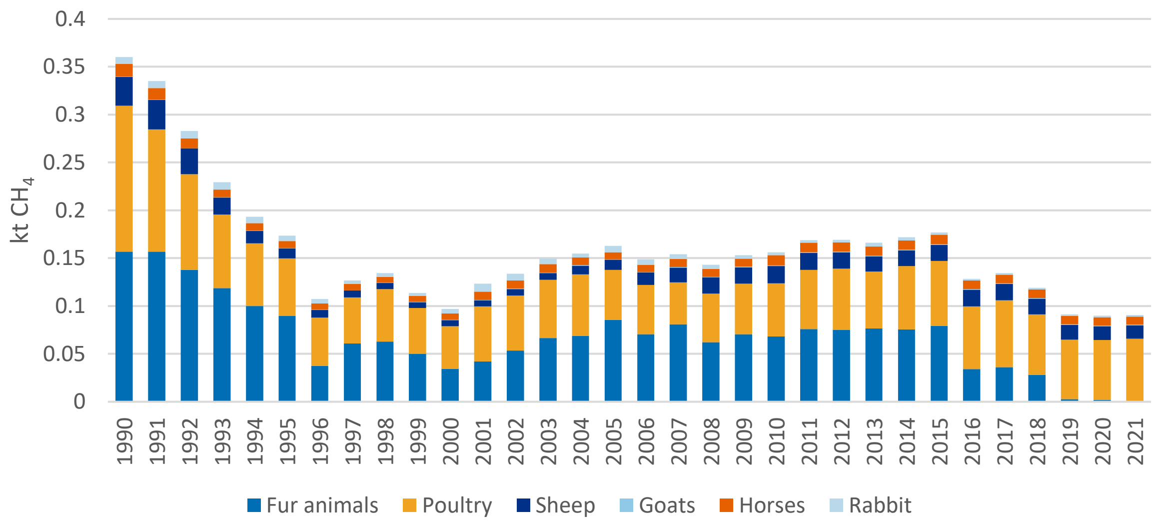


Figure 5.17. CH_4 emissions from other livestock MMSs in 1990–2021 in Estonia, kt

[211] 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.
[212] 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).

5.3.1.4. Category-specific recalculations

CH_4 emissions from manure management were recalculated due to the following corrections/updates in 3.A category: adding pregnancy rate, milk yield etc. for mature female cattle, updating the number of horses, rounding activity data and correcting the average winter temperature for 2020 (see Chapter 5.2.7). These corrections and updates also influenced emissions from manure management category.

A comparison of the changed values of CH_4 emissions due to the recalculations between 2023 and 2022 submissions is shown in Table 5.26.

Table 5.26. Reported CH_4 emissions in the 2022 and 2023 submissions from manure management, kt

Manure management	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
2022 submission	6.58	3.33	2.43	3.43	4.67	5.28	6.52
2023 submission	6.64	3.35	2.45	3.45	4.74	5.41	6.80

5.3.1.5. Category-specific planned improvements

Developing a methodology suitable for Estonian conditions to estimate reduced CH_4 emissions from anaerobically digested slurry.

5.3.2. Direct N_2O emissions from Manure management

5.3.2.1. Category description

Production of N_2O during the storage and treatment of animal wastes can occur via combined nitrification-denitrification of nitrogen contained in the wastes[213].

5.3.2.2. Cattle manure management

5.3.2.2.1. Methodology, data availability, data sources and emission factors

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 5.21[214]

$$N_2O_{D(mm)} = \sum_{(S)} \{[\sum_{(T)} N_{(T)} \times Nex_{(T)} \times MS_{(T,S)}] \times EF_{3(S)}\} \times \frac{44}{28}$$

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;

[213] 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.
[214] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.54, equation 10.25.

$EF_{3(S)}$ =	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.

The data on the livestock population by categories were obtained from the database of SE (Annex A.2.2_I). Nitrogen excretion factors for all categories of cattle were calculated based on the nitrogen balance described in Equation 5.22[215]:

Equation 5.22

$$N_{excreta_j} = N_{feed_j} - (N_{milk} + N_{weight\_gain} + N_{embryo})_j$$

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;
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 Chapter 5.2.2.1 as well as the average rates of nitrogen content in animal feed (Annex A.2.2_V.1). N_{milk}, N_{gain} and N_{embryo} were estimated as follows[216]:

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.2.2_V. Values of the average milk protein content in Estonia in 1990–2021 were obtained from EARC.

The trend in (implied) nitrogen excretion rates reported in the CRF are presented in Table 5.27.

Table 5.27. Weight, milk yield per cow and protein content of milk in 1990–2021 (Annexes A.2.2_III.1, A.2.2_II.1–2, A.2.2_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
1995	559.2	3 588	3.17	67.62
2000	574.1	4 660	3.28	78.10
2005	588.7	5 886	3.34	93.22
2010	604.0	7 021	3.36	117.43
2015	619.5	8 442	3.38	133.70
2016	622.5	8 878	3.36	137.53
2017	625.5	9 159	3.38	138.63
2018	629.3	9 287	3.39	139.22
2019	632.6	9 633	3.41	141.27

[215] 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.
[216] DIAS. Standard Values for Farm Manure. [www] https://dcapub.au.dk/djfpublikation/djfpdf/djfhd7.pdf (15.12.2021).

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
2020	635.9	9 943	3.39	140.05
2021	636.3	9 966	3.40	140.22
IPCC default				
EE[217]	550	2 555[217]	-	96.4[218]
WE	600	5 986	-	105.1

The calculation of nitrogen excretion rates for non-dairy cattle categories was performed based on the algorithm presented in the Equation 5.22. The N excretion rates are reported in Table 5.28.

Table 5.28. Nitrogen excretion rates of non-dairy cattle in 2021, kg N/head/year

Livestock category of non-dairy cattle	Nitrogen excretion rate, kg N/head/yr
Mature males (2 years and over)	75.4
Mature females (2 years and over)	75.5
Bovine animals (aged between 1 and 2 years)	56.5
Calves (6–12 months)[219]	16.0
Calves (0–6 months)	2.9

5.3.2.2.2. Quantitative overview – Nitrogen excretion by cattle livestock in 2021

The total quantity of nitrogen generated by cattle was 18 811 tonnes in Estonia in 2021. The allocation of nitrogen excreted among different types of MMSs is presented in Table 5.29.

Table 5.29. The allocation of the quantity of nitrogen (in manure) excreted by cattle, kg

Year	Liquid system	Solid storage	Deep litter	Pasture range and paddock	Total nitrogen
1990	NO	25 894 721	NO	7 302 122	33 196 843
1995	NO	13 497 328	NO	3 906 828	17 404 156
2000	NO	10 935 975	NO	2 844 666	13 780 641
2005	2 219 634	9 235 469	391 544	3 108 840	14 955 487
2010	6 420 320	7 252 556	697 713	1 368 329	15 738 918
2015	2 219 634	3 845 564	611 991	2 362 003	18 506 551
2016	11 656 631	3 228 983	1 214 490	2 136 017	18 236 121
2017	11 977 793	2 671 287	1 826 523	1 928 743	18 404 346
2018	12 123 775	2 101 379	2 480 972	1 743 457	18 449 583
2019	12 475 623	1 528 142	3 131 674	1 535 694	18 671 133
2020	12 531 271	911 645	3 929 062	1 360 721	18 732 699
2021	12 499 774	908 965	4 014 383	1 387 842	18 810 964

[217] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.72, table 10A.1.
[218] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.59, table 10.19.
[219] 2-round production cycle was applied for calves (0–6 months and 6–12 months).

5.3.2.3. Swine manure management

5.3.2.3.1. Methodology, data availability, data sources and emission factors

Activity data on the swine population were obtained from national statistics. A method used in the emission estimation was employed from the IPCC Guidelines (Chapter 6.3.3.1). Nitrogen excretion rates were taken from the Regulation of the Minister of the Environment no 66, 14/12/2016[220] (Table 5.30). Applied emission factors are indicated in Table 5.34.

Nitrogen (implied) excretion rates reported in the CRF are demonstrated in Figure 5.18. The rate has slightly changed over the entire time series due to changes in the structure of the swine population.

Table 5.30. 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[221]	–	–
Market (average 50 kg)	–	10
Breeding (average 180 kg)	–	30

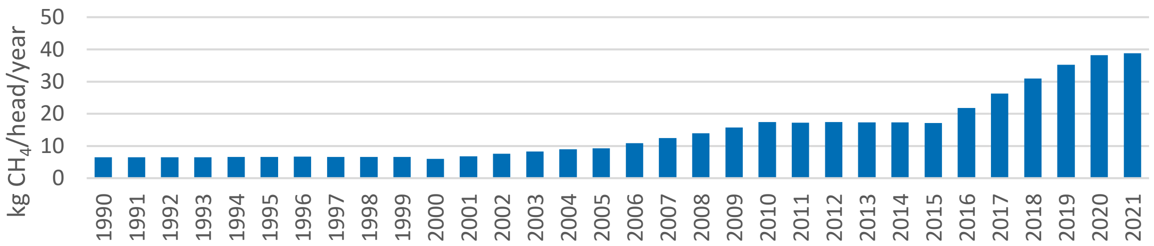


Figure 5.18. Implied swine nitrogen excretion rates reported in the CRF for 1990–2021, kg N/head/year

5.3.2.3.2. Quantitative overview – Nitrogen excretion by swine in 2021

The total quantity of nitrogen generated by pigs was 2 891 tonnes in Estonia in 2021. The allocation of nitrogen excreted among different types of MMSs is presented in Table 5.31. As the formation of a natural crust cover for uncovered pig slurry is highly unlikely, Estonia has

[220] 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# (24.01.2022).
[221] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.59, table 10.19.

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 5.31. The allocation of the amount of nitrogen (contained in manure) excreted by pigs and stored in different types of MMSs, kg N/year

Year	Liquid system	Solid storage	Deep litter	Total nitrogen
1990	6 622 353	1 009 930	0	7 632 283
1995	3 158 136	805 025	0	3 963 161
2000	2 410 945	709 334	0	3 120 278
2005	2 610 231	718 517	0	3 328 747
2010	2 825 555	730 023	0	3 555 577
2015	2 700 922	72 089	80 538	2 853 549
2016	2 424 792	59 374	73 355	2 557 520
2017	2 593 540	62 123	88 876	2 744 539
2018	2 563 209	55 678	96 598	2 715 486
2019	2 645 701	47 059	87 394	2 780 153
2020	2 860 157	43 279	110 680	3 014 116
2021	2 749 149	40 918	101 330	2 891 397

5.3.2.4. Other livestock

5.3.2.4.1. Methodology, data availability, data sources and emission factors

Activity data on other livestock population were obtained from national statistics, the module on MMS was used from Table 5.25 and nitrogen excretion rates (Table 5.32) were obtained from the IPCC 2006 Guidelines.

Table 5.32. Nitrogen excretion rates per head of animal, kg N/head/year

Livestock category[222]	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

5.3.2.4.2. Quantitative overview – Nitrogen excretion by other livestock in 2021

The total amount of nitrogen generated by other livestock was 2 871 tonnes in 2021. The breakdown of the quantity of nitrogen excreted by other livestock categories is reported in Table 5.33.

[222] 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).

Table 5.33. 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
1995	846 850	36 965	277 035	970 375	1 305 058	607 532	4 043 815
2000	509 508	69 575	252 945	702 657	558 823	486 510	2 580 018
2005	848 211	58 493	289 080	843 713	869 845	676 293	3 585 635
2010	1 464 883	93 347	409 530	935 590	554 574	283 492	3 741 416
2015	1 348 449	95 888	379 418	1 127 481	644 563	247 609	3 843 408
2016	1 396 424	101 756	343 283	1 096 778	277 808	170 983	3 387 032
2017	1 372 803	105 849	343 283	1 159 269	294 876	170 983	3 447 063
2018	1 312 544	114 053	343 283	1 074 672	229 147	170 983	3 244 682
2019	1 237 842	100 373	332 743	1 066 593	21 209	170 983	2 929 743
2020	1 152 310	93 010	335 393	1 097 927	16 685	161 587	2 856 912
2021	1 142 473	91 478	324 191	1 128 902	2004	181 536	2 870 584

5.3.3. 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.

5.3.3.1. N losses due to volatilization from manure management

The *Tier 2* method (Equation 5.23–Equation 5.25) of the IPCC 2006 Guidelines[223] was applied to estimate indirect N_2O emissions from manure management due to volatilization:

Equation 5.23

$$N_2O_{G(mm)} = (N_{volatilization-MMS} \times EF_4) \times 44/28$$

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)$^{-1}$;

$$N_{volatilization-MMS} = \mathrm{NO_X - N + NH_3 - N};$$

Where:

$N_{volatilization-MMS}$ = 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

[223] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.54–10.56.

Informative Inventory Report. The emission estimates have been calculated with the methodology provided by the EMEP/EEA guidebook 2019.

5.3.3.2. N losses due to leaching from manure management systems

The *Tier 2* methodology for the estimation of N losses due to leaching from MMSs is applied and the respective IPCC 2006[224] equations are used:

Equation 5.24

$$N_2O_{L(mm)} = (N_{leaching-MMS} \times EF_5) \times \frac{44}{28}$$

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 5.25

$$N_{leaching-MMS} = \sum_S \left[\sum_T \left[(N_T \times Nex_T \times MS_{T,S}) \times \left(\frac{Frac_{leachMS}}{100}\right)_{T,S}\right]\right]$$

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%).

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.

The leak-tightness of manure storage facilities was studied in a 2010 survey[225] 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 leakage was determined by visual inspection and on the ground 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

---

[224] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.56–10.57.

[225] Keskkonnaministeerium. Algab sõnnikukäitluse inventuur. [www] https://envir.ee/uudised/algab-sonnikukaitluse-inventuur (16.02.2021).

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.

The value of $Frac_{leachMS}$ = 5% is taken from the *Best Available Technique manual for intensive cattle farming*[226] for Estonian farmers.

5.3.4. Quantitative overview – N_2O emissions from Manure management systems in Estonia in 2021

The total quantity of nitrogen generated by livestock and stored in solid, liquid and deep litter types of MMSs was 22 443 tonnes in 2021 (Table 5.35). 0.170 kt of direct and 0.066 kt of indirect N_2O emissions (Table 5.35 and Table 5.36) occurred from the stored manure. The breakdown of the emission factors used to estimate N_2O emissions released from different types of MMSs is reported in Table 5.34. 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 5.34. Applied emission factors of manure management practice

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

Table 5.35. Total nitrogen (in manure) excreted by livestock and direct N_2O emissions from MMSs in Estonia during 1990–2021

Year	Nitrogen excreted, kg[227]				N_2O emissions, kt			
	Liquid/ Slurry	Solid storage	Deep Litter	Total	Liquid/ Slurry	Solid storage	Deep Litter	Total [228]
1990	6 622 353	33 333 672	NO	39 956 025	NO	0.211	NO	0.211
1995	3 158 136	17 796 409	NO	20 954 545	NO	0.112	NO	0.112
2000	2 410 944	13 835 763	NO	16 246 707	NO	0.092	NO	0.091
2005	4 829 865	12 973 623	391 544	18 195 032	0.017	0.078	0.006	0.102
2010	9 245 875	10 787 159	697 713	20 730 747	0.051	0.063	0.011	0.124
2015	14 387 915	6 892 773	692 529	21 973 217	0.092	0.031	0.011	0.133
2016	14 081 423	5 795 396	1 287 845	21 164 664	0.092	0.026	0.020	0.138
2017	14 571 333	5 310 112	1 915 399	21 796 844	0.094	0.022	0.030	0.146
2018	14 686 985	4 557 052	2 577 570	21 821 607	0.095	0.017	0.041	0.153
2019	15 121 324	3 708 179	3 219 067	22 048 570	0.098	0.012	0.051	0.161
2020	15 391 428	3 059 798	4 039 742	22 490 968	0.099	0.008	0.063	0.169

[226] 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 (16.12.2021).
[227] Deep Litter is reported under Other MMS type in CRF 3.B.2 N_2O emissions per MMS. Deep litter includes manure from growing cattle and mature non-dairy cattle.
[228] N_2O emissions from 'Pasture/range and paddock' were considered under Direct soil emissions.

Year	Nitrogen excreted, kg[227]				N_2O emissions, kt			
	Liquid/ Slurry	Solid storage	Deep Litter	Total	Liquid/ Slurry	Solid storage	Deep Litter	Total [228]
2021	15 248 923	3 078 639	4 115 713	22 443 275	0.098	0.008	0.065	0.170

Table 5.36. Indirect N_2O emissions from Manure management in 1990–2021

Year	N losses due to volatilization from manure management, kt N_2O	N losses due to leaching from MMSs, kt N_2O	Total Indirect N_2O emissions from manure management, kt N_2O
1990	0.101	0.014	0.115
1995	0.052	0.007	0.060
2000	0.041	0.005	0.046
2005	0.052	0.004	0.055
2010	0.065	0.002	0.067
2015	0.067	0.001	0.071
2016	0.067	0.001	0.068
2017	0.066	0.001	0.068
2018	0.066	0.001	0.067
2019	0.066	0.001	0.066
2020	0.066	0.001	0.067
2021	0.066	0.001	0.066

5.3.5. Uncertainties and time series consistency

CH_4 emissions from Manure management were calculated based on activity data and emission factors.

Uncertainties in the estimates of CH_4 emissions from sheep, goats, horses, and poultry manure management are reported in (IPCC, 2006) (Table 5.37).

Emission factors for cattle and swine were calculated using IPCC default parameters (volatile solids, CH_4 producing capacity, methane conversion factors, MMS).

N_2O emissions from livestock manure management were calculated based on activity data (livestock population), nitrogen excretion factors (Nex, kg/head/year) were calculated based on the nitrogen balance of animals and N emission factor related to MMSs. In spite of the use of nitrogen balance, default uncertainty rates for Nex (by categories of livestock) were used from the IPCC Guidelines.

IPCC nitrogen emission factors default uncertainty estimates for all systems of manure management used in Estonia's estimates of N_2O emissions from animal manure are reported in Table 5.37.

Uncertainties associated with indirect N_2O emission factors are presented in Chapter 5.4.2.4. discussing indirect N_2O EF uncertainty of Agricultural soils. Default IPCC 2006 uncertainty ranges for total N losses ($Frac_{LossMS}$)[229] are implemented in the estimates.

[229] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.67, table 10.23 (Range of $Frac_{LossMS}$).

Table 5.37. Estimated values of uncertainties used in the Agriculture sector

Category	Uncertainties	References
Activity data		
Estonia's dairy cattle population	± 0.72%	Statistics Estonia
Estonia's non-dairy cattle population	± 1.11%	Statistics Estonia
Estonia's swine population	± 0.49%	Statistics Estonia
Estonia's sheep population	± 6.53%	Statistics Estonia
Estonia's other livestock population (goats, horses, poultry and fur animals)	± 10%	Rypdal and Winiwarter, 2001
Emission factors		
Manure management (CH_4) (cattle, swine)	± 20%	IPCC, 2006. Agriculture. p. 10.48
Manure management (CH_4) (sheep, goats, horses, fur animals)	± 30%	IPCC, 2006. Agriculture. p. 10.48
Manure management (N_2O)	-50... +100	IPCC, 2006. Agriculture. p. 10.66
Nitrogen excretion factor (Nex)	± 50%	IPCC, 2006. Agriculture. p. 10.66
Anaerobic lagoon	±25... ±50	IPCC, 2006. Agriculture. p. 10.67
Liquid system	±25... ±50	IPCC, 2006. Agriculture. p. 10.67
Solid storage	±25... ±50	IPCC, 2006. Agriculture. p. 10.67
Pasture/range and paddock	±25... ±50	IPCC, 2006. Agriculture. p. 10.67
Other systems (deep litter, poultry manure with bedding, anaerobic digestion)	±25... ±50	IPCC, 2006. Agriculture. p. 10.67

5.3.6. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.2.3.

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.

5.3.7. Category-specific recalculations

Nitrogen retention in calves coefficient for mature females

Values for the nitrogen retention in calves coefficient were added for mature female cattle because they are also suckler cows and spend some time suckling their young. Milk yield, protein content in milk, fat content in milk and pregnancy rate were also added for mature female cattle for calculating the values for nitrogen retention in calves coefficient.

Following equation, developed based on the QA conducted by A. Kaasik in 2020, was used for calculating the nitrogen retention coefficient in calves:

Equation 5.26[194]

$$N\ retention\ in\ calves = m\ X\ N\ content\ X\ pregnancy\ rate$$

Where:

M = weight of the calf at birth, kg;
N content = nitrogen content of calf tissue, kg/h/year;
Pregnancy rate = fraction of cows giving birth in a year, %/year.

Values for nitrogen retention in calves coefficient for mature female cattle are shown in Table 5.38.

Table 5.38. Added values for retention in calves coefficient for mature female cattle in the 2022 submission, kg/h/year

Year	1990	1995	2000	2005	2010	2015	2020
Retention in calves	0.95	0.95	0.95	0.95	0.95	0.95	0.95

NOx and NH_3 values for the whole timeseries

In 2023 submission, values for NOx and NH_3 for the whole time-series were corrected due to the updates made in the Estonian Informative Inventory Report 1990–2020. It influences Indirect N_2O emissions from the Agriculture sector. Therefore, Indirect N_2O emissions were recalculated for 1990-2020.

For further insight regarding the trends and activity data and methodology applied for NH_3 and NO_x emission estimations, see Estonian Informative Inventory Report 1990–2021 submitted under the Convention on Long-Range Transboundary Air Pollution[157].

A comparison of the recalculations in N_2O emissions between 2023 and 2022 submissions is shown in Table 5.39.

Table 5.39. N_2O emissions in 2022 and 2023 submissions from manure management, kt

Manure management	1990	1995	2000	2005	2010	2015	2020
2022 submission	0.370	0.196	0.153	0.177	0.209	0.222	0.39
2023 submission	0.379	0.200	0.156	0.181	0.214	0.229	0.254

5.3.8. Category-specific planned improvements

Estonia is making efforts to increase cooperation between the two different institutions compiling the separate inventories of the GHG inventory and Informative inventory (Air Pollutant Emission Inventory) and to harmonize emission estimates.

5.4. Agricultural soils (CRF 3.D)

5.4.1. Direct N_2O emissions from managed soils (CRF 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[230].

[230] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.53.

The following agricultural activities influence N flows in agricultural soils:

- synthetic fertilizers;
- animal excreta nitrogen used as fertilizer;
- sewage sludge application on agricultural soils;
- compost application on agricultural soils;
- 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.

5.4.1.1. Category description

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 28 years ago. Accordingly, direct N_2O emissions from managed soils decreased by 33% in 2021 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 5.19). In 2021, the main contributor to the direct N_2O emissions from agricultural soils was the use of synthetic fertilizers (35%), followed by emissions originating from the cultivation of organic soils (25%), crop residues left on the fields (23%), animal manure applied to soils (13%), animals grazing (3%), and the use of other organic fertilizers (1%). In 2021, mineralization associated with the loss/gain of soil organic matter did not occur (Figure 5.20). The total direct N_2O emissions from Agricultural soils were 2.6 kt in Estonia in 2021 (Figure 5.19).

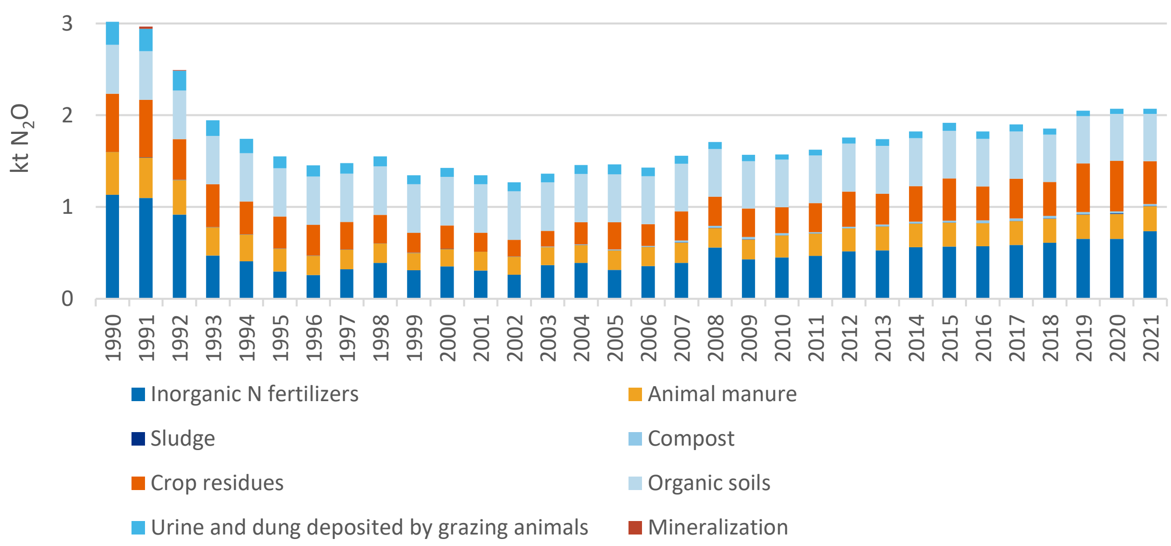


Figure 5.19. Direct N_2O emissions from Agricultural soils in Estonia in 1990–2021, kt

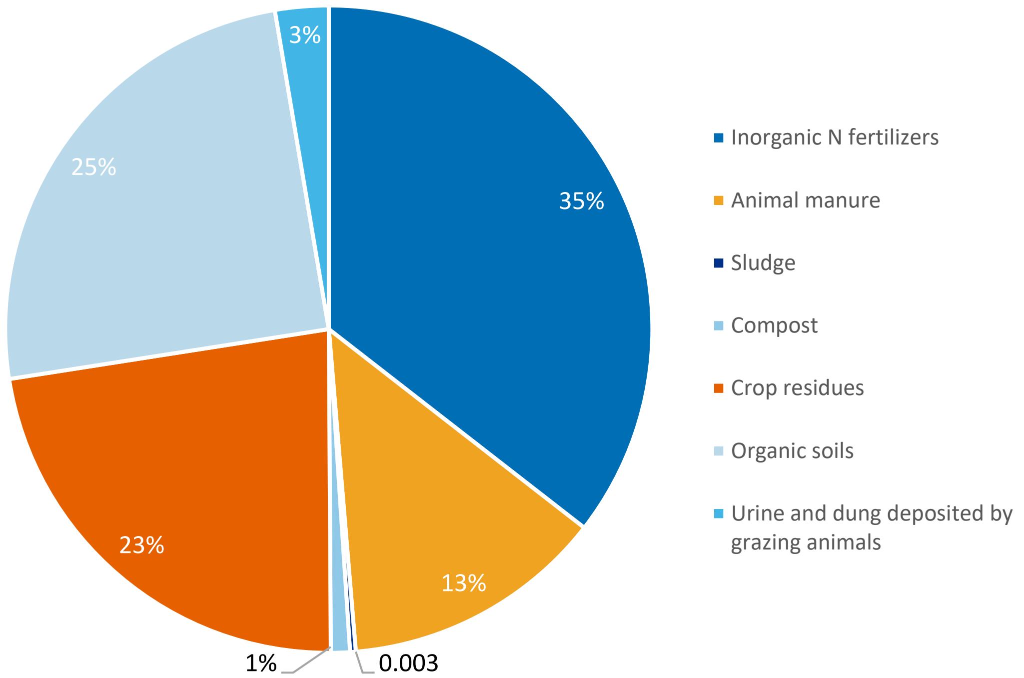


Figure 5.20. Direct N_2O emissions from Agricultural soils in Estonia in 2021, %

5.4.1.2. Activity data employed

Activity data on the amounts of synthetic fertilizers and crop production in Estonia were obtained from the datasets of SE. The data on the amounts of sludge used on agricultural lands, compost applied on agricultural fields and the area of cropland on mineral soils converted to cropland were received from the EstEA. The data on areas of histosols under cultivation in Estonia were obtained in the framework of the National Forest Inventory (see Chapter 6 LULUCF).

Table 5.40. 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

Category	Emission factor			Source
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, and dung and urine deposited by grazing animals	$Frac_{GASM}$	0.2	(kg NH_3–N + NO_x–N) (kg N applied or deposited) $^{-1}$	IPCC (2006), Table 11.3
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

5.4.1.3. N_2O emissions from Inorganic nitrogen fertilizers applied to soils (CRF 3.D.1.1)

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 5.40);

N_2O emissions into the atmosphere from the use of synthetic nitrogen were calculated based on the Equation 5.27:

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.

5.4.1.3.1. Quantitative overview – N_2O emissions from synthetic fertilizers applied to soils in 2021

The total N_2O emissions from synthetic fertilizers applied onto agricultural soils were 0.73 kt in Estonia in 2021 (Figure 5.21). The emissions declined by 35% in 2021 compared with the base year due to the decrease in the amounts of synthetic fertilizers applied to agricultural fields (Figure 5.21, Annex A.2.2_VI). Compared to 2020, emissions from mineral fertilizers increased by 11.29% in 2021. This is part of a trend in the mineral fertilizer usage growth that started in 2009. This is due to the increase of agricultural crop production area and is also 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 fertilizers and have a larger area for crop production, is rising. Therefore, the emissions from mineral fertilizers have been increasing with a few fluctuations since 2009. 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 Agricultural Research Centre in the framework of the Farm Accountancy Data Network (FADN). FADN data were also reported to the European Commission by SE.

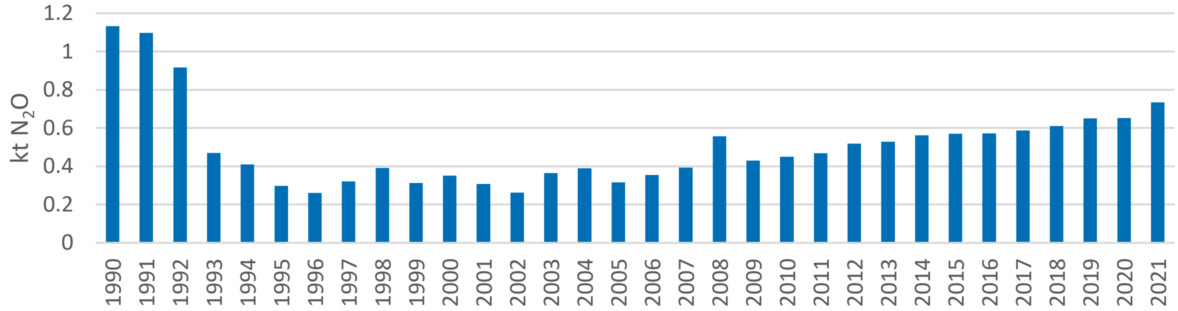


Figure 5.21. Emissions from synthetic fertilizers applied to agricultural soils in 1990–2021 in Estonia, kt N_2O

5.4.1.4. N_2O emissions from Animal manure applied to soils (CRF 3.D.1.2.a)

N_2O emits from agricultural soil through manure application to fields as organic fertilizer.

5.4.1.4.1. Methodology, data availability, data sources and emission factors

N_2O emission 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 5.28–Equation 5.30):

Equation 5.28

$$N_2O_{direct} - N = F_{AM} \times EF_l$$

Equation 5.29[231]

$$F_{AM} = N_{MMS\ Avb} \times [1 - (Frac_{FEED} + Frac_{FUEL} + Frac_{CNST})]$$

Where:

EF_1 = emission factor;
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.

[231] 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.

Equation 5.30[232]

$$N_{MMS\ Avb} = \sum_{S}\left\{\sum_{(T)}\left[\left[\langle N_{(T)} \times Nex_{(T)} \times MS_{(T,S)}\rangle \times \langle 1 - \frac{Frac_{LossMS}}{100}\rangle\right] + \left[N_{(T)} \times MS_{(T,S)} \times N_{beddingMS}\right]\right]\right\}$$

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.

Nitrogen excreted per head of different categories of animals and per waste management systems was estimated in N_2O emissions from the manure management chapter. IPCC default factors were used to estimate nitrogen input to Agricultural soils (Table 5.41).

Table 5.41. 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

5.4.1.4.2. Quantitative overview – N_2O emissions from Animal manure applied to soils in 2021

Direct N_2O emissions from animal manure applied on agricultural soils were 0.272 kt in Estonia in 2021 (Figure 5.19). The emission decreased by 42% in 2021 compared to the base year, due to the decline in the number of the livestock population.

5.4.1.5. N_2O emissions from Sewage sludge applied to soils (CRF 3.D.1.2.b)

Sludge from domestic wastewater treatment plants is used on agricultural land. Table 5.42 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 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

[232] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.65, equation 10.34.

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 (Table 5.42). According to 2022 ERT observation, we are looking into sewage sludge historical data and working on finding evidence to support that assumption made by TalTech.

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. The reported sewage sludge data for 2004-2019 is also available online in JATS - (https://jats.keskkonnainfo.ee/main.php?page=statquery2public - in Estonian). 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 Environment and published in EstEA's Tableau.[373]

EstEA is doing data processing and validating the accuracy. Estonian Environmental Research Centre expert is validating data by asking companies and EstEA to clarify the amount of R10 sewage if there are significant fluctuations occurring. The time series is fluctuating, but this is in line with the official sewage sludge data as sewage sludge is also composted (and reported under 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 Waste, Table 7.13. Please note that "sludge" in Table 7.13 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. That can be seen by an increasing trend of sewage sludge applied to soils starting from the year 1994. 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.[233]

Since 2017, especially large amounts of R10 were reported by two companies due to the construction works of an industrial park and larger landscaping activities.

Table 5.42. Amounts of municipal sludge application on agricultural land, tonnes[234]

Year	R10
1990	7 434
1995	27 073
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

[233] 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.
[234] R10 of the European Waste Catalogue (2002) – Land treatment resulting in benefit to agriculture or improvement.

Year	R10
2017	33 437
2018	33 733
2019	54 971
2020	72 795
2021	76 140

5.4.1.5.1. Methodology, data availability and sources, emission factors

The IPCC 2006 *Tier 1* (Equation 5.31) approach was employed in order to estimate N_2O emissions from sludge applied on agricultural land:

Equation 5.31

$$N_2O_{direct} = F_{SL} \times EF_1 \times \frac{44}{28}$$

Where:

F_{SL}= annual amount of sewage sludge N applied to soils, kg N yr^{-1};
EF_1= emission factor.

The factors used in the estimates are presented in Table 5.40 and Table 5.43.

Table 5.43. Parameters and factors used in the estimates

Factor	Value	Unit
N content of sewage sludge[235]	4.9	% dry matter

5.4.1.5.2. Quantitative overview – N_2O emissions from sludge applied on agricultural land in 2021

The total N_2O emissions from sewage sludge applied on agricultural land were 0.006 kt in Estonia in 2021 (Figure 5.22).

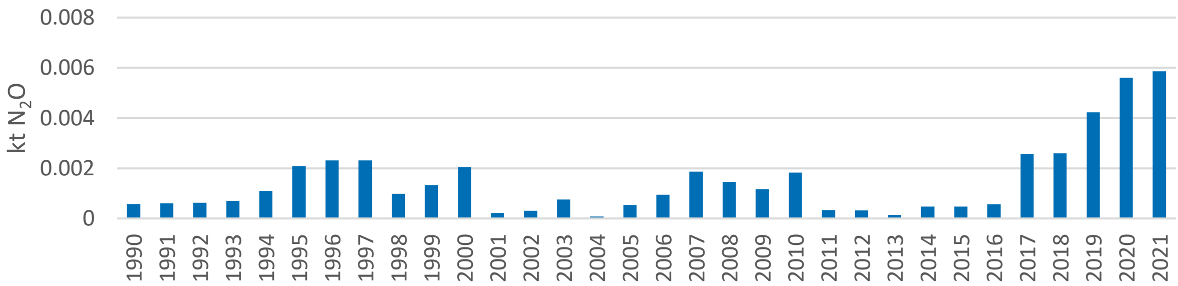


Figure 5.22. N_2O emissions from sewage sludge applied on agricultural land in Estonia in 1990–2021, kt

[235] Milieu Ltd, WRc and RPA. Environmental, economic and social impacts of the use of sewage sludge on land. [www] https://ec.europa.eu/environment/archives/waste/sludge/pdf/part_i_report.pdf (24.01.2022).

5.4.1.6. N_2O emissions from Compost applied to soils (CRF 3.D.1.2.c)

Waste handling companies are obligated to report the amount of waste biologically treated to EstEA which checks the accuracy of 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 the Environment and published in EstEA's Tableau[373]. Tableau provides information about the entire waste stream, including quantities of composted (recovery code R3o and R12o). (See Waste sector, Chapter 7).

5.4.1.6.1. Methodology, data availability and sources, emission factors

Since 2021 submission, the emission calculations from compost are based on dry weight of compost instead of formerly used wet weight. The IPCC 2006 *Tier 1* (Equation 5.32) approach was employed to estimate N_2O emissions from organic fertilizers applied to agricultural land:

Equation 5.32

$$N_2O_{direct} = F_{ON} \times EF_1 \times \frac{44}{28}$$

Where:

F_{ON} = annual amount of organic fertilizer N applied to soils, kg N yr^{-1};
EF_1 = emission factor.

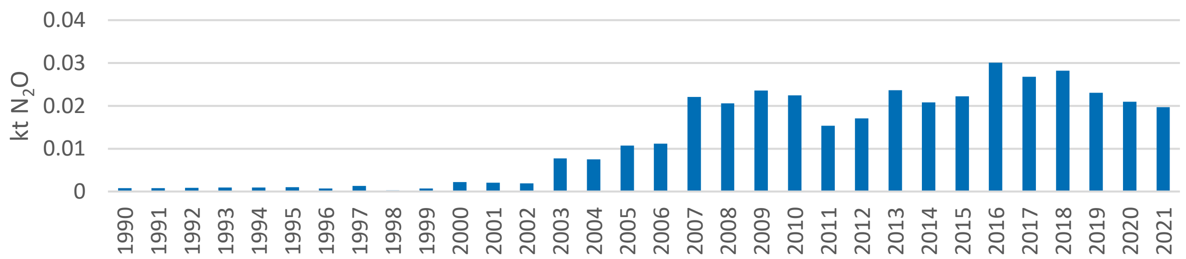
The factors used in the estimates are presented in Table 5.40 and Table 5.44.

Table 5.44. Parameters used in the estimates

Factor	Value	Unit
N content of compost[236]	1.83	% dry matter

5.4.1.6.2. Quantitative overview – N_2O emissions from compost applied on agricultural land in 2021

The total N_2O emissions from compost applied on agricultural land were 0.020 kt in Estonia in 2021 (Figure 5.23). Additional information on the fluctuations of composted waste can be found in Chapter 7.3 Biological treatment of solid waste.



[236] Linnasmägi, M.-L. (2012). Ülevaade Eestis toodetud jäätmekompostidest. Bachelor thesis, page 53.

Figure 5.23. N_2O emissions from compost applied on agricultural land in Estonia in 1990–2021, kt

5.4.1.7. N_2O emissions from Urine and dung deposited by grazing animals (CRF 3.D.1.3)

5.4.1.7.1. Methodology, data availability, data sources and emission factors

The method reported in Chapter 5.3.2 was used to estimate N_2O emissions from animal pasture, range, and paddock.

5.4.1.7.2. Quantitative overview – N_2O emissions from pasture, range and paddock in 2021

The total N_2O emissions from pasture, range and paddock made up 0.055 kt in 2021. The emission decreased by 78% compared to the base year due to the decline in number of the livestock population and due to the decline in animal grazing. (Figure 5.24).

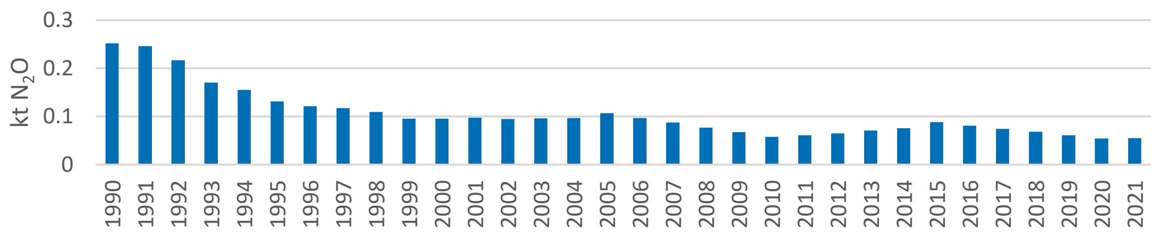


Figure 5.24. N_2O emissions from urine and dung deposited by grazing animals in 1990–2021, kt

5.4.1.8. N_2O emissions from nitrogen input from Crop residues (CRF 3.D.1.4)

Amount of nitrogen returned to soils annually through the incorporation of crop residues.

5.4.1.8.1. Methodology, data availability, data sources and emission factors

The IPCC *Tier 1* (Equation 5.33) method was used to estimate emissions from crop residues returned to the soil.

Equation 5.33[237]

$$F_{CR} = \sum_T \{ Crop_T \times Frac_{Renew(T)} \times [(Area_{(T)} - Area\ burnt_{(T)} \times C_f) \times R_{AG(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)}) + Area_{(T)} \times R_{BG(T)} \times N_{BG(T)}]\}$$

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

[237] 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.

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[238].

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};
$Crop_{(T)}$ = 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.)$^{-1}$, = $AG_{DM(T)} \times 1000$ / $Crop_{(T)}$;
$N_{AG(T)}$ = 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 $R_{BG\text{-}BIO}$ 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 5.34.

Equation 5.34[239]

$$N_2O_{direct} = F_{CR} \times EF_1 \times \frac{44}{28}$$

The selected crop residue statistics and factors used in the algorithm to estimate emissions from crop residues are presented in Table 5.45.

Table 5.45. Factors used in the algorithm to estimate N_2O emissions from crop residues, kg N/kg crop-N [240]

Factor	Value
$Frac_{REMOVE}$	0 [241]
$Frac_{RENEW\ annual}$	1
$Frac_{RENEW\ herbacous}$	8
$Frac_{RENEW\ legumes}$	4

[238] 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.
[239] 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.
[240] Expert opinion of the Estonian Agricultural Research Centre.
[241] $Frac_{REMOVE}$ at a value of 0 was applied because of a recommendation of the TERT (conducted in 2012).

5.4.1.8.2. Quantitative overview – N_2O emissions from Crop residues in 2021

Crop production declined for most crop types in 2021 compared to last year, due to a rather arid summer and low quantities of precipitation.[242] According to Statistics Estonia[243], the total production of cereals was 1 285 749 tonnes, which is 21% lower than a year before. The total production of potatoes was 71 170 tonnes, which is 25% lower than last year. Cereal production record was set last year, in 2020, being the highest in 27 years. The total production of cereals in 2021 included 736 268 tonnes of wheat, 396 369 tonnes of barley and 42 961 tonnes of rye. Cereal yield per hectare was 3.5 tonnes. Regardless of the decline is production and yield for most crops, the sown area of cereals was only 0.8% less than a year before, being 367 117 hectares. Winter crops accounted for almost a half of the sown area of cereals and more than a half of production. 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 also declined, being 79 189 tonnes, which is 34% less than last year. On the other hand, production of winter rape and turnip rape seeds was record high, i.e. 200 450 tonnes, which is 13.5% more than a year before. The sown area of dry pulses was 48 972 hectares, which is only 1.1% lower than last year. However, the sown area of winter rape and winter turnip rape increased to 66 934 hectares, which is also a record high outcome. The yield per hectare of dry pulses was 1.6 tonnes which is 33.5% less than a year before; the yield of winter rape seeds and turnip rape seeds also decreased to 2.9 tonnes per hectare, which is 2.8% lower than a year before. The production of potatoes and open-field vegetables also declined because of the dry and hot summer. The sown area of potatoes and open-field vegetables were 3 370 and 1 818 hectares, respectively, which is the record lowest. The average yield per hectare for potatoes hit a record in 2020, being 26.0 tonnes per hectare. In 2021, the average yield per hectare was 21.1 tonnes per hectare, which is 18.6% lower than last year. The yield per hectare of open-field vegetables was of 24.2 tonnes, which is 3.8% higher than a year before.[243]

The production of different crops throughout the time-series is illustrated in Figure 5.25 and Figure 5.26 and in the tables of Annexes A.2.2_VII. The inter-annual changes in crop production are explained by changes in the total sown area (Annex A.2.2_VII.2) and by weather conditions (Annex A.2.2_X).

[242] The Estonian Chamber of Agriculture and Commerce. Suvekuumus kahandas põllukultuuride saagikust. [www] https://epkk.ee/suvekuumus-kahandas-enamiku-pollumajanduskultuuride-saagikust/ (22.11.2022).
[243] Statistics Estonia. Agricultural land and crops by county. [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__taimekasvatussaaduste-tootmine/PM0281 (02.02.2023).

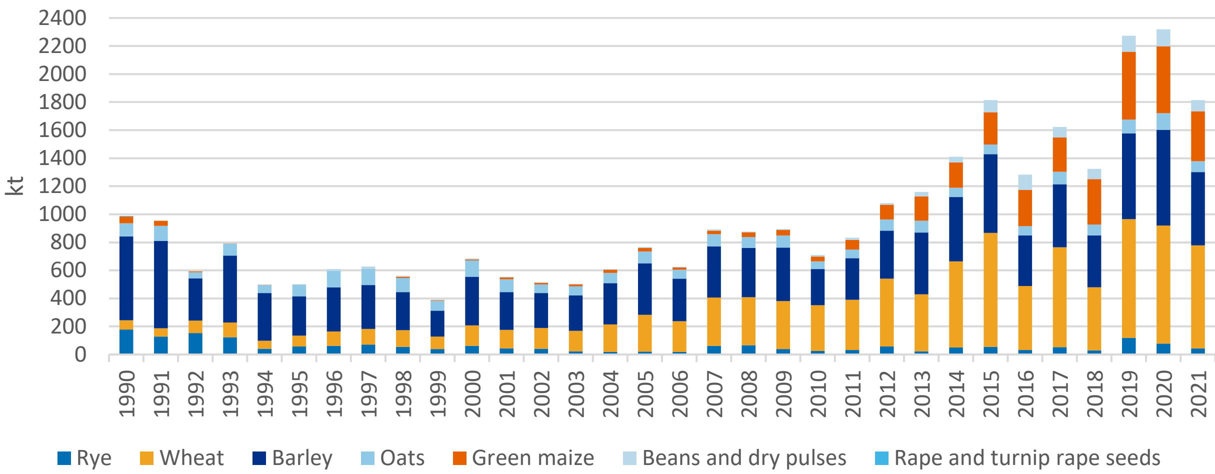


Figure 5.25. Cereals, maize, dry pulses and rape seed production in 1990–2021 in Estonia, kt

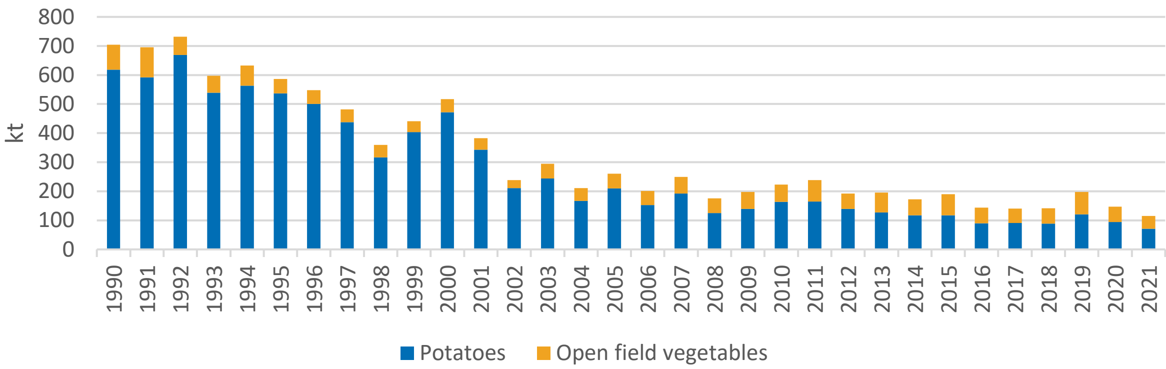


Figure 5.26. Potato and open-field vegetables production in 1990–2021, kt

The total N_2O emissions from crop residues left on agricultural land was 0.468 kt in 2021 (Figure 5.27). The respective emissions have declined by 26% compared with the base year of 1990. 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.

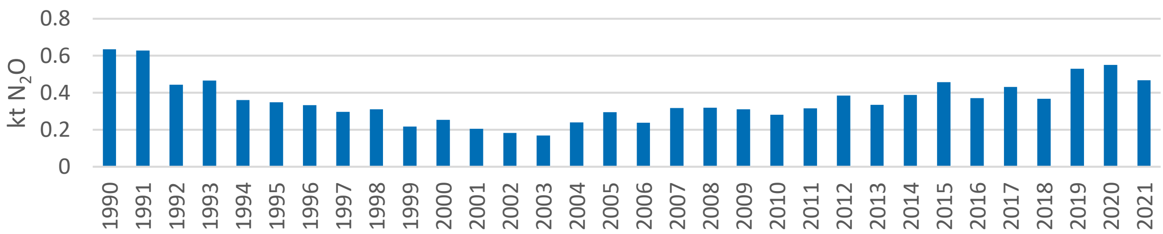


Figure 5.27. N_2O emissions from crop residues left on agricultural fields in 1990–2021 in Estonia, kt

5.4.1.9. N_2O emissions from Mineralization/immobilization associated with the loss/gain of soil organic matter (CRF 3.D.1.5)

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.

5.4.1.9.1. Methodology, data availability, data sources and emission factors

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 to 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 5.35. 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.

Equation 5.35[244]

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,\ LU} \times \frac{1}{R} \right) \times 1000 \right]$$

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;
$\Delta C_{Mineral,\ LU}$ = average annual loss of soil carbon for each land-use type (LU), tonnes C;
R = C:N ratio of the soil organic matter;
LU = land-use and/or management system type.

5.4.1.9.2. Quantitative overview – Mineralization/immobilization associated with the loss/gain of soil organic matter

In 2021, N_2O emissions from mineralization of the loss of soil organic matter did not occur. Since 1990, the emissions have occurred only in 1991 and 1992, respective amounts of N_2O were 0.024 and 0.008 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. N_2O emissions are being reported only about the years when carbon stock in mineral soils has decreased compared to the previous year.

[244] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.16, equation 11.8.

5.4.1.10. N_2O emissions from Cultivation of organic soils (CRF 3.D.1.6)

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[245].

5.4.1.10.1. Methodology, data availability, data sources and emission factors

The 2006 IPCC *Tier 1* method was applied to estimate N_2O emissions from organic soils cultivation (Equation 5.36). Since the 2019 submission, in addition to croplands, areas of drained grasslands have been included in emission estimates of cultivated organic soils. According to the expert opinion by. Sims from Estonian Environment Agency (documented in archive according to the instruction of the 2006 IPCC Guidelines (Volume 1, chapter 2, Annex 2A.1)), in Estonia, natural grasslands are the areas where usually only mowing has been carried out or former arable lands were abandoned few decades ago and are now used for grazing. Today, about 37% of grasslands are covered with sparse woody plants already, which indicates that even mowing has not been carried out in those areas at least for 10 years. Therefore, the allocation of non-drained grasslands is included under the LULUCF sector.

Equation 5.36[246]

$$N_2O_{direct} = F_{OS} \times EF_2 \times \frac{44}{28}$$

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 5.40).

5.4.1.10.2. Quantitative overview – N_2O emissions from organic soils cultivated in 2021

N_2O emissions from cultivation of organic soils were 0.513 kt in 2021 in Estonia (Figure 3.28**.**). The estimation was carried out based on the data received in the framework of the National Forest Inventory (see Chapter 6 LULUCF).

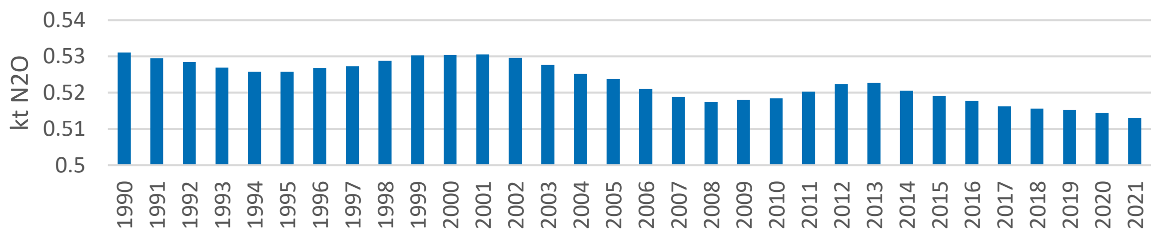


Figure 5.28. N_2O emissions from cultivation of organic soils in Estonia in 1990–2021, kt

[245] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.91.

[246] 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.

5.4.1.11. Uncertainties and time series consistency

The estimation of N_2O emissions from synthetic fertilizers used was carried out based on activity data and emission factors.

Investigations made into the estimates of uncertainties related to the activity data (synthetic fertilizers applied on agricultural soils) are presented by Rypdal and Winiwarter[247]. The authors report uncertainties at ±5% in Austria, at ±5% in Norway, at ±10–50% in the Netherlands, at ±2% in the USA and at ±10% in Finland[248]. No similar research has been carried out in Estonia; therefore, the uncertainty of Finland was used in the estimates (Table 5.46).

Nitrogen emission factors have been used as the IPCC default in the estimates of N_2O emissions. The IPCC gives an uncertainty of the factor of ±80%, the factor is 0.0125 with a range of 0.0025–0.0225[249].

The estimation of N_2O emissions from animal manure applied and urine and dung deposited by grazing animals to soils was carried out based on activity data (amounts of nitrogen produced by livestock) and emission factors. Uncertainties of N generated were described in the 'Manure management' chapter above. The nitrogen emission factor was taken as the IPCC default.

The estimation of N_2O emissions from crop residues was carried out based on activity data (crop production) and emission factors (N emission factor, crop residue ratios, nitrogen content in crops and fraction of residues left on fields).

Data on the uncertainty of crop production, sewage sludge and compost application in Estonia are not available. In the second order draft of the LULUCF Good Practice Guidance, an uncertainty of <±20% in the amount of organic waste used as fertilizer is given. In the case of crop residues, the uncertainty of Finland was used in the estimates (Table 5.46).

Table 5.46. Estimated values of uncertainties used in the Agriculture sector

Input	Uncertainties	References
Activity data		
Estonia's livestock population (cattle, swine, sheep, goats, horses, poultry)	± 10%	Rypdal and Winiwarter, 2001
Synthetic fertilizers (applied to agricultural soils)	± 10%	Rypdal and Winiwarter, 2001
Cropland remaining cropland – mineral soils	33.24%	IPCC 2006; Kõlli et al., 2009[250]
Cropland remaining cropland – organic soils	21.41%	IPCC 2006
Sewage sludge, compost applied to soils	±20%	LULUCF GPG 2003
Crop residues	±30%	Monni and Syri, 2003
Emission factors		
EF_1 (mineral fertilizers, organic amendments, crop residues, N mineralized from soil as a	0.003–0.03	Table 11.1 of the 2006 IPCC Guidelines, pp. 11.11

[247] Rypdal, K., Winiwarter, W. (2001). Uncertainties in greenhouses gas emission inventories – evaluation, comparability and implications. Environmental Science and Policy, no.4, p. 107–116.
[248] Monni, S., Syri, S. (2003). Uncertainties in the Finnish 2001 Greenhouse Gas Emission Inventory. VTT Research Notes, no. 2209. Espoo: Otamedia Oy, p. 55–56. .
[249] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.89.
[250] 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 (2), p. 95–108.

Input	Uncertainties	References
result of the loss of soil carbon), kg N_2O–N/kg N		
EF_2 for temperate organic crop and grassland soils, kg N_2O–N/ha	2–24	Table 11.1 of the 2006 IPCC Guidelines, pp. 11.11
EF_{3PRP} for cattle (dairy, non-dairy and buffalo), poultry and pigs, kg N_2O–N/ (kg N)	0.007–0.06	Table 11.1 of the 2006 IPCC Guidelines, pp. 11.11
$EF3_{PRP}$, SO for sheep and 'other animals', kg N_2O–N / kg N	0.003–0.03	Table 11.1 of the 2006 IPCC Guidelines, pp. 11.11

5.4.1.12. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.2.3.

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.

5.4.1.13. Category-specific recalculations

- The N_2O emissions from Animal Manure Applied to Soils (CRF 3.D.1.2.a), Other Organic Fertilizers Applied to Soils (CRF 3.D.1.2.c) and Urine and Dung Deposited by Grazing Animals (CRF 3.D.1.3) were recalculated for 1990-2020 due to the corrected activity data and updated methodology in Livestock categories (see explanations in Chapter 5.2.7 and Chapter 5.3.7).
- The N_2O emissions from Sewage Sludge Applied to Soils (3.D.1.2.b) were recalculated for 2020 due to corrected amount of sewage sludge used for 2020.
- The N_2O emissions from Mineralization/Immobilization Associated with the Loss/Gain of Soil Organic Matter (CRF 3.D.1.5) for the years 1991-1992 and from Cultivation of organic soils (CRF 3.D.1.6) for the whole time-series were updated in the framework of the NFI (see Chapter 6 LULUCF).
- The N_2O emission from Crop residues were recalculated due to the corrected activity data for barley’s production, yield and production area, rye's, oats' and potatoes’ crop yield. The calculation errors were connected to updating the calculation templates and therefore such inconsistencies are minimized in future submissions.
- The N_2O emissions from Urine and Dung Deposited by Grazing Animals (CRF 3.D.1.3) were recalculated for 1990-2020 due to the corrected activity data and updated methodology in Livestock categories (see explanations in Chapter 5.2.7 and Chapter 5.3.7).
- The N_2O emissions from Atmospheric Deposition (3.D.2.1) were recalculated for the whole timeseries due to activity data rounding (see explanation in Chapter 5.2.7).

The results of the recalculations are presented in Table 5.47.

.

Table 5.47. Reported direct N_2O emissions in 2022 and 2023 submissions from Agricultural soils, kt

Direct N_2O emissions from agricultural soils	1990	1995	2000	2005	2010	2015	2020
2022 submission	2.97	1.50	1.38	1.42	1.52	1.86	1.77
2023 submission	3.79	1.86	1.70	1.75	1.91	2.35	2.55

5.4.1.14. Category-specific planned improvements

There are no category-specific planned improvements.

5.4.2. Indirect N_2O emissions from managed soils (CRF 3.D.2)

Nitrous oxide is produced naturally in soils and aquatic systems through the microbial processes of nitrification and denitrification. A number of 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[251].

5.4.2.1. Category description

The total indirect N_2O emissions from agricultural soils were 0.49 kt in 2021 (Figure 5.29). The emissions declined compared to the base year (1990) by 37% in 2021 due to the decrease in the number of the livestock population and synthetic and organic fertilizer application onto agricultural land.

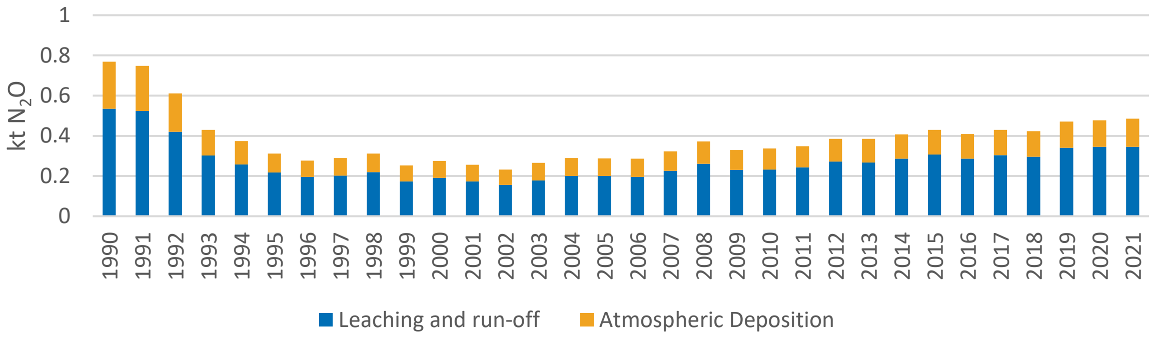


Figure 5.29. Indirect N_2O emissions from Agricultural soils in Estonia in 1990–2021, kt

5.4.2.2. Atmospheric deposition of NO_X and NH_4 (CRF 3.D.2.1)

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[252]. Total N_2O emissions from atmospheric deposition were 0.140 kt in 2021 in Estonia.

[251] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.53.

5.4.2.2.1. Methodology, data availability, data sources and emission factors

The *Tier 1* (Equation 5.37) method was used to estimate emissions from the Atmospheric deposition.

Equation 5.37[252]

$$N_2O_{(ATD)} - N = \left[(F_{SN} \times Frac_{GASF}) + \left((F_{ON} + F_{PRP}) \times Frac_{GASM}\right)\right] \times EF_4$$

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 5.40);
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 5.40);
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 5.40).

5.4.2.3. Leaching/run-off of applied or deposited nitrogen (CRF 3.D.2.2)

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[253]. The total N_2O emissions from leaching and run-off were 0.345 kt in 2021 in Estonia.

5.4.2.3.1. Methodology, data availability, data sources and emission factors

The *Tier 1* method was used to estimate emissions from Leaching/run-off (Equation 5.38).

Equation 5.38[254]

$$N_2O_{(L)} - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH-(H)} \times EF_5$$

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};

[252] 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.
[253] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.70.
[254] 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.

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 5.40);

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 5.40).

5.4.2.4. Uncertainties and time series consistency

Atmospheric deposition

The estimation of N_2O emissions from Atmospheric deposition was carried out based on activity data (synthetic fertilizers, organic amendments applied to soils, urine and dung deposited by grazing animals) and emission factors.

Nitrogen (N_2O) emission factor was used from IPCC, 2006. IPCC Guidelines provide the factor at 0.01 with a range of 0.002–0.05.

Nitrogen leaching and run-off

The estimation of N_2O emissions from Nitrogen leaching was carried out based on activity data (synthetic fertilizers, organic amendments applied to soils, urine and dung deposited by grazing animals and crop residues) and emission factors (fraction of the synthetic fertilizers, organic amendments applied to soils, urine and dung deposited by grazing animals, crop residues and nitrogen lost to leaching and surface run-off and N_2O emission factor).

N_2O emission factor is reported from IPCC 2006 GL. The value of the factor is 0.0075 with a range of 0.0005–0.025 (Table 5.48).

Table 5.48. Estimated values of uncertainties used in the Agriculture sector

Input	Uncertainties	References
Fraction of synthetic N fertilizers that volatilize as NH_3 and NO_x	0.03–0.3	IPCC 2006, Table 11.3, p-11.24
Fraction of organic N fertilizers applied, and dung and urine deposited by grazing animals that volatilize as NH_3 and NO_x	0.05–0.5	IPCC 2006, Table 11.3, p-11.24
Emission factor (Atmospheric deposition)	0.002–0.05	IPCC 2006, Table 11.3, p-11.24
Emission factor (N leaching and run-off)	0.0005–0.025	IPCC 2006, Table 11.3, p-11.24
Fraction of the fertilizer and manure nitrogen lost to leaching and surface run-off	0.1–0.8	IPCC 2006, Table 11.3, p-11.24

5.4.2.5. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.2.3.

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.

5.4.2.6. Category-specific recalculations

Indirect N_2O emissions from agricultural soils were revised due to the recalculations under the Manure management subcategory (CRF 3.B) and Direct N_2O emissions from managed soils (CRF 3.D.1.2. a, b and c, 3.D.2.1, 3.D.1.3, 3.D.1.5 and 3.D.1.6) subcategory (see Chapter 5.2.7, Chapter 5.3.7 and Chapter 5.4.1.13). The results of the recalculations are presented in Table 5.49.

Table 5.49. Reported indirect N_2O emissions in 2022 and 2023 submissions from Agricultural soils, kt

Indirect N_2O emissions from Agricultural soils	1990	1995	2000	2005	2010	2015	2020
2022 submission	0.767	0.311	0.275	0.289	0.337	0.427	0.469
2023 submission	0.768	0.311	0.276	0.289	0.338	0.430	0.477

5.4.2.7. Category-specific planned improvements

There are no category-specific planned improvements.

5.5. Field burning of agricultural residues (CRF 3.F)

In 2007, the burning of crop residues was prohibited by Estonian law[255]. 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 were 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 burned varies substantially by country and crop type. This is an area where locally developed, country-specific data are highly desirable'[256].

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 Rural Affairs

[255] Riigi Teataja. Põllumajandusliku keskkonnatoetuse saamise täpsemad nõuded ning toetuse taotlemise, taotluse menetlemise ja toetuse maksmise täpsem kord. [www] https://www.riigiteataja.ee/akt/960819 (24.01.2022); Riigi Teataja. Ühtse pindalatoetuse, põllukultuuri kasvatamise ja põllumajanduskultuuri täiendava otsetoetuse saamise nõuded ning toetuse taotlemise ja taotluse menetlemise täpsem kord. [www] https://www.riigiteataja.ee/akt/12821418 (24.01.2022); Riigi Teataja. Maa heas põllumajandus- ja keskkonnaseisundis hoidmise nõuded. [www] https://www.riigiteataja.ee/akt/116012015006?leiaKehtiv (24.01.2022).

[256] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.89.

(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 Rural Affairs (MoRA) in accordance with the ERT 2022 review's recommendation. MoRA confirms that no widespread practice of agricultural residues burning has taken place during the reporting period. It is a common practise in Estonia that if the farmer has no animals or has no straw buyers located in the vicinity, then crop residues are ploughed into soil to enrich the soil with nitrogen. 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 CRF 1.A.4).

Since 2021 submission, notation key 'NO' was applied for the whole timeseries,

5.6. CO_2 emissions from liming (CRF 3.G)

5.6.1. Category description

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 of this area needs liming due to the different calcium contents.[257]. Total CO_2 emissions from lime applied on agricultural land were 28.5 kt in Estonia in 2021, from which CO_2 emissions from dolomite were 6.1 kt and 22.4 kt from limestone (Figure 5.30). The emissions have increased by 81.1% compared to the previous year.

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 in 2019-2020, emissions from liming reached its peak in 2021, being record high in the whole timeseries.

5.6.2. Methodology, emission factors and activity data employed

The *Tier 1* (Equation 5.39) method was used to estimate CO_2 emissions from the liming of croplands. Activity data on agricultural land areas on which lime was applied were obtained from the Estonian Ministry of Rural Affairs for the period of 1990–2003. Data about liming were then not implicit, as they were 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 liming carried out at a landowner's own expense was considered to be marginal according to the Estonian Ministry of Rural Affairs. 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[258].

[257] Loide, V. (2019). Põllumuldade kaltsiumisisaldusest ja lupjamisest. Presentation, 10th World Soil Day, Tartu, Estonia.
[258] Järvan, M. (2005). Põldude lupjamine. Saku: Maalehe Kirjastus, lk 6.

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 Ministry of Rural Affairs in 2003 and from the data of Statistics Estonia in 2005. The area of liming has fluctuated widely over the years, depending significantly on government subsidies and on the economic situation.

Equation 5.39[259]

$$\Delta C_{CC\ Lime} = M_{Limestone} \times EF_{Limestone} + M_{Dolomite} \times EF_{Dolomite}$$

Where:

$\Delta C_{CC\ Lime}$ = annual C emissions from agricultural lime application, tonnes C yr^{-1};

M = annual amount of calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), tonnes yr^{-1};

EF = emission factor, tonnes C (tonne limestone or dolomite)$^{-1}$; these are equivalent to carbonate carbon contents of the materials (12% for $CaCO_3$, 13% for $CaMg(CO_3)_2$).

In order to estimate the fractions of different fertilizer types used for neutralization of acidic soils resulting in CO_2 emissions, data reported by E. Turbas[260] for the time 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.2.2_VIII.

The emissions resulting from limestone application were calculated using data on clinker dust, powdered limestone, other meliorate and dolomite. 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).

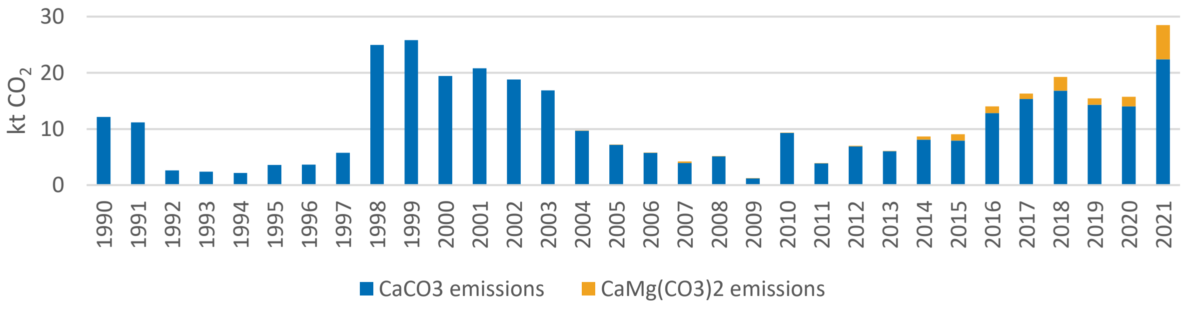


Figure 5.30. CO_2 emission from $CaMg(CO_3)_2$ and $CaCO_3$ in 1990–2021, kt

Yearly differences in the use of specific fertilizer types used for liming contribute to the CO_2 emission fluctuations in the time series. No CO_2 emissions occur from the use of some lime fertilizers (oil shale ashes, ash) as they do not contain inorganic carbon (Table 5.50).

[259] 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.

[260] Turbas, E. (2000). Muldade lupjamise mõtte ja lupjamistööde arengust Eestis. Agraarteadus, nr 11 (2), lk 117–131.

Table 5.50. Amounts of lime fertilizers applied on the fields 1990–2021, kt/yr

Fertilizer	1990	1995	2000	2005	2010	2015	2020	2021
Clinker dust	68	13.4	39.1	22.9	31.5	0	0	0
Other lime fertilizer	NO	NO	NO	NO	NO	6	4.4	2.2
Powder limestone	NO	2.7	28.3	7	8.3	12	27.5	48.7
Oil shale ash	68	8.7	NO	NO	NO	9.3	25.0	17.6
Ash	NO	NO	NO	NO	7.9	2.2	8.6	9.4
Powder dolomite	NO	NO	NO	0.1	0.2	2.3	3.6	12.8
Total	136	24.8	67.4	30	47.9	31.9	69.1	90.7

5.6.3. Uncertainty and time series consistency

CO_2 emissions from liming are estimated in line with the IPCC 2006 GL. Activity data were obtained from the Estonian NFI, national statistics and the Ministry of Rural Affairs, emission factors were employed from IPCC 2006 and uncertainties from GPG-LULUCF 2003. The uncertainty rates of activity data and the emission factors used are reported in Table 5.51.

Table 5.51. Uncertainties in the Liming category

IPCC category		Uncertainties %		EF references
		Activity data[261]	Emission factors	
5.B\5(IV)	CO_2 emissions from agricultural lime application	29.15	50	LULUCF GPG 2003

5.6.4. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.2.3.

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

There were no category-specific recalculations.

5.6.6. Category-specific planned improvements

There are no category-specific planned improvements.

5.7. Urea application (CRF 3.H)

5.7.1. Category description

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 range

[261] All activity data uncertainty estimates are obtained from the NFI.

from 0.01 to 1.55 kt CO_2 per year (Figure 5.31.). In 2021, the emissions from urea application were 0.13 kt.

5.7.2. Methodology, emission factors and activity data employed

Equation 5.40[262]

$$CO_2\ Emission = M \times EF \times \frac{44}{12}$$

Where:

CO_2–C Emission = annual C emissions from urea application, tonnes C yr^{-1};
M = annual amount of urea fertilization, tonnes urea yr^{-1};
EF = emission factor, tonne of C (tonne of urea)$^{-1}$ IPCC 2006 GL default value of 0.20 is applied.

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 LLC Nitrofert in Estonia. 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 5.40 (see also Annex A.2.2_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[263]. 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 proper data and suggestions made by the ERT (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 since the year 2010, when only marketing data was available, except the year 2013, when data from the LLC Nitrofert were 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. We have been working on finding a new methodology to estimate emissions from urea fertilizers since 2021. We have been looking into different databases for urea fertilizers but no institution in Estonia collects national data on urea consumption. We have also contacted urea resellers and manufacturers and are now, in accordance with the 2022 ERT review's recommendation, validating their sales data and working on developing a methodology to implement the data to our emission estimates.

[262] 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.
[263] 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.

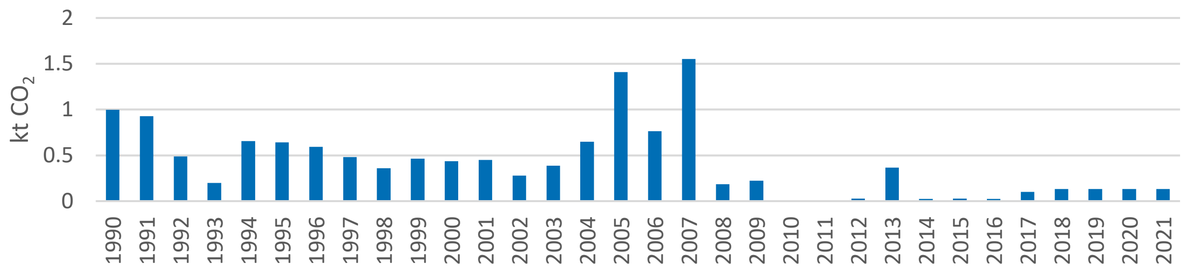


Figure 5.31. CO_2 emissions from urea fertilizer application 1990–2021, kt

5.7.3. Uncertainties and time series consistency

For the uncertainty of the emission factor, default values (-50%) associated with the EF specified in the 2006 IPCC Guidelines were applied. For activity data, 2% of the weighing uncertainty for the urea fertilizer sales records of LLC Nitrofert were applied in the calculations.

5.7.4. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.2.3.

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.

5.7.5. Category-specific recalculations

There were no category-specific recalculations.

5.7.6. Category-specific planned improvements

We are working on updating the methodology to calculate emissions from Urea application.

6. LAND USE, LAND-USE CHANGE AND FORESTRY (CRF 4)

6.1. Overview of the sector

6.1.1. Description and quantitative overview

The methodology used for calculating emissions and removals from the Land use, land-use change, and forestry (LULUCF) sector follows the IPCC 2006 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. Since the 2011 submission, the area of Estonia has been reported using the *Approach 2* method that allows tracking land-use transitions between categories.

In 2021, LULUCF sector acted as a net CO_2 source, resulting in net GHG emissions of 2 882.57 kt CO_2 equivalent, meaning that total emissions arising from the sector exceeded total removals.

The LULUCF sector sink is mainly affected by the age structure of forests, management practices in forestry and agriculture, usage of peat soils and horticultural peat, and C sequestration in HWP. Forest land is the most important category 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% of forest stands are more than 60 years old[264], 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 biomass has decreased in recent decade. 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 annual estimate of average growing stock per hectare is also influenced by variability caused by the NFI sampling design, which is based on the systematic random sampling. In 2021, HWP and Grassland were the only net sink categories and unable to compensate emissions from other LULUCF categories. The highest GHG emissions (1 446.24 kt CO_2 eq.) originated from the Wetlands category and were mainly related to the peat extraction areas and off-site emissions from the horticultural use of peat.

In the 2023 annual submission, Estonia reports emissions and removals about the following subcategories:

- Forest land (FL; CRF 4.A): C stock changes in living biomass, deadwood, litter (only 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; CRF 4.B): C stock changes in living biomass, dead organic matter (only 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 (CRF 3.D);
- Grassland (GL; CRF 4.C): C stock changes in living biomass, dead organic matter, mineral soils (only to GL), drained organic soils, and non-CO_2 emissions from wildfires;

[264] Estonian Environment Agency (2022). NFI 2021. Table 13 (Distribution of stands by age classes and dominant tree species, 10-year age classes). [www] https://keskkonnaportaal.ee/sites/default/files/Teemad/Mets/SMI2021_tulemused_0.pdf (08.02.2023).

- Wetlands (WL; CRF 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 Forest land and Grassland conversion to peatland/wetlands. Emissions from wildfires are reported under the Grassland category;
- Settlements (SL; CRF 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; CRF 4.F): CO_2 and N_2O emissions from Forest land, Cropland, Grassland and Wetlands conversion to Other land; and
- Harvested wood products (HWP; CRF 4.G): C stock changes in Solid wood (sawnwood and wood panels), Paper and paperboard and Semi-chemical wood pulp.

The *Tier 2* method has been applied to estimate carbon flows associated with living biomass and deadwood on land remaining and land-use change categories (Table 6.1) for the whole time series. 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 2022[265] (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 6.2.6, 6.3.6, 6.4.6, 6.6.6 and 6.7.6, Category-specific planned improvements). Also, studies by Kõlli *et al.* (2009[266], 2010[267]) 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[268]) have been implemented for peat extraction sites (*Tier 2*).

Table 6.1. 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/ CS, D, OTH	T1, T2/ CS, D	T1, T2/ CS, D
4.A.1 Forest land remaining forest land	T1, T2/ CS, D,OTH	T2/D	T2/D
4.A.2 Land converted to forest land	T1, T2/ CS, D,OTH	NA/NA	T1/D
4.B.1 Cropland remaining cropland	T1, T2/ CS, D,OTH	NA/NA	NA/NA
4.B.2 Land converted to cropland	T2/ CS, D,OTH	NA/NA	T1/D
4.C.1 Grassland remaining grassland	T1, T2/ D,OTH	T2/D	T2/D
4.C.2 Land converted to grassland	T2/ CS, D,OTH	NA/NA	NA/NA
4.D.1 Wetlands remaining wetlands[269]	T2/ CS,D	NA/NA	NA/NA
4.D.2 Land converted to wetlands	T2/ CS, D,OTH	NA/NA	NA/NA
4.E.1 Settlements remaining settlements[270]	NA/NA	NA/NA	NA/NA
4.E.2 Land converted to settlements	T2/ CS, D,OTH	NA/NA	T1/D

[265] This approach is approved by ERT (FCCC/ARR/2012/EST para.94, 104; FCCC/ARR/2013/EST para. 63).
[266] 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.
[267] 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.
[268] 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.
[269] 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.
[270] Settlements remaining settlements reporting is not mandatory.

	Method applied / EF used		
GHG SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O
4.F.2 Land converted to other land	T2/ CS, D,OTH	NA/NA	T1/D
4.G. HWP	T2/ CS, D	-	-
4(II) Emissions from drainage	NA/NA	T1, T2/CS, D	T1, T2/CS, D
4(III) N_2O from mineralization	-	-	T1/D
4(IV) Indirect N_2O emissions from managed soils	-	-	T1/D
4(V) Biomass burning	NA[271]/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 6.2) have been used in the estimation of greenhouse gas fluxes related to the LULUCF sector.

Table 6.2. 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 Service	www.rescue.ee	ERS	- collecting and publishing data on forest fires (location, type, cause, etc.)
Statistics Estonia	www.stat.ee/en	SE	- providing data for calculating Cropland mineral soil emissions (areas with different land use and input regimes within the Cropland category) - data on peat extraction - foreign trade and production data for HWP calculations
Land Parcel Identification System	www.pria.ee/en/Registers	IACS/LPIS	- providing data for calculating Cropland mineral soil emissions
Centre of Estonian Rural	https://metk.agri.ee/	METK	providing know-how for calculating Cropland mineral soil emissions (share

[271] The stock-difference method used for biomass estimates includes CO_2 loss from burning.

References	Link	Abbreviation	Activity
Research and Knowledge			of areas with different tillage practises and C input of different cropping systems)
Estonian Land Board	www.maaamet.ee	ELB	- collecting and providing additional data on land areas - providing data on peat extraction
Estonian Forest and Wood Industries Association	www.empl.ee		- expert assessment of sawnwood production data for HWP calculations

The areas of land-use categories defined in accordance with the IPCC land use definitions (see chapter 6.1.2) are reported in Table 6.3. Areas of managed wetlands in Table 6.3 include peat extraction sites, flooded lands and lands that have been converted to wetlands.

Table 6.3. The area of different land-use categories in 1990[272]–2021 (NFI)[273], kha

	Forest land	**Cropland**	**Grassland**	**Unmanaged wetlands**	**Managed wetlands**	**Settlements**	**Other land**
1989	2 364.0	1 046.7	299.3	407.4	32.5	330.4	53.8
1990	2 365.7	1 046.2	298.7	407.4	32.5	329.9	53.6
1991	2 368.5	1 044.8	298.0	407.3	32.6	329.6	53.2
1992	2 372.4	1 042.7	297.2	407.2	32.6	329.1	52.7
1993	2 377.4	1 039.3	296.8	407.0	32.7	328.7	52.1
1994	2 382.4	1 034.8	297.7	406.7	32.7	328.4	51.4
1995	2 387.8	1 029.4	298.9	406.4	32.6	328.1	50.8
1996	2 393.5	1 023.3	300.6	406.0	32.6	327.7	50.2
1997	2 399.5	1 016.3	303.0	405.7	32.4	327.4	49.6
1998	2 405.3	1 009.9	305.5	405.5	32.0	326.9	49.0
1999	2 411.3	1 003.8	307.3	405.5	31.7	326.3	48.0
2000	2 416.9	998.3	309.1	405.3	31.4	325.9	47.1
2001	2 421.2	993.9	311.0	405.1	30.9	325.6	46.3
2002	2 424.8	990.5	312.2	404.9	30.7	325.6	45.4
2003	2 428.6	987.0	312.6	404.5	30.5	326.2	44.6
2004	2 431.8	983.9	312.5	404.1	30.4	327.1	44.1
2005	2 434.9	981.4	311.4	403.7	30.6	328.4	43.7
2006	2 437.5	979.0	309.4	403.3	31.0	330.2	43.6
2007	2 439.7	977.0	307.2	402.8	31.4	332.1	43.7
2008	2 441.2	975.6	305.2	402.4	31.9	334.0	43.8
2009	2 442.1	974.8	302.8	402.0	32.5	335.8	43.9
2010	2 442.9	974.0	301.0	401.6	33.1	337.5	44.0
2011	2 444.0	973.4	299.3	401.2	33.4	338.9	43.7

[272] These are area estimates at the end of the year, e.g., 1989 is the area on 31.12.1989 and is applied as the initial area in 1990.
[273] Differences between national and IPCC land-use categories are explained in Table 6.6.

	Forest land	Cropland	Grassland	Unmanaged wetlands	Managed wetlands	Settlements	Other land
2012	2 445.3	972.9	297.0	400.8	33.7	340.6	43.6
2013	2 446.3	972.8	294.5	400.6	34.0	342.2	43.6
2014	2 447.0	973.2	291.8	400.3	34.2	343.8	43.6
2015	2 447.4	974.2	288.7	400.1	34.4	345.6	43.6
2016	2 447.3	975.0	285.9	399.7	34.7	347.4	43.9
2017	2 447.0	976.0	283.6	399.3	35.0	348.9	44.1
2018	2 446.8	976.8	281.3	398.9	35.3	350.7	44.2
2019	2 446.9	977.0	279.4	398.5	35.5	352.4	44.3
2020	2 447.1	976.9	278.0	398.2	35.6	353.9	44.4
2021	2 447.4	976.9	276.8	398.0	35.6	354.9	44.3

Land-use changes are tracked on National Forest Inventory (NFI) sample plots that cover the whole country and are re-inventoried every fifth year. Formerly, the NFI registered only the present type of land use, while starting from 2009, the transition of land use is determined on each sample plot, as well, and assessed in retrospect for the past 20 years, if necessary.

All area estimates are being re-estimated annually in the GHG inventory due to the method used by the NFI. The NFI was established in 1999, and since then the estimations have been obtained from the annual field inventory. The sampling design of the Estonian NFI and the method of estimation of land-use changes are described in Chapter 6.1.3.

The net CO_2 emissions/removals of the Estonian LULUCF sector are presented in Figure 6.1. 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. Emissions and uptake of Forest land are predominantly determined by changes in forest growing stock. Inter-annual variability in NFI estimates of growing stock have been smoothed, further explanations are provided in Chapter 6.2.2.1.

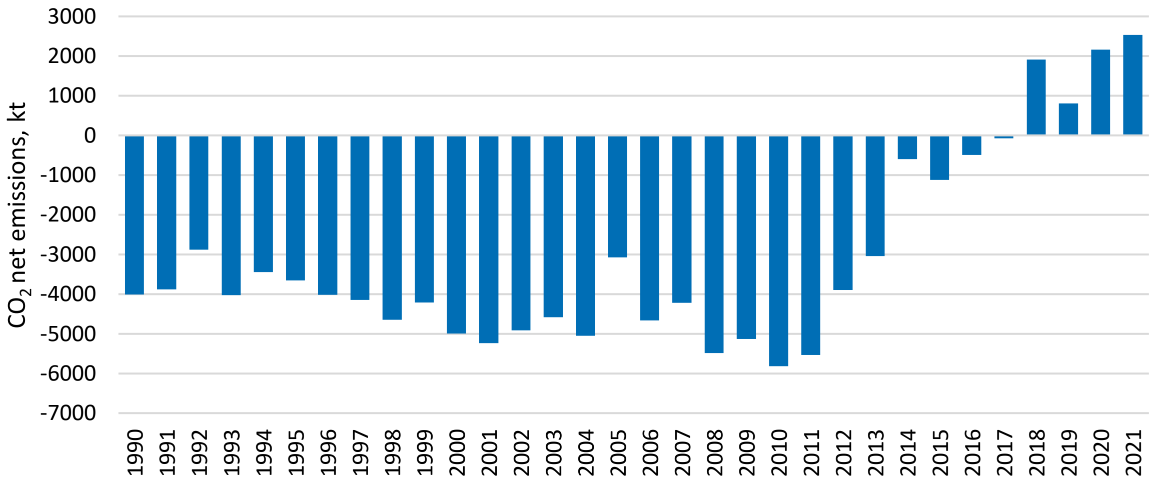


Figure 6.1. Annual change in emissions/removals of CO_2 from the Estonian LULUCF sector in 1990−2021, kt CO_2

Figure 6.2 and Figure 6.3 show total emitted quantities of CH_4 and N_2O during the period 1990–2021. 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.

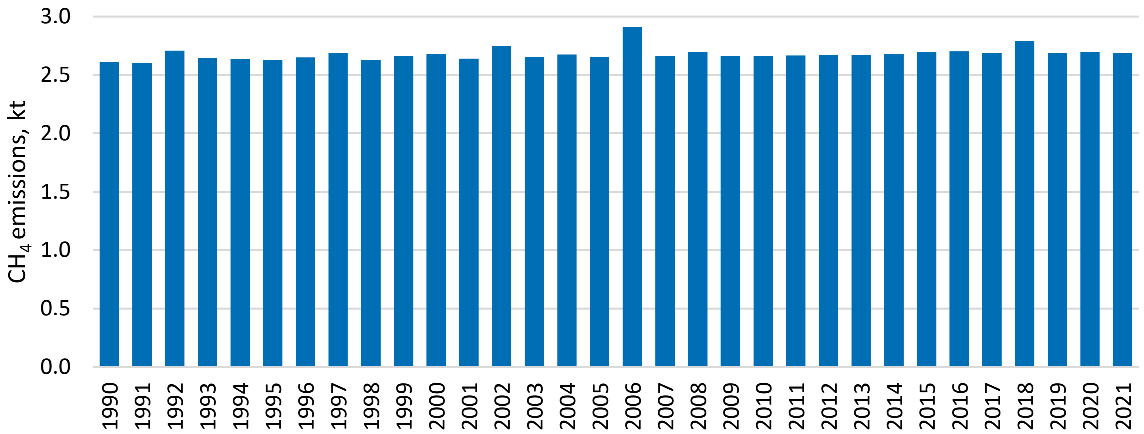


Figure 6.2. Emissions of CH_4 from the LULUCF sector in Estonia in 1990–2021, kt CH_4

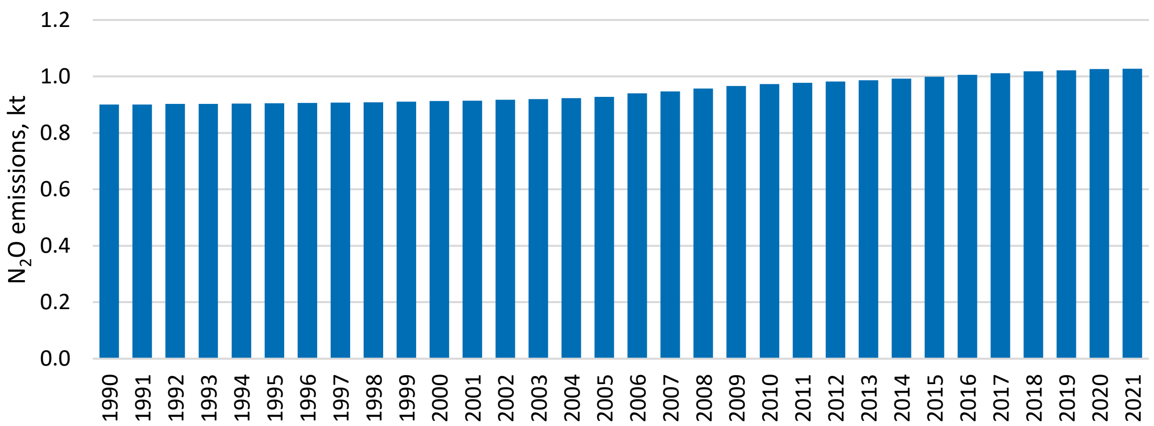


Figure 6.3. Emissions of N_2O from the LULUCF sector in Estonia in 1990–2021, kt N_2O

Key categories

The key categories in 1990 and 2021 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3.

6.1.2. Land areas and land-use categories used in the Estonian inventory

LULUCF land categories presented in the inventory report are consistent with the land-use categories given in the IPCC 2006 Guidelines.

Area estimates for land-use categories are obtained from the 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 6.4) 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 6.6). Table 6.4 gives an overview of land-use transitions between 31.12.1989 and 31.12.2021. The largest decrease in area has occurred in the Cropland category (-69.76 kha) as due to the lack of active management, many croplands have turned into grasslands. The area of the Grassland category has decreased by 7.4% during the last 32 years. At the same time, Forest Land area has increased by 3.5%. These changes result mostly from the reallocation of grasslands to the Forest land category when their tree crown cover corresponds to the Forest land definition as a result of natural succession.

Table 6.4. The land-use change matrix for IPCC land-use categories from 31.12.1989 to 31.12.2021 (kha). Implementation of IPCC land-use categories in the Estonian inventory is described below.

	Initial						Final area
Final	**FL**	**CL**	**GL**	**WL**	**SL**	**OL**	
Forest land	2 328.15	38.66	50.69	10.73	7.86	11.33	2 447.41
Cropland	1.7	950.82	24.10	0.21	0.09	0.00	976.92
Grassland	9.3	47.60	215.80	0.95	1.75	1.39	276.80
Wetlands	3.5	0.10	0.60	427.74	1.68	0.00	433.64
Settlements	18.1	8.93	7.85	0.18	319.01	0.89	354.93
Other land	3.2	0.57	0.26	0.12	0.00	40.14	44.29
Initial area	2 363.96	1 046.68	299.29	439.92	330.38	53.75	4 533.99
Change since 1990, kha	83.44	-69.76	-22.49	-6.28	24.55	-9.46	
Change since 1990, %	3.5	-6.7	-7.5	-1.4	7.4	-17.6	

6.1.2.1. Forest land definitions

Forest area is estimated according to the FRA (UNFAO – Forest Resources Assessment) definition[274] (Table 6.5). 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 6.5. Parameters for forest definition

Minimum tree crown cover	10%
Minimum land area	0.5 ha
Minimum tree height	5 m

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

[274] FAO (2018). Terms and definitions FRA 2020. Forest resources assessment working paper 118. [www] https://www.fao.org/3/I8661EN/i8661en.pdf (08.02.2023)

- 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.

6.1.2.2. 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.

6.1.2.3. 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’).

6.1.2.4. 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.

6.1.2.5. 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 peat extraction areas) are reported under the Settlements land-use category (Table 6.3).

6.1.2.6. 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.

6.1.3. National Forest Inventory

The estimation of emitted/removed quantities of carbon is carried out based on data measured in the process of the NFI. 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.

In 2021, the Estonian Land Board updated the coastline with Geographic information systems (GIS) data that led to a total area increase of Estonia. The total land area of Estonia is updated to 45 340 km^2 (formerly 45 339 km^2) and this figure is used in the NFI and GHG inventory.

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)[275] of sample plots (Figure 6.4), covering the whole country, has been planned for five years with 20% or approximately 370 clusters (ca 5 500 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.

[275] In FCCC/ARR/2014/EST, paragraph 68, the ERT recommended increasing the sampling frequency.

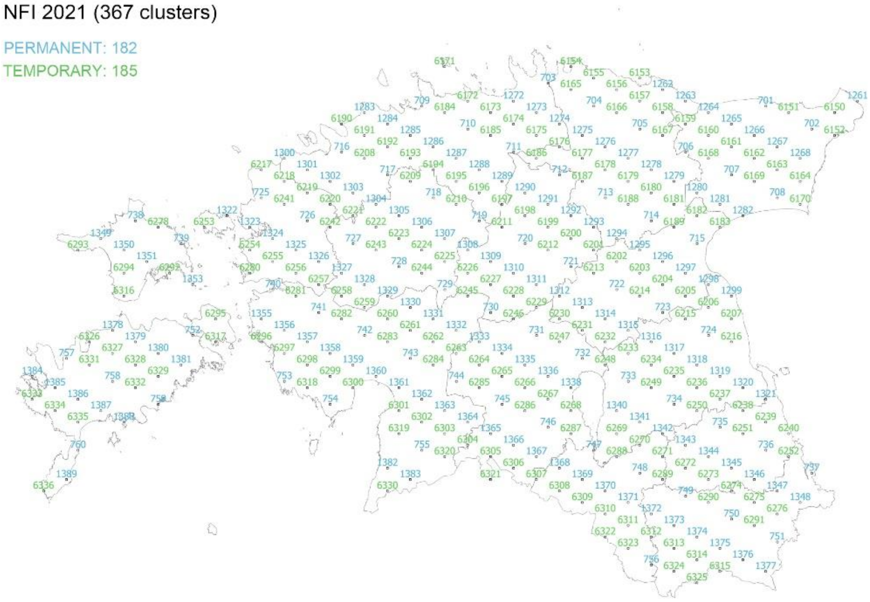


Figure 6.4. Cluster network of the Estonian National Forest Inventory

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 6.5) 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.

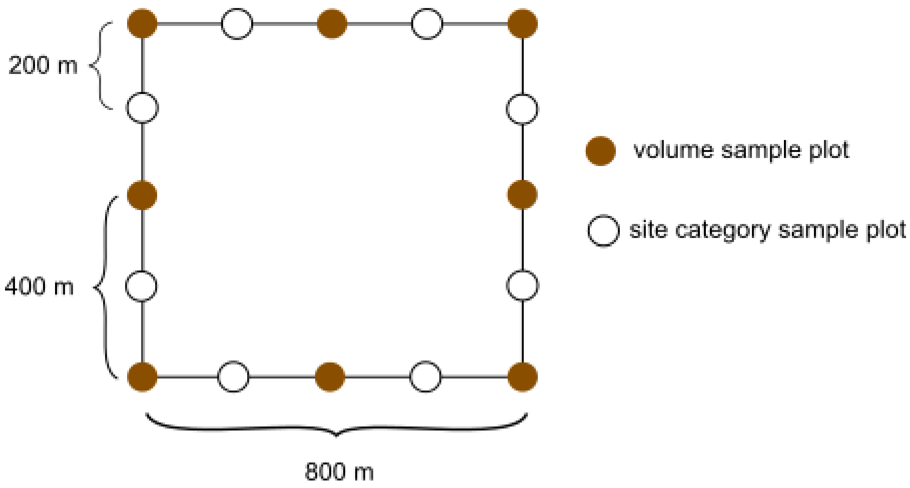


Figure 6.5. Estonian NFI cluster design

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)[276].

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 6.6, Figure 6.7 and Figure 6.8, 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.

[276] 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.

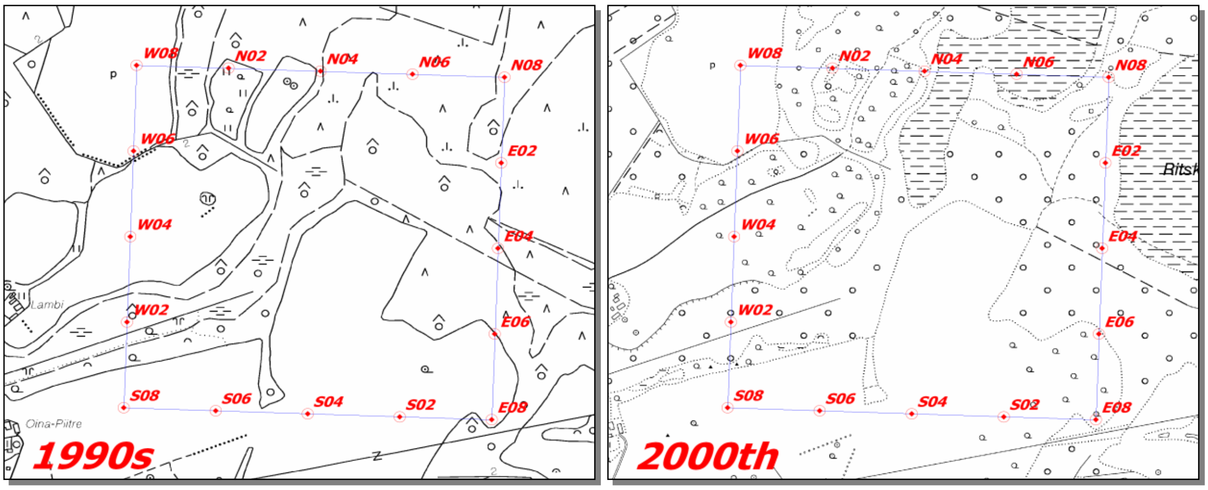


Figure 6.6. Base maps of the 1990s and the year 2000

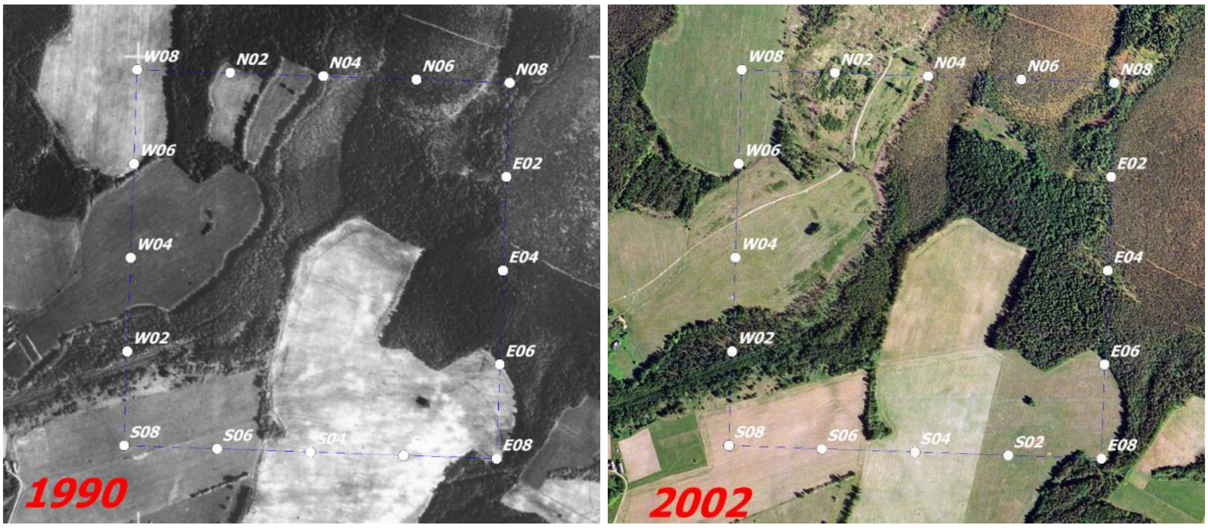


Figure 6.7. Orthophotos of 1990 and 2002

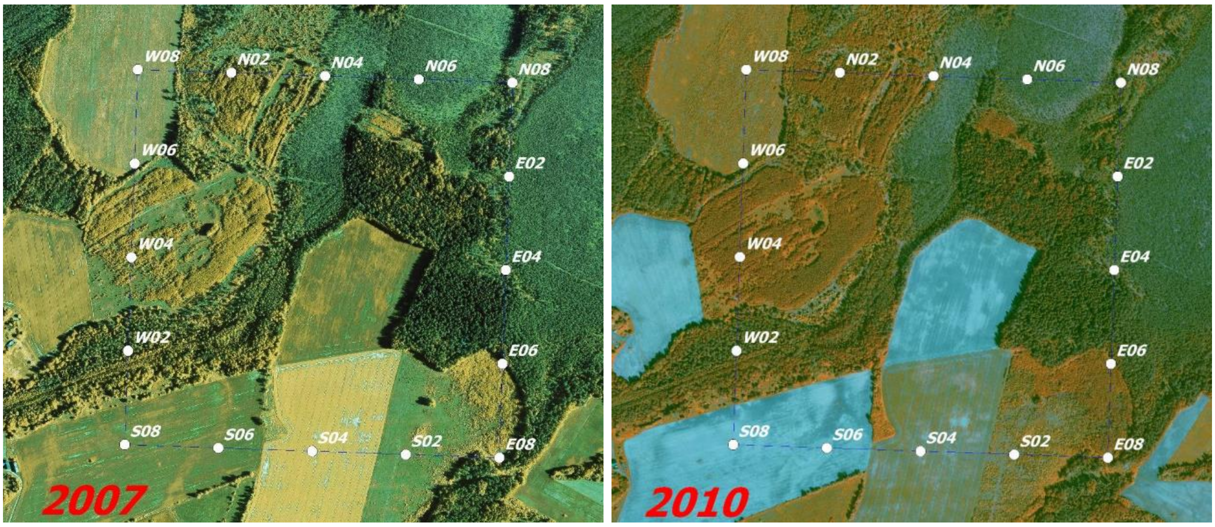


Figure 6.8. Orthophotos of 2007 and 2010

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.

In 2020, all temporary plots from 2013–2019 were additionally checked using a series of orthophotos to detect land use changes that were not recorded in the field. As a result, the estimated areas of lands under land use change increased significantly over the last years compared to the previous submission.

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 6.6. 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 6.6. National definitions for land-use categories and relevant land-use categories defined by IPCC 2006 in 2021 (kha)

	Forest land	**Cropland**	**Grassland**	**Wetlands**	**Settlements**	**Other land**
Forest land (M)	2 117.87					
Unstocked forest land (MM)	207.77					
Arable land (excluding PK, PR) (PM)		663.14				
Permanent crops (PK)		2.66				
Long-term cultural grassland (PR)		311.13				
Bushes (P)	20.37		41.19			
Natural grassland (RM)	36.40		207.72			
Mire (S)	60.78		25.24	141.77		
Inland water bodies (SV)				266.36		
Peat quarry (KT)				25.51		
Opencast pit (excl. KT) (K)					7.89	
Settlements (excl. T, TR) (A)					201.04	
Roads and railways (T)					65.15	
Lines, power lines, etc. (TR)					80.86	
Unusable mineral land (KK)	4.22		2.65			36.49
Other land (Y)						7.81
Total	**2 447.41**	**976.92**	**276.80**	**433.64**	**354.93**	**44.29**

6.1.4. LULUCF cross-cutting issue: climate zones

According to the IPCC 2006 Guidelines, Vol. 4, Chapter 4, Estonia is near the transitional border of the boreal and cold temperate climatic zones, falling under the cold temperate moist climate designation. However, the general understanding (e.g., the State of Europe’s Forests

2011[277]) and the statement by national biologists is that Estonian forest vegetation is typical of boreal forests. Thus, input values from the boreal zone are selected for the Forest land category, except for the drained organic soils, for which the default emission factor for temperate zone is applied, as recommended by the 2022 ERT. Grassland woody biomass parameters are also chosen from the boreal zone. All other land-use categories follow the default allocation by IPCC 2006.

6.2. Forest land (CRF 4.A)

6.2.1. Category description

Forest land category covered 2 447.41 kha in 2021, which is more than half of Estonia's territory. In total the Forest land area has increased by 81.72 kha compared to 1990 (Figure 6.9). 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.

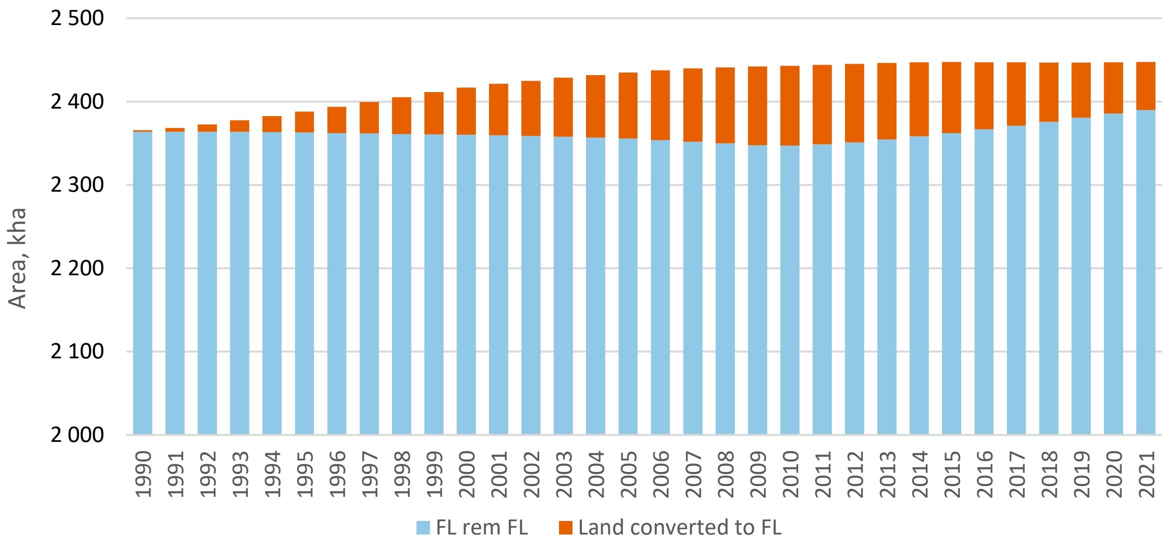


Figure 6.9. Forest land area in Estonia in 1990–2021, kha

The net emissions from Forest land were 1 400.87 kt CO_2 eq. (Figure 6.10) in 2021. Estimations include emissions and removals from living biomass, dead organic matter, mineral and organic soils, and non-CO_2 emissions from drained forest, direct N_2O emissions from N mineralization and emissions from wildfires.

[277] Forest Europe, UNECE & FAO (2011). State of Europe's forests 2011. Status and trends in sustainable forest management in Europe. Oslo: Ministerial Conference on the Protection of Forests in Europe, Forest Europe Liaison Unit.

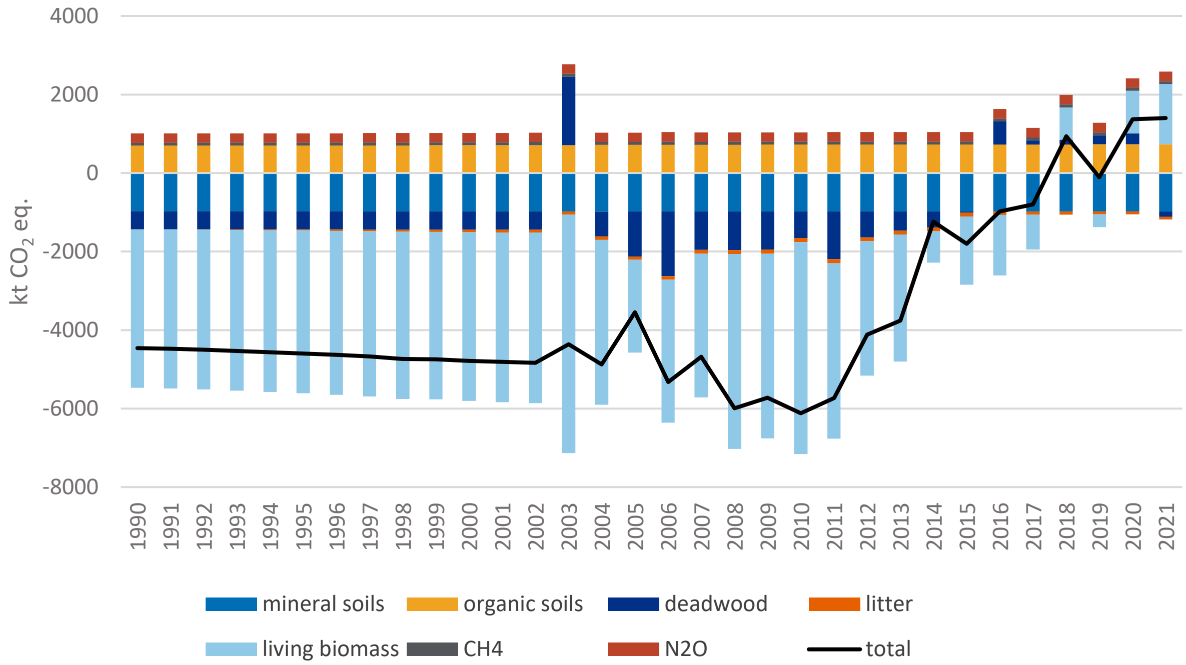


Figure 6.10. Annual net change in GHG emissions (+) and removals (-) from the Forest land category in 1990–2021, kt CO_2 eq.

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 share of young and middle-aged stands led to the growing net annual increment. The felling volume also increased, but the impact of other factors, such as the age structure of forests and increasing forest land area, was more important. Therefore, 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, fellings and increasing proportion of forest area belonging to the first development classes (treeless area, area under regeneration and young stands)[278]. In addition, the annual increase in conversion from other land categories to Forest land has been slowing, and the total forest area has stabilized. Since 2018, Forest land category has been a net emitter, except in 2019, when the average forest growing stock remained stable, and C was sequestered mainly to the mineral soils.

6.2.2. 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:

[278] Estonian Environment Agency (2022). NFI 2021. Table 13 (Distribution of stands by age classes and dominant tree species, 10-year age classes).
https://keskkonnaportaal.ee/sites/default/files/Teemad/Mets/SMI2021_tulemused_0.xlsx

Equation 6.1[279]

$$\Delta C_{LU} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO}$$

Where:

ΔC_{LUi} =	carbon stock change for a stratum of land-use category;
AB =	above-ground biomass;
BB =	below-ground biomass;
DW =	deadwood;
LI =	litter;
SO =	soils.

Equation 6.1 is also used for calculations on the subcategory of land converted to Forest land.

6.2.2.1. Change in carbon stocks in living biomass

Living biomass on Forest land includes the biomass of perennial woody plants. For estimating carbon stock changes in living biomass under the Land remaining forest land category, the *Tier 2* approach and *Method 2* – the stock-difference method (Equation 6.2) was applied. The NFI annually provides data for growing stock and area for Forest land remaining forest land, also on Land converted to forest land.

Equation 6.2[280]

$$\Delta C_B = \left[C_{t_o} - C_{t_{(0-1)}}\right] \times A$$

where

$$C = V \times BCEF_S \times (1 + R) \times CF$$

Where:

ΔC_B =	annual change in carbon stocks in living biomass (B) (the sum of above- and below-ground biomass), tonnes C yr^{-1};
C_{t_2} =	average carbon stock in biomass calculated at time t_0, tonnes C;
C_{t_1} =	average carbon stock in biomass calculated at time $t_{(0-1)}$, tonnes C;
A =	area of Land remaining in the same land-use category, ha;
V =	merchantable growing stock volume, m^3 ha^{-1};
$BCEF_S$ =	biomass conversion and expansion factor for expansion of merchantable growing stock volume to above-ground biomass, tonnes above-ground biomass (m^3 growing stock volume)$^{-1}$ (Table 6.7);
R =	ratio of below-ground biomass to above-ground biomass, tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$ (Table 6.8);
CF =	carbon fraction of dry matter (default = 0.47), tonnes C (tonne d.m.)$^{-1}$.

It should be noted that 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

[279] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.7, Equation 2.3.

[280] After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.12, Equation 2.8.

carbon stock change figures. However, CH_4 and N_2O emissions from biomass burning in forest areas have been estimated (Chapter 6.9).

A net carbon stock change is the output of the stock-difference method, therefore gains and losses are not listed separately neither in the CRF Table 4.A nor in the NIR.

The calculation of carbon changes in living biomass includes the usage of 15-year trend. Based on 15 years, a linear trend of average growing stock per hectare is calculated for each year. If there are seven years of data going back and forth from the accounting year, the trend is calculated based on those years. If there is not yet such a long data series ahead, earlier years are added to the trend calculation, i.e., 15 years of data have always been used. For all years before 2010, the trend based on 2003–2017 data is used. In case of the accounting year, 75% of the estimate originate from the 15-year trend and 25% from the annual assessments.

Due to the usage of NFI temporary plots the two consecutive years are based on independent samples and average standing volume estimates have higher uncertainty; therefore, the methodology is statistically accurate. However, because of the data smoothing, the estimates of average growing stocks for the last 7 years are recalculated every year, and the assessment of annual changes in biomass has lower accuracy. Planned improvements to the methodology for estimating C stock changes in forest biomass are described in Chapter 6.2.6.

In 2014–2018, the network of plots was intensified. By increasing the number of plots, it was also necessary to improve the methodology so that the years with smaller plots in the past would have a fairer weight in the calculation of the results. These improvements influenced standing volume calculations for forest land. Although the NFI started in 1999, the first cycle ended in 2003, and since the average growing stock of one year's stands is calculated based on five-year data, it is more correct to take 2003 as a base year and extrapolate the growing stocks of previous years.

According to the NFI, growing stock on Land converted to forest land areas was assumed to increase at a rate of 3.04 m^3 ha^{-1} yr^{-1}. Increase rate of growing stock was estimated using time series data from all the NFI Land converted to forest land plots.

Table 6.7. Implemented values of BCEFs[281]

Boreal	Growing stock level (m^3)			
Forest type	< 20	21–50	51–100	> 100
Pinus sylvestris	0.573	0.600	0.600	0.549
Picea abies	0.693	0.683	0.637	0.542
Hardwoods	0.717	0.703	0.697	0.653
Weighted average BCEFs	FL rem FL		0.596	
	CL to FL		0.640…0.648	
	GL to FL		0.685	
	WL to FL		0.644…0.648	
	SL to FL		0.641…0.649	
	OL to FL		0.681…0.692	

281 Country-specific values

Estonian country-specific $BCEF_S$ values (Table 6.7) were calculated based on NFI and sample trees data. A total of 165 pine, 127 spruce and 117 birch sample trees were felled and measured during the project "Elaboration of country-specific biomass models for Estonian forests,"[282] carried out by the Estonian University of Life Sciences. Above ground biomass contains living and dead branches, stem, bark and needles or leaves. Above ground biomass and tree volume relation model was created for each tree species and the models were applied on the NFI sample plots trees. Sample plots were divided by growing stock into groups and average $BCEF_S$ values were calculated for every group for Land remaining forest land and for each land-use conversion to forest separately.

Weighted average R values (Table 6.8) were calculated based on tree species distribution and above-ground biomass. Land converted to forest land subcategories were divided into human-induced (CL to FL, WL to FL, SL to FL) and natural regeneration (GL to FL, OL to FL) categories. The boreal climatic zone default IPCC parameter values were applied (see Chapter 6.1.4 for more information).

Table 6.8. Default values of root-to-shoot ratio R[283]

Domain	Land remaining forest land		Land converted to forest land	
	Above-ground biomass, t/ha	**Root-shoot ratio R**	**Above-ground biomass, t/ha**	**Root-shoot ratio R**
Boreal coniferous forest	> 75	0.24	< 75	0.39
Temperate, other broadleaf forest	75–150	0.23	< 75	0.46
Weighted average		0.235		Human-induced 0.393 Natural 0.442

The distribution of the main tree species on Forest land remaining and land converted to forest land is presented in Table 6.9.

Table 6.9. Distribution of tree species on FL rem FL and land converted to FL[284]

Tree species	Forest land remaining forest land	Land converted to forest land	
		Human induced	**Natural regeneration**
Pinus sylvestris	0.298	0.40	0.16
Picea abies	0.249	0.56	0.09
Betula spp	0.222		
Populus tremula	0.073		
Alnus glutinosa	0.070		
Alnus incana	0.048		
Other	0.041	0.04 (mainly *Betula*)	0.75 (broadleaf)

[282]Uri, V. (2020). Riigihanke 191205 „Eesti puistute biomassi mudelite väljatöötamine" lõpparuanne. [Elaboration of country-specific biomass models for Estonian forests.] Estonian University of Life Sciences. Report. [www] https://keskkonnaportaal.ee/et/kasvuhoonegaaside-heitkoguste-inventuuri-uuringud-riikliku-aruandluse-t%C3%A4itmiseks (08.02.2023)

[283] IPCC 2006 Guidelines, Volume 4, Chapter 4: Forest Land, page 4.49, Table 4.4.

[284] Sims, A. (Forest statistics by NFI, 2021).

Data presented in Figure 6.11 characterizes carbon stock changes in living biomass under Land remaining forest land and Land converted to forest land in 1990−2021. Carbon stock changes in biomass depend on forest age structure, management practices and forest land area. Forest C sequestration in living biomass has declined in recent years as a result of the high proportion of mature and near-mature forest stands, the relatively high felling volume of the last decade, 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.

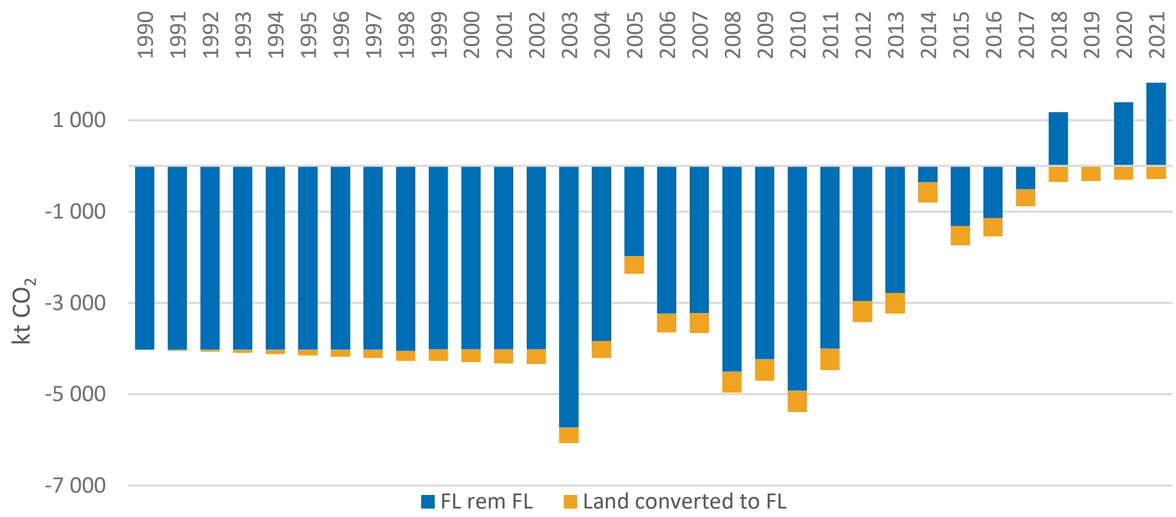


Figure 6.11. Annual carbon stock changes in Forest land living biomass in 1990–2021, kt CO_2

6.2.2.2. CO_2 emissions/removals from/by deadwood

Deadwood includes wood lying on the surface, dead roots and stumps larger than or equal to 10 cm in diameter. Standing deadwood is also considered in the deadwood pool. For estimating carbon stock changes in the deadwood pool, the *Tier 2* and stock change method was applied. The NFI annually provides data about the volume of deadwood for the entire forest area (land remaining FL and conversion to FL). 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. Values of deadwood densities and C content were acquired from Köster *et al*. 2015[285].

Equation 6.3[286]

$$\Delta C_{DW} = \left[A \times \frac{(DW_{t_2} - DW_{t_1})}{T}\right] \times D \times CF$$

Where:

ΔC_{DW} = annual change in carbon stocks in deadwood (DW), tonnes C yr^{-1};

[285] 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.
[286] After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.23, Equation 2.19.

A = area of managed Forest land remaining forest land, ha;
DW_{t_1} = deadwood stock at t_1 for Forest land remaining forest land, m^3 ha^{-1};
DW_{t_2} = deadwood stock at t_2 (the previous time) for Forest land remaining forest land, m^3 ha^{-1};
T = (t_2-t_1) = time period between time of the second stock estimate and the first stock estimate, yr;
D = weighted average DW density for Forest land, 0.265 tonne d.m. m^{-3};
CF = carbon fraction of dry matter, 0.487 tonne C (tonne d.m.)$^{-1}$.

According to the NFI on Land converted to forest land areas, deadwood stock was assumed to increase at rate of 0.045 m^3 ha^{-1} yr^{-1}.

Figure 6.12 illustrates annual deadwood stock changes on Land remaining forest land and Land converted to forest land. Average deadwood volume for Forest land remaining forest land was calculated based on five-year measurements. For earlier years, for which the measurements were not available, deadwood stocks were extrapolated using linear trend. Since 2003, the actual measurement data have been used. The deadwood carbon stock has decreased slightly in 2016–2020 due the increasing proportion of forest area belonging to the first development classes (treeless area, area under regeneration and young stands)[278]. It is expected, and it is also evident from the estimated C stock change in 2021, that C sequestration in deadwood pool will increase in the future 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.

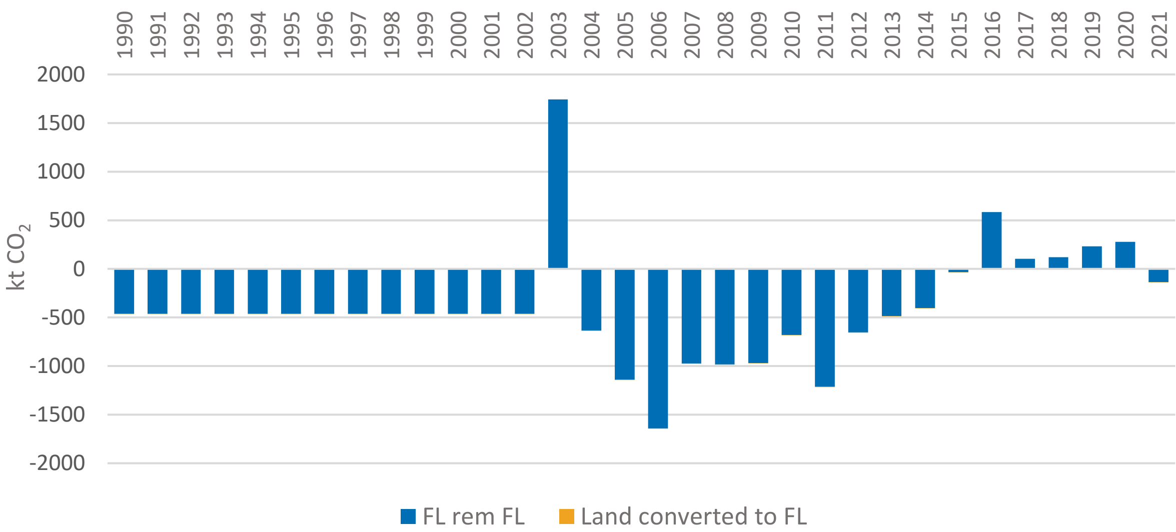


Figure 6.12. Net carbon stock change in forest deadwood pool in 1990–2021, kt CO_2

6.2.2.3. CO_2 emissions/removals from/by 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[287] (0.3 t C ha^{-1} yr^{-1}) was used for litter. It was also possible to apply the Swedish EF for litter on Land remaining

[287] National Inventory Report Sweden 2022: Annexes, pp. 141–142

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.

6.2.2.4. CO_2 emissions/removals from/by mineral forest soils

In Table 6.10 the cumulative areas and proportions of Land-use changes to Forest land in 2021 are shown, as well as applied emission factors for mineral and organic soils. In case of missing or insufficient country-specific data, emission factors from the Sweden 2022 annual submission were implemented with the agreement of ERT[288].

Table 6.10. Cumulative Land-use changes to Forest land in 2021 and implemented soil emission factors [289]

Land-use change	kha	%	EF mineral soil t C ha^{-1}	EF organic soil t C ha^{-1}
Cropland→ Forest land	12.36	21.5	0.18	-
Grassland→ Forest land	31.15	54.1	-0.12	-0.68
Wetlands→ Forest land	7.30	12.7	-	-0.68
Settlements→ Forest land	2.70	4.7	0.15	-0.68
Other land→ Forest land	4.04	7.0	0.15	-
Total	57.56	100.0		

Due to insufficient country-specific data regarding carbon stock changes in forest mineral soil, the emission factor from Sweden NIR[290] (0.149 t C ha^{-1} yr^{-1}) was implemented for Land remaining forest land. For some conversion categories, EFs from Sweden were used as well (Table 6.10), except for Cropland and Grassland converted to Forest land, where country-specific EFs were applied. Changes in mineral soil SOC stocks due to land-use conversions were obtained from the literature (Kõlli *et al.* 2010[267]) 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[266]). 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 6.2.5).

In 2021, there was a C uptake in forest mineral soils by -980.94 kt CO_2, of which -981.81 kt CO_2 was contributed by Land remaining forest land. Under the Land converted to forest land subcategory, net emissions were 0.88 kt CO_2. Overall, the annual carbon sequestration by forest mineral soils has remained at the same level compared to 1990 (Figure 6.13).

[288] FCCC/ARR/2012, para 94.

[289] EFs for organic and mineral soils are taken from the Swedish 2021 annual submission, except CL→FL and GL→FL mineral soil, which are based on Estonia's country-specific data.

[290] The average implied emission factor of 1990–2020 in Sweden CRF 4.A tables, Sweden 2022 Submission.

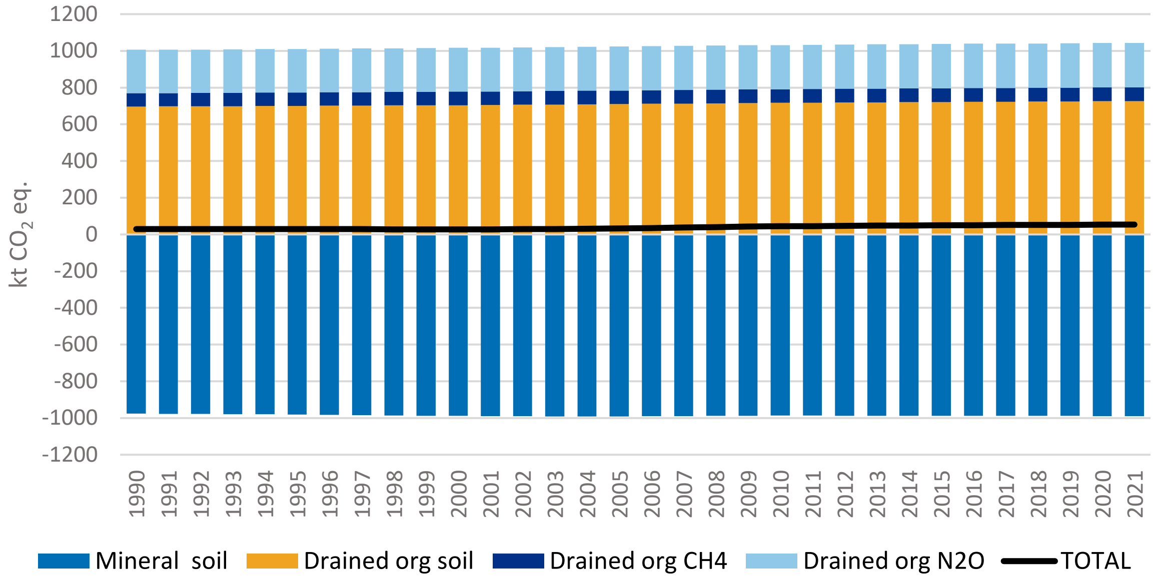


Figure 6.13. Annual stock change in Forest land mineral and drained organic soil pools including non-CO_2 emissions from drained soils in 1990–2021, kt CO_2 eq.

6.2.2.5. CO_2 emissions from drained organic forest 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[291]

$$L_{Organic} = A \times EF$$

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[292] was applied according to the 2022 ERT recommendation.

Approximately 24.7% of all Estonian forest soils are organic soils, of which about 47.9% are drained according to the NFI. Emissions from drained organic forest soils have increased only by 0.01% since 1990 (Figure 6.13).

[291] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.35, Equation 2.26.
[292] IPCC 2006 Guidelines, Volume 4, Chapter 4: Forest Land, page 4.53, Table 4.6 (Temperate).

6.2.2.6. Non-CO_2 emissions from drained organic forest 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 categorised as nutrient-rich and III–V are categorised as nutrient-poor. Respective areas in 1990 and 2021 are presented in Table 6.11.

Equation 6.5 with factors from the IPCC 2013 Wetlands Supplement[293] (*Tier 1)* was applied for estimating CH_4 emissions from drained organic forest land and drainage ditches.

Equation 6.5[294]

$$CH_{4\_OS} = \sum_n A_n \times \left((1 - Frac_{ditch}) \times EF_{CH_4\_land_n} + Frac_{ditch} \times EF_{CH_4\_ditch} \right)$$

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 CH4 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} 1 yr^{-1} (Table 6.11);
$Frac_{ditch}$ = 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 N2O emissions from drained organic forest land.

Equation 6.6[295]

$$N_2O_{OS} = \left[\left(A_{NR} \times EF_{N_2O-N,NR} \right) + \left(A_{NP} \times EF_{N_2O-N,NP} \right) \right] \times \frac{44}{28}$$

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);
$EF_{N_2O\text{-}N}$ = 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 2021, non-CO_2 emissions from drained organic forest soils were equal to 316.64 kt CO_2 eq., which is 2.4% higher compared to the base year (Figure 6.13).

---

[293] IPCC (2014b). 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (*IPCC 2013 Wetlands Supplement*).
[294] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.22, Equation 2.6.
[295] After IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.31, Equation 2.7.

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 2021, kha	Emission factors			$Frac_{ditch}$[296]
			N_2O-N[297], kg N ha^{-1} yr^{-1}	CH_4 land[298], kg CH_4 ha^{-1} yr^{-1}	CH_4 ditch[296], kg CH_4 ha^{-1} yr^{-1}	
Nutrient-rich	169.88	173.35	3.2	2.0	217	0.025
Nutrient-poor	109.65	114.68	0.22	7.0		

6.2.3. Uncertainties and time series consistency

Uncertainties of activity data and emission factors are presented in Table 6.12.

Table 6.12. Uncertainties in the Forest land category

IPCC category		Activity data, %[299]	Emission factor, %	EF References
4.A.1	Forest land remaining forest land – living biomass	2.0	50.0	IPCC 2006, NFI; Uri 2020
4.A.1	Forest land remaining forest land – mineral soils	1.4	60.0	Sweden NIR 2022
4.A.1	Forest land remaining forest land – organic soils	3.0	90.0	IPCC 2006
4.A.1	Forest land remaining forest land – deadwood	0.9	19.8	Köster *et al*. 2015
4.A.2.1	Cropland converted to forest land – living biomass	11.1	47.0	IPCC 2003 & 2006
4.A.2.1	Cropland converted to forest land – mineral soil	14.2	60.0	Kõlli *et al*. 2009 & 2010
4.A.2.1	Cropland converted to forest land – deadwood	5.3	19.8	Köster *et al*. 2015
4.A.2.2	Grassland converted to forest land – living biomass	12.0	47.0	IPCC 2003 & 2006
4.A.2.2	Grassland converted to forest land – mineral soils	12.4	60.0	Kõlli *et al*. 2009 & 2010
4.A.2.2	Grassland converted to forest land – organic soils	42.3	90.0	IPCC 2006
4.A.2.2	Grassland converted to forest land – deadwood	6.8	19.8	Köster *et al*. 2015
4.A.2.3	Wetlands converted to forest land – living biomass	29.9	47.0	IPCC 2003 & 2006
4.A.2.3	Wetlands converted to forest land – organic soils	32.3	90.0	IPCC 2006
4.A.2.3	Wetlands converted to forest land – deadwood	16.7	19.8	Köster *et al*. 2015
4.A.2.4	Settlements converted to forest land – living biomass	114.4	47.0	IPCC 2006
4.A.2.4	Settlements converted to forest land – mineral soils	35.8	60.0	Sweden NIR 2022

[296] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.30, Table 2.4 (boreal).
[297] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.33, Table 2.5 (boreal).
[298] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.25, Table 2.3 (boreal).
[299] All activity data uncertainty estimates are obtained from NFI.

IPCC category		Activity data, %[299]	Emission factor, %	EF References
4.A.2.4	Settlements converted to forest land – organic soils	82.9	90.0	IPCC 2006
4.A.2.4	Settlements converted to forest land – deadwood	14.6	19.8	Köster *et al*. 2015
4.A.2.5	Other land converted to forest land – living biomass	45.4	47.0	IPCC 2006
4.A.2.5	Other land converted to forest land – mineral soil	27.4	60.0	Sweden NIR 2022
4.A.2.5	Other land converted to forest land – deadwood	10.0	19.8	Köster *et al*. 2015
4(II) A	Emissions and removals from drainage and rewetting – CH_4	2.9	55.0	IPCC 2014b
4(II) A	Emissions and removals from drainage and rewetting – N_2O	2.9	39.0	IPCC 2014b

6.2.4. Category-specific QA/QC and verification

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.

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)[300] 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[301]). 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)[302] 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.

6.2.5. Category-specific recalculations

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.

Emissions from living biomass and deadwood have changed compared to the previous submission for forest land remaining forest land due to the recalculation of average growing stocks and deadwood volumes. The biggest impact was observed in biomass recalculations for

[300] Varik, M., Kukumägi, M., Aosaar, J., Becker, H., Ostonen, I., Lõhmus, K., Uri, V. (2015). Carbon budgets in fertile Silver birch (*Betula pendula* Roth) chronosequence stands. Ecological Engineering, 77, 284–296.
[301] Aosaar, J., Varik, M., Lõhmus, K., Ostonen, I., Becker, H., Uri, V. (2013). Long-term study of above- and below-ground biomass production in relation to nitrogen and carbon accumulation dynamics in a grey alder (*Alnus incana* (L.) Moench) plantation on former agricultural land. European Journal of Forest Research, 126, 495–506.
[302] Lutter, R., Tullus, A., Kanal, A., Tullus, T., Tullus, H. (2016). The impact of former land-use type to above- and below-ground C and N pools in short-rotation hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) plantations in hemiboreal conditions. Forest Ecology and Management, 378, 79–90.

the period 2014–2020, as the previous submission did not use the 2003 and 2018 measurement data in living biomass calculations; these were considered as outliers. In the previous submission, average deadwood stocks were smoothed, but in the current submission, smoothing is not applied. This has led to higher emissions in deadwood pool since 2016.

Estimated emissions from drained organic soils have significantly increased as the default emission factor from the IPCC 2006 Guidelines has been applied for organic soils since the current submission, according to the 2022 ERT recommendation. In addition, the calculation of EFs for mineral soils has been updated, which has resulted in lower C sequestration in mineral soils. In Table 6.13 changes in soil emission factors and in Table 6.14 a quantitative overview of recalculations is shown.

Table 6.13. Soil emission factors used in Forest land category compared to the 15.04.2022 submission

Land-use category	Parameter	2022 submission	Source	2023 submission	Source
Forest land remaining forest land	EF organic soil, t C ha^{-1} yr^{-1}	-0.329	Sweden 2021, CRF (1990–2019 average)	-0.68	IPCC 2006, Vol. 4 (Table 4.6, Temperate)
	EF mineral soil, t C ha^{-1} yr^{-1}	0.162	Sweden 2021, CRF (1990–2019 average)	0.149	Sweden 2022, CRF (1990–2020 average)
Land converted to forest land	EF organic soil, t C ha^{-1} yr^{-1}	-0.34	NIR Sweden 2021: Annexes, Table A3:2.12, pp. 141	-0.68	IPCC 2006, Vol. 4 (Table 4.6, Temperate)
	EF mineral soil, CL→ FL, t C ha^{-1} yr^{-1}	0.167	Country-specific data by Kõlli *et al.* (2009, 2010)	0.178[303]	Country-specific data by Kõlli *et al.* (2009, 2010)
	EF mineral soil, GL→ FL, t C ha^{-1} yr^{-1}	-0.055	Country-specific data by Kõlli *et al.* (2009, 2010)	-0.118	Country-specific data by Kõlli *et al.* (2009, 2010)
	EF mineral soil, SL→ FL, t C ha^{-1} yr^{-1}	0.17	NIR Sweden 2021: Annexes, Table A3:2.12, pp. 141	0.15	NIR Sweden 2022: Annexes, Table A3:2.12, pp. 144
	EF mineral soil, OL→ FL, t C ha^{-1} yr^{-1}	0.17	NIR Sweden 2021: Annexes, Table A3:2.12, pp. 141	0.15	NIR Sweden 2022: Annexes, Table A3:2.12, pp. 144

Table 6.14. Quantitative overview of recalculations compared to the 15.04.2022 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	940.78	43.88	289.99	-90.36	2.40	0.54	0.12	-0.05	-4 353.41

303 According to the 2022 ERT recommendations, Estonia has changed soil emission factors compared to the previous submission: the calculation of country-specific factors for mineral soils in Land converted to forest land areas was corrected

		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	
	Current submission	1 097.84	126.31	263.98	-190.01	2.40	0.54	0.06	-0.10	-4 770.44
	Difference %	**16.7**	**187.9**	**-9.0**	**110.29**	**-0.06**	**0.0**	**-45.0**	**100.0**	**9.6**
1995	Previous submission	940.35	43.55	289.84	-90.26	33.57	7.62	1.96	-0.70	-4 495.12
	Current submission	1 097.34	126.25	263.85	-189.81	33.56	7.62	1.43	-1.39	-4 909.13
	Difference %	**16.7**	**190.0**	**-9.0**	**-110.3**	**-0.04**	**0.0**	**26.8**	**100.0**	**9.2**
2000	Previous submission	947.42	62.67	289.42	-90.18	76.27	17.37	4.92	-1.59	-3 385.74
	Current submission	1 096.07	126.11	263.46	-189.65	76.25	17.37	3.90	-3.17	-5 097.88
	Difference %	**15.7**	**101.2**	**-9.0**	**-110.3**	**-0.03**	**0.0**	**20.8**	**100.0**	**6.4**
2005	Previous submission	326.00	43.12	288.80	-90.25	106.36	24.18	6.58	-2.68	-2 574.77
	Current submission	538.87	310.87	262.89	-189.79	106.32	24.19	5.12	-5.36	-3 861.39
	Difference %	**65.3**	**621.0**	**-9.0**	**110.3**	**-0.03**	**0.01**	**-22.3**	**100.0**	**50.0**
2010	Previous submission	1 226.60	40.54	287.46	-90.22	128.61	29.23	6.94	-3.72	-5 959.92
	Current submission	1 342.32	185.10	261.91	-189.73	128.55	29.23	4.95	-7.45	-6 434.61
	Difference %	**9.4**	**356.6**	**-8.9**	**110.3**	**-0.04**	**0.01**	**-28.6**	**100.0**	**8.0**
2015	Previous submission	621.32	31.67	289.19	-90.60	114.45	26.01	5.12	-4.02	-3 641.47
	Current submission	360.24	9.13	264.04	-190.52	114.40	26.01	3.17	-8.05	-2 120.90
	Difference %	**-42.0**	**-71.2**	**-8.7**	**-110.3**	**-0.05**	**0.01**	**-38.1**	**100.0**	**-41.8**
2020	Previous submission	-280.82	35.38	292.78	-91.16	80.02	18.06	2.05	-3.57	-193.38
	Current submission	-380.33	-76.16	267.23	-191.62	83.34	18.80	0.20	-7.60	1 049.15
	Difference %	**35.4**	**-315.3**	**-8.7**	**-110.2**	**4.2**	**4.1**	**-90.36**	**113.0**	**-642.5**

6.2.6. Category-specific planned improvements

A few improvements are required to be carried out to assure complete, transparent and accurate emission estimations for the Forest land category.

The Estonian University of Life Sciences had a project “Forest litter, research and modelling” that could help make the estimation of C stock changes in litter more accurate. The project finished in 2018 resulting in a country-specific litter model that is dependent on the main tree species and site type. The model will be tested before it is used for the greenhouse gas inventory.

Estonia was selected to participate in the Specific Contract (SC) 12 taskforce on harmonization of LULUCF inventories: modelling forest soil with Yasso. The Specific Contract 12 is a framework contract for the provision of forest data and services in support of the European Forest Data Centre. Estonia has some first results on modelling the carbon stock change in forest mineral soils with Yasso07, but it needs further research to provide data for the UNFCCC reporting. An additional project has been launched to provide missing data and enhance the accuracy for implementing the Yasso model.

Remote sensing project for forest resources was launched in 2018 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.

Estonia plans to develop the gain-loss method based on estimates of annual changes in biomass from estimates of biomass gain and loss. It is supported by several completed, ongoing and planned NFI developments, 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. EstEA has plans for further research related to the use of models and to specify error estimates and has also an ongoing consulting contract with the Estonian University of Life Sciences to develop different aspects of NFI (including NFI design and models used).

Estonian University of Life Sciences had a project "Development of new forest growth models". The aim was to verify and specify forest biomass estimates. The model allows to specify the time series of changes in forest growing stock from 1990. The project ended in 2022, and the model will be revewed before it is used for the greenhouse gas inventory.

Project "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland" (LIFE OrgBalt, LIFE18 CCM/LV/001158)[304] 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. In addition, University of Tartu is also creating a map layer for operational ditches and developing GHG emission factors for ditches in all land use categories. Results of these projects are planned to be implemented at latest in the 2026 inventory submission.

6.3. Cropland (CRF 4.B)

6.3.1. Category description

Total net emissions from croplands were 585.87 kt CO_2 eq. in 2021 (Figure 6.14). The Cropland category includes carbon stock changes in living biomass, dead organic matter, mineral and organic soils and N_2O emissions related to land conversion to croplands (see Chapter 6.8). 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.

[304] LIFE OrgBalt project. [www] https://www.orgbalt.eu/ (23.02.2023).

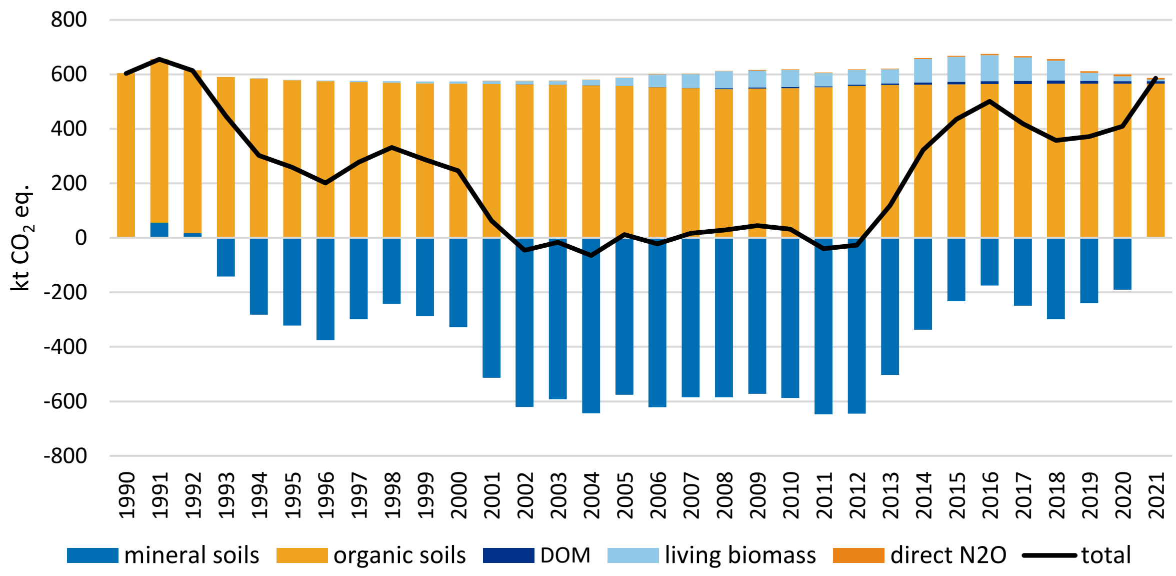


Figure 6.14. Annual GHG emissions (+) and removals (-) from the Cropland category in 1990–2021, kt CO_2 eq

The area of croplands in Estonia has decreased by 6.6% since 1990 (Figure 6.15). From 1991, when Estonia regained its independence, until 2005, an overall decline characterised Estonia's agriculture. Arable lands were abandoned due to the reduced demand for local food products, which was caused by the availability of cheap import goods as a result 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 and forests due to the reduced need for arable land Table 6.4. 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 6.20). Conversions to cropland occur mainly from the Grassland category.

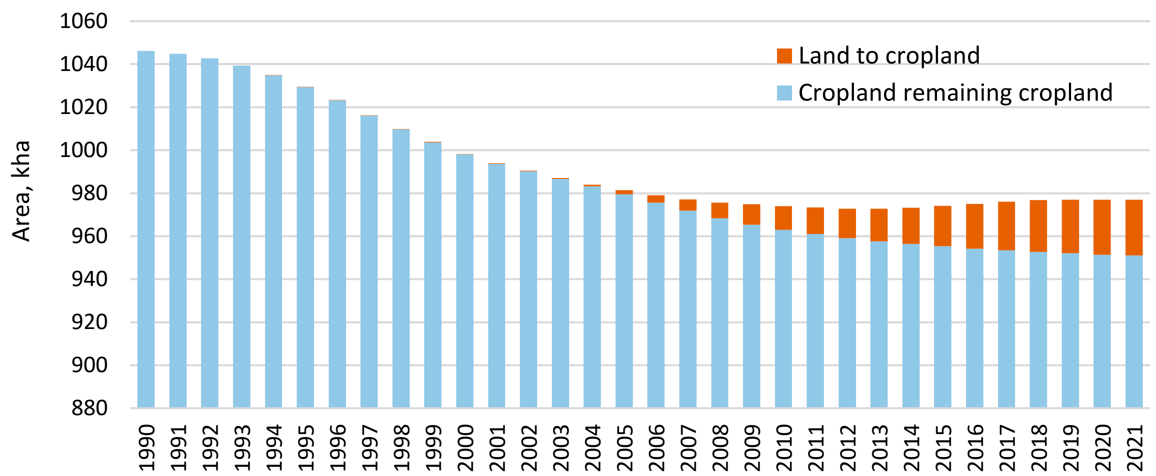


Figure 6.15. Cropland area in Estonia in 1990–2021, kha

6.3.2. Methodological issues

6.3.2.1. Change in carbon stocks 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 *Repola* biomass function for birch[305], which was implemented to estimate the average above-ground, below-ground and total biomass of orchards. The results are shown in Table 6.15.

Table 6.15. Average biomass stock in cropland orchards [306]

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

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

$$\Delta C_B = \left[B_{total} \times \left(A_{t_2} - A_{t_2}\right) \times CF\right]$$

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 6.15)

A_{t_1} = orchards area in the previous year, ha;

A_{t_2} = orchards area in the current year, ha;

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 1 350 ha in 2021, thus the carbon stocks have decreased also, as seen in Figure 6.16.

[305] 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.

[306] Metsaruum OÜ (2012). Põllumajandusmaadel kasvava puitse biomassi määramine. Report, unpublished.

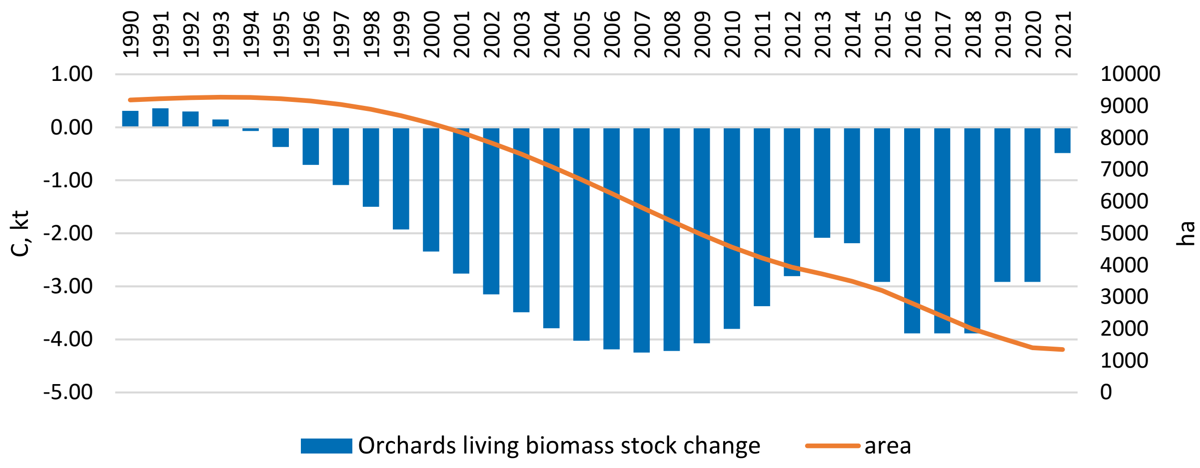


Figure 6.16. Area (ha) and annual change in the cropland perennial woody crops (orchards)

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. Average growing stock volumes in the Forest land and Grassland in the year of conversion were obtained from NFI (Table 6.16). $BCEF_S$ and R parameters for Forest land are presented in Table 6.7 and Table 6.8, respectively, and for Grassland in Table 6.23 and Table 6.24.

Equation 6.8[307]

$$\Delta C_{CONVERSION} = \sum_i [(B_{AFTER_i} - B_{BEFORE_i}) \times \Delta A_{TO\_OTHERS_i}] \times CF$$

where

$$B = V_i \times BCEF_{S_i} \times \frac{1}{R_i}$$

Where:

$\Delta C_{CONVERSION}$ = initial change in living biomass carbon stocks on land converted to another land category;

B_{AFTER_i} = biomass stocks on land type *i* immediately after the conversion, tonnes d.m. ha^{-1}. In case of land conversions to Cropland, $B_{AFTER} = 0$;

B_{BEFORE_i} = biomass stocks on land type *i* before the conversion, tonnes d.m. ha^{-1};

$\Delta A_{TO\_OTHERS_i}$= area of land use *i* converted to another land-use category in a certain year, ha;

CF = carbon fraction of dry matter (default = 0.47), tonnes C (tonne d.m.)$^{-1}$;

V = merchantable growing stock volume, m^3 ha^{-1};

$BCEF_S$ = biomass conversion and expansion factor for expansion of merchantable growing stock volume to above-ground biomass, tonnes above-ground biomass (m^3 growing stock volume)$^{-1}$;

R = ratio of below-ground biomass to above-ground biomass, tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$;

i = type of land use converted to another land-use category.

[307] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.20, Equation 2.16.

Table 6.16. Average living biomass and deadwood stocks in Forest land and Grassland

C pool	FL rem FL		GL rem GL	
	1990	**2021**	**1990**	**2021**
Living biomass, m^3 ha^{-1}	171.46	201.06	8.39	8.39
Deadwood, m^3 ha^{-1}	9.56	20.73	1.31	1.31

6.3.2.2. CO_2 emissions from dead organic matter

Dead organic matter (DOM) C pool comprises deadwood and litter pools. The *Tier 1* method was implemented to estimate C stock change in DOM under the Cropland remaining cropland subcategory, assuming that deadwood and litter stocks are not at present in Cropland or are at equilibrium in orchards. Small changes in DOM pool occur due to removal or establishment of orchards, but these emissions were not estimated, as they 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 deadwood was estimated for Forest land and Grassland converted to cropland using the *Tier 2* method and Equation 6.3, where A represents the area of land transition in a certain year, DOM_{t1} is the average deadwood stock before and DOM_{t2} after the conversion (equal to zero in Cropland), and T is one year. The volumes of deadwood per area in Forest Land and Grassland were obtained from the NFI (Table 6.16), values of deadwood densities and C content from Köster *et al*. 2015[285285] (Table 6.24).

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[308] (Table 6.20) was used.

6.3.2.3. CO_2 emissions/removals from/by mineral soils

For mineral soils, the *Tier 2* method and Equation 6.9 were applied to estimate changes in soil organic carbon stocks. 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.

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 land had medium input. The shares of areas with different input regimes were acquired from Statistics Estonia and IACS/LPIS, 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 6.17 and their relative shares in Figure 6.17. Table 6.18 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

[308] National Inventory Report Sweden 2022: Annexes, pp. 141–142.

practice until 1999, but as of 2013 its share has decreased to only 35% (on average). Shares of different tillage practices for the period 2000–2012 were interpolated linearly.

Equation 6.9[309]

$$\Delta C_{Mineral} = \frac{\left(SOC_0 - SOC_{(0-T)}\right)}{D}$$

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 6.19);
F_{LU} / F_{MG} / F_I =	stock change factors for land-use systems/ management regime/ input of organic matter, dimensionless (Table 6.19);
A =	land area of the stratum being estimated, ha;
i =	set of management systems.

Table 6.17. Areas with different land use and input regimes on mineral soils within the Cropland remaining cropland category in 1990 and 2021

Land use	**Area in 1990, kha**	**Area in 2021, kha**
Long-term cultivated	894.26	644.53
High input	406.89	145.78
Medium input	420.30	489.49
Low input	67.07	9.27
Perennial	9.20	1.35
Set aside	109.71	275.94
Total CL rem CL, mineral soil	1 013.17	921.82

309 After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.30, Equation 2.25.

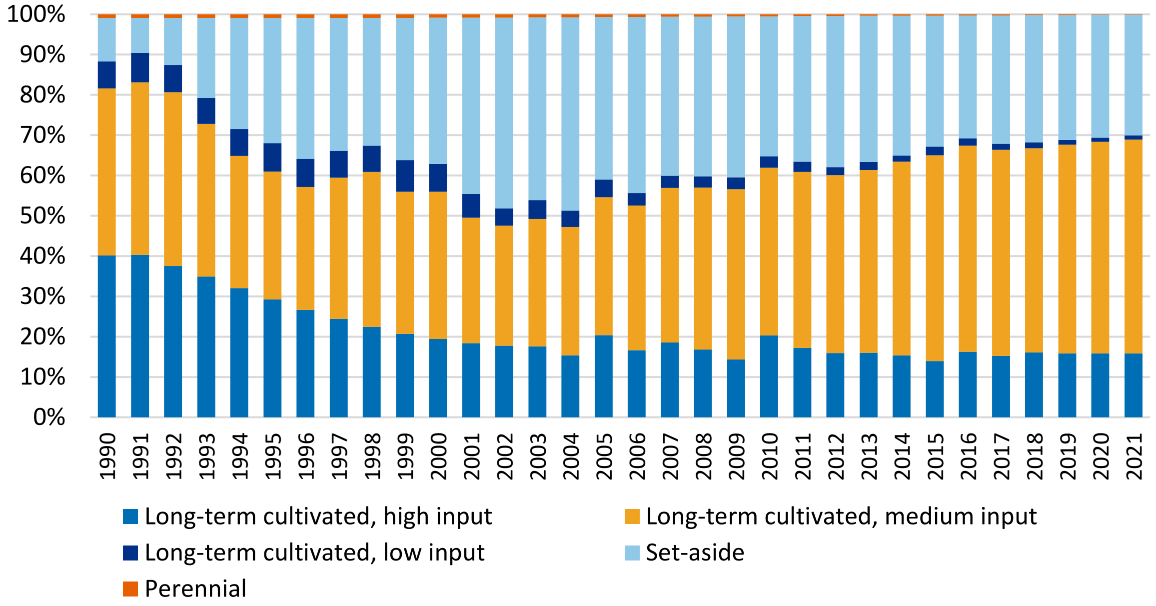


Figure 6.17. Relative shares of areas with different land use and input regimes within the Cropland remaining cropland category (mineral soils) in 1990–2021, %

Table 6.18. Proportions of different tillage practices in croplands[310] and related stock change factors[311]

Tillage practice	Full tillage	Reduced tillage	No-till
Proportion of cropland area 1990	1.00	0	0
Proportion of cropland area 2021	0.35	0.6	0.05
F_{MG}	1.00	1.08	1.15

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[266]). 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[312]), 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 6.19).

[310] Expert judgement by the Centre of Estonian Rural Research and Knowledge (former Estonian Crop Research Institute) (documented in archive).

[311] IPCC 2006 Guidelines, Volume 4, Chapter 5: Cropland, page 5.17, Table 5.5 (Temperate/Boreal, moist).

[312] Kõlli, E., Ellermäe, O. (2003). Humus status of postlithogenic arable mineral soils. Agronomy Research, 1, 161–174.

Table 6.19. Stock change factors, SOC_{REF} and estimated SOC stocks for different management categories in Cropland

Land use	Stock change factors[313]			SOC_{REF} t C ha^{-1}	IPCC 2006 default SOC_{REF}[314], t C ha^{-1}	Average SOC stocks, t C ha^{-1}	
	F_{LU}	F_{MG}	F_I			1990	2021
Long-term cultivated							
High input	0.69	1–1.06	1.11	98.34	93.30	75.32	79.50
Medium input	0.69	1–1.06	1.0			67.85	71.62
Low input	0.69	1–1.06	0.92			62.42	65.89
Perennial	1.0					98.34	98.34
Set aside	0.82					80.64	80.64

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[267]) 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 (data from Kõlli *et al.* 2009[266]). For Settlements converted to cropland subcategory, 2002–2021 average implied emission factor for Cropland remaining cropland was applied. EFs for mineral and organic soil are presented in Table 6.20.

Table 6.20. Cumulative land-use changes to Cropland in 2021 and soil emission factors

Land-use category	Area, kha	%	EF mineral soil, t C ha^{-1} yr^{-1}	EF organic soil[315], t C ha^{-1} yr^{-1}	EF litter[308], t C ha^{-1} yr^{-1}
Cropland remaining cropland	951.07	-	0.024[316]	-5.0	-
Forest land→ Cropland	1.70	6.6	-0.930	-	-1.50
Grassland→ Cropland	24.06	93.1	-0.904	-5.0	NA
Wetlands→ Cropland	NO	-	-	-5.0	NA
Settlements→ Cropland	0.09	0.4	0.141[317]	-	NA
Total Land to cropland	25.85	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 6.14) 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 6.17), but mineral soils on arable land have continued to sequester carbon due to changes in management practices (Table 6.19), although at a decreasing rate in recent decade.

[313] IPCC 2006 Guidelines, Volume 4, Chapter 5: Cropland, page 5.17, Table 5.5, (Temperate/Boreal, moist); Centre of Estonian Rural Research and Knowledge (Table 6.18)
[314] IPCC 2006 Guidelines, Volume 4, Chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories, page 2.31, Table 2.3 (Cold temperate, moist).
[315] IPCC 2006 Guidelines, Volume 4, Chapter 5: Cropland, page 5.19, Table 5.6 (Boreal/Cool Temperate).
[316] Implied emission factor (IEF) in 2021, varies between years.
[317] 2002–2021 average IEF for Cropland remaining cropland, mineral soils.

6.3.2.4. CO_2 emissions from organic soils

All croplands on organic soil are considered drained in Estonia. The *Tier 1* method and Equation 6.4 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 Guidlines (Table 6.20) was implemented due to the lack of country-specific data.

Emissions from organic soils have been relatively stable over the years (Figure 6.14) since the area of cultivated organic soils has not changed considerably (32.99 kha in 1990 to 30.85 kha in 2021).

6.3.3. Uncertainties and time series consistency

The uncertainty rates of activity data and the emission factors used are reported in Table 6.21. The uncertainties for activity data are obtained mainly from NFI and for emission factors from IPCC 2006, Sweden NIR 2022, and national publications. The uncertainties for mineral soil emission factors in the Land converted to cropland subcategories are based on expert judgements.

Table 6.21. Uncertainties in the Cropland category

IPCC category		Uncertainties %		EF References
		Activity data[318]	Emission factors	
4.B.1	Cropland remaining cropland – living biomass	39.3	4.3	Metsaruum OÜ 2012, IPCC 2006
4.B.1	Cropland remaining cropland – mineral soils	2.2	60.0	IPCC 2006, Kõlli *et al*. 2009
4.B.1	Cropland remaining cropland – organic soils	14.2	90.0	IPCC 2006
4.B.2.1	Forest land converted to cropland – dead organic matter	68.0	50.0	Köster *et al*. 2015, Sweden NIR 2022
4.B.2.2	Grassland converted to cropland – living biomass	47.9	50.0	IPCC 2006, NFI, Uri 2020
4.B.2.2	Grassland converted to cropland – deadwood	40.2	19.8	Köster *et al*. 2015
4.B.2	Land converted to cropland – mineral soils	17.3	60.0	Kõlli *et al*. 2009 & 2010
4.B.2	Land converted to cropland – organic soils	76.9	90.0	IPCC 2006

6.3.4. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Section 1.2.3. The QC/QA plan for the LULUCF sector includes the QC activities described in the IPCC 2006. The activities are carried out every year during the inventory and the QC check list is used during the inventory.

[318] Activity data uncertainty estimates are obtained from NFI.

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 6.19). The estimate that Cropland mineral soils are C sinks is supported also by the study by Tammik *et al*. 2018[319]. 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}.

6.3.5. Category-specific recalculations

A quantitative overview of recalculations is shown in Table 6.22, except for recalculations of direct N_2O emissions which are presented in Chapter 6.8.5. 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. Also, average growing stocks and deadwood volumes in Forest land and Grassland are updated annually, which has resulted in changes in estimated C losses in living biomass and dead wood pools after land use change to croplands.

According to the 2022 ERT recommendations, Estonia has changed soil emission factors compared to the previous submission: the calculation of country-specific factors for mineral soils in Land converted to cropland areas was corrected, and default emission factor from the IPCC 2006 Guidelines was applied for organic soils.

Table 6.22. Quantitative overview of recalculations compared to the 15.04.2022 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	-182.33	NO	NO	NO	NO	667.40
	Current submission	0.31	NO	-164.93	NO	NO	NO	NO	603.60
	Difference %	**NO**	**-**	**-9.5**	**-**	**-**	**-**	**-**	**-9.6**
1995	Previous submission	-0.37	87.75	-173.26	NO	NO	NO	-0.50	316.75
	Current submission	-0.37	87.79	-157.50	NO	NO	NO	-0.41	258.48
	Difference %	**NO**	**0.04**	**-9.1**	**-**	**-**	**-**	**-18.0**	**-18.4**
2000	Previous submission	-2.34	89.36	-168.09	NO	NO	NO	-1.25	301.86
	Current submission	-2.34	89.45	-153.26	NO	NO	NO	-1.03	246.31
	Difference %	NO	0.10	-8.8	-	-	-	-18.0	-18.4
2005	Previous submission	-4.02	158.74	-165.26	-5.29	-0.07	-0.69	-1.25	65.44
	Current submission	-4.02	158.49	-150.94	-3.87	-0.18	-1.48	-1.03	11.12
	Difference %	**NO**	**-0.2**	**-8.7**	**-26.9**	**143.7**	**114.0**	**-18.0**	**-83.0**

[319] 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.

		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	
2010	Previous submission	-3.80	169.99	-159.42	-15.37	-0.94	-4.49	-4.54	68.09
	Current submission	-3.80	169.49	-146.15	-13.35	-1.08	-9.35	-3.73	29.24
	Difference %	**NO**	**-0.3**	**-8.3**	**-13.1**	**14.6**	**108.3**	**-18.0**	**-57.1**
2015	Previous submission	-2.92	79.68	-158.81	-24.55	-2.35	-7.65	-9.67	462.95
	Current submission	-2.92	79.17	-145.65	-22.10	-2.56	-15.59	-7.93	431.13
	Difference %	**NO**	**-0.6**	**-8.3**	**-10.0**	**8.9**	**103.9**	**-18.0**	**-6.9**
2020	Previous submission	-2.92	74.37	-159.56	-1.99	-2.57	-10.44	-9.73	413.74
	Current submission	-2.92	73.57	-146.27	-2.02	-2.64	-21.61	-7.98	402.78
	Difference %	**NO**	**-1.1**	**-8.3**	**1.7**	**2.6**	**106.9**	**-18.0**	**-2.6**

6.3.6. Category-specific planned improvements

The Estonian Agricultural Research Centre of Estonia has established 30 monitoring plots to estimate C stock changes in cultivated organic soils. In these plots, soil C content and bulk density were measured in 2015; country-specific emission factors will be developed as soon as the re-measurements have been carried out. In addition, an ongoing project "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland" (LIFE OrgBalt, LIFE18 CCM/LV/001158)[304] aims to improve the GHG accounting methods and activity data for nutrient-rich organic soils in the temperate cool and moist climate region.

A project for developing a model-based soil organic carbon inventory system for cropland mineral soils was launched in 2021. As a result of the project, it was found that the average SOC stock of agricultural soils and the change in the carbon stock predicted using the Rothamsted carbon model[320] (RothC) were comparable to the measured values. The input data and parameters of the model still need to be specified before being used in the inventory.

6.4. Grassland (CRF 4.C)

6.4.1. Category description

The Grassland category includes CO_2 emissions and removals from living biomass, deadwood, mineral and organic soils, and non-CO_2 emissions from biomass burning. Net emissions from Grassland were -27.26 kt CO_2 eq. in 2021 (Figure 6.18). The Grassland category has been a CO_2 sink since 2002, mainly due to C sequestration in mineral soils after land-use change to grasslands. Highest emissions originate from the living biomass pool in the years of higher deforestation rates.

[320] Rothamsted carbon model. [www] https://www.rothamsted.ac.uk/rothamsted-carbon-model-rothc (28.02.2023)

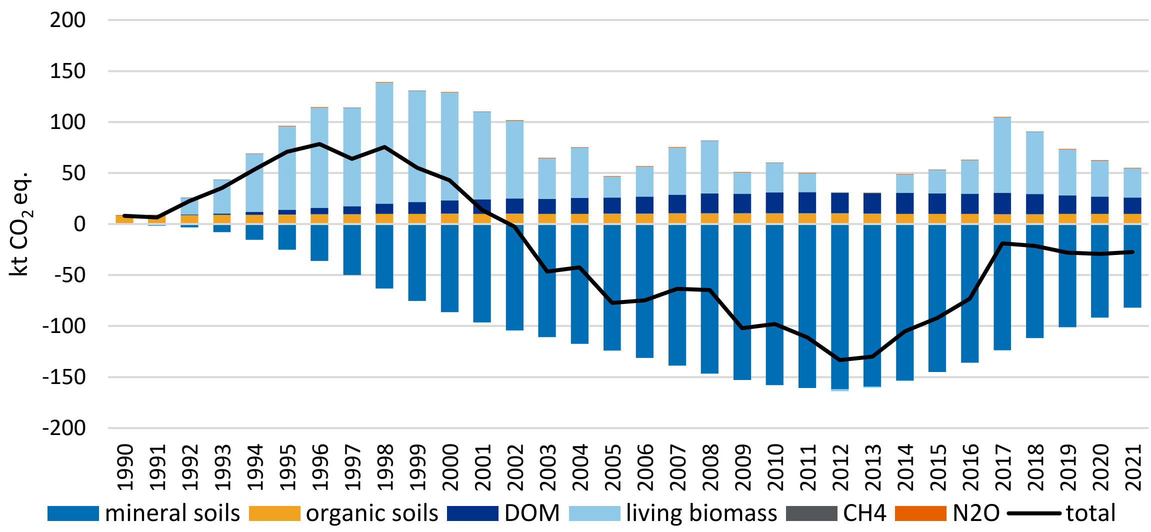


Figure 6.18. Annual GHG **e**missions (+) and removals (-) from the Grassland category in 1990−2021, kt CO_2 eq

The spatial share of the Grassland category was 6.1% of the overall Estonian area in 2021. The area of grasslands has decreased by 7.3% since 1990 (Figure 6.19). Due to natural succession, when the tree crown cover of grasslands exceeds 30%, the land is reallocated to the Forest land category, which is the main reason behind the decrease in the Grassland area.

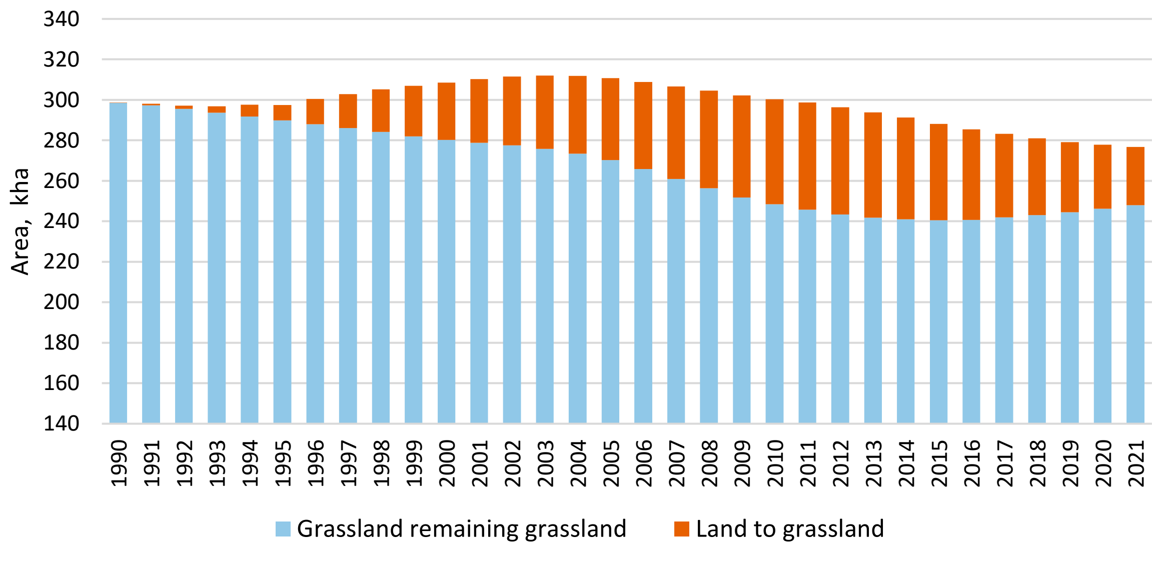


Figure 6.19. Grassland area in Estonia in 1990–2021, kha

6.4.2. Methodological issues

6.4.2.1. Change in carbon stocks in living biomass

For estimating carbon stock changes in living biomass, the *Tier 2* approach and *Method 2* – the stock-difference method (Equation 6.2) was applied. Only the change in woody biomass was considered. The NFI provides annually updated data about the grassland area, species distribution and growing stock volumes on grasslands. Weighted average $BCEF_S$ values were calculated for Land remaining grassland and for each land-use conversion to grassland separately, depending on the growing stock level and species composition (Table 6.23). Weighted average R values were calculated based on the average tree species distribution (Table 6.24). When calculating biomass losses due to the conversion of Forest land to grassland, same $BCEF_S$ and R values were assumed as for the Forest land remaining forest land category (Table 6.7and Table 6.8). The default carbon fraction (0.47) was used in calculations.

According to the NFI, average growing stock in the Grassland remaining grassland subcategory was 8.39 m^3 ha^{-1}. However, interannual changes in biomass were not estimated, as the number of NFI plots on grasslands where growing stock was measured was too small to make reliable assessments. Biomass C stock losses occurring in the year of transition from Forest land to grassland were calculated using Equation 6.8, where B_{AFTER} and B_{BEFORE} were equal to the average tree biomass in GL rem GL and FL rem FL categories for that particular year, respectively (growing stocks are presented in Table 6.16). 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.

Table 6.23. Implemented values of $BCEF_S$

Species	**Growing stock level (m^3 ha^{-1})[321]**			
	< 20	**21–50**	**51–100**	**> 100**
Pinus sylvestris	0.57	0.60	0.60	0.55
Picea abies	0.69	0.68	0.64	0.54
hardwoods	0.72	0.70	0.70	0.65
Weighted average $BCEF_S$	GL rem GL		0.644	
	FL to GL, biomass loss[322]		0.597	
	FL to GL, biomass increment		0.644	
	CL, WL, SL, OL to GL[323]		0.698	

Table 6.24. Average species distribution in the Grassland category and implemented values of root-shoot ratios (R), deadwood densities and carbon fractions

Species	**Distribution of tree species, living biomass (%)**	**R[324]**	**Distribution of tree species, deadwood (%)**	**Deadwood density (g cm^{-3})[325]**	**Deadwood CF**
Pinus sylvestris	11.1	0.39	16.4	0.270	0.495
Picea abies	15.4	0.39	48.5	0.272	0.491
Betula spp.	24.0	0.46	4.4	0.262	0.482
Alnus incana	11.7	0.46	3.6	0.266	0.482
Alnus glutinosa	5.3	0.46	0.1	0.236	0.482

321 Country-specific values (see Chapter 6.2.2.1)
322 Same as FL rem FL (Table 6.7)
323 Growing stock level < 20 m^3 ha^{-1}
324 IPCC 2006 Guidelines, Volume 4, Chapter 4: Forest Land, page 4.49, Table 4.5 (Boreal, above-ground biomass < 75 t ha^{-1}). For estimating biomass loss from the FL to GL conversion, the same R value was used as for the FL rem FL category (Table 6.8).
325 Deadwood densities and carbon fractions from Köster *et al*. 2015. For estimating biomass loss from the FL to GL conversion, same DW density and CF values were used as for the FL rem FL category.

Species	Distribution of tree species, living biomass (%)	R[324]	Distribution of tree species, deadwood (%)	Deadwood density (g cm^{-3})[325]	Deadwood CF
Other (hardwoods)	32.5	0.46	27.1	0.257	0.484
Weighted average		0.44		0.267	0.489
FL→GL, biomass and deadwood loss		0.235		0.265	0.487

Figure 6.20 illustrates annual changes in the living biomass carbon pool in Land converted to grassland subcategories. Emissions due to land-use change arise from deforestation (Forest land converted to grassland); other land-use changes result in increased biomass C stock.

The stock-difference method used for living biomass C stock change calculations comprises also carbon loss from biomass burning. CH_4 and N_2O emissions from biomass burning on grassland areas are described in Chapter 6.9.

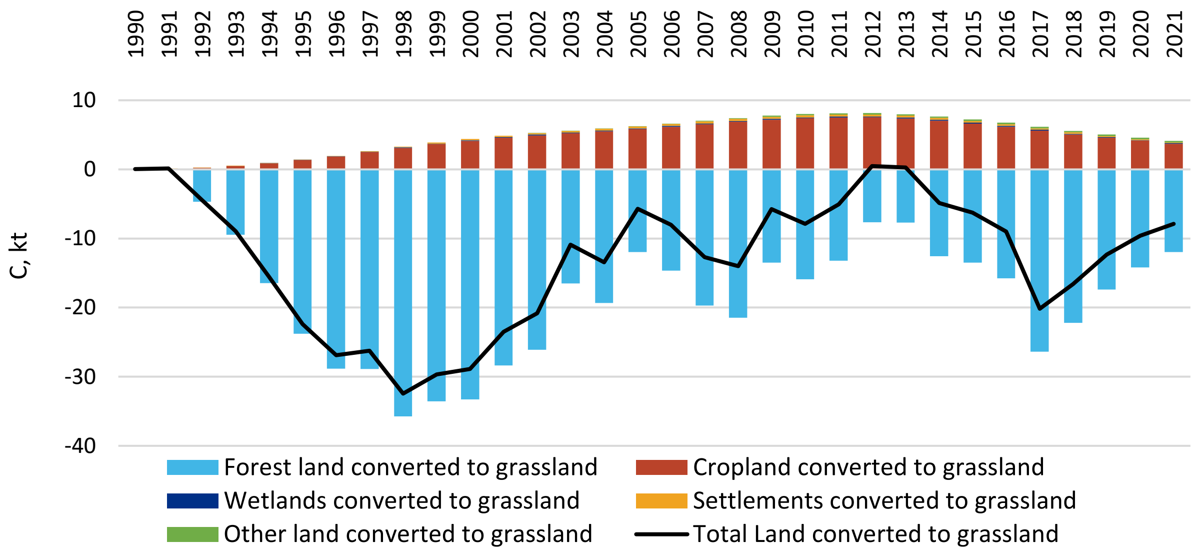


Figure 6.20. Carbon stock change in Grassland living biomass in 1990–2021, kt C

6.4.2.2. CO_2 emissions/removals from/by dead organic matter

The DOM pool consists of deadwood and litter pools. The NFI estimates annually the volume of deadwood for the whole grassland area, data is provided for the Grassland remaining grassland and Land converted to grassland subcategories. Deadwood densities and the C content are obtained from Köster *et al*. 2015[285] (Table 6.24). Carbon stock changes in the deadwood are estimated using the same method (*Tier 2*, stock-difference method) as under the Forest land category (Chapter 6.2.2.2). Average deadwood stock in the Grassland remaining grassland subcategory was 1.31 m^3 ha^{-1}; interannual changes in deadwood were not estimated due to the small number of NFI plots where grassland deadwood stocks were measured.

When Forest land is converted to grassland, deadwood C stock losses occur in the year of transition, similarly to the living biomass pool. Average deadwood stocks in the Forest land and Grassland categories are shown in Table 6.16. Other conversion types were assumed to have no losses in deadwood in the year of conversion. After the transition, deadwood volume was assumed to increase at a rate of 0.017 m^3 ha^{-1} yr^{-1}.

Estonia does not have sufficient country-specific data regarding forest and grassland litter stocks, thus under Grassland remaining grassland, for the litter pool the *Tier 1* method was implemented, assuming that carbon stocks are in equilibrium. Under the Land converted to grassland subcategory, the UNFCCC in-country review (2012) recommended the use of the litter emission factor from Sweden (Table 6.25) to avoid underestimation of emissions from deforestation.

Figure 6.18 illustrates the annual change in the DOM carbon stock in the Grassland category. All emissions derive from the conversion of Forest land to grassland; in the Grassland remaining grassland subcategory C stocks in deadwood and litter have been constant and thus the C stock change is equal to zero.

6.4.2.3. CO_2 emissions/removals from/by mineral soils

Since grasslands are not actively managed in Estonia, nor are additional inputs added to grassland soils, no changes are assumed in the Grassland remaining grassland mineral soil pool. Emission estimates 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[267]). 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[266]). 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 6.25).

Table 6.25. Cumulative land-use changes to Grassland in 2021, soil and litter emission factors

Land-use category	**Area, kha**	**%**	**EF mineral soil, t C ha^{-1} yr^{-1}**	**EF organic soil[326], t C ha^{-1} yr^{-1}**	**EF litter, t C ha^{-1} yr^{-1}**
Grassland remaining grassland	247.93	-	-	-0.25	-
Forest land→ Grassland	5.22	18.1	0.159	-0.25	-0.750[308]
Cropland→ Grassland	21.38	74.1	1.080	-0.25	NA
Wetlands→ Grassland	0.32	1.1	No emissions, soil C is not considered lost after LUC to Grassland	-0.25	NA
Settlements→ Grassland	0.57	2.0		NA	NA
Other land→ Grassland	1.39	4.8		NA	NA
Total Land to grassland	28.87	100.0			

6.4.2.4. CO_2 emissions from drained organic soils

The *Tier 1* method and Equation 6.4 were implemented to estimate the loss of carbon from drained organic grassland soils. The default emission factor from the 2006 IPCC Guidlines (Table 6.25) 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

[326] IPCC 2006 Guidelines, Volume 4, Chapter 6: Grassland, page 6.17, Table 6.3 (Boreal/Cold Temperate)

from 15–18% in the Grassland remaining grassland subcategory during 1990–2021. All organic soils falling under Land converted to grassland are considered drained in calculations.

Emissions from grassland organic soils have increased by 17.2% compared to the base year (from 8.49 to 9.94 kt CO_2), mainly due to the increased area of land conversion to grasslands.

6.4.3. Uncertainties and time series consistency

The uncertainty estimates related to the activity data and the emission factors are presented in Table 6.26. The uncertainties for activity data are obtained from NFI and for emission factors from IPCC 2006, Sweden NIR 2022 and national publications, or based on expert judgement (Land converted to grassland mineral soil EFs).

Table 6.26. Uncertainties in the Grassland category

IPCC category		Uncertainties %		EF References
		Activity data[327]	Emission factors	
4.C.1	Grassland remaining grassland – organic soils	10.8	90.0	IPCC 2006
4.C.2.1	Forest land converted to grassland – living biomass	53.3	50.0	IPCC 2006, NIR, Uri 2020
4.C.2	Land converted to grassland – living biomass (excl. FL)	46.5	50.0	IPCC 2006, NIR, Uri 2020
4.C.2.1	Forest land converted to grassland – deadwood	46.4	19.8	Köster *et al.* 2015
4.C.2.1	Forest land converted to grassland – litter	29.1	50.0	Sweden NIR 2022
4.C.2	Land converted to grassland – deadwood (excl. FL)	38.5	19.8	Köster *et al.* 2015
4.C.2	Land converted to grassland – mineral soils	11.9	60.0	Kõlli et al 2009 & 2010
4.C.2	Land converted to grassland – organic soils	41.4	90.0	IPCC 2006

6.4.4. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Chapter 1.2.3. The QC/QA plan for the sector includes the QC activities described in the IPCC 2006 Guidelines. The activities are carried out every year during the inventory. The QC check list is used during the inventory.

6.4.5. Category-specific recalculations

Activity data from NFI is updated and if necessary, corrected every year. Emissions from living biomass and DOM have changed compared to the previous submission for Land converted to grassland subcategory (Table 6.27) due to the recalculation of average growing stocks and deadwood volumes in Forest land. Estimated emissions from drained organic soils have significantly decreased because default emission factor from the IPCC 2006 Guidelines is

[327] Activity data uncertainty estimates are obtained from NFI

applied for organic soils since the current submission, according to the 2022 ERT recommendation. In addition, the calculation of country-specific factors for mineral soils in Land converted to grassland areas has been corrected, which has resulted in higher C sequestration in mineral soils.

Table 6.27. Quantitative overview of recalculations compared to the 15.04.2022 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	NO	NO	-12.71	0.04	0.0004	0.05	-0.12	46.74
	Current submission	NO	NO	-2.29	0.04	0.0004	0.09	-0.02	8.03
	Difference %	**-**	**-**	**-81.9**	**-0.3**	**NO**	**91.8**	**-83.3**	**-82.8**
1995	Previous submission	NO	NO	-11.83	-22.50	-1.59	3.63	-2.59	127.93
	Current submission	NO	NO	-2.15	-22.38	-1.22	6.88	-0.43	70.79
	Difference %	**-**	**-**	**-81.9**	**-0.5**	**-23.2**	**89.5**	**-83.3**	**-44.7**
2000	Previous submission	NO	NO	-11.52	-28.81	-3.96	12.37	-4.73	134.37
	Current submission	NO	NO	-2.10	-28.89	-3.54	23.53	-0.79	43.24
	Difference %	**-**	**-**	**-81.8**	**0.3**	**-10.4**	**90.2**	**-83.3**	**-67.8**
2005	Previous submission	NO	NO	-11.02	-5.54	-4.40	17.74	-5.51	31.97
	Current submission	NO	NO	-2.01	-5.70	-4.25	33.85	-0.92	-76.86
	Difference %	**-**	**-**	**-81.7**	**3.0**	**-3.4**	**90.7**	**-83.3**	**-340.4**
2010	Previous submission	NO	NO	-10.60	-7.58	-5.58	22.53	-6.66	28.92
	Current submission	NO	NO	-1.94	-7.88	-5.53	43.04	-1.11	-97.44
	Difference %	**-**	**-**	**-81.7**	**4.1**	**-1.0**	**91.01**	**-83.3**	**-436.9**
2015	Previous submission	NO	NO	-11.32	-6.05	-5.47	20.68	-4.86	25.77
	Current submission	NO	NO	-2.06	-6.25	-5.48	39.57	-0.77	-91.69
	Difference %	**-**	**-**	**-81.8**	**3.3**	**0.2**	**91.4**	**-84.1**	**-455.8**
2020	Previous submission	NO	NO	-12.56	-9.73	-4.65	12.65	-3.13	63.87
	Current submission	NO	NO	-2.25	-9.60	-4.61	24.98	-0.48	-29.46
	Difference %	**-**	**-**	**-82.1**	**-1.3**	**-0.8**	**97.4**	**-84.6**	**-146.1**

6.4.6. Category-specific planned improvements

A project titled "Applied research of greenhouse gases in the LULUCF sector in the framework of UNFCCC and Kyoto Protocol reporting" was launched in June 2013, funded by the Environmental Investment Centre. One of the objectives of the project was to determine changes in grassland soil organic carbon stocks. Project activities included conducting fieldwork, resampling previous sample plots and estimating carbon stock changes. Since the number of existing sample plots in natural and semi-natural grasslands was too small, detected changes were statistically not significant. However, new plots were established during the project and presumably it is possible to develop country-specific emission factors for grassland soils after remeasurement of C stocks.

An ongoing project "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland" (LIFE OrgBalt, LIFE18 CCM/LV/001158)[304] aims to improve the GHG accounting methods and activity data for nutrient-rich organic soils in the temperate cool and moist climate region.

6.5. Wetlands (CRF 4.D)

6.5.1. Category description

Wetlands covered 9.6% of the Estonia's territory in 2021. The area of wetlands (including peatland and inland water bodies) decreased until the beginning of the 1990s, since then the area has remained stable (Figure 6.21). 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 1 446.24 kt CO_2 eq. in 2021. Emissions derive mainly from peat extraction, especially horticultural peat (Figure 6.22), and only a small part from land conversion to other wetlands (0.3% of total Wetland GHG emissions in 2021). Emissions related to peat extraction fluctuate between years due to variation in off-site emissions from the horticultural use of peat.

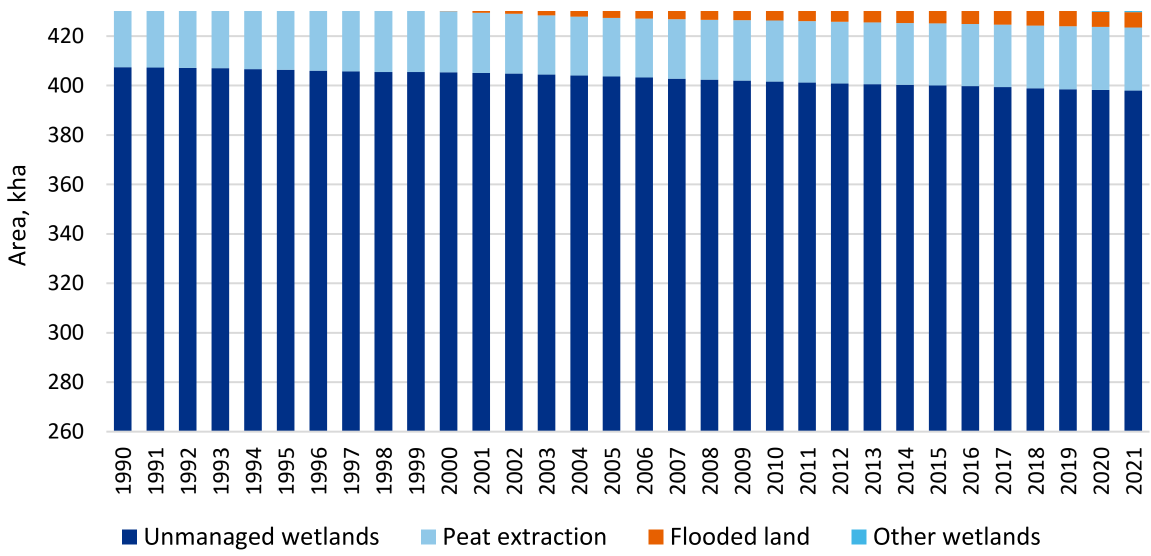


Figure 6.21. Area of Wetlands in Estonia in 1990–2021, kha

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 CRF Table 4.D and instead reflected in Table 4.1, as recommended by the ERT [328]. 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 CRF 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.

Activity data for the estimation of emissions related to peat extraction was obtained from the NFI, Estonian Land Board and Statistics Estonia. In 2021, the total area of peat extraction fields was 25.51 kha (Figure 6.21). The transition period for the Land being converted for peat

[328] FCCC/ARR/2016/EST L.3

extraction category is five years, as recommended in the IPCC 2006 Guidelines. Peat extraction usually proceeds in the same production area during several years. After extraction the area is restored.

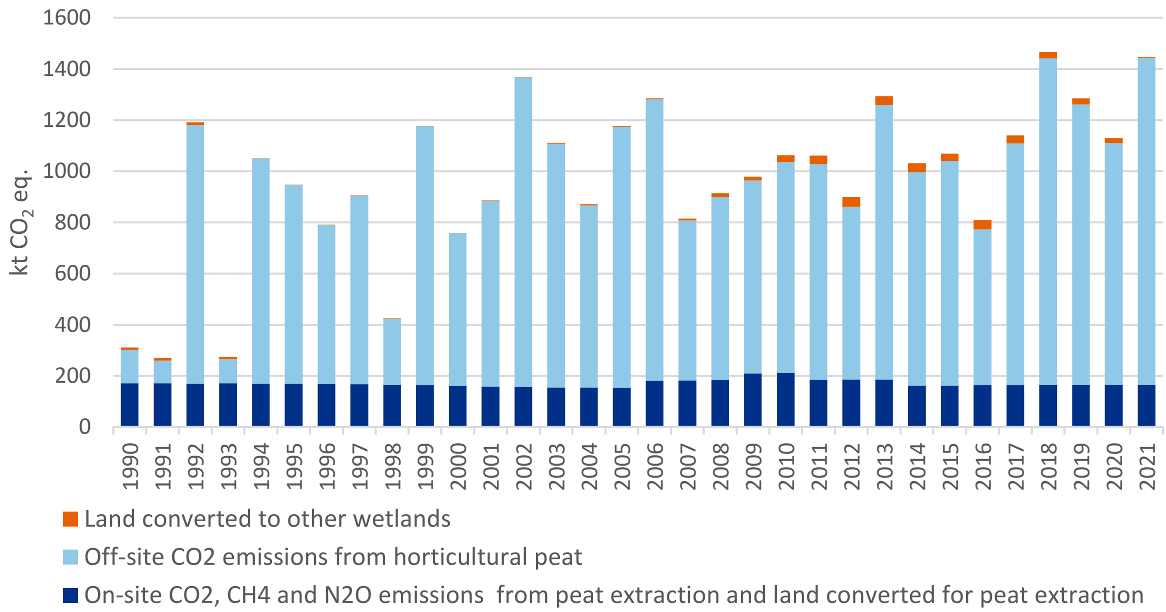


Figure 6.22. Annual GHG emissions from the Wetlands category in 1990−2021, kt CO_2 eq

6.5.2. Methodological issues

6.5.2.1. Change in carbon stocks in 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 DOM pools occurred during land conversion to wetlands (areas in Table 6.28) and were estimated using Equation 6.10 (*Tier 2*). It was assumed that all biomasses will be lost after the land-use change. In the case of Forest land conversion to peat extraction, the average growing stock and deadwood stock of the bog forest site types was applied (data from NFI). Also, parameters for converting growing stock volumes to biomass were calculated based on species distribution and growing stock level of bog forests. Average living biomass and deadwood C stocks in bog forests were 34.09 and 1.43 t C ha^{-1}, respectively. Litter stock was negligible, as litter production in bog forests is small and litter layer is normally inseparable from the peat layer. This assumption is confirmed by the data from the BioSoil soil survey, which was part of the programme 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[329]. Therefore, no losses in litter pool are expected. When Forest land is converted to Other wetlands, the average growing stock and deadwood volume across all forest types were used (Table 6.16). Since there is no country-specific EF for litter, Swedish factor was applied (Table 6.28).

[329] Data is available upon request through the Programme Co-ordinating Centre of ICP Forests (see http://icp-forests.net/page/plots-data).

Equation 6.10[330]

$$\Delta C_{CONVERSION} = \sum_i \left[\left(0 - B_{BEFORE_i}\right) \times \Delta A_{TO\_OTHERS_i}\right] \times CF$$

Where:

$\Delta C_{CONVERSION}$ =	initial change in biomass carbon stocks on land converted to another land category, tonnes C yr^{-1};
$B_{BEFOREi}$ =	biomass stocks on land type i before the conversion, tonnes d.m. ha^{-1};
$\Delta A_{TO\_OTHERSi}$ =	area of land use i converted to another land-use category in a certain year, ha yr^{-1};
CF =	carbon fraction of dry matter, tonne C (tonnes d.m.)$^{-1}$, the same factors as for Forest land and Grassland were used;
i =	type of land use converted to another land-use category

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 6.23). Deforestation to wetlands, and therefore also C losses due to land-use change have decreased in recent years.

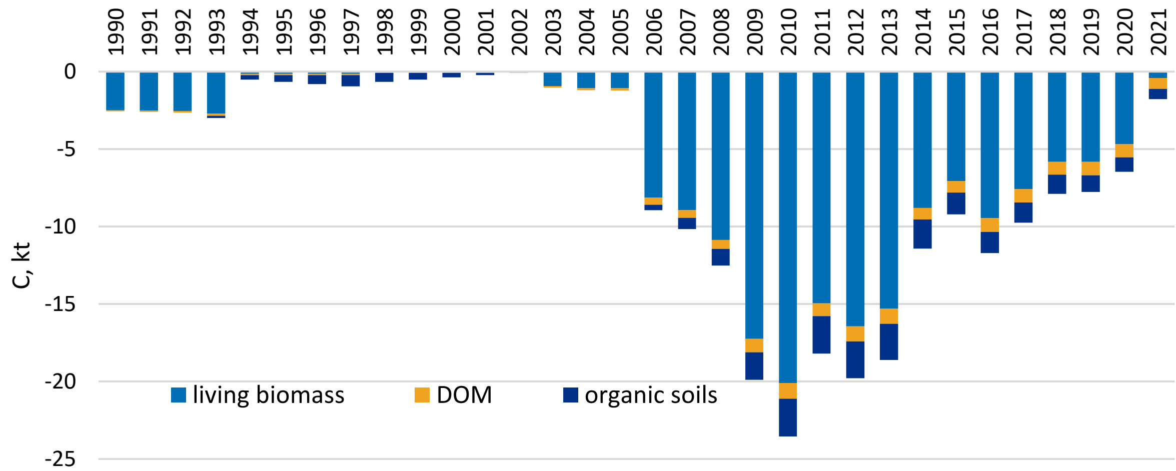


Figure 6.23. Carbon loss in living biomass, dead organic matter and soil after land conversion to peat extraction sites and other wetlands in 1990–2021, kt C

6.5.2.2. CO_2 emissions from organic soils

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 Equation 6.4 and a country-specific emission factor by Salm *et al.* 2012[268] (Table 6.28). Equation 6.11 was implemented for estimating off-site CO_2-C emissions.

[330] After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.20, Equation 2.16.

Equation 6.11[331]

$$CO_2\text{-}C_{WW_{peat_{off-site}}} = \frac{Wt_{dry\_peat} \times Cfraction_{wt\_peat}}{1000}$$

Where:

$CO_2\text{-}C_{WW\ peat\ off\text{-}site}$ = off-site CO_2-C emissions from peat removed for horticultural use, kt C yr^{-1};

Wt_{dry_peat} = air-dry weight of extracted peat, tonnes yr^{-1};

$Cfraction_{wt\_peat}$ = carbon fraction of air-dry peat by weight, tonnes C (tonnes of air-dry peat)$^{-1}$ (default 0.40[332]).

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 2021, 905.8 kt of peat was extracted, (data from the Estonian Land Board[333]), of which the production of energy peat was 35.0 kt[334]. Estimated production of horticultural peat was 870.8 kt in 2021, which is 35.2% more than in the previous year.

Cumulative land-use changes to peat extraction sites and other wetlands and applied emission factors are presented in Table 6.28. Emission estimates are illustrated in Figure 6.22 and Figure 6.23.

Table 6.28. Cumulative land-use changes to wetlands and peat extraction sites in 2021, 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	25.13	-1.741[268] (on-site C emissions) -15.60[335](total C emissions)	NA
Forest land→Peat extraction Wetlands→ Peat extraction	NO 0.37	-1.741	NA[336] NA
Flooded land			
Flooded land remaining flooded land	6.18	NA	NA
Land to flooded land	NO	-	-
Other wetlands			

[331] IPCC 2006 Guidelines, Volume 4, Chapter 7: Wetlands, page 7.11, Equation 7.5.
[332] IPCC 2006 Guidelines, Volume 4, Chapter 7: Wetlands, page 7.13, Table 7.5 (Boreal and Temperate, Nutrient-Rich).
[333] Roosalu, R. (2022). Eesti Vabariigi 2021. aasta maavaravarude koondbilansid (seisuga 31.12.2021. a.). Tallinn: Maa-amet. [www] https://geoportaal.maaamet.ee/docs/geoloogia/koondbilanss_2021_seletuskiri.pdf (31.01.2023).
[334] 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 (31.01.2023). Emissions related to the usage of peat for energy generation are reported under the Energy sector (Chapter 3).
[335] Implied EF in 2021, varies between years depending on off-site CO_2 emissions.
[336] 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}
Other wetlands remaining other wetlands	0.36	NA	NA
Forest land→ Other wetlands Cropland→ Other wetlands Grassland→ Other wetlands Settlements→ Other wetlands	1.39 0.10 0.41 1.68	no emissions, soil C is not considered lost after LUC to other wetlands	-0.495[337] NA NA NA

6.5.2.3. Non-CO_2 emissions from managed peatlands (CRF 4(II))

Equation 6.12 with a country-specific emission factor by Salm *et al.* 2012[268] (*Tier 2*) was implemented for estimating CH_4 emissions from organic soils managed for peat extraction.

Equation 6.12

$$CH_{4\,WW_{peatExtraction}} = \left(A_{peatExtraction} \times EF_{CH_4}\right) \times \frac{16}{12} \times 10^{-6}$$

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;

EF_{CH_4} = emission factor for actively managed peatland soils, kg CH_4-C ha^{-1} yr^{-1} (Table 6.30).

Equation 6.13 with a country-specific emission factor by Salm *et al.* 2012[268] (*Tier 2*) was used for estimating N_2O emissions from peat extraction sites.

Equation 6.13[338]

$$N_2O_{WW_{peatExtraction}} = \left(A_{peatExtraction} \times EF_{N_2O\text{-}N}\right) \times \frac{44}{28} \times 10^{-6}$$

Where:

$N_2OWW_{peatpxtraction}$ = 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;

$EF_{N_2O\text{-}N}$ = emission factor for actively managed peatland soils, kg N_2O-N ha^{-1} yr^{-1} (Table 6.30).

In 2021, non-CO_2 emissions from peat extraction areas were 4.08 t CH_4 and 7.62 t N_2O. Both emissions have decreased by 3.1% compared to the base year.

[337] 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 2022: Annexes, pp. 141–142).

[338] After IPCC 2006 Guidelines, Volume 4, Chapter 7: Wetlands, page 7.15, Equation 7.7.

6.5.3. Uncertainties and time series consistency

The uncertainty rates related to the activity data and the emission factors used in the estimates are presented in Table 6.29.

Table 6.29. Uncertainties in the Wetlands category

IPCC category		Uncertainties %		EF References
		Activity data[339]	Emission factors	
4.D.1.1	Peat extraction remaining peat extraction – organic soils	28.5	50.0	Salm *et al.* 2012, IPCC 2006
4.D.2.1	Land converted for peat extraction – organic soils	135.8	50.0	Salm *et al.* 2012
4.D.2.3	Land converted to other wetlands – living biomass	72.0	50.0	IPCC 2006, NFI, Uri 2020
4.D.2.3	Land converted to other wetlands – dead organic matter	72.0	48.9	Köster *et al.* 2015, Sweden NIR 2022
4(II) D.1	Emissions and removals from drainage and rewetting – CH_4	28.1	100.0	Salm *et al.* 2012
4(II) D.1	Emissions and removals from drainage and rewetting – N_2O	28.1	100.0	Salm *et al.* 2012

6.5.4. Category-specific QA/QC and verification

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 6.30). 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 6.30. Comparison of country-specific (Salm *et al.* 2012[268]) 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[340]	1.2 … 8.25[341]	-0.03 … 0.64[342]

[339] Activity data uncertainty estimates are obtained from NFI
[340] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.14, Table 2.1.
[341] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.26, Table 2.3.
[342] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.34, Table 2.5.

6.5.5. Category-specific recalculations

Updated activity data, growing stocks and deadwood volumes from the NFI were used for estimating GHG emissions from peatlands and land converted to wetlands. This has resulted in minor recalculations of GHG emissions from the Wetlands category (Table 6.31).

Table 6.31. Quantitative overview of recalculations compared to the 15.04.2022 submission

Wetlands TOTAL emissions		CO_2, kt	CH_4, t	N_2O, t
1990	Previous submission	308.58	4.22	7.87
	Current submission	307.92	4.21	7.86
	Difference %	**-0.2**	**-0.2**	**-0.2**
1995	Previous submission	944.56	4.19	7.82
	Current submission	944.11	4.18	7.81
	Difference %	**-0.05**	**-0.2**	**-0.2**
2000	Previous submission	755.57	3.98	7.43
	Current submission	755.29	3.97	7.41
	Difference %	**-0.04**	**-0.2**	**-0.2**
2005	Previous submission	1176.49	3.80	7.09
	Current submission	1175.96	3.79	7.08
	Difference %	**-0.04**	**-0.2**	**-0.2**
2010	Previous submission	1060.79	3.96	7.40
	Current submission	1060.25	3.96	7.38
	Difference %	**-0.05**	**-0.2**	**-0.2**
2015	Previous submission	1066.22	4.01	7.49
	Current submission	1065.84	4.01	7.48
	Difference %	**-0.04**	**-0.2**	**-0.2**
2020	Previous submission	1128.40	4.09	7.63
	Current submission	1127.78	4.08	7.62
	Difference %	**-0.06**	**-0.2**	**-0.2**

6.5.6. Category-specific planned improvements

Estonia has an ongoing research project that aims to determine country-specific C content in peat removed for horticultural use.

6.6. Settlements (CRF 4.E)

6.6.1. Category description

Settlements, including all built-up areas, covered 7.8% of Estonia's territory in 2021. The area of settlements has been increasing continuously in Estonia (Figure 6.24) mainly on behalf of forest lands (Table 6.4 and Table 6.32). Carbon flows under Settlements remaining settlements have not been calculated in the current submission 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 319.10 kt CO_2 eq. in 2021 (Figure 6.25).

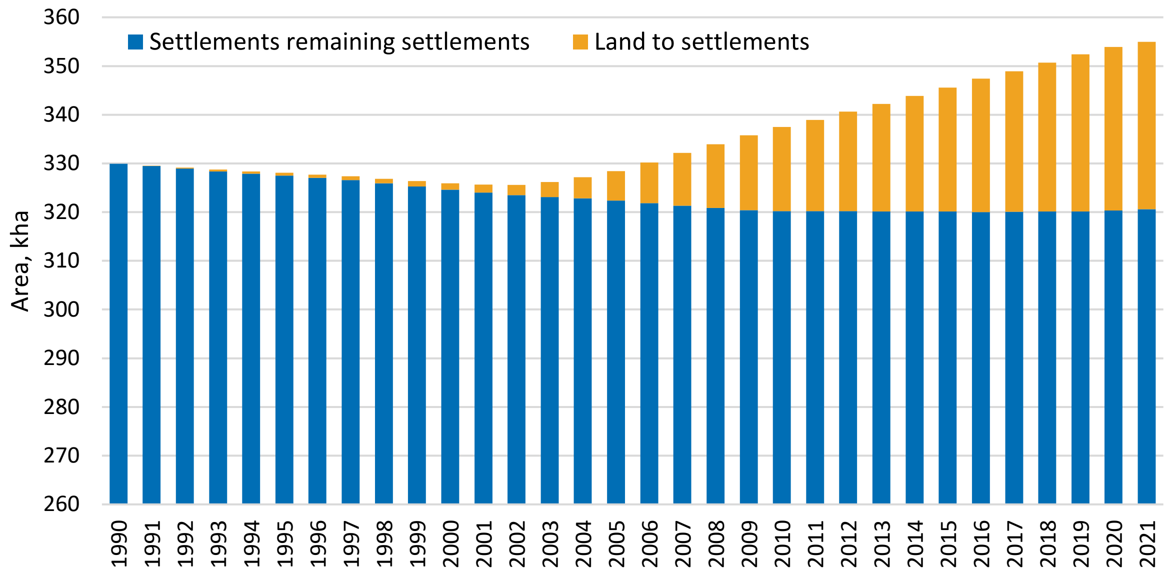


Figure 6.24. Area of Settlements in Estonia in 1990–2021, kha

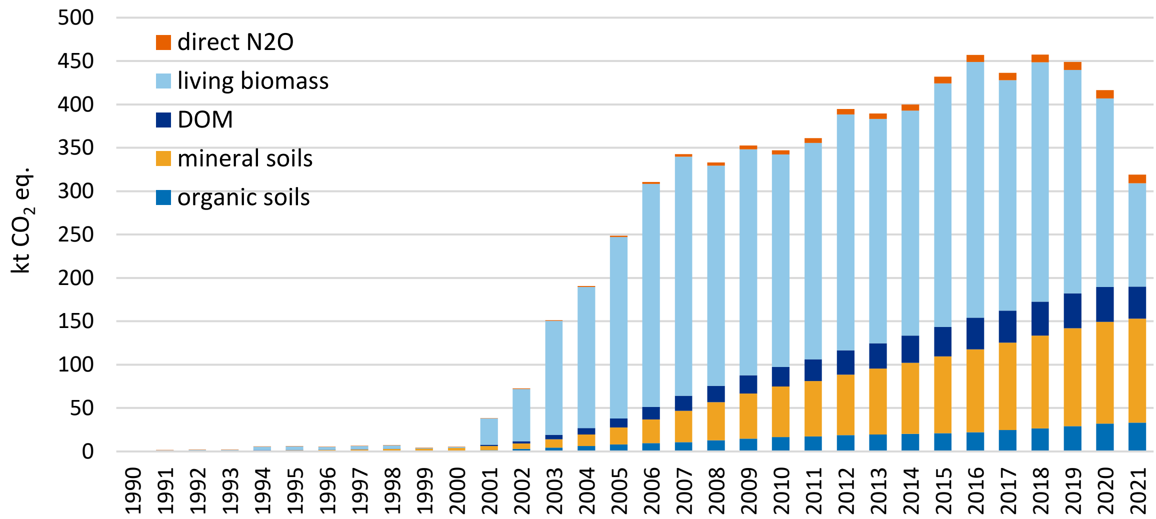


Figure 6.25. Emissions related to land conversion to settlements, 1990–2021, kt CO_2 eq.

6.6.2. Methodological issues

Carbon stocks in living biomass and deadwood pools in Forest land and Grassland were assumed to be lost during land-use conversion and emissions were calculated using Equation 6.10. Biomass stocks prior to the land-use change (B_{BEFORE}) were obtained from the NFI (Table 6.16).

Due to missing country-specific emission factors for litter and soil pools, EF from Sweden was implemented for litter[308] and *Tier 1* method from the IPCC 2006 Guidelines for soils. As it was not possible to stratify Land converted to settlements areas as suggested in the IPCC 2006 Guidlines[343], 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

[343] IPCC 2006 Guidelines, Volume 4, Chapter 8: Settlements, page 8.24.

average SOC stock in mineral forest soils in Estonia is 108.0 t C ha^{-1} [344], in Grassland category 107.3 t C ha^{-1} [345], and in Cropland 88.2 t C ha^{-1} [346]. It was also assumed that SOC stocks in Other land category are negligible and 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[347].

Table 6.32. Cumulative land-use changes to settlements in 2021, 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	17.89	52.1	-1.080	-5.0	-0.495
Cropland→ Settlements	8.40	24.5	-0.882	-5.0	NA
Grassland→ Settlements	7.17	20.9	-1.073	-	NA
Wetlands→ Settlements	0.18	0.5	-	-5.0	NA
Other land→ Settlements	0.69	2.0	NO	-	NA
Total Land to settlements	34.32	100.0			

6.6.3. Uncertainties and time series consistency

The uncertainty rates related to activity data and emission factors in the Settlements category are presented in Table 6.33.

Table 6.33. Uncertainties in the Land converted to settlements category

IPCC category		Uncertainties %		EF References
		Activity data[348]	Emission factors	
4.E.2	Land converted to settlements – living biomass	19.6	50.0	IPCC 2006, NFI, Uri 2020
4.E.2	Land converted to settlements – deadwood	19.3	19.8	Köster *et al.* 2015
4.E.2	Land converted to settlements – litter	20.1	50.0	Sweden NIR 2022
4.E.2	Land converted to settlements – soils	16.1	58.2	IPCC 2006, Kõlli *et al.* 2004, 2007, 2009

6.6.4. Category-specific QA/QC and verification

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 1.2.3.

[344] Kõlli, R., Asi, E., Köster, T. (2004). Organic carbon pools in Estonian forest soils. Baltic Forestry 10, 19–26.
[345] Kõlli, R., Köster, T., Kauer, K. (2007). Organic matter of Estonian grassland soils. Agronomy Research 5, 109–122.
[346] 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.
[347] IPCC 2006 Guidelines, Volume 4, Chapter 5: Cropland, page 5.19, Table 5.6 (Boreal/Cool Temperate).
[348] Activity data uncertainty estimates are obtained from NFI

6.6.5. Category-specific recalculations

A quantitative overview of recalculations is shown in Table 6.34, except for recalculations of direct N_2O emissions which are presented in Chapter 6.8.5. Updated activity data, growing stocks and deadwood volumes from the NFI were used for estimating carbon losses due to land conversion to Settlements. For instance, corrected annual land conversion areas were somewhat higher for recent years compared to the previous submission, causing also increase in emissions from the living biomass and DOM pools. More significant changes in estimated emissions have occurred in mineral and organic soils, as tier 1 methodology from the IPCC 2006 Guidelines was applied for these pools, according to the 2022 ERT recommendations.

Table 6.34. Quantitative overview of recalculations in the Settlements compared to the 15.04.2022 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 %	**-**	**-**	**-**	**-**	**-**
1995	Previous submission	-1.27	-0.05	-0.49	NO	6.65
	Current submission	-1.15	-0.05	-0.45	NO	6.04
	Difference %	**-9.5**	**-6.7**	**-8.7**	**-**	**-9.2**
2000	Previous submission	-0.42	-0.04	-1.76	NO	8.13
	Current submission	-0.30	-0.05	-1.07	NO	5.24
	Difference %	**-26.9**	**20.6**	**-39.0**	**-**	**-35.6**
2005	Previous submission	-57.94	-3.36	-8.90	-1.10	261.41
	Current submission	-56.99	-2.86	-5.28	-2.23	246.99
	Difference %	**-1.6**	**-14.9**	**-40.6**	**102.0**	**-5.5**
2010	Previous submission	-67.41	-6.21	-25.80	-2.52	373.77
	Current submission	-66.73	-6.16	-15.95	-4.48	342.17
	Difference %	**-1.0**	**-0.8**	**-38.2**	**78.0**	**-8.5**
2015	Previous submission	-77.40	-9.13	-40.57	-3.08	477.32
	Current submission	-76.53	-9.32	-24.13	-5.73	424.28
	Difference %	**-1.1**	**2.1**	**-40.5**	**86.1**	**-11.1**
2020	Previous submission	-38.83	-9.72	-49.66	-4.30	375.84
	Current submission	-59.19	-10.96	-31.99	-8.79	406.73
	Difference %	**52.4**	**12.7**	**-35.6**	**104.6**	**8.2**

6.6.6. Category-specific planned improvements

There are no category-specific planned improvements.

6.7. Other Land (CRF 4.F)

6.7.1. Category description

The Other land category includes all land that does not fall into the five previously described land-use categories, comprising 1.0% of the total Estonian land territory. In the 2023 submission, CO_2 emissions from the Forest land, Cropland and Grassland conversion to Other land are reported. Land-use change from Wetlands to Other land was assumed not to cause any changes in C pools, and land conversions from Settlements to Other land have not occurred. In addition, N_2O emissions from N mineralisation and leaching associated with land-use change to Other land are estimated (methodology described in Chapter 6.8).

Conversions to the Other land category have taken place since 2004 according to the NFI, mainly from the Forest land (Table 6.35) resulting in high emissions from the living biomass C pool (Figure 6.26). Total emissions from Land converted to other land were estimated at 101.55 kt CO_2 eq. in 2021.

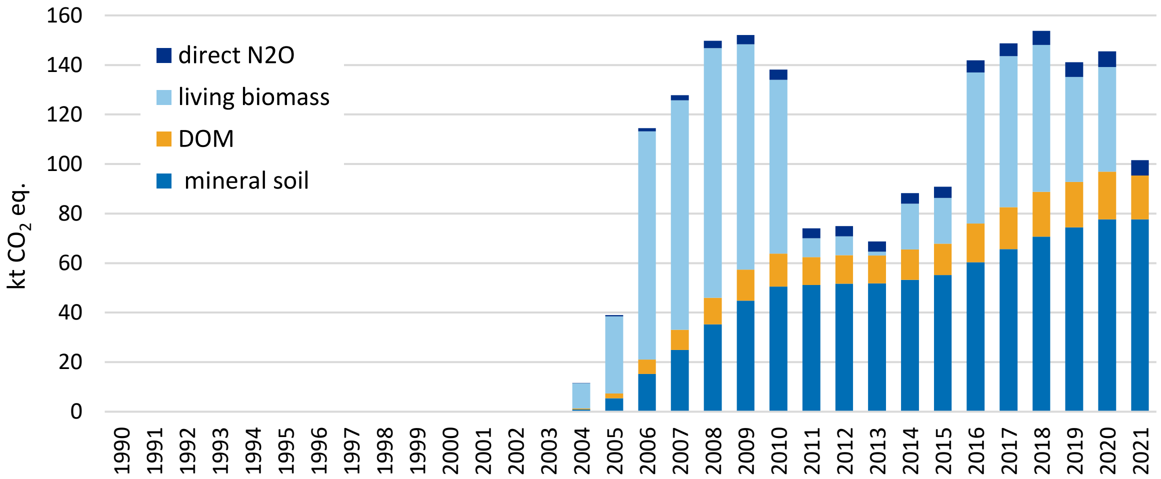


Figure 6.26. Emissions related to land-use changes to other land, 1990–2021, kt CO_2 eq.

6.7.2. Methodological issues

It was assumed that all C stocks are lost after land use change to Other land (default assumption according to the IPCC 2006 Guidelines[349]). C stock changes in the living biomass and deadwood pools were estimated by implementing Equation 6.10. Biomass stocks prior to the land-use change (B_{BEFORE}) were obtained from the NFI (Table 6.16). C stock changes in litter and mineral soil pool were divided over 20 years. Emissions from litter pool were calculated using average litter C stock in Swedish forests (30 t C ha^{-1} [350]). The average SOC stock in mineral forest soils in Estonia is 108.0 t C ha^{-1} [342], in Grassland category 107.3 t C ha^{-1} [343], and in Cropland 88.2 t C ha^{-1} [344].

[349] IPCC 2006 Guidelines, Volume 4, Chapter 9: Other Land.
[350] National Inventory Report Sweden 2022: Annexes, page 141.

Table 6.35. Cumulative land-use changes to Other land in 2021, soil and litter emission factors. (Assumptions are described in the text.)

Land-use change	**kha**	**%**	**EF mineral soil, t C ha^{-1}**	**EF litter, t C ha^{-1}**
Forest land→ Other land	3.21	77.2	-5.40	-1.5
Cropland→ Other land	0.57	13.7	-4.41	NA
Grassland→ Other land	0.26	6.1	-5.37	NA
Wetlands→ Other land	0.12	2.9	NO	NA
Total Land to other land	4.15	100.0		

6.7.3. Uncertainties and time series consistency

The uncertainty rates related to the activity data and emission factors used in the estimates are presented in Table 6.36.

Table 6.36. Uncertainties used in the Land converted to other land category

IPCC category		**Uncertainties %**		**EF References**
		Activity data[351]	**Emission factors**	
4.F.2.1	Forest Land converted to other land – dead organic matter	50.9	50.0	Sweden NIR 2022
4.F.2	Land converted to other land – soils	48.1	70.0	IPCC 2006, Kõlli *et al.* 2004, 2007, 2009

6.7.4. Category-specific QA/QC and verification

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 1.2.3.

6.7.5. Category-specific recalculations

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 Table 6.37 a quantitative overview of recalculations is shown, except for recalculations of direct N_2O emissions which are presented in Chapter 6.8.5.

Significant increases in emissions compared to the previous submission have occurred in the DOM and soil C pools. As in the Settlements category, *Tier 1* methodology from the IPCC 2006 Guidelines was applied for mineral soils, assuming that all SOC is lost during land conversion to Other land. The same assumption was also used for the litter pool.

[351] Activity data uncertainty estimates are obtained from the NFI.

Table 6.37. Quantitative overview of recalculations compared to the 15.04.2022 submission

		C stock change, kt			Total Other land net CO_2, kt
		Living biomass	DOM	Mineral soils	
1990/ 1995/ 2000	Previous submission	NO	NO	NO	NO
	Current submission	NO	NO	NO	NO
	Difference %	**-**	**-**	**-**	**-**
2005	Previous submission	-8.63	-0.40	-0.52	35.02
	Current submission	-8.51	-0.50	-1.49	38.49
	Difference %	**-1.4**	**22.9**	**189.2**	**9.9**
2010	Previous submission	-19.18	-1.69	-4.42	92.74
	Current submission	-19.13	-3.63	-13.78	133.99
	Difference %	**-0.3**	**114.6**	**211.6**	**44.5**
2015	Previous submission	-5.07	-1.27	-4.85	41.00
	Current submission	-5.04	-3.46	-15.05	86.35
	Difference %	**-0.6**	**173.1**	**210.6**	**110.6**
2020	Previous submission	-9.51	-1.87	-6.60	65.98
	Current submission	-11.53	-5.25	-21.19	139.21
	Difference %	**21.2**	**179.8**	**220.9**	**111.0**

6.7.6. Category-specific planned improvements

There are no category-specific planned improvements.

6.8. N_2O emissions from N mineralization and leaching

6.8.1. 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 during 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 (CRF 3.D).

In 2021, direct N_2O emissions from N mineralization were 23.32 kt CO_2 eq. Most emissions occurred due to the expansion of Settlements (Figure 6.27). 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 2021, indirect N_2O emissions equalled 5.25 kt CO_2 eq.

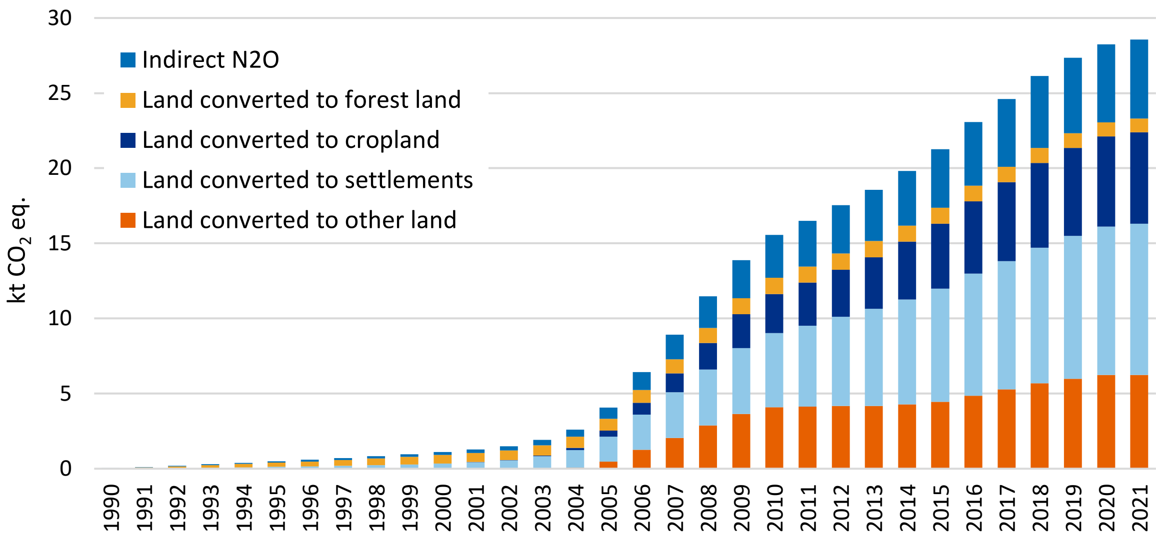


Figure 6.27. N_2O emissions from nitrogen mineralization and leaching, kt CO_2 eq.

6.8.2. Methodological issues

6.8.2.1. Direct N_2O emissions from N mineralization (CRF 4(III))

The *Tier 1* method (Equation 6.14) 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 6.14[352]

$$N_2O_{Min} = F_{SOM} \times EF_1 \times \frac{44}{28}$$

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$)^{-1}$ (default 0.01[353])
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;
LU = land use and/or management system type.

[352] 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.
[353] 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.

6.8.2.2. Indirect N_2O emissions from leaching/runoff (CRF 4(IV)

Indirect N_2O emissions from leaching and runoff were estimated using Equation 6.15 (*Tier 1*).

Equation 6.15[354]

$$N_2O_{(L)} = F_{SOM} \times Frac_{LEACH\text{-}(H)} \times EF_5 \times \frac{44}{28}$$

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 6.14);

$Frac_{LEACH\text{-}(H)}$ = 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[355] was applied in calculations;

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 0.0075[355]).

6.8.3. Uncertainties and time series consistency

The uncertainty rates of activity data and the emission factors used are reported in Table 6.38. The uncertainties for activity data are the same as for mineral soil C stock change values (direct N_2O emissions) or for total F_{SOM} (indirect N_2O emissions). Uncertainties for emission factors are obtained from IPCC 2006. Since the uncertainties for N_2O emissions are very large and the estimates must be non-negative, the uncertainty ranges are asymmetric with respect to the mean (lognormal distribution was assumed).

Table 6.38. Uncertainties related to N_2O emissions from N mineralization and leaching

IPCC category		Uncertainties %			EF References
		Activity data	Emission factor		
			low	high	
4(III) A.2	Land converted to forest land – Direct N_2O emissions from N mineralization	61.3	-80	230	IPCC 2006
4(III) B.2	Land converted to cropland – Direct N_2O emissions from N mineralization	62.5	-80	230	IPCC 2006
4(III) E.2	Land converted to settlements – Direct N_2O emissions from N mineralization	71.8	-80	220	IPCC 2006
4(III) F	Land converted to other land – Direct N_2O emissions from N mineralization	84.9	-80	225	IPCC 2006
4(IV)	Indirect N_2O emissions from managed soils – Nitrogen leaching and runoff	53.1	-90	350	IPCC 2006

[354] 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.
[355] 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.

6.8.4. Category-specific QA/QC and verification

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 1.2.3.

6.8.5. Category-specific recalculations

A quantitative overview of recalculations is shown in Table 6.39. Changes in estimated N_2O emissions compared to the previous submission result mainly from the recalculation of mineral soil C stock changes in Forest land (Chapter 6.2.5), Cropland (Chapter 6.3.5), Grassland (Chapter 6.4.5), Settlements (Chapter 6.6.5), and Other land (Chapter 6.7.5) categories.

Table 6.39. Quantitative overview of recalculations of N_2O emissions from N mineralization and leaching/runoff compared to the 15.04.2022 submission

N_2O emissions, t		**N_2O_{Min}** (CRF 4(III))				**$N_2O_{(L)}$** (CRF 4(IV))
		L to FL	**L to CL**	**L to SL**	**L to OL**	
1990	Previous submission	0.04	NO	NO	NO	0.01
	Current submission	0.09	NO	NO	NO	0.02
	Difference %	**114.0**	**-**	**-**	**-**	**114.0**
1995	Previous submission	0.49	NO	0.51	NO	0.23
	Current submission	1.05	NO	0.47	NO	0.34
	Difference %	**114.0**	**-**	**-8.7**	**-**	**51.1**
2000	Previous submission	1.00	NO	2.42	NO	0.77
	Current submission	2.13	NO	1.31	NO	0.78
	Difference %	**114.1**	**-**	**-45.6**	**-**	**1.0**
2005	Previous submission	1.39	0.73	11.55	0.66	3.22
	Current submission	2.99	1.55	6.27	1.76	2.83
	Difference %	**114.1**	**114**	**-45.7**	**167**	**-12.3**
2010	Previous submission	1.89	4.70	33.05	5.21	10.09
	Current submission	4.04	9.80	18.69	15.40	10.78
	Difference %	**114.1**	**108.3**	**-43.4**	**195.2**	**6.9**
2015	Previous submission	1.85	8.01	52.01	5.70	15.21
	Current submission	3.97	16.34	28.42	16.80	14.74
	Difference %	**114.1**	**103.9**	**-45.4**	**194.7**	**-3.0**
2020	Previous submission	1.58	10.94	62.86	7.72	18.69
	Current submission	3.57	22.64	37.28	23.51	19.57
	Difference %	**126.1**	**106.9**	**-40.7**	**204.8**	**4.7**

6.8.6. Category-specific planned improvements

There are no category-specific planned improvements.

6.9. Non-CO_2 emissions from biomass burning (CRF 4 (V))

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 due to the stock change (stock-difference) method used for calculations, thus CO_2 emissions are not reported under the current category in order 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.

6.9.1. Methodology, data availability and sources, emission factors

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 highest level of emissions from biomass burning reported in the period 1990–2021 was 8.0 kt CO_2 eq. in 2006, that constituted 0.04% of the national total GHG emissions (without LULUCF) and that the 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 6.28). The detected burnt area is separated into several land-use categories, if necessary.

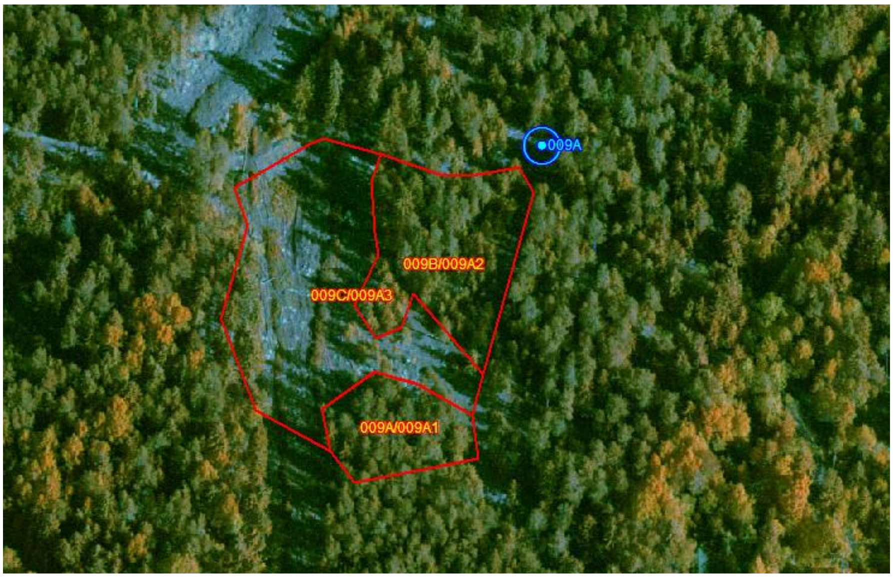


Figure 6.28. Reported fire location (blue circle), actual location (red border) and data analyses

The *Tier 2* method and Equation 6.16 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 6.16[356]

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

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};[357]
C_f = combustion efficiency (or fraction of the biomass combusted), dimensionless; for 1990–2011 the value 0.15[358] 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 6.40.

According to ERS and EstEA wildfires occurred on 22.54 ha of forests and 12.05 ha of Grasslands in 2021 (Figure 6.29). Fluctuations in the area burnt are caused mainly by the weather conditions in different years (e.g. extremely hot and dry summers).

Table 6.40. Emission factors (G_{ef}, g kg^{-1} dry matter burnt) used for estimation of non-CO_2 greenhouse gas emissions from fires [359]

	CH_4	N_2O
Forest land	6.1	0.06
Grassland, Wetland	2.3	0.21

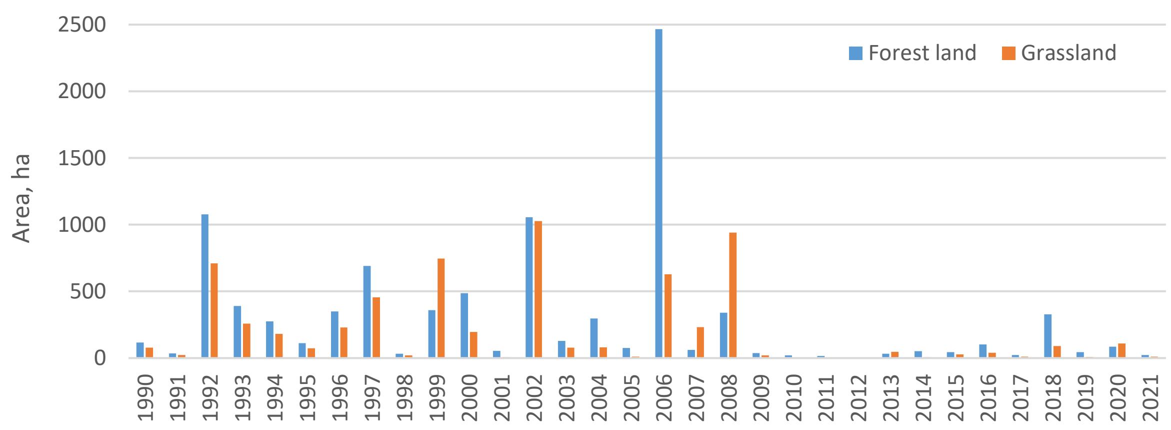


Figure 6.29. Annual area of Forest land and Grassland (incl. WL areas) affected by fires in 1990−2021, ha

[356] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.42, Equation 2.27.
[357] For 1990–2011 year-specific average forest biomass growing stock was used as the basis for M_B.
[358] 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).
[359] 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).

The total amount of CH_4 and N_2O released after wildfires in 2021 was 2.26 t and 0.04 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.

6.9.2. Uncertainties and time series consistency

Uncertainty estimates of CH_4 and N_2O emissions from wildfires were carried out based on IPCC Guidelines. Activity data concerning the area burnt was obtained from the Estonian Rescue Service and the Estonian Environment Agency. The uncertainty rates are shown in Table 6.41.

Table 6.41. Uncertainties of non-CO_2 emission estimates from biomass burning

IPCC category	Uncertainties %		EF References
	Activity data[360]	Emission factors	
Biomass burning (CH_4)	34.5	70.0	IPCC 2006, Vol 4, Table 2.5 p. 2.47
Biomass burning (N_2O)	34.5	70.0	IPCC 2006, Vol 4, Table 2.5 p. 2.47

6.9.3. Category-specific QA/QC and verification

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 1.2.3.

Activity data obtained from the Estonian Rescue Service is verified and corrected, if necessary, during field inventory carried out by the Estonian Environment Agency.

6.9.4. Category-specific recalculations

Non-CO_2 emissions from biomass burning were recalculated for the period 1990–2011 using updated average growing stocks for Forest land and Grassland (Table 6.42). Estimated emissions have decreased compared to the previous submission, since recalculated average aboveground biomass stocks are lower for the 1990–2011 period.

Table 6.42. Quantitative overview of recalculations of non-CO_2 emissions from biomass burning compared to the 15.04.2022 submission

		Forest land		Grassland		Total, CO_2 eq.
		CH_4, t	N_2O, t	CH_4, t	N_2O, t	
1990	Previous submission	11.22	0.11	0.23	0.02	0.36
	Current submission	10.95	0.11	0.14	0.01	0.34
	Difference %	**-2.5**	**-2.5**	**-37.5**	**-37.5**	**-3.6**
1995	Previous submission	11.11	0.11	0.22	0.02	0.35
	Current submission	10.90	0.11	0.14	0.01	0.34
	Difference %	**-1.9**	**-1.9**	**-37.5**	**-37.5**	**-3.0**
2000	Previous submission	49.85	0.49	0.59	0.05	1.56
	Current submission	49.20	0.48	0.37	0.03	1.53
	Difference %	**-1.3**	**-1.3**	**-37.5**	**-37.5**	**-2.0**

[360] All activity data uncertainty estimates are obtained from the NFI.

2005	Previous submission	8.03	0.08	0.03	0.00	0.25
	Current submission	7.96	0.08	0.02	0.00	0.24
	Difference %	**-0.8**	**-0.8**	**-37.5**	**-37.5**	**-1.0**
2010	Previous submission	2.24	0.02	0.01	0.00	0.07
	Current submission	2.24	0.02	0.01	0.00	0.07
	Difference %	**-0.2**	**-0.2**	**-37.5**	**-37.5**	**-0.5**
2015	Previous submission	12.06	0.12	2.47	0.23	0.50
	Current submission	12.06	0.12	2.47	0.23	0.50
	Difference %	**NO**	**NO**	**NO**	**NO**	**NO**
2020	Previous submission	6.14	0.06	5.32	0.01	0.47
	Current submission	6.14	0.06	5.32	0.01	0.47
	Difference %	**NO**	**NO**	**NO**	**NO**	**NO**

6.9.5. Category-specific planned improvements

There are no planned category-specific improvements.

6.10. Harvested wood products (CRF 4.G)

6.10.1. Category 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 Semi-chemical wood pulp[361]. Pulp is an input for paper production. All 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[362] was made to get estimates for these years (Chapter 6.10.2).

The net emissions form the HWP category in 2021 were -949.05 kt CO_2 and the net emissions during the reporting period are shown in Figure 6.30. 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 Semi-chemical wood pulp subcategories the contribution and impact to the carbon cycle is short-term and small for those pools.

[361]Semi-chemical wood pulp is defined as code 4705 00 00 in Combined Nomenclature 2019 (https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CN_2019&StrLanguageCode=EN&IntPcKey=42711923&StrLayoutCode=HIERARCHIC)
[362] FCCC/ARR/2018/EST KL.12

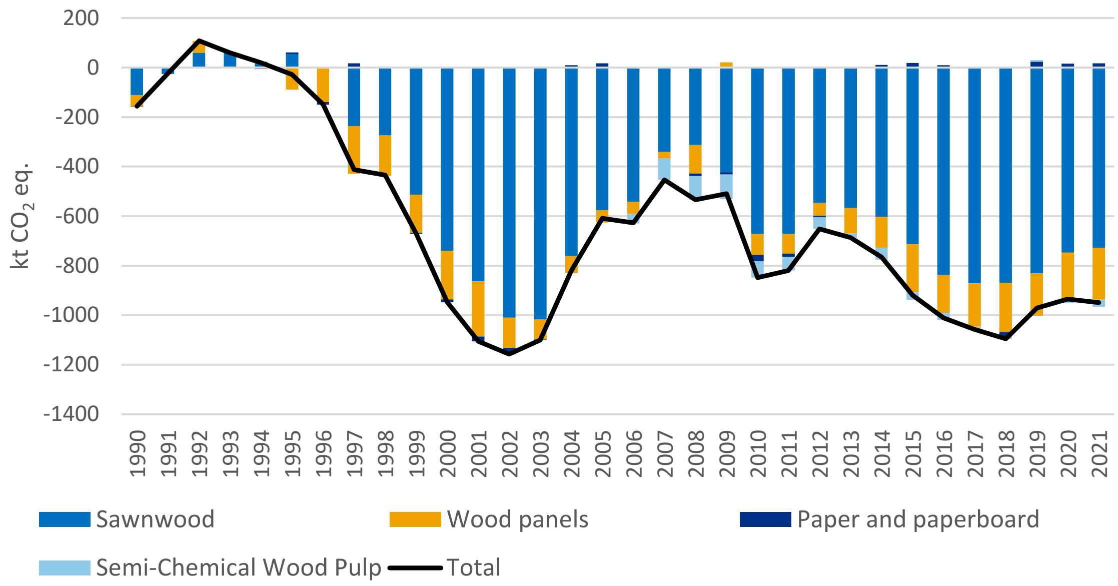


Figure 6.30. Net emissions from HWP categories of Solid wood, Paper and paperboard and Semi-chemical wood pulp in Estonia in 1990–2021, kt CO_2

6.10.2. 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[363], resulting values are presented in Table 6.43. Forestry data originates from the NFI and foreign trade data comes from Statistics Estonia. In order to use equations 2.8.4–2.8.6[364], 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 6.44) and half-lives from Table 2.8.2[365] were used to calculate Paper and paperboard and Solid wood removals (*Tier 2* method). C stock changes in Semi-chemical wood pulp were estimated with the country-specific C conversion factor (0.4275 t C m^{-3}) for 2006–2021. 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.

[363] IPCC 2013 KP Supplement, pp. 2.115 & 2.116
[364] IPCC 2013 KP Supplement, pp. 2.118, 2.120 & 2.121
[365] IPCC 2013 KP Supplement, Chapter 2.8.3.2, p. 2.123, Table 2.8.2.

Table 6.43. 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[366], t C	Initial stock in Paper and paperboard, t C	Initial stock in Semi-chemical wood pulp, t C	Total initial stock in HWP, t C	f_{IRW}[367]	f_{PULP}[368]
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	5 780 615	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	5 739 104	44 529	NO	5 783 633	0.912	0.999
1997	5 776 780	47 243	NO	5 824 023	0.898	0.885
1998	5 893 854	42 480	NO	5 936 335	0.827	0.990
1999	6 013 325	41 416	NO	6 054 742	0.829	0.990
2000	6 195 441	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	6 746 845	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	7 354 883	58 750	NO	7 413 634	0.688	1.000
2005	7 581 141	56 307	NO	7 637 449	0.577	0.985
2006	7 751 685	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	8 445 425	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
2013	8 813 341	68 497	133 999	9 015 837	0.938	0.822
2014	8 996 007	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	9 442 031	59 700	160 609	9 662 340	0.965	0.646
2017	9 712 079	57 211	168 757	9 938 047	0.962	0.688
2018	9 997 292	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	0.921	0.585
2021	10 819 151	51 039	174 942	11 045 131	0.868	0.494
2022	11 074 456	46 260	183 247	11 303 964	-	-

[366] Data about production of the particular HWP commodities are provided by the Statistics Estonia and Estonian Wood Industries Association
[367] Data from NFI (production of industrial roundwood) and Statistics Estonia (import and export of roundwood)
[368] Data from Statistics Estonia

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 6.44 Default conversion factors for default HWP categories and their subcategories[369]

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)		**(t C / t)**
Paper and paperboard	0.9		0.386
Semi-chemical wood pulp	0.95		0.428

6.10.3. Uncertainties and time-series consistency

The uncertainty rates related to the activity data and emission factors used in the estimates are presented in Table 6.45.

Table 6.45. Uncertainties in the HWP category

IPCC category	Uncertainties %		EF References
	Activity data[370]	Emission factors	
Wood panels and sawnwood	39	57	IPCC 2006, Vol 4, p. 12.22 Table 12.6 Lamlom and Savidge, 2003
Paper and paperboard	30	57	IPCC 2006, Vol 4, p. 12.22 Table 12.6 Lamlom and Savidge, 2003
Semi-chemical wood pulp	30	57	IPCC 2006, Vol 4, p. 12.22 Table 12.6 Lamlom and Savidge, 2003

[369] IPCC 2013 KP Supplement, Chapter 2.8.3.1, page 2.122, Table 2.8.1 (except for semi-chemical wood pulp).
[370] Activity data uncertainty estimates are obtained from the NFI and expert judgement.

6.10.4. Category-specific QA/QC and verification

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 1.2.3.

6.10.5. Category-specific recalculations

Activity data (mostly deforestation time series) is being updated and if necessary, corrected each year. In Table 6.46, a quantitative overview of recalculations has been shown.

Table 6.46. Quantitative overview of recalculations compared to the 15.04.2022 submission

		Harvested wood product, C stock change, kt			**TOTAL** HWP net CO_2, kt
		Solid wood	**Paper and paperboard**	**Semi-chemical wood pulp**	
1990	Previous submission	42.62	0.00	NE	-156.27
	Current submission	42.62	0.00	NE	-156.27
	Difference %	**NO**	**NO**	**-**	**NO**
1995	Previous submission	9.67	-1.83	NE	-28.75
	Current submission	9.67	-1.83	NE	-28.75
	Difference %	**NO**	**NO**	**-**	**NO**
2000	Previous submission	255.19	3.2	NE	-947.59
	Current submission	255.19	3.2	NE	-947.59
	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**
2010	Previous submission	206.45	6.88	18.14	-848.75
	Current submission	206.45	6.88	18.14	-848.75
	Difference %	**NO**	**NO**	**NO**	**NO**
2015	Previous submission	247.47	-5.03	8.18	-918.97
	Current submission	247.47	-5.03	8.18	-918.97
	Difference %	**NO**	**NO**	**NO**	**NO**
2020	Previous submission	254.43	-4.25	1.34	-922.24
	Current submission	257.40	-4.18	1.67	-934.58
	Difference %	**1.2**	**-1.7**	**24.0**	**1.3**

6.10.6. Category-specific planned improvements

The Estonian University of Life Sciences has a project "Evaluation and improvement of activity data on harvested wood products". The aim is to provide more accurate and complete data for the HWP calculations, including quality control of statistical data.

7. WASTE (CRF 5)

7.1. Overview of the sector

Waste management in Estonia is based on the EU and national legislation and the National Waste Management Plan for years 2014–2020 (valid until a new waste plan is established)[371]. The new waste management plan will be completed in the first half of 2023 but will be integrated and adopted together with the Environmental Development Plan (KEVAD) (planned to be adopted at the end of 2023). 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 summarises 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.C.1 Waste incineration	T2a/D	T1/D	T1/D
5.C.2 Open burning of waste	T1/D	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 317.16 kt in 2021 and covered 2.05% of total GHG emissions in 2021 (Figure 7.1).

[371] Waste Management Plan 2014–2020. Ministry of the Environment. [www] https://envir.ee/ringmajandus/jaatmed/riigi-jaatmekava (08.02.2023).

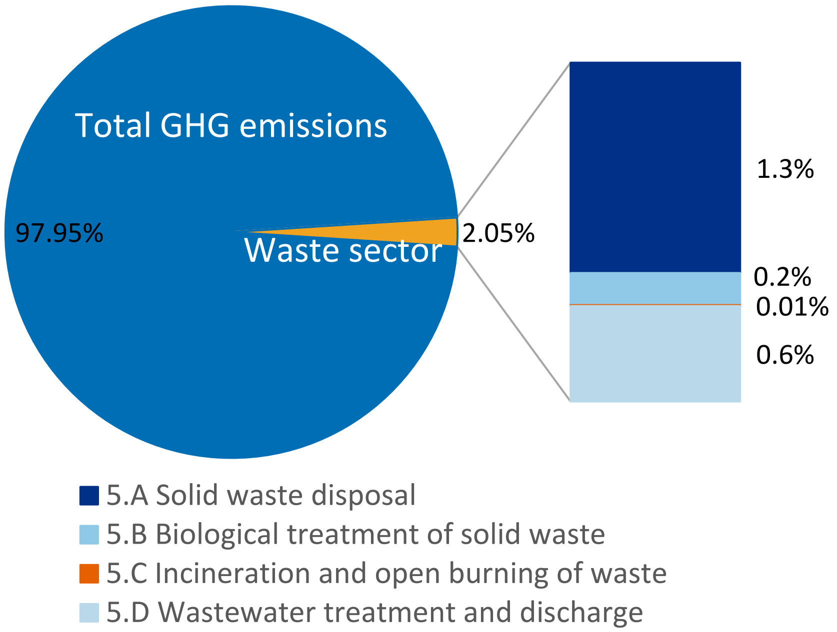


Figure 7.1. CO_2 eq. emissions from the Waste sector compared to total GHG emissions in Estonia in 2021, %

Total CO_2 eq. emissions from the Waste sector (Table 7.2) in 2021 increased by 0.71% compared to 2020. Compared to the base year of 1990, the amount of CO_2 eq. emissions in 2021 were 21.7% smaller. Compared to the base year, CO_2 eq. emissions from Solid waste disposal (SWD) have decreased by 17.7%, CO_2 eq. emissions from Waste incineration and Open burning of waste by 76.7%, 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 2424.1%.

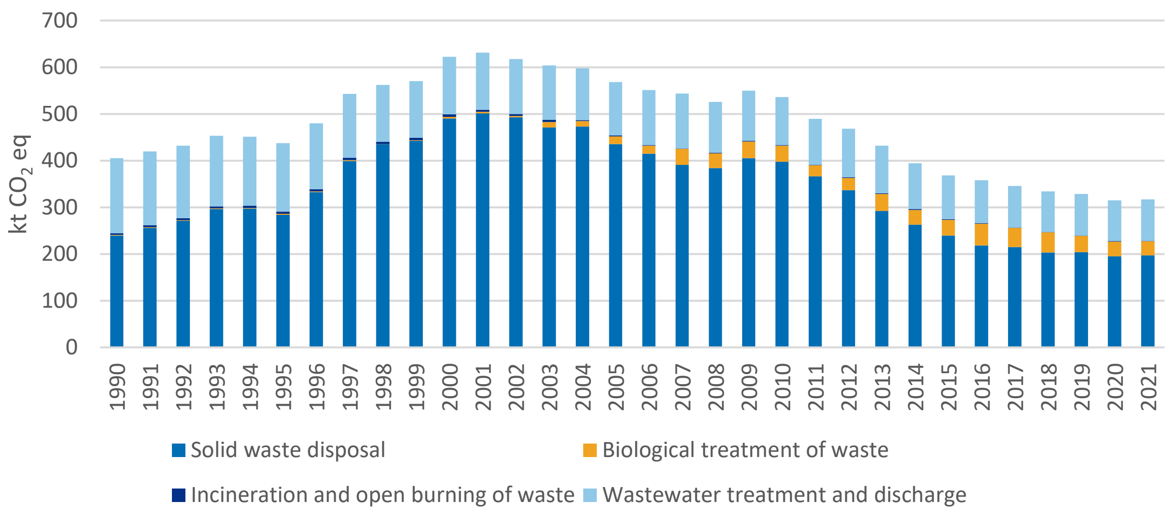


Figure 7.2. Trends of GHG emissions in the Waste sector by source categories in 1990–2021, kt CO_2 eq.

As seen in Figure 7.2 and Table 7.2 GHG emissions from the Waste sector are in decreasing trend until 2020. 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.

The lowest CO_2 eq. emissions occurred in 2020, which was mainly connected to the decreasing amount of waste deposited in landfills. Due to the COVID-19 pandemic, emissions decreased 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 2021 census.

Table 7.2. GHG emissions from the Waste sector in Estonia in 1990–2021, 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	0.03	0.002	0.13	4.51	NO	404.97
1995	10.15	2.99	0.07	0.0010	0.04	0.002	0.11	4.15	NO	437.33
2000	17.50	2.82	0.08	0.0012	0.08	0.005	0.10	3.42	0.06	622.40
2005	15.54	1.46	0.03	0.0005	0.37	0.022	0.10	2.84	0.29	568.29
2010	14.21	0.84	0.02	0.0003	0.78	0.047	0.11	2.06	0.61	535.98
2011	13.09	0.80	0.01	0.0002	0.53	0.032	0.11	2.05	0.47	489.72
2012	12.02	0.86	0.02	0.0003	0.59	0.036	0.10	2.04	0.69	468.05
2013	10.44	1.04	0.02	0.0003	0.82	0.049	0.11	2.04	0.55	431.63
2014	9.38	0.97	0.02	0.0003	0.73	0.044	0.11	2.03	0.46	394.04
2015	8.54	0.51	0.01	0.0002	0.77	0.046	0.11	1.94	0.38	367.56
2016	7.81	0.60	0.01	0.0002	1.05	0.063	0.11	1.94	0.31	357.26
2017	7.68	0.53	0.01	0.0002	0.93	0.056	0.11	1.94	0.24	345.93
2018	7.26	0.58	0.01	0.0002	0.98	0.059	0.11	1.94	0.12	333.79
2019	7.27	0.57	0.01	0.0002	0.80	0.048	0.11	1.95	0.20	328.51
2020	6.96	0.50	0.01	0.0002	0.73	0.044	0.11	1.95	0.17	314.91
2021	7.03	0.60	0.01	0.0001	0.68	0.041	0.11	2.04	0.15	317.16

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 emissions are mainly calculated by using actual emissions data reported by the companies as well as by using the EMEP/EEA Guidebook 2019.

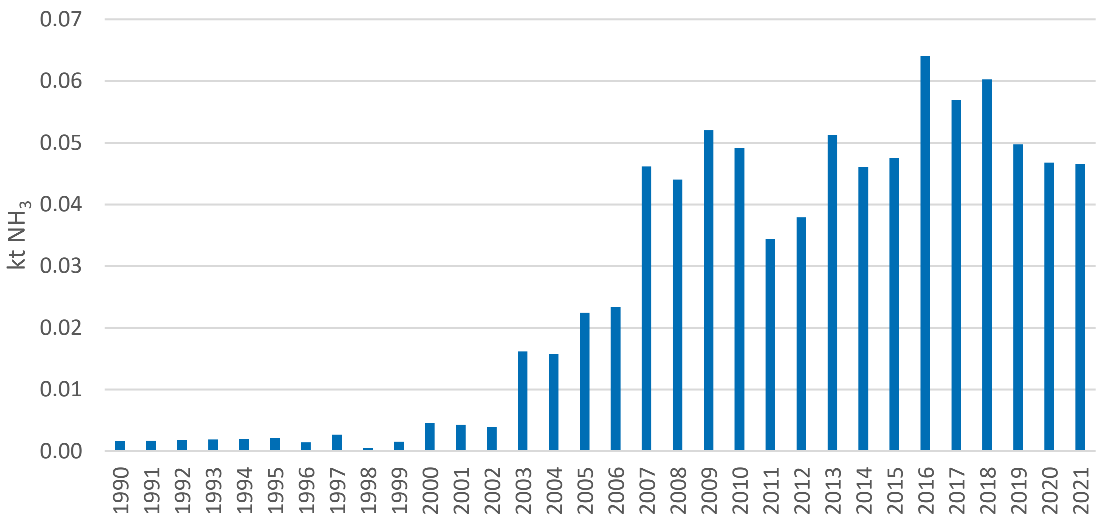


Figure 7.3. NH_3 emissions from SWD, Biological treatment of solid waste, Industrial waste incineration, and Industrial and domestic wastewater treatment, kt

Key categories

The key categories in1990 and 2021 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3.

Uncertainty assessment

All calculated uncertainties of emission factors and activity data used are in accordance with methodology used in emission estimations, derived from IPCC 2006 Guidelines, and use Equation 7.1. In Table 7.3, all categories comprising uncertainty estimates are presented; detailed uncertainty values used in uncertainty assessment are presented under the sub-categories' descriptions below.

Equation 7.1[372]

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

[372] IPCC 2006 vol 1, Chapter 3. Equation 3.1, p 3.28.

Table 7.3. Combined uncertainties in the Waste sector, %

Source category	Gas	Combined uncertainty %
5.A Solid waste disposal	CH_4	89%
5.B.1 Composting	CH_4	76%
5.B.1 Composting	N_2O	67%
5.B.2 Anaerobic digestion at biogas facilities	CH_4	96%
5.C.1 Waste incineration	CH_4	50%
5.C.1 Waste incineration	N_2O	100%
5.C.1 Waste incineration	CO_2	40%
5.C.2 Open burning of waste	CH_4	59%
5.C.2 Open burning of waste	N_2O	105%
5.C.2 Open burning of waste	CO_2	51%
5.D.1 Domestic wastewater	CH_4	90%
5.D.1 Domestic wastewater	N_2O	109%
5.D.2 Industrial wastewater	CH_4	62%

7.2. Solid waste disposal (CRF 5.A)

7.2.1. Category description

In 2021, Estonia had five functioning landfills (Tallinn Recycling Center, Uikala, Väätsa, Torma and Paikre) classified as managed SWD sites and one landfill for construction 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.

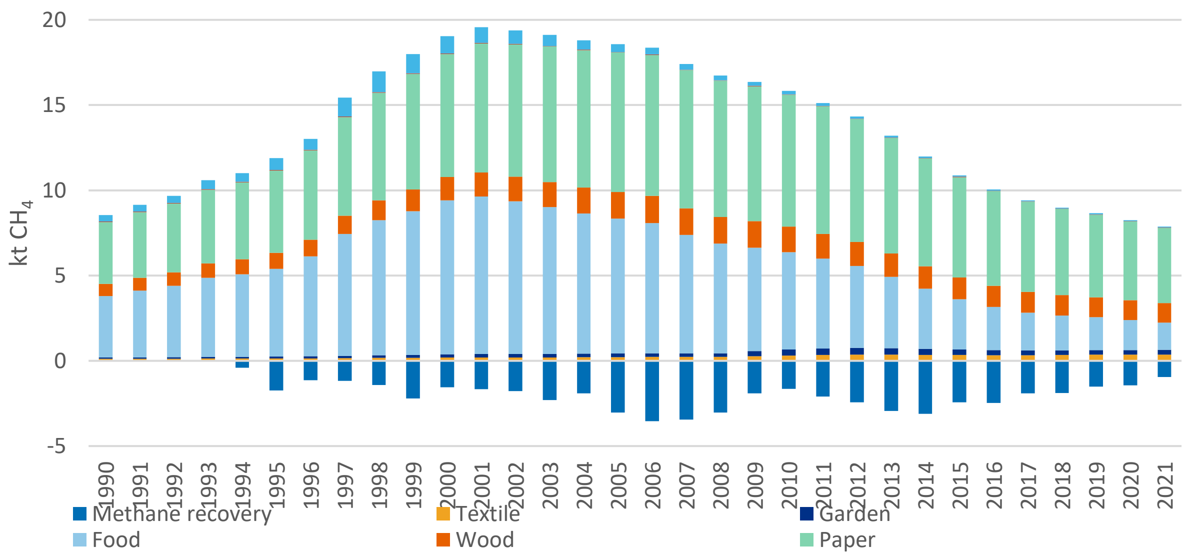


Figure 7.4. CH_4 emissions and recovery from landfills in Estonia in 1990–2021, kt CH_4

Estonia's total CH_4 emissions from SWD into landfills in 2021 amounted to 7.03 kt CH_4 (Table 7.4). In 2021 emissions increased, because less landfill gas was collected and therefore methane recovery rate was lower compared to 2020. Figure 7.5 shows CH_4 emissions from SWD with and without energy recovery.

Table 7.4. Quantities of CH_4 emissions and recovery from biodegradable solid waste deposited in landfills in 1990–2021, 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	0.4	0.03	0.0	8.55
1995	5.1	0.1	4.8	0.9	0.1	0.7	0.04	–1.7	10.15
2000	9.0	0.2	7.2	1.4	0.2	1.0	0.03	–1.5	17.50
2005	7.9	0.2	8.2	1.6	0.2	0.5	0.03	–3.0	15.54
2010	5.8	0.3	7.8	1.5	0.3	0.2	0.03	-1.6	14.21
2011	5.4	0.4	7.7	1.5	0.3	0.2	0.03	-2.1	13.09
2012	5.0	0.4	7.5	1.5	0.4	0.1	0.03	-2.4	12.02
2013	4.5	0.4	7.2	1.4	0.4	0.1	0.02	-2.9	10.44
2014	3.8	0.4	6.8	1.4	0.4	0.1	0.02	-2.8	9.38
2015	3.3	0.3	6.5	1.4	0.4	0.1	0.02	-2.6	8.54
2016	2.8	0.3	6.1	1.4	0.4	0.1	0.02	-2.5	7.81
2017	2.4	0.3	5.8	1.3	0.4	0.1	0.02	-1.9	7.68
2018	2.2	0.3	5.6	1.3	0.4	0.1	0.02	-1.9	7.26
2019	2.1	0.3	5.3	1.3	0.4	0.1	0.02	-1.5	7.27
2020	1.9	0.3	5.1	1.3	0.4	0.1	0.02	-1.4	6.96
2021	1.8	0.3	4.9	1.2	0.4	0.1	0.02	-1.0	7.03

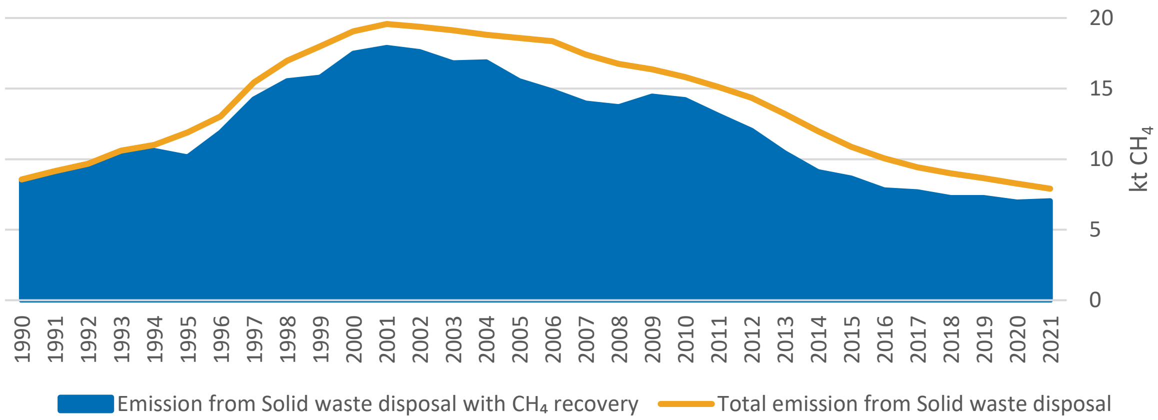


Figure 7.5. CH_4 emissions from SWD with and without energy recovery, kt CH_4

7.2.2. Methodological issues

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 Environment and published in Tableau[373] 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, exporting 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 2015, then the amount of waste generated by this company will be included in the total amount of waste at the beginning of 2015 and is not included in the stock of waste at the end of 2014 (because this company did not have the obligation to report waste in 2014).
- 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 2014, then the amount of waste is counted in the stock at the end of 2014. This waste is not included in the stock at the beginning of 2015, 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.

[373] The Information Technology Centre of the Ministry of the Environment Waste data visualizing system (Tableau). [www] https://public.tableau.com/app/profile/keskkonnaagentuur (08.02.2023).

- 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 2021 was 269,691 tonnes, of which the majority was inert (34%), metal (28%) and wood waste (15%) (Figure 7.6). 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. Only imported waste fuel (5%) is included in GHG emission calculations under Energy sector (NIR Ch 3.2.4), as energy and heat are produced from waste fuel. Other 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).

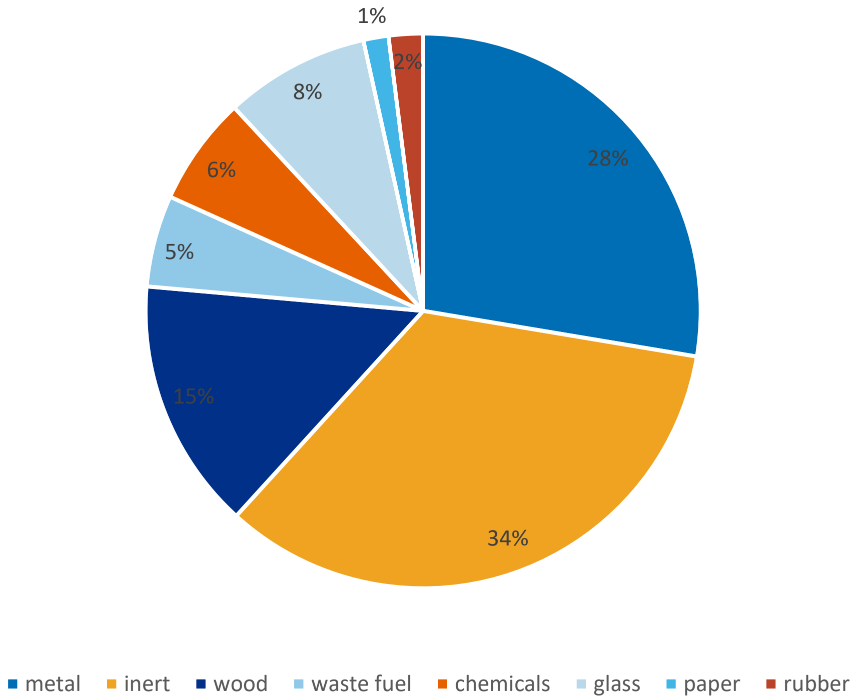


Figure 7.6. Imported waste in Estonia in 2021, %

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 the 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 2021 was about 19.3 million tonnes, which is 16% lower than in 2020. The proportion of degradable and inert waste generated in 2021 was 3.89% and 94.28%, respectively. The proportion of separately collected waste was 1.83% of the total waste generated. The annual trend of inert and degradable waste generated in Estonia in 1990–2021 is presented in Figure 7.7.

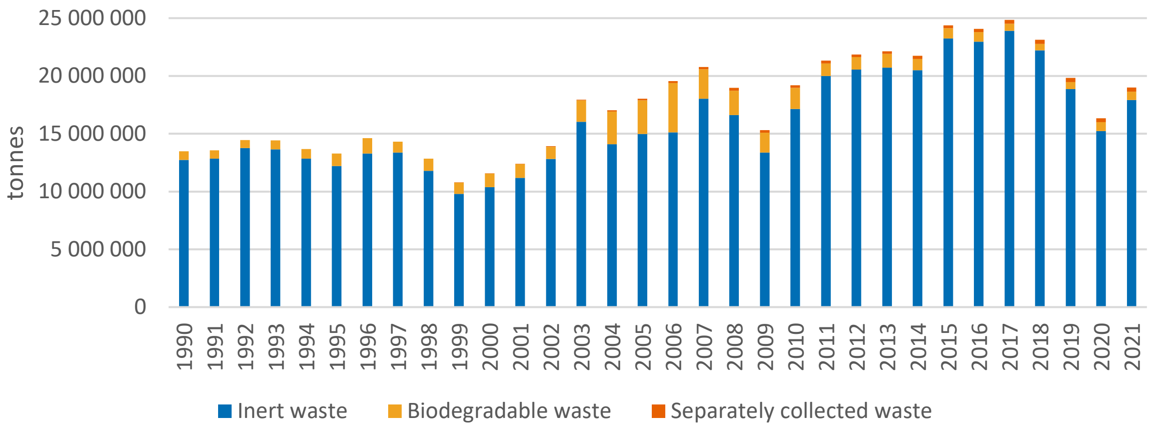


Figure 7.7. Quantities of waste generated in Estonia in 1990–2021, tonnes

In 2021, waste generated by the oil shale industry constituted 70% 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[374]. In comparison, the waste of the oil shale industry in 2020 covered 68.8% of the total waste generated. Oil shale mining remained at the same level compared to 2020. 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 2021 was about 317 271 tonnes in addition to a separately collected fraction, which amounted to 348 236 tonnes. The total amount of MSW generated was about 1.64% of the total waste generated. The total amount of waste deposited in landfills was 6.5 million tonnes, from which MSW comprised 54.8 thousand tonnes and industrial waste 6.5 million tonnes (Table 7.5 and Table 7.6). Separately collected MSW and deposited MSW are shown separately in Table 7.5, as the deposited MSW is calculated based on the mixed MSW sorting studies (Table 7.10). Separately collected MSW is separately reported in Tableau.

Table 7.5. 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
1995	192.5	4.6	115.7	15.1	4.1	0.9	125.3	NE	457.3	NO
2000	231.0	5.5	138.8	18.1	4.9	8.2	150.3	NE	548.7	1.7

[374] 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.

Year	Food	Garden	Paper	Wood	Textile	Sludge	Inert	Nappies	Deposited MSW	Separately collected and deposited MSW
2005	152.2	3.6	91.5	11.9	3.3	0.2	99.1	NE	361.6	6.7
2010	72.3	11.7	42.0	2.3	9.3	0.2	95.6	NE	233.2	4.0
2011	60.5	9.8	35.1	2.0	7.8	0.1	80.0	NE	195.2	7.1
2012	30.2	4.1	14.6	2.2	5.5	NO	51.3	NE	107.9	3.7
2013	12.4	1.7	6.0	0.9	2.3	0.1	21.1	NE	44.4	5.5
2014	8.1	1.1	3.9	0.6	1.5	0.1	13.8	NE	28.9	4.9
2015	7.1	1.0	3.4	0.5	1.3	NO	12.1	NE	25.5	6.3
2016	12.1	1.6	5.8	0.9	2.2	NO	20.6	NE	43.3	7.3
2017	21.8	3.0	10.5	1.6	4.0	NO	37.1	NE	77.8	8.2
2018	24.1	3.3	11.6	1.7	4.4	NO	41.0	NE	86.2	10.1
2019	13.2	4.8	9.6	0.7	3.3	NO	22.1	2.8	56.5	10.7
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

NO – not occurring, NE – not estimated

Table 7.6. 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	45.9	10 187.0
1995	48.7	0.1	8.0	1.2	0.2	NO	32.2	10 071.9
2000	47.3	0.9	5.3	0.2	0.2	NO	25.5	9 261.2
2005	4.6	1.2	5.9	NO	NO	NO	1.0	11 058.9
2010	0.8	0.6	1.5	NO	NO	NO	0.3	11 390.9
2011	0.9	0.5	1.1	NO	NO	NO	1.5	9 054.9
2012	1.2	0.4	0.9	NO	NO	NO	1.2	8 029.7
2013	1.1	0.5	2.0	NO	0.1	NO	0.4	10 643.0
2014	1.4	0.8	0.8	NO	0.07	NO	0.8	13 571.2
2015	1.4	0.6	0.2	NO	NO	NO	0.8	12 183.5
2016	2.9	0.9	0.3	NO	NO	NO	2.3	12 800.6
2017	4.4	0.9	0.2	NO	0.1	0.0	2.9	13 139.7
2018	6.5	0.8	0.3	NO	0.1	0.0	4.9	13 108.5
2019	6.3	0.8	0.2	0.0	0.0	NO	2.4	7 431.2
2020	6.8	0.8	0.2	0.0	0.2	NO	1.2	5 922.2
2021	5.4	0.7	0.2	0.0	0.1	NO	0.9	6 444.2

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 2021 (Figure 7.8) increased by approximately 11.0% compared to the base year of 1990. In comparison with the year 2020, the amount of DOC has increased by about 5.8%, due to decreased waste generation. The ratio of DOC landfilled to DOC generated has increased slightly from 4.60% to 4.48%.

Calculated DOC content values for Municipal in Table 7.7 and Table 7.9 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 7.9).

Table 7.7. DOC content of mixed MSW in Estonia in 1950–2021

	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.

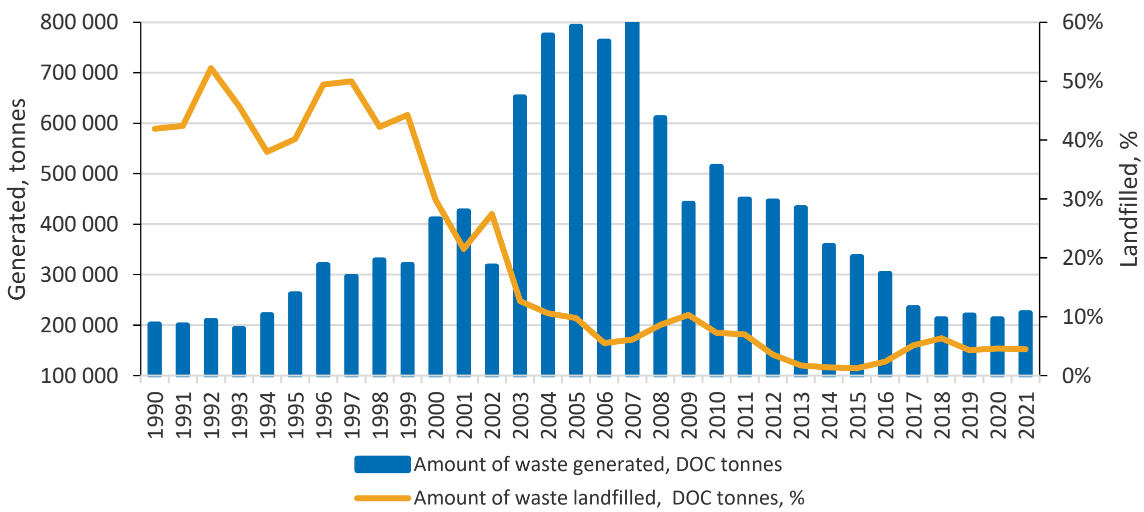


Figure 7.8. Quantity of DOC generated (tonnes) and ratio of DOC landfilled to DOC generated (%) in 1990–2021

Production of biogas

Biogas is a gas fuel obtained via anaerobic fermentation, which is comprised of 50–70% methane (CH_4), 30–40% carbon dioxide (CO_2) and other components, such as N_2, O_2, NH_4, H_2S. A biogas station in landfills is provided with pre-preservation storage and mixing containers, biogas reactors, fermenting waste storage area, gas storage units, and heating and power station for the use of gas. The amount of CH_4 is calculated using a density of 0.717 and the CH_4 composition of 55%[375].

The data on the amount of recovered methane in 1994–2006 is based on REN-Estonia – an annual questionnaire on renewables and waste[376]. 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 2021 was 0.96 kt (Figure 7.9).

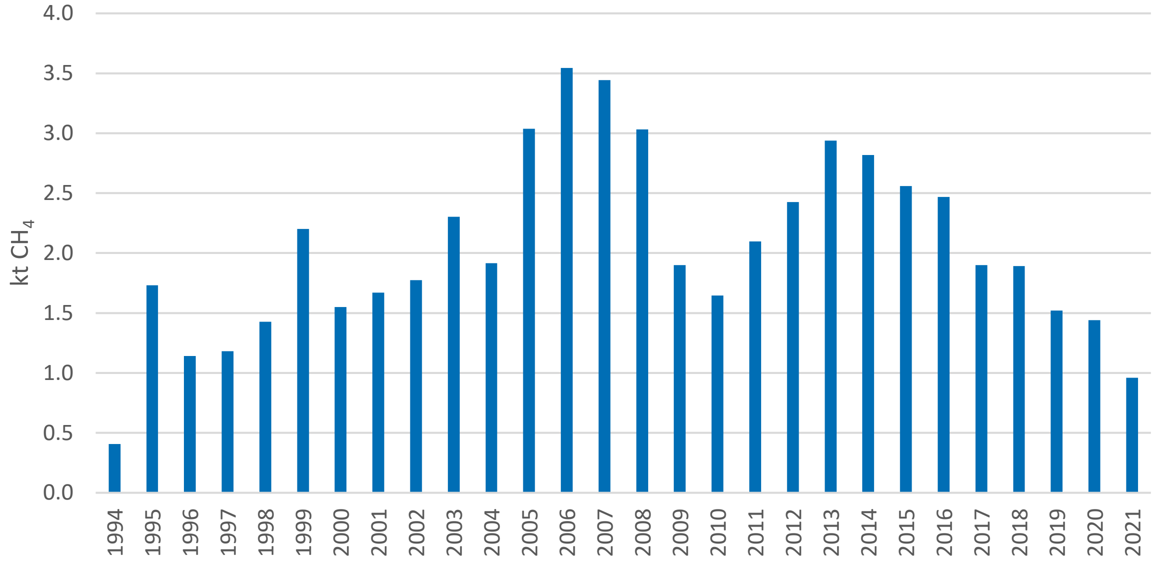


Figure 7.9. CH_4 recovered from landfills in 1994–2020, kt

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.

---

[375] Parameters were determined during consulting with EstEA

[376] REN. 2013. IEA – Eurostat-UNECE. Energy Questionnaire – Renewables and Waste.

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.

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.

Emission factors

Emission factors used in the calculations of emissions from SWD sites are default emission factors from IPCC 2006 Guidelines (Table 7.8). Methane generation rate constants used in the calculations are default values from IPCC 2006 Guidelines (Table 7.8).

Table 7.8. Emission factors and parameters used in calculations

Factor/Parameter	Value
MCF – anaerobic[377]	1
MCF – uncategorised SWD sites[377]	0.6
DOCf[378]	0.5
F[379]	0.5
OX[380]	0.09
Methane generation rate constant[381]	
k1 = paper/textile waste	0.06
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 7.9. Default DOC content of different waste types (wet basis)[382]

Waste group	DOC content (fraction)
Municipal solid waste	
Food/Grease	0.15
Municipal	see Table 7.7
Garden	0.2
Paper	0.4
Textile	0.24
Wood	0.43
Municipal sludge	0.05
Industrial waste	

[377] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.14, table 3.1.
[378] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.13.
[379] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.15.
[380] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.15, table 3.2.
[381] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.17, table 3.3.
[382] IPCC 2006 Guidelines, Volume 5, Chapter 2: Waste generation, composition and management data, pages 2.14, 2.16, table 2.4 and 2.5.

Waste group	DOC content (fraction)
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 7.10). 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 NIR, as the waste model used for calculations does not allow reporting emissions separately.

Table 7.10. Composition of MSW, %

	1950–1999[383]	**2000–2007**[383]	**2008–2011**[384]	**2012–2018**[385]	**2019-onward**[386]
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

[383] Vaania, (2000). Study on the composition of municipal solid waste including different regions in Estonia (in Estonian).
[384] 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 (01.02.2023).
[385] 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 (01.02.2023).
[386] 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 (01.02.2023).

The composition of furniture waste (Table 7.11) is based on an expert judgement and a study carried out by the Stockholm Environment Institute Tallinn Centre[387].

Table 7.11. Composition of furniture waste, % in 1990–2021

Composition of furniture waste	%
Wood	49.3%
Textile	24.3%
Metal	12.2%
Plastic	14.2%

7.2.3. Uncertainties and time series consistency

The estimation of CH_4 emissions from MSW disposal is carried out based on activity data and emission factors.

Uncertainties of default emission factors and activity data used in the estimations are derived based on methodology from IPCC 2006 Guidelines. Values are presented in Table 7.12.

The combined uncertainty rates related to the sub-category of SWD are reported in Table 7.3.

Table 7.12. Default uncertainty ranges for SWD

Input	Uncertainties
Activity data[388]	
Total MSW	±10%
Total uncertainty of waste composition	±10%
MSW sent to SWD sites	±10%
Emission factors	
Uncertainty for default half-life($t_{1/2}$)[389]	
Food waste	(0.185) 0.1–0.2
Garden	(0.1) 0.06–0.1
Paper	(0.06) 0.05–0.07
Wood and straw	(0.03) 0.02–0.04
Textiles	(0.06) 0.05–0.07
Disposable nappies	(0.1) 0.06–0.1
Sewage sludge	(0.185) 0.1–0.2
DOC[388]	±20%
Fraction of DOC decomposed (DOC_f)[388]	±20%
Methane correction factor 1.0[388]	–10%
Methane recovery[388]	±30%
Fraction of CH_4 in generated landfill gas[388]	±5%

[387] 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 (01.02.2023).
[388] IPCC 2006 Guidelines, Volume 5, Chapter 3. Solid Waste Disposal, page 3.27, table 3.5.
[389] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.18, table 3.4.

7.2.4. Category-specific QA/QC and verification

Complete Quality Assurance (QA) and Quality Control (QC) were carried out pursuant to the procedures described in IPCC 2006 Guidelines[390]. 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 given in Section 1.2.3.

7.2.5. Category-specific recalculations

There were no category-specific recalculations.

DOCf values in CRF have been corrected due to the UNFCCC ERT's observation (W.5, in the draft 2022 report) of including DOC instead of DOCf. This correction did not affect emissions.

7.2.6. Category-specific planned improvements

Estonia has a project in 2023 to review landfill gas data in order to specify the emissions of greenhouse gases and air pollutants in the waste sector.

7.3. Biological treatment of solid waste (CRF 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 and from anaerobic digestion in biogas facilities.

Total emissions from Biological treatment of solid waste in 2021 comprised 0.68 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 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 2020, the emissions from Biological treatment on solid waste decreased slightly because the amount of biodegradable waste composted decreased. Main driver for the decrease was sludge which is treated under other waste handling activities. As of 2021, there were 18 biogas facilities in Estonia, so the use of biowaste for biogas production has increased. With an ongoing project (2020-2023) Estonia is developing a methodology to estimate GHG emissions from the production of biomethane from agricultural (and waste) sources and developing country-specific emission factors for biomethane production. Emissions from biogas production will be reported under the Energy sector.

[390] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance / Quality Control and Verification.

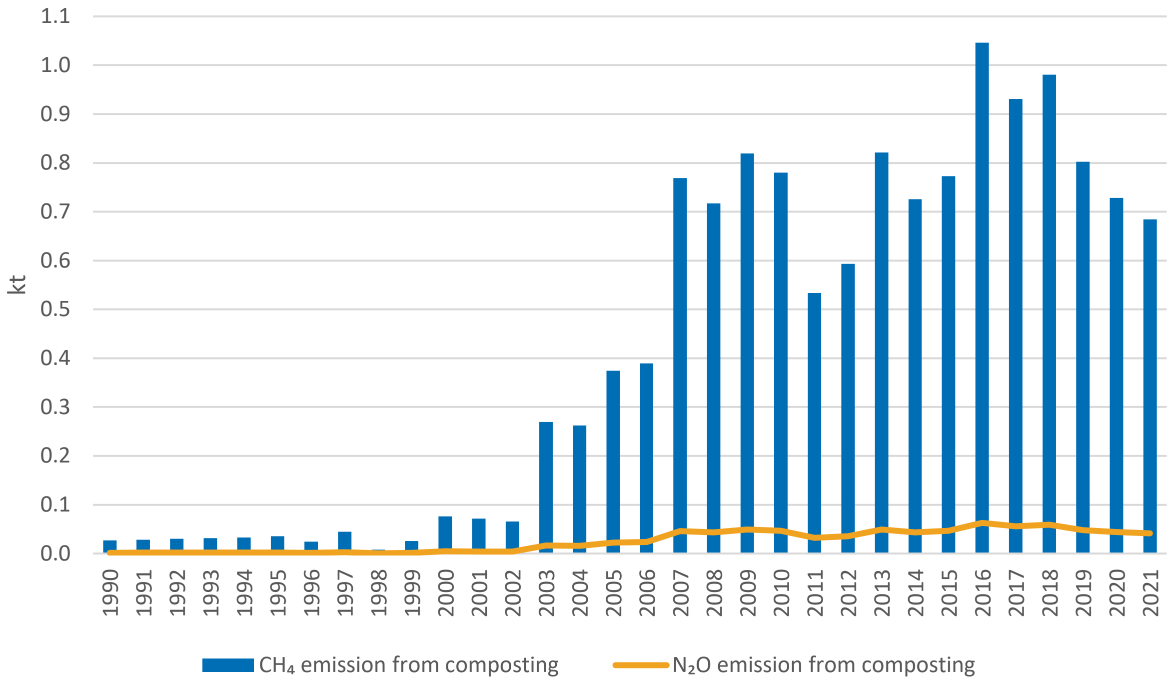


Figure 7.10. CH_4 and N_2O emissions from Biological treatment of solid waste in 1990–2021, kt

Emissions from anaerobic digestion with energy recovery have been reported under the Energy sector (CRF 1.A.1.A) as aggregated total biogas production in Estonia. There is currently no anaerobic digestion taking place without energy recovery. Nevertheless, during the UNFCCC ERT review, the issue of potential leakages emerged. Estonia launched anaerobic digestion at the 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. On the basis of 24/CP.19 National Inventory reporting guidance paragraph 37(b)[391] of the UNFCCC Annex 1 inventory reporting guidelines, the CH_4 leakage calculations resulted in a percentage lower than 0.02 for each year starting from 1994. (For 2021, the leakages comprised 0.05 kt which is 0.0003% of total emissions) Therefore, CH_4 leakages from anaerobic digestion have been reported as NE. Based on the IPCC 2006 Guidelines, N_2O emissions from anaerobic digestion at biogas facilities are assumed to be negligible.

7.3.2. Methodological issues

Activity data

The quantities of waste composted in 2021 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 2021, 68 403 tonnes (dry weight) of waste were composted. Companies report the waste amounts in wet weight basis which are recalculated to dry weight basis for the GHG emission calculations. 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. As seen in Table 7.13 organic, sludge and wood waste contribute the most to composting in Estonia. Abbreviation NO indicates that the waste type was not composted.

[391] Paragraph 37(b) – emissions should only be considered insignificant if the likely level of emissions is below 0.05% of the total national GHG emissions (without LULUCF).

During some years (1995, 2003, 2014 and 2017) waste management companies reported composted waste with a MSW code which is not a common practice and therefore switched to reporting waste amount under the respective waste groups in future years.

Table 7.13. Quantities of waste composted in 1990–2021, tonnes dry weight [392]

Year	MSW	Organic waste	Paper	Sludge	Textiles	Wood	Total
1990	NO	1 500	NO	51	58	1 101	2 710
1995	0.4	1 939	0.3	51	146	1 423	3 560
2000	NO	6 078	NO	48	168	1 311	7 604
2005	NO	1 543	NO	27 056	NO	8 832	37 431
2010	NO	4 351	0.4	56 942	NO	16 708	78 001
2011	NO	3 742	11	34 631	NO	14 970	53 353
2012	NO	4 441	19	39 547	NO	15 338	59 345
2013	NO	4 277	48	60 539	NO	17 295	82 160
2014	2 112	4 443	37	53 203	NO	12 734	72 530
2015	NO	5 832	1	57 329	NO	14 091	77 255
2016	NO	4 676	1082	76 239	NO	22 645	104 642
2017	20	4 619	30	58 909	NO	29 524	93 102
2018	NO	4 754	22	79 061	NO	14 200	98 038
2019	NO	5 774	25	52 480	NO	21 924	80 202
2020	NO	5 092	NO	42 939	NO	24 767	72 797
2021	NO	5 820	NO	34 783	NO	27 800	68 403

NO – not occurring

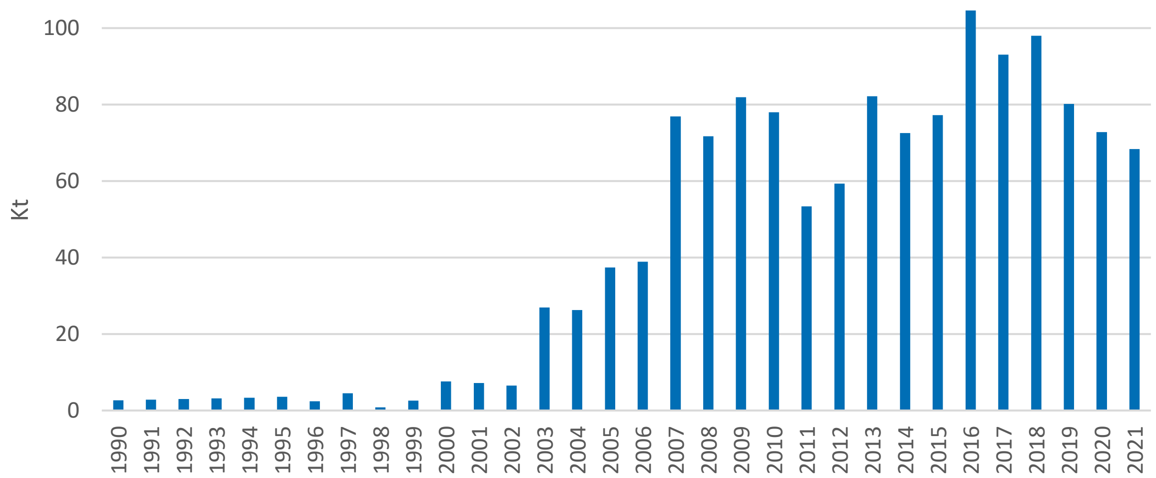


Figure 7.11. Composted organic waste in 1990–2021 (kt, dry weight)

As seen in Figure 7.11 in the amount of organic waste used in biological treatment was marginal in the first decade of the period but started to grow rapidly in 2000 and has increased significantly – from 2 710 tonnes (dry weight) in 1990 to 104 642 tonnes (dry weight) in 2016.

[392] 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 sludge and textile waste for that period therefore it remained on the level of 1995.

The decline in biologically treated 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 2020-2021 is mostly caused by the opening of three biogas facilities in Estonia and using sludge for biogas production.

Methods

In order to estimate emissions from composting, IPCC 2006 *Tier 1* approach (Equation 7.2 and Equation 7.3) was used. In addition, 40% of dry weight in compostable waste is included in the calculations based on the remark in IPCC 2006[393] noting it is assumed that the moisture content in wet waste is 60%.

Equation 7.2[394]

$$CH_4\ Emissions = \sum_i (M_i \times EF_i) \times 10^{-3} - R$$

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 7.3[395]

$$N_2O\ Emissions = \sum_i (M_i \times EF_i) \times 10^{-3}$$

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.

393 IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.6, table 4.1, remark
394 IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.5, equation 4.1.
395 IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.5, equation 4.2.

Emission factors

IPCC 2006 Guidelines default dry weight emission factors are used in the calculations (Table 7.14).

Table 7.14. Default emission factors for calculating CH_4 and N_2O emissions from Biological treatment of solid waste[396]

Type of biological treatment	**CH_4 emission factor (g CH_4/kg waste treated, dry weight)**	**N_2O emission factor (g N_2O/kg waste treated, dry weight)**
Composting	10	0.6

7.3.3. Uncertainties and time series consistency

The estimation of GHG emissions from Biological treatment of solid waste (Table 7.15) is carried out by considering emission factors and the quantities of waste composted per waste type.

The combined uncertainty rates related to the sub-category of Biological treatment of solid waste have been reported in Chapter 7.1.2. For activity data uncertainty, the uncertainty percentage from SWD is used.

Table 7.15. Default uncertainty ranges for Biological treatment of solid waste

Input	**Value**
Activity data[397]	
Waste composition	±10%
Total MSW	±10%
Emission factor[398]	
CH_4 (Composting)	(4) 0.03…8
N_2O (Composting)	(0.3) 0.06…0.6

7.3.4. Category-specific QA/QC and verification

Complete QA and QC were carried out pursuant to the procedures described in IPCC 2006 Guidelines[399]. 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 Section 1.2.3.

[396] IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.6, table 4.1.
[397] IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.27, table 3.5.
[398] IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological Treatment of Solid Waste, page 4.6, table 4.1.
[399] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance/Quality Control and Verification.

7.3.5. Category-specific recalculations

There were no category-specific recalculations.

7.3.6. Category-specific planned improvements

The activity data is kept under consideration and will be updated as necessary.

7.4. Waste incineration and Open burning of waste (CRF 5.C)

7.4.1. Category description

CO_2, CH_4 and N_2O emissions from Waste incineration and Open burning of waste are estimated under CRF 5.C. Emissions from waste incineration with energy recovery are reported under the Energy sector and without energy recovery in the Waste sector.

CO_2 emissions from the combustion of biomass materials (e.g., paper, food waste, wood) are biogenic emissions and are not to be included in national total emission estimates but reported as an informational item under the Waste sector. CO_2 emissions from oxidation during the incineration of carbon in waste of fossil origin (e.g., plastic, rubber, liquid solvents, waste oils) are considered net emissions and are reported under the Waste sector. N_2O and CH_4 emissions include both biogenic and non-biogenic sources of emission.

CO_2 emissions from waste incineration without energy recovery (Figure 7.12) from non-biogenic sources in 2021 amounted to 0.17 kt and from biogenic sources to 0.002 kt. The biogenic emissions outlier in 1999 and 2000 is connected to the high volume of wood waste combustion. The non-biogenic CO_2 emissions in 1990–1995 were mainly caused by inert, oil and petroleum waste incineration and in 2000–2005, non-biogenic CO_2 emissions were the result of the high volume of inert waste incineration. After 2006, only minor quantities of waste have been incinerated without energy recovery, for example in 2020 only 4.4 tonnes. In 2008 and 2011, no waste without energy recovery was incinerated and therefore no CO_2 emissions occurred. The specific quantities of waste incinerated by category are presented in Table 7.16.

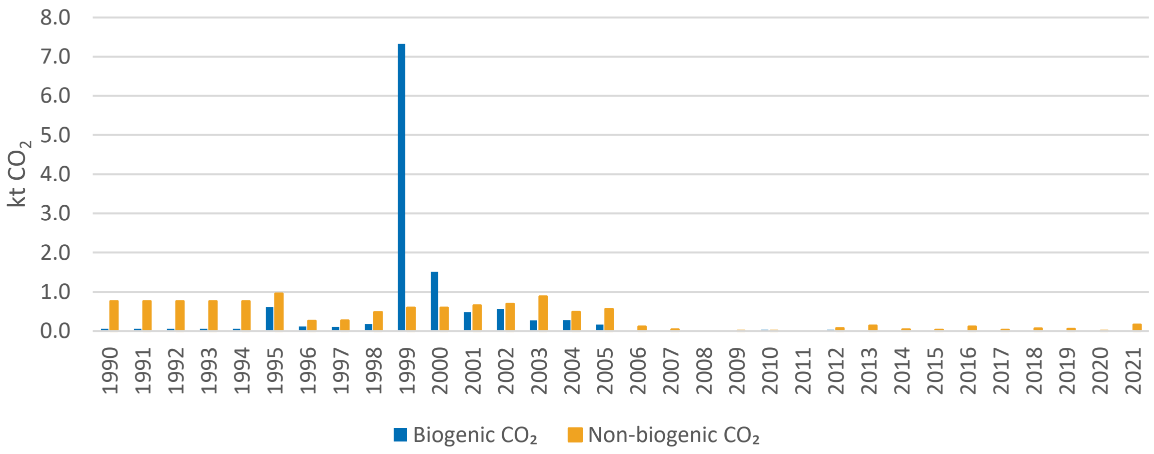


Figure 7.12. CO_2 emissions from Waste incineration without energy recovery in Estonia in 1990–2021, kt

Total CH_4 emissions (Figure 7.13) from Waste incineration without energy recovery in 2021 amounted to 0.00044 kt, of which 0.0000051 kt was of biogenic origin and 0.00043 kt of non-biogenic origin. The biogenic emission outlier in 1999 is connected to the high volume of wood waste combustion. In 2000–2005, non-biogenic CH_4 emissions were caused by the high volume of inert waste incineration. After 2006, only minor quantities of waste have been incinerated without energy recovery. In 2020 only 0.65 tonnes of waste were incinerated and in addition, no waste was combusted in 2008 and 2011. The specific quantity of waste incinerated by category is presented in Table 7.16.

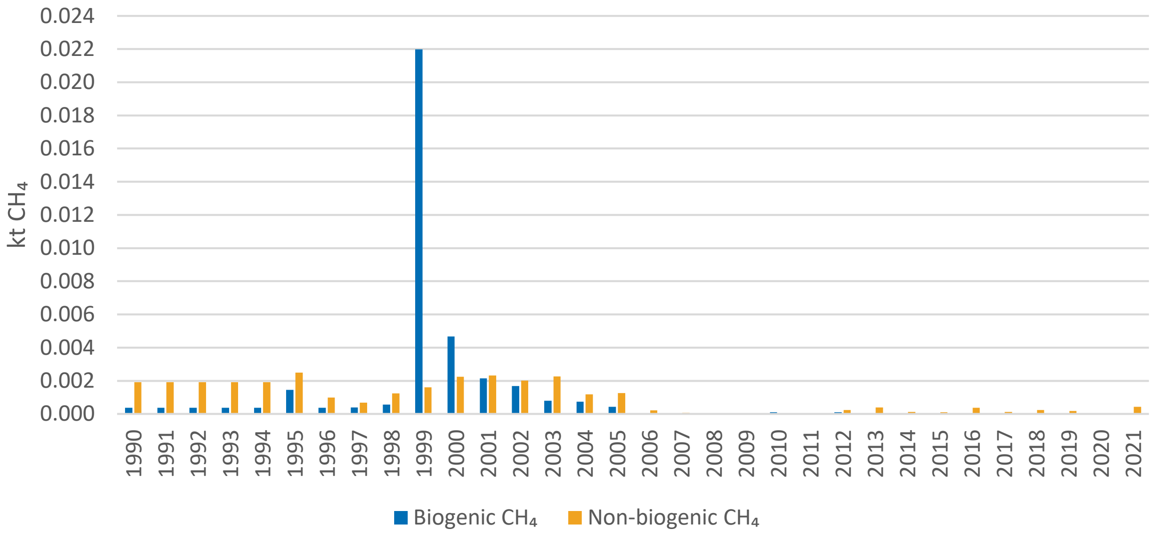


Figure 7.13. CH_4 emissions from Waste incineration without energy recovery in Estonia in 1990–2021, kt

N_2O emissions (Figure 7.14) from Waste incineration in 2021 was 0.14 kg, of which 0.114 kg was non-biogenic and 0.024 kg biogenic. Emissions from non-biogenic waste increased considerable in 2000 and 2001, when clinical, plastic and inert waste was incinerated. N_2O emissions from the combustion of fossil liquid waste can be considered negligible; therefore, it is not included in emission calculations. Since 2001, the proportion of non-biogenic emissions has decreased because waste is more likely to be incinerated in order to generate energy. In 2002–2005, emissions from the incineration of organic materials decreased; some emissions occurred from the incineration of textile, organic and paper waste. After 2006, only minor quantities of waste have been incinerated without energy recovery. In 2020 only 4.4 tonnes of waste were incinerated and in addition, no waste was combusted in 2008 and 2011. The specific quantity of waste incinerated by category is presented in Table 7.16.

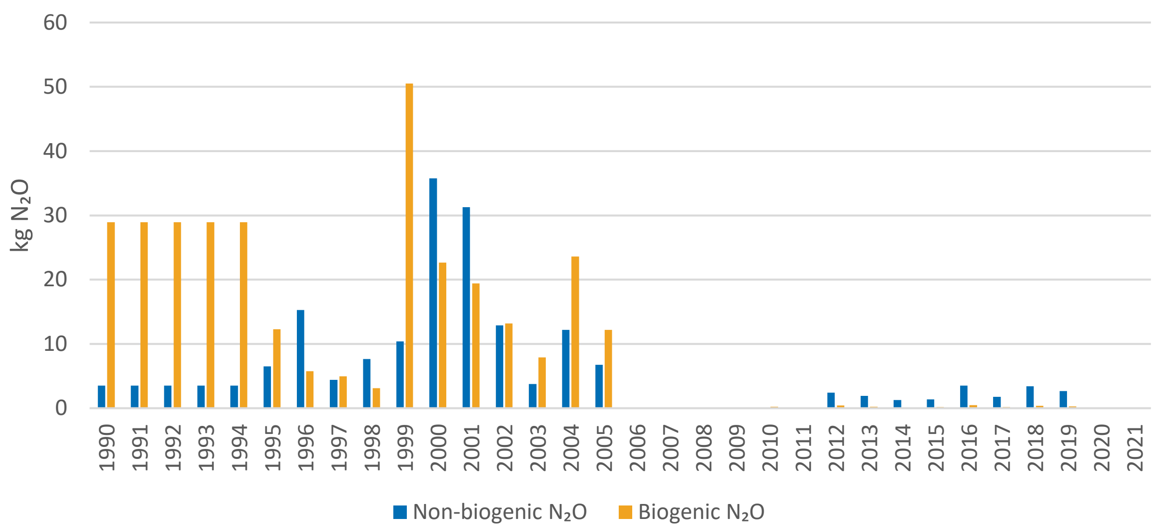


Figure 7.14. N_2O emissions from Waste incineration without energy recovery in Estonia in 1990–2021, kg

In Estonia, open burning of waste is not a common practice for eliminating waste, as it is considered an illegal activity and is forbidden. To include it in the emission calculations, an expert judgement by the Ministry of the Environment (MoE) was used. The expert judgement of MoE indicates that in 1990–2003, 2% and in 2004-2014 1% of MSW was open burned which starting from 2015, decreased to 0.5%. The fluctuation of emissions correlates with the total amount of waste generated and the composition changes in MSW.

CO_2, CH_4 and N_2O emissions (Figure 7.15, Figure 7.16, Figure 7.17) from the sub-category of Open burning of waste are divided into biogenic and non-biogenic emissions based on the fraction of fossil and biogenic carbon in the combusted waste material. Biogenic CO_2 emissions are not included in national total emission estimates.

In 2021, Open burning of waste resulted in 0.4 kt biogenic CO_2 and 0.4 kt non-biogenic CO_2.

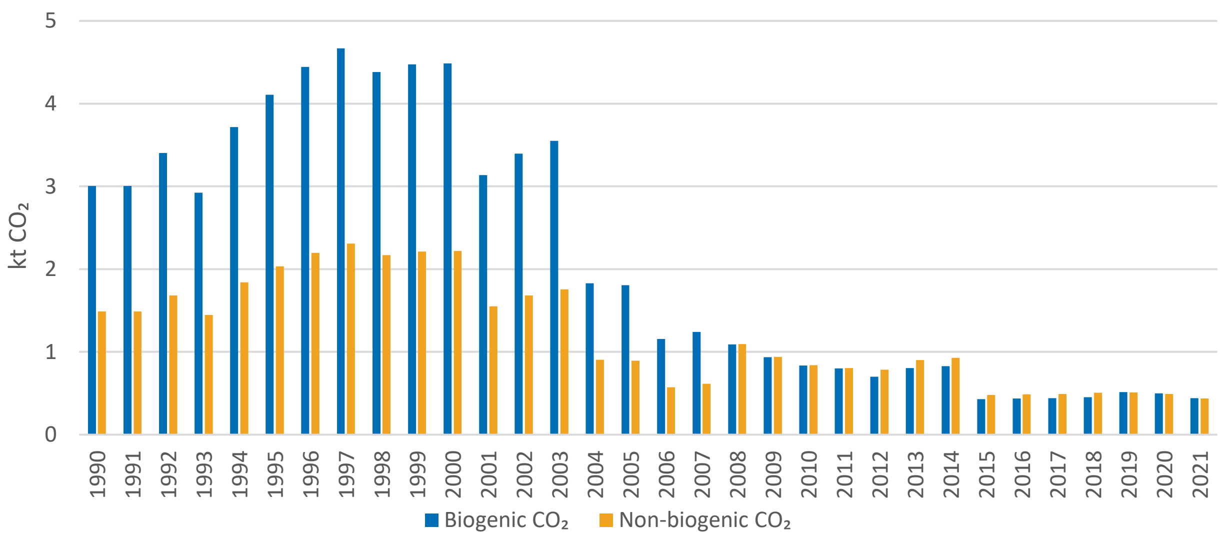


Figure 7.15. CO_2 emissions from Open burning of waste in Estonia in 1990–2021, kt

Total CH_4 emissions of 0.008 kt are divided into 0.005 kt biogenic CH_4 and 0.003 kt non-biogenic CH_4.

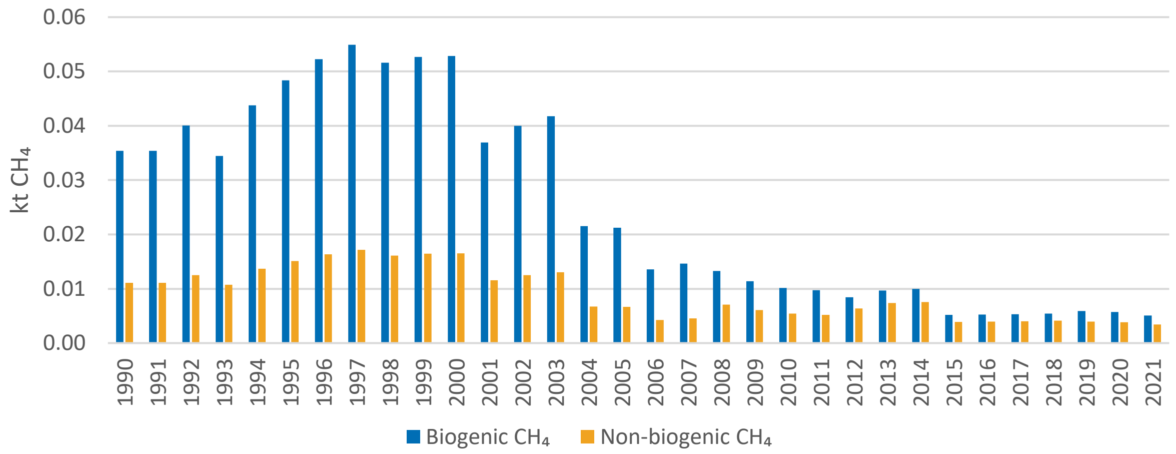


Figure 7.16. CH_4 emissions from Open burning of waste in Estonia in 1990–2021, kt

Total N_2O emissions of 0.0001 are divided into 0.00007 kt biogenic N_2O and 0.00007 kt non-biogenic N_2O.

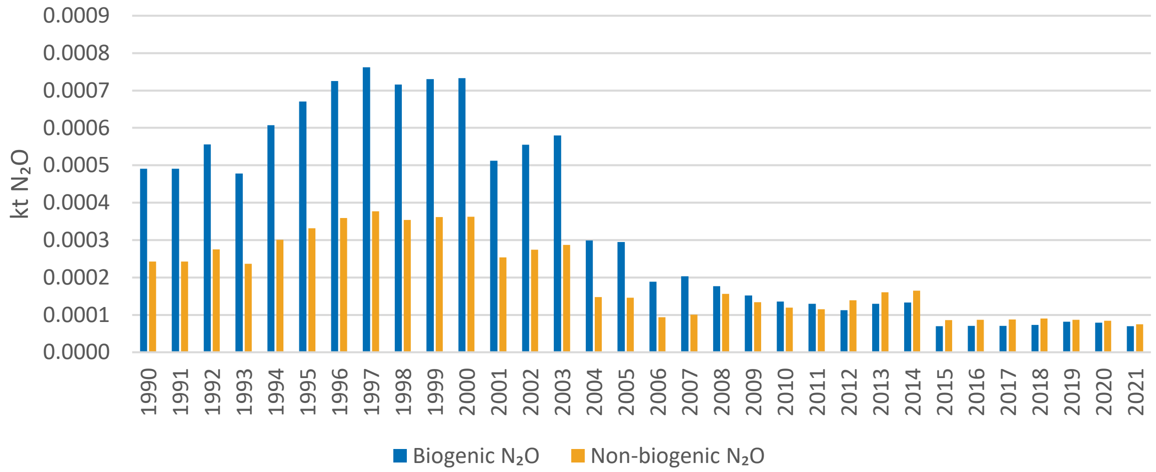


Figure 7.17. N_2O emissions from Open burning of waste in Estonia in 1990–2021, kt

7.4.2. Methodological issues

Activity data

Under the sub-category of Waste incineration and Open burning of waste, only emissions from waste incineration without energy recovery are reported. The activity data on the quantities of waste incinerated is collected and verified by the EstEA. Every company that incinerates waste is obligated to report to EstEA, which processes data and checks its accuracy. For 1990–1993, the quantities of incinerated waste from 1994 were used, as there is no available information on the quantities of incinerated waste during that period. Nevertheless, it is assumed that the quantity of incinerated waste was similar to that of 1994.

In 2021, the quantity of waste incinerated without energy recovery was 58.06 tonnes (Table 7.16) Waste incineration with energy recovery is part of the Energy sector and therefore has been reported under the Energy sector.

There was an increase in the quantities of waste incinerated in 1995 and 1999. The significant fluctuation of the quantities of incinerated waste is related to large quantities of waste from paper, wood, inert, petroleum products and oil combustion during those years. Generally, the trend of waste incineration has decreased throughout the years since 2000. The marginal quantities of waste combusted without energy recovery are caused by the fact that more waste is recycled, composted, or incinerated with the purpose of generating energy, and the amount of waste for combustion without energy recovery is therefore minimised. EstEA has verified that in 2008 and 2011, no waste was incinerated without energy recovery.

Table 7.16. Quantities of waste incinerated without energy recovery in Estonia in 1990–2021, tonnes[400]

	Inert	Leather Rubber	MSW	Petroleum	Oil	Solvents	Organic	Garden	Paper	Plastic	Sludge	Textile	Wood	Clinical	Total
1990	23	1	4	94	148	1	17	NO	20	6	60	3	NO	5	381
1995	34	6	23	248	37	15	15	NO	389	5	2	61	NO	12	846
2000	362	78	3	NO	3	NO	41	NO	2	5	NO	20	815	12	1 341
2005	50	NO	NO	NO	106	60	0.3	NO	2	NO	NO	128	10	10	366
2010	NO	NO	NO	NO	NO	NO	NO	NO	3	NO	NO	NO	18	NO	21
2011	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2012	27	NO	NO	NO	10	1	NO	NO	NO	NO	NO	NO	18	NO	56
2013	21	NO	NO	NO	34	4	NO	NO	NO	NO	NO	NO	NO	NO	59
2014	14	NO	NO	NO	NO	6	NO	NO	NO	NO	NO	NO	NO	NO	20
2015	15	NO	NO	NO	0.7	2	NO	NO	NO	NO	NO	NO	NO	NO	18
2016	39	NO	NO	NO	7	11	NO	NO	NO	NO	NO	1	NO	NO	58
2017	19.8	NO	NO	NO	NO	1.7	NO	NO	NO	NO	NO	NO	NO	NO	21.5
2018	37.8	NO	NO	NO	0.8	3.6	NO	NO	NO	NO	NO	NO	0.7	NO	43
2019	29.4	NO	NO	NO	0.8	3.4	NO	NO	NO	NO	NO	NO	NO	NO	33.6
2020	0.6	NO	NO	NO	1.0	2.2	NO	NO	NO	NO	NO	NO	0.6	NO	4.4
2021	1.3	NO	NO	NO	NO	55.7	NO	NO	0.5	NO	NO	NO	0.6	NO	58.1

NO – not occurring

Time series of open burning of MSW is shown in Figure 7.18. An MoE expert judgement indicates that in 1990–2003, 2% of MSW was open burned, in 2004-2014 1% of MSW was open burned and starting from 2015, the amount of open burned waste decreased to 0.5%. The change in the open burning percentage is connected to the development of an organised waste collection system.

By 2012, 95% of the population had been connected to the organised waste collection system. MSW from households not connected to the official collection system, however, is believed to still reach the official waste collection system (through public waste containers, packaging containers, waste abandonment in forests etc.). Consequently, it can be assumed that people are not burning waste to dispose of it but rather, it could be considered a habitual behaviour.

As the activity is forbidden and no studies have been carried out on the specific composition of MSW burned, MoE's expert judgement was given about the open burning of MSW (mix of fractions). Without any available studies, it is currently impossible to define which type of waste

[400] D10 operation of waste disposal activities – Incineration on land.

is most used for open burning or eliminate any waste fractions. The fluctuation of burned MSW seen in Figure 7.18 is connected to the fluctuation of MSW generation.

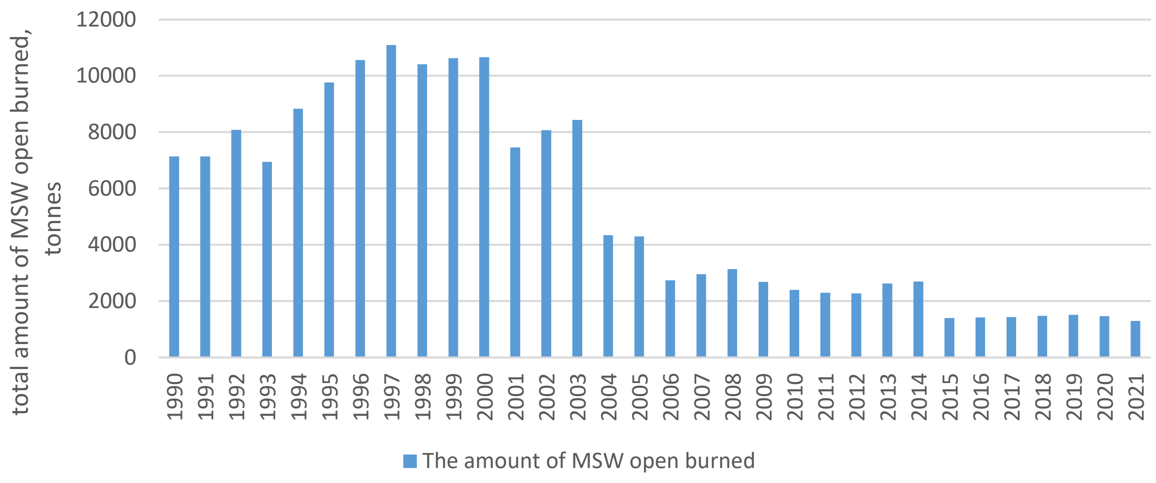


Figure 7.18. Quantities of waste open burned in Estonia in 1990–2021, tonnes

The specific composition of open burned MSW is based on the MSW sorting studies (Table 7.17). Only the fractions of food, paper/cardboard, wood, garden, textiles, plastic and other waste (flammable materials) are included in calculations (the emission calculations did not include metal and glass waste).

Table 7.17. Specific composition of open burned MSW, tonnes

Year	**Food waste**	**Paper/ Cardboard**	**Wood**	**Garden**	**Textiles**	**Plastic**	**Other**	**Total**
1990	3 215	1937	254	NO	72	886	782	7146
1995	4 392	2 646	346	NO	98	1 211	1 069	9 763
2000	4 800	2 892	379	NO	107	1 323	1 168	10 670
2005	1 932	1 164	152	NO	43	532	470	4 294
2010	852	470	12	141	119	499	306	2 398
2011	818	451	11	136	114	479	294	2 302
2012	709	342	51	96	129	458	496	2 280
2013	816	393	58	111	149	527	571	2 624
2014	838	404	60	114	153	542	587	2 697
2015	435	210	31	59	79	281	305	1 401
2016	441	213	32	60	80	285	309	1 420
2017	444	214	32	60	81	287	311	1 430
2018	458	221	33	62	84	296	321	1 475
2019	387	283	21	140	96	297	292	1 518
2020	375	274	21	136	94	287	283	1 470
2021	333	242	18	120	83	255	251	1 303

NO – not occurring

Methods

CO_2 emissions from incineration were calculated with IPCC 2006 *Tier 2a* (Equation 7.4) method and for open burning IPCC 2006 *Tier 1* approach was used (Equation 7.5).

Equation 7.4[401]

$$CO_2 Emissions = \sum_i (SW_i \times dm_i \times CF_i \times FCF_i \times OF_i) \times 44/12$$

Equation 7.5[402]

$$CO_2 Emissions = MSW \times \sum_j \left(WF_j \times dm_j \times CF_j \times FCF_j \times OF_j\right) \times 44/12$$

Where:

CO_2 emissions = CO_2 emissions in inventory year kt/year;
SW_i = total amount of solid waste of type *i* (wet weight) incinerated or open burned kt/year;
WF_j = total amount of solid waste of type *i* (wet weight) incinerated or open burned kt/year;
dm_{ij} = dry matter content in waste (wet weight) incinerated or open burned (fraction);
CF_{ij} = fraction of carbon in dry matter (total carbon content) (fraction);
FCF_{ij} = fraction of fossil carbon in the total carbon (fraction);
OF_{ij} = oxidation factor (fraction);
44/12 = conversion factor from C to CO_2;
i = type of waste incinerated specified as follows:
MSW: municipal solid waste;
ISW: industrial solid waste;
SS: sewage sludge;
HW: hazardous waste;
CW: clinical waste;
j = component of MSW open burned.

For calculating CO_2 emissions from open burning of MSW fractions of solid waste by type *i* presented in Table 7.10 under SWD on land were used.

Emission factors

IPCC 2006 Guidelines' default oxidation factor (Table 7.18) and emission factors (Table 7.19) have been used for calculating CO_2 emissions from both sub-categories of Waste incineration and Open burning of waste.

---

[401] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.7, equation 5.1.
[402] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.7, equation 5.2.

Table 7.18. Default oxidation factors used in Waste incineration and Open burning of waste calculations[403]

	Incineration of waste	Open burning of MSW
Oxidation factor in % of carbon input	100%	58%

Table 7.19. Default dry matter content total carbon content and fossil carbon content of different waste components used for calculating emissions from Waste incineration and Open burning of waste

Waste component	Dry matter content in % of wet weight	Total carbon content in % of dry matter	Fossil carbon fraction in % of total carbon
MSW[404]			
Food waste	40	38	0
Wood	85	50	0
Paper/cardboard	90	46	1
Textiles	80	50	20
Garden and park waste	40	49	0
Rubber and Leather	84	67	20
Plastics	100	75	100
Other inert waste	90	3	100
Industrial waste[405]			
Textile	80	40	16
Pulp and paper	90	41	1
Clinical waste	65	40	25
Industrial waste[406]	90[405]	50	90
Sewage sludge	10[407]	45	0

For estimating N_2O emissions from Waste incineration and Open burning of waste IPCC 2006 *Tier 1* approach with Equation 7.6 was used.

Equation 7.6[408]

$$N_2O\ Emissions = \sum_i (IW_i \times EF_i) \times 10^{-6}$$

Where:

N_2O emissions = N_2O emissions in inventory year kt/year;
IW_i = amount of incinerated / open burned waste of type *i* kt/year;
EF_i = N_2O emission factor for waste of type *i* kg N_2O/kt of waste;

[403] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and open burning of waste, page 5.18, table 5.2.
[404] IPCC 2006 Guidelines, Volume 5, Chapter 2: Waste generation, composition and management data, page 2.14, table 2.4.
[405] IPCC 2006 Guidelines, Volume 5, Chapter 2: Waste generation, composition and management data, page 2.15 and 2.16, table 2.5 and 2.6.
[406] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and open burning of waste, page 5.18, table 5.2.
[407] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and open burning of waste, page 5.15.
[408] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and open burning of waste, page 5.14, eq 5.5.

10^{-6} = conversion factor from kilogram to kiloton;
i = category or type of waste incinerated / open burned specified as follows: MSW: municipal solid waste; ISW: industrial solid waste; SS: sewage sludge; HW: hazardous waste; CW: clinical waste other (must be specified).

IPCC 2006 default EFs are used in calculations of N_2O emissions from Waste incineration and Open burning of waste (Table 7.20).

Table 7.20. N_2O emission factors used in calculations of Waste incineration and Open burning of waste[409]

Waste category	Emission factor g N_2O/t waste incinerated	Weight basis
Waste incineration		
MSW Industrial waste Sludge (except sewage sludge)	50 100 450	Wet weight Wet weight Wet weight
Open burning		
MSW	150 g N_2O/t	Dry matter

There are not enough EFs in the Waste sector guidelines for calculating CH_4 emissions from incineration therefore *Tier 1* approach with an equation (Equation 7.7) from the Energy sector was implemented. For open burning *Tier* 1 method was used from the Waste sector (Equation 7.8).

Equation 7.7[410]

$$Emissions_{GHG\ fuel} = Fuel\ Consumtpion_{fuel} \times Emission\ factor_{GHG\ fuel}$$

Where:

$Emissions_{GHG\ fuel}$ = emissions of a given GHG by type of fuel (kg GHG);
Fuel Consumption $_{fuel}$ = amount of fuel combusted (TJ);
Emission $Fator_{GHG\ fuel}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ).

Equation 7.8[411]

$$CH_4Emissions = \sum_i (IW_i \times EF_i) \times 10^{-6}$$

Where:

CH_4 emissions = CH_4 emissions in inventory year kt/year;
IW_i = amount of solid waste of type 1 incinerated / open burned *i* kt/year;
EF_i = aggregate CH_4 emission factor kg CH_4/kt of waste;

[409] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.22, table 5.6, for incineration; page 5.22 for open burning.
[410] IPCC 2006 Guidelines, Volume 2, Chapter 2: Stationary Combustion, page 2.11, equation 2.1.
[411] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.12, eq 5.4.

10^{-6} =	conversion factor from kilogram to kiloton;
i =	category or type of waste incinerated / open burned specified as follows: MSW: municipal solid waste; ISW: industrial solid waste; SS: sewage sludge; HW: hazardous waste; CW: clinical waste other (must be specified).

For calculating CH_4 emission with the equation from the Energy sector the calorific values from Table 7.21 and emission factors from Table 7.22 were implemented in calculations.

Table 7.21. Calorific values for calculating CH_4 emissions from incineration without energy recovery

Type of waste	Calorific value	MJ/kg = TJ/kt	Source
Inert	17.79	MJ/kg	Kunda Nordic Cement value for other waste / fossil waste
Leather and rubber			
MSW	10.25	MJ/kg	Iru waste incineration plant
Clinical waste			
Petroleum products	25.667	MJ/kg	Kunda Nordic Cement value for waste oil
Oil			
Solvents			
Organic	11.6	TJ/kt	D – municipal waste (biomass fraction) D – other primary solid biomass
Garden			
Sludge			
Paper	10	TJ/kt	D – municipal waste (non-biomass fraction)
Plastic			
Textile			
Wood	15.6	TJ/kt	D – wood

D – IPCC default factors [412]

Table 7.22. Emission factors for calculating CH_4 emissions from incineration without energy recovery and open burning of waste

Waste category	Emission factor
Waste incineration[413]	
Wood; industrial waste; MSW (non-biomass fraction); MSW (biomass fraction); other primary solid biomass; waste oil	300 kg CH_4 /TJ
Open burning[414]	
MSW	6500 g/t MSW wet weight

7.4.3. Uncertainties and time series consistency

The estimation of GHG emissions from waste incineration is carried out by considering the activity data (amount of burned waste) and emission factors. Uncertainties of default emission

[412] IPCC 2006 Guidelines, Volume 2, Chapter 1: Introduction, page 1.18, table 1.2.
[413]. IPCC 2006 Guidelines, Volume 2, Chapter 2: Stationary Combustion, page 2.21, table 2.4.
[414] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.20.

factors and activity data used in the estimations are derived based on methodology from IPCC 2006 Guidelines. Values used in the estimates are presented in Table 7.23.

The combined uncertainty rates related to the sub-category of Waste incineration are given in Table 7.3.

Table 7.23. Default uncertainty ranges for Waste incineration

Input	Uncertainties
Activity data[415]	
Quantities of waste incinerated without energy recovery	±5%
Quantity of waste open burned	
Dry matter content	±30%
Waste composition[388]	±10%
Quantity of waste open burned	±5%
Emission factors[416]	
CO_2	±40%
CH_4	±50%
N_2O	±100%

7.4.4. Category-specific QA/QC and verification

Complete QA and QC were carried out pursuant to the procedures described in IPCC 2006 Guidelines[417]. To ensure accuracy country-specific data has been cross-checked.

The quality objectives and the QA/QC plan for the Estonian GHG inventory at the national level are presented in Section 1.2.3.

7.4.5. Category-specific recalculations

Recalculation was done due to fixing calculation error for 2020 N_2O emissions in Open burning of waste subcategory (Table 7.24).

Table 7.24. Recalculated N_2O emissions in 2020

	Year	N_2O emissions, kt
2022 submission	2020	0.00016297
2023 submission	2020	0.00016288

EstEA corrected the amount of waste incinerated without energy recovery in 2020, therefore CO_2, CH_4 and N_2O emissions has been recalculated (Table 7.25).

Table 7.25. Corrected amount of waste incinerated in 2020 and recalculated emissions

	2020			
	Amount of waste incinerated, tonnes	CO_2 emissions	CH_4 emissions	N_2O emissions
2022 submission	0.65	0.000074250	0.000003075	0.000000011
2023 submission	4.36	0.000865755	0.000439853	0.000000064

[415] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.24.
[416] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.23.
[417] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance / Quality Control and Verification.

7.4.6. Category-specific planned improvements

The activity data is kept under consideration and will be updated as necessary.

7.5. Wastewater treatment and discharge (CRF 5.D)

7.5.1. Category description

Total CH_4 emissions from Wastewater treatment and discharge in 2021 consists of 2.04 kt from domestic wastewater handling (Figure 7.19) and 0.15 kt from industrial wastewater handling (Figure 7.20).

CH_4 from domestic wastewater handling has increased 4.6% compared to 2020. There were two main reasons: degree of population connected to wastewater treatment plants increased by 1% due to a change in data collecting methodology in EstEA. Until 2020 companies reported data by operational areas but started from 2021 they report data by settlements. Additionally based on the 2021 census, the population in low population settlements has increased and due to the recalculation, the emission has increased.

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 channelled 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 being 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.

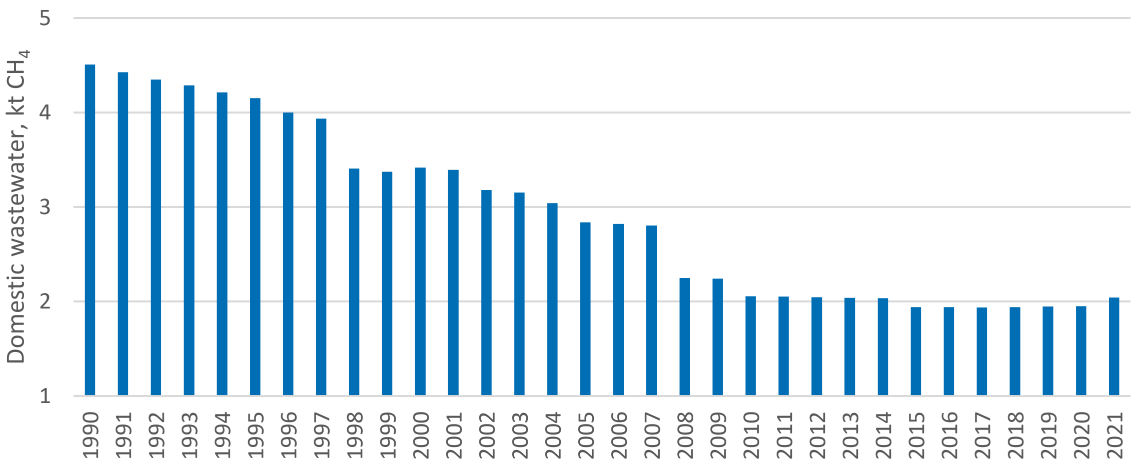


Figure 7.19. CH_4 emissions from domestic wastewater handling in 1990–2021, kt CH_4

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.

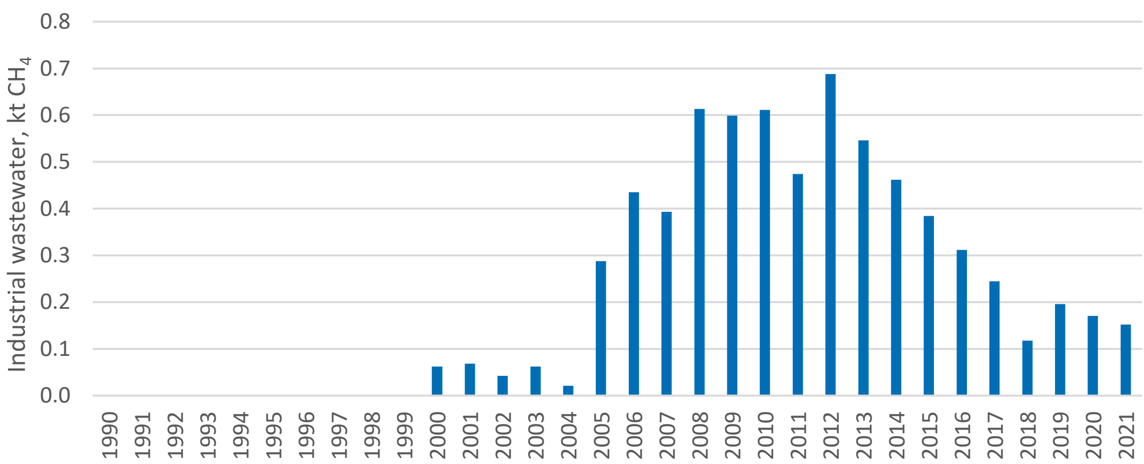


Figure 7.20. CH_4 emissions from industrial wastewater handling in 1990–2021, kt CH_4

N_2O emissions from domestic sources are presented in Figure 7.21. The total amount of N_2O emissions from wastewater in 2021 was 0.11 kt. The minor fluctuation in the time series is related to changes in protein consumption values per capita.

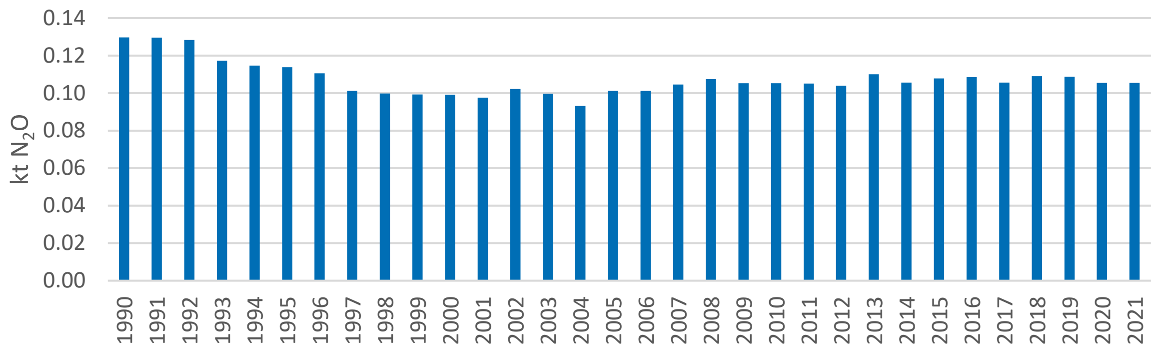


Figure 7.21. N_2O emissions from domestic wastewater handling in 1990–2021, kt N_2O

7.5.2. Methodological issues

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[418]. As suggested by the ESD review team in 2017, the balance scheme of wastewater pathways was added (Figure 7.22) which are also shown in Table 7.26 and Table 7.27.

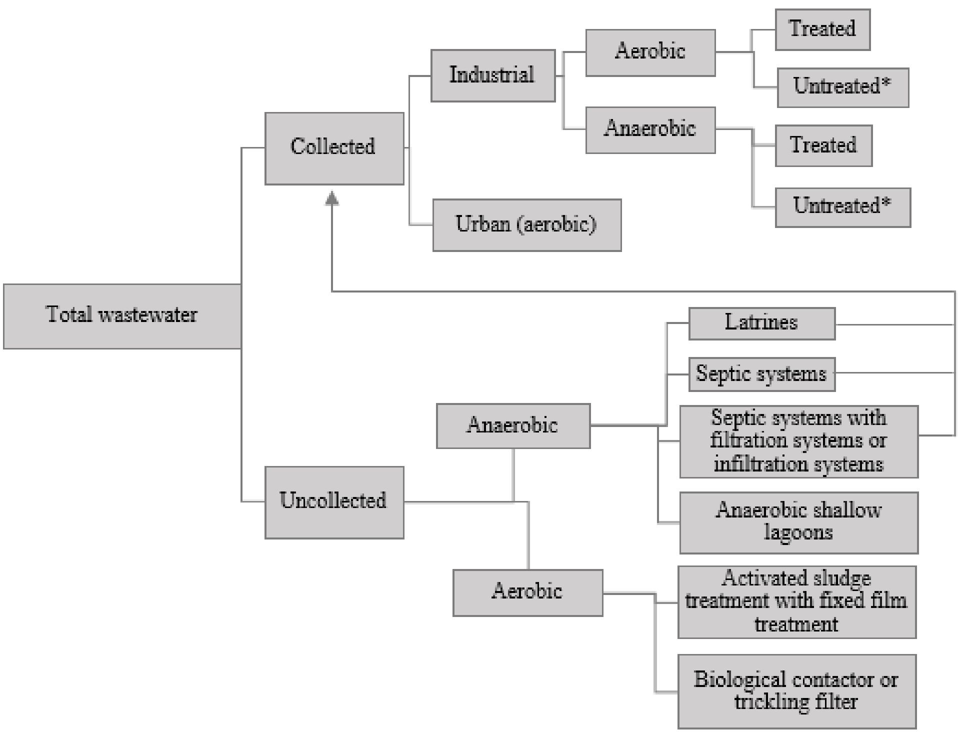


Figure 7.22. Typical balance of wastewater pathways for domestic wastewater in Estonia

[418] Table is based on a study by Infragate, (2014). Hajaasustuse reovee kohtkäitlussüsteemide inventuuri aruanne.

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 (Table 7.26):

- 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 7.26. Wastewater treatment systems in low population settlements %[418]

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
1995	NO	0.8	2.2	0.5	22.2	2.2	59.1	0.1	13.0	100
2000	0.01	0.8	2.1	0.6	21.0	2.1	58.2	0.2	15.0	100
2005	0.06	0.8	1.9	0.7	19.2	2.2	56.1	0.5	18.7	100
2010	0.08	0.8	1.7	0.7	17.9	2.2	54.1	0.8	21.8	100
2011	0.08	0.7	1.6	0.7	17.8	2.2	53.4	0.9	22.5	100
2012	0.08	0.7	1.6	0.7	17.7	2.2	52.8	1.0	23.2	100
2013	0.08	0.7	1.5	0.7	17.6	2.1	52.2	1.2	23.9	100
2014	0.08	0.7	1.5	0.7	17.6	2.1	52.2	1.2	23.9	100
2015	0.08	0.7	1.5	0.7	17.3	2.1	51.5	1.1	25.0	100
2016	0.08	0.7	1.5	0.7	17.0	2.0	50.7	1.1	26.1	100
2017	0.08	0.7	1.5	0.7	16.7	2.0	50.0	1.1	27.2	100
2018	0.08	0.7	1.5	0.7	16.4	1.9	49.2	1.1	28.4	100
2019	0.08	0.7	1.5	0.7	16.2	1.9	48.6	1.1	29.2	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

NO – not occurring

Anaerobic wastewater treatment systems in high population settlements (Table 7.27) (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 MoE. Data from 1998–2021 has been obtained from EstEA.

Table 7.27. 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
1995	11.7	22.2	66.1	100
2000	7.4	23.6	69	100
2005	5.7	20.3	74	100
2010	3.7	14.3	82	100
2011	3.7	14.3	82	100
2012	3.7	14.3	82	100
2013	3.7	14.3	82	100
2014	3.7	14.3	82	100
2015	3.4	13.6	83	100
2016	3.3	13.7	83	100
2017	3.3	13.7	83	100
2018	3.2	13.8	83	100
2019	3.2	13.8	83	100
2020	3.1	13.9	83	100
2021	3.2	14.8	82	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). Starting from 2014 one additional company started treating its wastewater anaerobically recovering CH_4 for energy. According to the SE, the energy data from this company has been included in the biogas data used by the Energy sector therefore it is included in the Energy sector.

The generated CH_4 was flared in 2000–2009 and starting from 2010 CH_4 was recovered for energy. Degradable Organic Component (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.

For calculating N_2O emissions data on the Estonian population was used as activity data and obtained from the dataset of the SE. The annual protein consumption per capita was used from FAO statistical database. Nitrogen in sludge is 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 $F_{IND\text{-}COM}$ fraction of 1.25 is applied to Equation 7.15 for calculating total nitrogen in the effluent.

Methodology

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 7.9 Equation 7.11 and Equation 7.12. CH_4 emission calculations from industrial sources were done by using Equation 7.10, Equation 7.11 and Equation 7.13.

Equation 7.9[419]

$$CH_4 Emissions = \sum \left(TOW_j \times EF_j\right) - S - R$$

Equation 7.10[420]

$$CH_4\ Emissions = \sum_i [(TOW_i - S_i) \times EF_i - R_i]$$

Equation 7.11[421]

$$EF_{j/i} = B_o \times MCF_{j/i}$$

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;
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 7.12 is used for calculating TOW in domestic wastewater and Equation 7.13 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 7.12[422]

$$TOW = P_j \times BOD_j \times 0.001 \times 365$$

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.

[419] Equation proposed by TERT.
[420] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.20, equation 6.4.
[421] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.12, equation 6.2
[422] Equation proposed by TERT.

Equation 7.13[423]

$$TOW_i = P_i \times W_i \times COD_i$$

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 7.14 and Equation 7.15.

Equation 7.14[424]

$$N_2O\ Emissions = N_{EFFLUENT} \times EF_{EFFLUENT} \times 44/28$$

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.

Equation 7.15[425]

$$N_{EFFLUENT} = (P \times PROTEIN \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM}) - F_{SLUDGE}$$

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.

[423] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.22, equation 6.6.
[424] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.25, equation 6.7.
[425] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.25, equation 6.8.

Emission factors

The IPCC 2006 Guidelines default emission factors used in calculations are presented in Table 7.28

Table 7.28. 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)[426]	0.6
Degradable organic component (g BOD/person/day)[427]	60
MCF anaerobic lagoon[428]	0.2
MCF septic system[428]	0.5
MCF latrines[428]	0.7
MCF centralised wastewater treatment[428]	0
CH_4 from industrial wastewater	
Bo (kg CH_4/kg COD)[429]	0.25
MCF[430]	0.8
N_2O from wastewater[431]	
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

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. A couple of years ago it was popular for households to have a garbage disposal unit to shred 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. Uncertainties and time series consistency

The estimation of CH_4 emissions from Wastewater treatment and discharge is carried out by considering activity data and emission factors. Default uncertainty ranges for domestic and industrial wastewater are presented in Table 7.29. The data on protein consumption per capita was received from FAO databases; the uncertainty of this parameter is not recorded.

---

[426] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.12, table 6.2.
[427] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.14, table 6.4.
[428] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.13, table 6.3.
[429] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.21.
[430] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.21, table 6.8.
[431] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.27, table 6.11.

Table 7.29. Default uncertainty ranges for Wastewater treatment and discharge

Input	Uncertainties
CH_4 from domestic Wastewater[432]	
Activity data	
Human population	±5%
BOD/person	±30%
Fraction of people income group	±15%
Degree of utilisation of treatment/discharge pathway or system for each income group	±50%
Emission factor	
Latrines centralised well-managed treatment systems lagoons	±50%; ±10%; ±30%;
Maximum methane producing capacity (B_o)	±30%
CH_4 from industrial Wastewater[433]	
Activity data	
Industrial production	±5%[1]
Wastewater/unit production	±50%
COD/unit wastewater	
Emission factor	
Maximum methane producing capacity (Bo)	±30%
Methane correction factor[429]	±20%
N_2O from wastewater[434]	
Activity data	
Human population	±10%
Protein	±10%
FNRP (kg N/year)	(0.16) 0.15–0.17
$F_{NON\text{-}CON}$	(1.4) 1.0–1.5
$F_{IND\text{-}COM}$	(1.25) 1.0–1.5
Emission factor	
$EF_{EFFLUENT}$ (kg N_2O-N/kg-N)	(0.005) 0.0005–0.25
EF_{PLANTS}	(3.2) 2–8

[1]Activity data for calculating emissions from industrial wastewater is plant-based and therefore an expert judgement has been used.

7.5.4. Category-specific QA/QC and verification

Complete QA and QC were carried out pursuant to the procedures described in IPCC 2006 Guidelines[435]. 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 given in Section 1.2.3.

[432] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.17, table 6.7.
[433] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.23, table 6.10.
[434] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.27, table 6.11.
[435] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance / Quality Control and Verification.

7.5.5. Category-specific recalculations

The population in low population settlements was corrected based on the 2021 census, and therefore the CH_4 emission has been recalculated (Table 7.30).

Table 7.30. Population changes in low population settlements between two submissions

	2022 submission		2023 submission	
	Population in low population settlements	CH_4 emission, kt	Population in low population settlements	CH_4 emission, kt
2014	62136	2.03375	62177	2.03398
2015	62257	1.93834	62338	1.93880
2016	62378	1.93970	62500	1.94040
2017	62499	1.93749	62662	1.93841
2018	62499	1.93919	62823	1.94103
2019	62499	1.94528	62985	1.94804
2020	62499	1.94806	63146	1.95174

Protein supply information from FAOSTAT in 2018-2020 has been updated and during the QC procedure, the amount of sewage sludge in 2020 has been changed, therefore N_2O emissions has recalculated (Table 7.31).

Table 7.31. Recalculated N_2O emissions

2022 submission				2023 submission		
	Per capita protein consumption kg/person/year	Sludge, tonnes	N_2O emissions, kt	Per capita protein consumption kg/person/year	Sludge, tonne	N_2O emissions, kt
2018	105.38		0.11033	104.16		0.10903
2019	105.38		0.10999	104.10		0.10540
2020	105.38	79 029.88	0.10941	101.40	72 795.42	0.10537

7.5.6. Category-specific planned improvements

The activity data for estimating N_2O from advanced centralised wastewater treatment plants is considered and the emission calculation will be included when the activity data is made available.

8. OTHER (CRF 6)

Estonia does not report any emissions under the Other sector.

9. INDIRECT CO_2 AND NITROUS OXIDE EMISSIONS

9.1. Description of sources of indirect emissions in GHG inventory

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

3. Solvent use;
4. Road paving with asphalt.

The indirect CO_2 emissions are reported under beforementioned subcategory on CO_2 emission rows.

Information on how the indirect CO_2 emissions were calculated, is provided in Chapters 4.5.3.2 Solvent use and 4.5.3.3 Road paving with asphalt.

10.RECALCULATIONS AND IMPROVEMENTS

10.1. Explanations and justifications for recalculations, including in response to the review process

10.1.1. GHG inventory

Explanations and justifications for the recalculations performed for this submission are given in Table 10.1

Table 10.1. Recalculations made for the 2023 inventory submission by the CRF category and their implications

SECTOR	IPCC CATEGORY	RECALCULATION
Energy	1.A.1. Energy industries	Emissions were recalculated in 1.A.1.a due to correcting natural gas, peat, and coal consumption data in calculations, updated peat consumption data by Statistics Estonia in 2020 in Joint Questionnaire, updating methodology for calculating emissions from waste incineration in 1.A.1.a in 2013-2021, updating solid biomass consumption data in 1990-1991, and dividing peat into peat briquette and milled&sod peat in calculations in the whole timeseries in 1.A.1.a.
	1.A.2 Manufacturing and construction	Emissions were recalculated in all subcategories due to dividing peat into milled&sod and peat briquette. In addition 1.A.2.c emissions were recalculated due to correcting the natural gas CEF value, and 1.A.2.f emissions were recalculated due to updating the share of 1-50MW boilers using solid biomass in calculations for CH_4 and N_2O emission factors,
	1.A.3.Transport	Emissions were recalculated in 1.A.3.a in 1990 due to correcting a minor error in consumption data, in 1.A.3.c due to corrected light fuel oil consumption data by Statistics Estonia in Joint Questionnaire in 2019 and 2020, in 1.A.3.d Domestic Navigation because of correcting light fuel oil consumption data in Joint Questionnaire for one of the water transport companies in 2002, and 2006-2008, in 1.A.3.b due to using updated version of COPERT 5 model and using updated carbon fossil part of biofuels in CO_2 calculations in 2005-2021.
	1.A.4 Other sectors	Emissions were recalculated in 1.A.4 all subsectors due to dividing peat into milled&sod peat and peat briquette for the whole timeseries, and in 1.A.4.b correcting the default emission factor value for diesel oil for CH_4 and N_2O and using country-specific emission factors for CH4 and N2O for biomass instead of default values.
	1.A.5 Other	Emissions from military vehicles in 1.A.5 Other are included in category 1.A.4.a Commercial/insitutional, because of Joint Questionnaire dataset
	1.B Fugitive emissions	Emissions were recalculated because of correcting natural gas consumption data in 1.A.1.a Public electricity and power production calculations for the entire timeseries, this affected the total activity data of natural gas.
IPPU	2.D.3 Other	Emissions have been recalculated for the years 2017-2020 due to updated COPERT 5 data on the consumption diesel and therefore urea-based DEF (AdBlue)

SECTOR	IPCC CATEGORY	RECALCULATION
	2.D.3 Other	NMVOC emissions and indirect CO_2 from them have been recalculated for the years 2014-2020. Recalculations of 2014-2020 emissions were done because of Estonian Environment Agency's correction of activity data.
	2.F.1 Refrigeration and air conditioning	The stock and emissions for the years 2011-2020 have been recalculated. Decommissioned reefer containers were not subtracted from average stock. In 2015-2020 the percentage of Estonian reefer container units was corrected (little difference each year, not constant through years). New F-gas HFC-513A was added to the reefer containers calculations 2018-2020.
	2.F.1 Refrigeration and air conditioning	Recalculations have been done considering changes in number of tractors and decommissioning 13 years old tractors.
	2.F.2 Foam blowing agents	Emissions of the years 2015-2020 have been recalculated because new data on HFC-containing spray foam sold in Estonia was obtained from two companies.
	2.F.3 Fire protection	Quantity of HFC-23 in stock 2020 has been recalculated because one service company did not report all the equipment. This equipment was not newly installed.
	2.F.4 Aerosols	There was a calculation error in the amount HFC-134a in operating system and therefore also in total emission of HFC-134a in Metered-dose inhalers in 2019
	2.G.1 Electrical equipment	Recalculation was done due to calculation error made in the year 2020 calculations.
	2.G.2 SF_6 and PFCs from Other product use	Recalculation was done due to calculation error in the annual stock of SF_6 in the year 2020 therefore the emission has been recalculated.
	2.G.3 N_2O from product uses	Recalculation was done due to calculation error in the amount of N_2O sold by one of the companies in 2019.
Agriculture	3.A Enteric fermentation	Added pregnancy rate, milk yield, fat and protein content of milk, nitrogen retention coefficient for mature female cattle, updated the number of horses for 2019-2021, livestock numbers were rounded to an integer for 1990-2020 for the following animal groups: sheep, goats, calves aged 0-6 months and 6-12 months, laying hens, other hens and roosters, broilers, swine, rabbits, fur animals. Average weight for dairy cattle and growing cattle and digestibility of feed for growing cattle were rounded. Average winter temperature was corrected for 2020.
	3.B.1 Manure management, CH_4 emissions	Nitrogen retention in calves coefficient was added for mature females. Average weight for dairy cattle and growing cattle, digestibility of feed for growing cattle, manure management splits for sheep, goats, horses and poultry were rounded.
	3.B.2 Manure management, N_20 and NMVOC emissions	Average weight for dairy cattle and growing cattle, digestibility of feed for growing cattle, manure management splits for sheep, goats, horses and poultry were rounded. Corrected activity data for calculating indirect N_2O emissions due to the updates made in the Estonian Informative Inventory Report 1990–2020.

SECTOR	IPCC CATEGORY	RECALCULATION
	3.D Agricultural soils	N_2O emissions from Animal Manure Applied to Soils (CRF 3.D.1.1.a) and Other Organic Fertilizers Applied to Soils (3.D.1.2.c) were recalculated for 1990-2020 due to the corrected activity data and corrected methodology in Livestock categories (see Chapter 5.2. and Chapter 5.3). The N_2O emissions from Mineralization/Immobilization Associated with the Loss/Gain of Soil Organic Matter (CRF 3.D.1.5) and from Cultivation of organic soils (CRF 3.D.1.6) – data on areas of organic soils cultivated were updated in the framework of the NFI (see Chapter 6 LULUCF). The N_2O emission from sewage sludge applied to soils were recalculated for 2020 due to the corrected activity data. N_2O emission from Crop residues were recalculated for 2020 due to the corrected activity data for barley production, yield and production area. The N_2O emissions from Urine and Dung Deposited by Grazing Animals (3.D.1.3) were recalculated for 1990-2020 due to the corrected methodology and data usage in Livestock categories (see Chapter 5.2. and Chapter 5.3). The N_2O emissions from Cultivation of Organic Soils (3.D.1.6) were recalculated for 1990-2020. The N_2O emissions from Atmospheric Deposition (3.D.2.1) were recalculated for the whole timeseries due to activity data rounding (see explanation in Chapter 5.2.7).
LULUCF	4.A Forest land	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. Also, average growing stocks and dead wood volumes in Forest land and Grassland are recalculated annually. Emission factors were updated for mineral soils and Tier 1 methodology was applied for organic soils. In Table 6.13 changes in soil emission factors and in Table 6.14 a quantitative overview of recalculations is shown.
	4.B Cropland	Updated activity data from the NFI were used in calculations. Emission factors were updated for mineral soils and Tier 1 methodology was applied for organic soils. Please see Chapter 6.3.5 and Table 6.22 and Table 6.39 for a quantitative overview of recalculations.
	4.C Grassland	Activity data from the NFI and emission factors for mineral soils were updated. Tier 1 methodology was applied for organic soils. Please see Chapter 6.4.5 and Table 6.27.
	4.D Wetlands	Updated activity data from the NFI (please see Chapter 6.5.5 and Table 6.31.
	4.E Settlements	Updated activity data from the NFI and Tier 1 methodology for estimating CSC in soils (please see Chapter 6.6.5, Table 6.34 and Table 6.39).
	4.F Other land	Updated activity data from the NFI and Tier 1 methodology for estimating CSC in soils (please see Chapter 6.7.5, Table 6.37 and Table 6.39).
	4.G Harvested wood products	Updated activity data. In Table 6.46, a quantitative overview of recalculations has been shown.
Waste	5.C Waste incineration and Open burning of waste	Recalculation was done due to calculation error for 2020 N_2O emissions in Open burning of waste subcategory.

SECTOR	IPCC CATEGORY	RECALCULATION
	5.D Wastewater treatment and discharge	The population in low population settlements was corrected based on the 2021 census, and therefore the CH_4 emission has been recalculated. Protein supply information from FAOSTAT in 2018-2020 has been updated and therefore N_2O emissions has been recalculated.

10.1.2. Implications for emission levels

10.1.3. GHG inventory

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 will be integrated into overall activity data which is the primary cause for recalculating the LULUCF sector emissions (Table 10.3)

Table 10.2. Recalculation performed in 2023 submission for years 1990–2020 in kt CO_2 eq. Differences in % between 2022 September submission and 2023 submission.

	National Total GHG emissions without LULUCF			
	Submission 2021	Submission 2022,	Recalculation difference,	Recalculation difference, %
	kt CO_2 eq.	kt CO_2 eq.	kt CO_2 eq.	
1990	40256.24	40276.36	20.12	0.05%
1991	37371.81	37402.71	30.91	0.08%
1992	27207.21	27215.51	8.31	0.03%
1993	21757.69	21751.65	-6.04	-0.03%
1994	22253.49	22225.02	-28.47	-0.13%
1995	20155.47	20063.92	-91.54	-0.45%
1996	21114.38	21007.74	-106.64	-0.51%
1997	20836.37	20719.25	-117.12	-0.56%
1998	19077.95	18992.04	-85.91	-0.45%
1999	17928.04	17829.24	-98.80	-0.55%
2000	17555.79	17453.34	-102.45	-0.58%
2001	17991.52	17888.00	-103.52	-0.58%
2002	17392.25	17300.08	-92.17	-0.53%
2003	19338.19	19233.28	-104.91	-0.54%
2004	19463.92	19362.26	-101.66	-0.52%
2005	19225.01	19140.62	-84.39	-0.44%
2006	18568.59	18490.05	-78.54	-0.42%
2007	22167.94	22046.44	-121.50	-0.55%
2008	20107.44	19941.84	-165.60	-0.82%
2009	16635.03	16508.26	-126.77	-0.76%
2010	21243.32	21111.60	-131.73	-0.62%
2011	21189.82	21079.73	-110.09	-0.52%
2012	20075.33	19962.93	-112.40	-0.56%
2013	21981.58	21865.08	-116.50	-0.53%
2014	21148.52	21040.76	-107.76	-0.51%

	National Total GHG emissions without LULUCF			
	Submission 2021	Submission 2022,	Recalculation difference,	Recalculation difference, %
	kt CO_2 eq.	kt CO_2 eq.	kt CO_2 eq.	
2015	18065.27	17972.59	-92.68	-0.51%
2016	19751.43	19603.13	-148.31	-0.75%
2017	20993.47	20896.11	-97.36	-0.46%
2018	20154.42	20030.10	-124.32	-0.62%
2019	14658.20	14537.85	-120.34	-0.82%
2020	11577.63	11407.08	-170.54	-1.47%

Table 10.3. Recalculation difference of Estonia's 2023 GHG emissions compared to the 2022 September submission by sector, kt CO_2 eq.

	Submission 2022		Submission 2023		Recalculation difference	
	1990	2020	1990	2020	1990	2020
Energy	36228.14	9472.69	36184.55	9233.15	-0.1%	-2.5%
IPPU	963.14	288.44	963.14	289.29	0%	0.3%
Agriculture	2659.99	1501.50	2723.70	1569.74	2.4%	4.5%
LULUCF	-3181.32	1272.13	-3695.48	2509.07	16.2%	97.2%
Waste	404.97	315.00	404.97	314.91	0%	-0.03%

10.2. Implications for emission trends, including time series consistency

10.2.1. GHG inventory

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 source is 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.

11.Planned improvements, including in response to the review response

11.1.1. GHG inventory

Table 11.1 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 11.2 summarises Estonia's responses to the 2015/2016 and 2018 inventory review report (FCCC/ARR/2020/EST) and observations from the draft 2022 review report.

Table 11.1. Sector-specific improvement needs of Estonia's national greenhouse gas inventory

SECTOR	IPCC CATEGORY	IMPROVEMENTS
Energy		There are no improvements planned for the next submission.
IPPU		There are no improvements planned for the next submission.
Agriculture	3.B Manure management	Estonia is making efforts to increase cooperation between the two different institutions compiling the separate inventories of the GHG inventory and Informative inventory (Air Pollutant Emission Inventory) and to harmonize emission estimates.
	3.B.2.5 Indirect N_2O emissions	Estonia is making efforts to increase cooperation between the two different institutions compiling the separate inventories of the GHG inventory and Informative inventory (Air Pollutant Emission Inventory) and to harmonize emission estimates.
	3.H Urea application	Estonia is working on updating the methodology to calculate emissions from Urea application.
LULUCF	4. General	Estonia plans to acquire the land-use change data for the period of 1970–1990.
	4. General	Estonia has an ongoing project for creation of a map layer of operational ditches and development of GHG emission factors for ditches.
	4.A Forest land	Estonia plans to develop the gain-loss method based on estimates of annual changes in biomass from estimates of biomass gain and loss and country-specific biomass parameters for the three main tree species in Estonia.
	4.A Forest land	Estonia has an ongoing project to develop new forest growth models and specify the time series of changes in forest growing stock from 1990. Estonia has plans for further research related to the use of models, specify error estimates and to develop different aspects of NFI (including NFI design and models used).
	4.A Forest land	Estonia had a remote sensing project with the purpose of annually calculating country-wide tree cover maps. The maps will be used to monitor changes in tree cover and to identify deforestation and areas converted to wooded land.
	4.A Forest land	Estonia had a research project to develop a country-specific litter model. The model will be tested and controlled before it is used for the greenhouse gas inventory.
	4.A Forest land	Estonia plans to implement Yasso model to estimate soil organic carbon (SOC) changes in Estonian mineral forest soils.
	4.A Forest land	Estonia has an ongoing research project for developing country-specific GHG emission factors for drained organic forest soils. Also, project LIFE OrgBalt aims to improve the GHG accounting methods and activity data for nutrient-rich organic soils in the temperate cool & moist (TCM) climate region.

SECTOR	IPCC CATEGORY	IMPROVEMENTS
	4.B Cropland	Estonia plans to develop country-specific stock change factors for cultivated organic soils after re-measurements of SOC stocks in monitoring plots have been carried out. Also, project LIFE OrgBalt aims to improve the GHG accounting methods and activity data for nutrient-rich organic soils in the TCM climate region.
	4.B Cropland	Estonia has an ongoing research project for estimating SOC changes in mineral agricultural soils using a simulation model.
	4.C Grassland	Estonia plans to develop country-specific stock change factors for grassland soils after re-measurements of SOC stocks in monitoring plots have been carried out.
	4.C Grassland	Project LIFE OrgBalt aims to improve the GHG accounting methods and activity data for nutrient-rich organic soils in the TCM climate region.
	4.D Wetlands	Estonia plans to acquire country-specific C content for peat removed for horticultural use.
Waste	5.A Solid waste disposal	Estonia has a project in 2023 to review landfill gas data in order to specify the emissions of greenhouse gases and air pollutants in the waste sector.
	5.B Biological treatment of solid waste	The activity data is kept under consideration and will be updated necessarily.
	5.C Incineration and open burning of waste	The activity data is kept under consideration and will be updated necessarily.
	5.D Wastewater treatment and discharge	The activity data for estimating N_2O from advanced centralised wastewater treatment plants is kept under consideration and the emission calculation will be included as soon as activity data is available.

Table 11.2. 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
Uncertainty analysis **(G.4, 2020) Convention reporting adherence**	Addressing. The Party documented in its NIR (section 1.6, p.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 case-by case whether a higher-tier method can be applied. Estonia uses the IPCC tier 1 methodology to estimate 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.	G.2, in the draft 2022 report	Estonia has harmonized energy sector uncertainty reporting with other sectors.		NIR Chapter 3
Uncertainty analysis **(G.5, 2020) Convention reporting adherence**	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.	G.3, in the draft 2022 report	Base year uncertainty estimates have been included in the 2023 submission.		NIR Chapter 1.5.1, Annex 1
1.A Fuel combustion – sectoral approach – other fossil fuels – CO2 **(E.4, 2020) (E.7, 2018) (E.11, 2016), (E.10, 2015) Transparency**	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 (nonmetallic 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 table 3.9 and in 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, e.g. if the fossil part of waste which are reported under categories 1.A.2.a and 1.A.1.f in the sectoral approach are all reported under non-biogenic waste in the reference approach or reported in other fuel categories, as explained	E.1, in the draft 2022 report	NIR 2023 includes detailed information on non-biogenic waste and under which fuel types in the reference approach it is included		NIR Chapter 3.2.1

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	during the 2015 review. Such an explanation would help improve the understanding of the carbon EF reported in CRF table 1.A(b).				
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**	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 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.	E.8, in the draft 2022 report	NIR 2023 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		NIR Chapter 3.2.5.8
1.A.3.b.iv Motorcycles – gasoline – CO2, CH4 and N2O **(E.23, 2020) Consistency**	Addressing. The Party corrected in its NIR the AD for 1990-2012 for the number of motorcycles, number of vehicles (table 3.25, p.99) and 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 information on motorcycles and mopeds will be included in the next annual submission to improve its transparency. The ERT considers that the recommendation has not yet been fully addressed because the Party has not yet included in the NIR an explanation of the data gap filling technique and other statistical methods used to correct the number of motorcycles and mopeds.	E.10, in the draft 2022 report	NIR 2023 includes a detailed explanation that the number of motorcycles was adjusted for 1995-2012 based on the corrections for 1990-1994 period		NIR Chapter 3.2.5.3
1.A.3.b.iv Motorcycles – gasoline – CO2 **(E.11, 2020) (E.26, 2018) Transparency**	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.	E.11, in the draft 2022 report	NIR 2023 includes a detailed explanation about the number of motorcycles used in COPERT and in national registry		NIR Chapter 3.2.5.3
1.A.4 Other sectors – liquid fuels – CO2, CH4 and N2O	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 in each questionnaire.	E.14, in the draft 2022 report	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-		

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
(E.25, 2020) Accuracy	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. The ERT considers that the recommendation has not yet been addressed because the Party has not yet updated the data-collection methodology, but concludes that any possible underestimation, if occurring, will be below the significance 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 not included in the list of potential problems and further questions raised.		statistics/methodology-and-quality/esms-metadata/20206#18-Statistical-processing-17). For this reason, the methodology used covers a significant part of this sector and is the best possible method for data gathering.		
International navigation – liquid fuels – CO2, CH4 and N2O **(E.1, 2020) (E.20, 2018) 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 is 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 sharp increase in emissions between 2011 and 2012.	E.16, in the draft 2022 report	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 a data revision when a new and more accurate data source is found and introduced.		
1.A.1.a Public electricity and heat production – Other fossil fuels – CO2, CH4, N2O Transparency	The Party reported in its NIR (section 3.2.1, p.64) that the difference in total CO2 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 CO2 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 CO2 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 (carbon emission factor) than the combustion of oil shale (some of the carbon is transferred into shale oil), while in the reference approach calculations all 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 CO2 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 CO2 calculations of oil shale and shale oil in the reference approach and the sectoral approach, as described in NIR section 3.2.1.	E.19, in the draft 2022 report	NIR 2023 includes more detailed explanation on the fossil and biogenic part of waste reported under 1.A.1.a Public heat and power production. The CO2 differences in SA and RA are checked and the correspondence of the information in CRF and NIR is ensured in future submissions.		NIR Chapter 3.2.1
Fuel combustion – reference approach – all fuels – CO2 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-tarbimineja-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)	E.17, in the draft 2022 report	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		NIR Chapter 3.2.1

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	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.		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 will be added into NIR 2023 submission. 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 will be added to NIR 2023 submission in Annex 3.		
Comparison with international data – Liquid Fuel – CO2, CH4, 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 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.	E.18, in the draft 2022 report	In the NIR 2023 submission the fossil and biogenic carbon emission factors of municipal solid waste incineration will be added including the explanation on fossil and biogenic emissions from municipal solid waste reported in the CRF tables.		NIR Chapter 3.2.1, Chapter 3.2.4.2
1.A.2.g Other (manufacturing industries and construction) – Biomass – CO2, CH4, 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 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 economical 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.	E.20, in the draft 2022 report	The NIR 2023 submission includes the explanation on the trend in 1.A.2.g		NIR Chapter 3.2.4.1

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
2.F.1 Refrigeration and air conditioning – HFCs **(I.7, 2020) (I.7, 2018) (I.10, 2016) (I.9, 2015) Accuracy**	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 F-gas equipment and servicing was overhauled in 2021, but still needs further improvements because the usage 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 AD and EFs to calculate emissions and 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 concluded 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 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 AD, it has not yet improved the uncertainty of the EFs in comparison with those used for the previous annual submission.	I.3, in the draft 2022 report	Continuos work in progress for improving inventory EF uncertainty. Additionally to data in FOKA database questionnaires are sent out to maintenance companies to compansate missing data from database.	2021 years activity data was collected partly from FOKA (database for equipment containing F-gases and ozone depleting substances) and partly by questionnaires sent to service companies by e-mail. The data on refilling (on which EF is calculated) was collected by questionnaires sent to service companies. Inventory team has forwarded this observation to the Estonian Environment Board and the Ministry of the Environment who are responsible for the development of FOKA. The discussions and development of the system are ongoing. Work is currently in progress for improving inventory EF uncertainty, that is connected with FOKA database. Updates in FOKA show less errors. Currently Ministry of the Environment and Estonian Environmental Board work on the matter to remind owners of the equipment and maintenance companies most efficiently about continuous obligation to add their maintenance data to the database, e.g. information letters are sent and it is considered to add automatic reminders to the database functionality.	NIR Chapter 4.6.1.1.3.
2.F.1 Refrigeration and air conditioning – HFC-143a **(I.8, 2020) Convention reporting adherence**	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 interannual change between 2010-2011 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. 261.3 per cent increase between 2010 and 2011).		During the review, the Party clarified that the AD for HFC-143a filled into new manufactured products for 2016 was corrected and the explanation was included in the NIR 2021 Chapter 4.6.1.3.5. We are looking into the interannual change between 2010-2011 for the next submission.		Chapter 4.6.1.3 NIR 2021
2.F.1 Refrigeration and air conditioning –	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 is 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	I.10, in the draft 2022 report	Overall additional information is added in 2023 NIR how blends and F-gases in pure form are calculated in 2.F.1.		Chapter 4.6.1.3

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
HFC-134a Transparency	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.				
2.A.2 Lime production – CO2 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 these EFs from the bigger 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 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 raw material. The EFs for CaO and MgO were calculated on the basis of the ratio of molecular weight of CO2 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. The ERT recommends that the Party improve the explanation in the NIR of the differences for different years in the values of its plant-specific CaO and MgO EFs used for estimating CO2 emissions from lime production and compare these EFs with the default EFs from the 2006 IPCC Guidelines (vol. 3, table 2.4).	I.6, in the draft 2022 report	Additional information is included in the in the 2023 NIR.		Chapter 4.2.2.2.
2.A.2 Lime production – CO2 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 companyspecific 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 productions 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 why it considers them more appropriate than a country-specific implied EF for 1990–1996.	I.7, in the draft 2022 report	Additional information for using IPCC 2006 default emission factors is included in the 2023 NIR.		Chapter 4.2.2.2.

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
2.B.1 Ammonia production –CO2 Comparability	The Party reported in its NIR (p.147) that it used plant-specific EFs for calculating CO2 emissions from NH3 production throughout the time series and that these NH3 production EFs varied between 1.276 and 1.516 t CO2/t NH3 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 CO2/t NH3. 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 both fuel and feedstock natural gas. The Party noted that it explained in the NIR (section 4.3.1.2) 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 states that "in the case of ammonia 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 to avoid double counting.	I.8, in the draft 2022 report	Ammonia production has stopped in 2013 and the company announced in 2021 that no longer plans to continue with ammonia production. We are looking into the historical time series correction for the next submission.	We are looking into the historical time series correction for the next submission.	
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 seek to explain the significant decrease in import data of lubricants over the time series.	I.9, in the draft 2022 report	Estonia will conduct category-specific QA/QC and verification and seek for the explanation of the significant reduction of lubricant use for the next submission.	Estonia is in the process of conducting category-specific QA/QC	
3.B.4 Other livestock – CH4 and N2O **(A.5, 2020) (A.7, 2018)** **Accuracy**	Addressing. The Party reported in NIR table 5.33 (p.258) that the allocation of "poultry" category manure is 99.41 per cent solid waste and 0.51 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" category manure is 99.41 per cent solid waste and 0.51 per cent pasture, range and paddock.	A.2, in the draft 2022 report	For 2023 NIR submission, N2O emissions in CRF table 3.B(b) are consistence with what was reported in NIR 2022 p.261 Table 5.25: the allocation of "poultry" category manure is reported as 99.41 per cent solid waste and 0.59 per cent pasture, range and paddock in the CRF.		Chapter 5.3.1.3.1.
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 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	A.6, in the draft 2022 report	NIR 2023 includes more detailed information about the decline in swine and cattle population. More information on the impact of African swine fever outbreak and Economic sanctions imposed by Russia on the EU is included.		Chapter 5.1.1.

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	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 that 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).				
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 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 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.	A.7, in the draft 2022 report	Estonia is working on looking into the evidence for the evaluation that 50% of the total amount of generated sewage sludge was used for improving the environmental situation in 1990-1998. (This evaluation was taken over from Tallinn University of Technology who was responsible for the inventory compilation until 2011)	Estonia is still looking into the assumtion made by TalTech University that 50% of the total amount of generated sewage sludge was used for improving the environmental situation in 1990-1998.	Chapter 5.4.1.5.
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 (FracBurn) 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".	A.8, in the draft 2022 report	Estonia has investigated the probability of potential field burning of agricultural residues and NIR 2023 includes a renewed expert judgement of the issue.		Chapter 5.5.
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	A.9, in the draft 2022 report	NIR 2023 includes an expert judgement for CaCO3 content in cement clinker dust used in estimating CO2 emissions from liming.		Chapter 5.6.2.

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	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.				
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 notexplained by the manager of IFASTAT. Therefore, using IFASTAT data to update Estonia's fertilizer time series was considered not possible. Going forward, Estonia contacted mineral fertilizer manufacturers and resellers to obtain data on the amount of urea fertilizers sold in Estonian markets per 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 and include information on its activities to obtain urea fertilizer use data reporting on the results of its evaluation of the manufacturers' data in the next annual submission.	A.10, in the draft 2022 report	Estonia is working on developing a new methodology for estimating CO2 emissions from Urea application for the years 2019-2021. As the Estonian Agricultural 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. We have been working on finding a new methodology to estimate emissions from urea fertilizers since 2021. We have been looking into different databases for urea fertilizers but no institution in Estonia collects national data on urea consumption. We have also contacted urea resellers and manufacturers and are now working on developing a methodology to implement the data to our emission estimates.	Estonia is still working on developing a new methodology for estimating CO2 emissions from Urea application for the years 2019-2021. As there is no other national data gathered about urea fertilizer use, than we have contacted urea resellers and manufacturers and are now working on developing a methodology to implement the data to our emission estimates.	Chapter 5.7.2.
4. General (LULUCF) – CO2, CH4 and N2O **(L.2, 2020) (L.3, 2018)** **Accuracy**	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 N2O emissions have been recalculated for the entire reporting period, but on the basis of updated and corrected land-use change data for the 1991-2020 period rather than by acquiring data for the 1970-1990 period. 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 N2O.	L.1, in the draft 2022 report	Estonia is working on obtaining the land-use change data for the 1970–1990 period and recalculating related GHG emissions. The progress will be described in the next submission.	Estonia is still working to estimate land-use change areas for this period. Estonia have 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.	
4.A Forest land – CO2 **(L.15, 2020)** **Transparency**	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.	L.5, in the draft 2022 report	Estonia has added additional information about the estimation of average forest growing stock to the NIR and updated the description of methodology for calculating CSC in living biomass. Estonia plans to		Chapter 6.2.1

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	On page 321 (section 6.2), the Party mentions summing estimates for "each given area" but does not specify what these areas are. On page 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 (a) Estimating standing volume on each plot; (b) Summing all plots to obtain the total national standing volume for each year; (c) Regressing standing volume against time over a 15-year window centred on each year; (d) 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; (e) Computing the difference with 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.		improve the method for calculating C stock changes in living biomass for the 2024 submission.		
4. General (LULUCF) – CO2, CH4, N2O	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 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, and, if the area subject to land-use changes is not nil, recalculate all estimates accordingly for 1990–2009.	L.12, in the draft 2022 report	Estonia is working on obtaining the land-use change data for the 1970–1990 period and recalculating related GHG emissions. Assumptions made on land-use changes will be described and taken into account in the next submission.	Estonia is still working to estimate land-use change areas for this period. Estonia have 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.	
4. General (LULUCF) – CO2	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 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	L.13, in the draft 2022 report	The default EFs from the 2006 IPCC Guidelines were applied for drained organic soils in the 2023 submission.		Chapter 6.2, Chapter 6.3, Chapter 6.4, Chapter 6.6

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	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.				
4.A Forest land – CO2	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.	L.14, in the draft 2022 report	The recommendation has not been implemented, as Estonia plans to improve the method for calculating C stock changes in living biomass for the 2024 submission. According to the new methodology, tree biomass is calculated for each NFI plot and the use of the BCEFs parameter is no longer necessary.	Estonia plans to improve the method for calculating C stock changes in living biomass for the 2024 submission. According to the new methodology, tree biomass is calculated for each NFI plot and the use of the BCEFs parameter is no longer necessary.	
4.A Forest land – CO2	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 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.	L.15, in the draft 2022 report	The recommendation has not been implemented, as Estonia plans to improve the method for calculating C stock changes in living biomass for the 2024 submission. According to the new methodology, tree biomass is calculated for each NFI plot and the use of the BCEFs parameter is no longer necessary.	Estonia plans to improve the method for calculating C stock changes in living biomass for the 2024 submission. According to the new methodology, tree biomass is calculated for each NFI plot and the use of the BCEFs parameter is no longer necessary.	
4.A.1 Forest land remaining forest land – CO2	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 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 occurs in 2003 and corresponds to a local maximum in harvest statistics. In general, a peak in harvest corresponds to lower removals. A similar feature, although less pronounced, occurs in 2018, where removals increase whereas harvest reaches 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	L.16, in the draft 2022 report	Estonia has provided in the NIR a description of the counteracting forces affecting CSC in forest biomass. Estonia plans to improve the method for calculating C stock changes in living biomass and switch to the gain-loss methodology, which directly takes into account harvest rates.		Chapter 2.2.4, Chapter 6.2

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	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 rises sharply between 2008 and 2012 whereas removals also increase over that period, and after a short plateau, harvest rises again sharply between 2014 and 2018 whereas removals are 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 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).				
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 shares of forest per soil type add up to 100 per cent) and report on the associated recalculations of emissions in the NIR.	L.17, in the draft 2022 report	Country-specific factors for mineral soils in conversion areas were corrected and calculations have been updated in the 2023 submission.		Chapter 6.2, Chapter 6.3, Chapter 6.4
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 in all subcategories of land converted to settlements, with the exception of forest land converted to settlements. The ERT noted that this is in principle a possibility, provided that Estonia has assessed that (1) the neighbouring country (here Sweden) likely has a comparable situation for	L.18, in the draft 2022 report	Estonia no longer uses Swedish EFs to estimate CSC in mineral soils for Land converted to settlements subcategories. Tier 1 methodology		Chapter 6.6

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	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 are very different between Estonia and Sweden 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 that the effects of land-use changes on soil carbon stocks are similar between Estonia and Sweden. 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.		from the 2006 IPCC Guidlines is applied since 2023 submission.		
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 KP Supplement, 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 (fIRW) and share of domestically produced pulp for the domestic production of paper and paperboard (fPULP)). 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 (fIRW) and share of domestically produced pulp for the domestic production of paper and paperboard (fPULP)) 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 KP Supplement).	L.19, in the draft 2022 report	Estonia has added in the NIR a table providing numerical values for key variables as well as relevant datasources.		Chapter 6.10
FM – CO2 (KL.4, 2020) (KL.6, 2018) (KL.7, 2016) (KL.7, 2015) Completeness	Obtain necessary data and apply a tier 2 method for estimating CSCs under the litter pool.	KL.2, in the draft 2022 report	As KP period is over, this observation is no longer topical.		
FM – CO2 (KL.10, 2020) Accuracy	Transparently explain the significant recalculations made for FM since the 2019 submission, including how updates to time-series management led to a revision that changed the 2013 estimate for FM sequestrations by over 50 per cent, and make a technical correction to the FMRL in accordance with the recalculations.	KL.5, in the draft 2022 report	As KP period is over, this observation is no longer topical.		
General (KP-LULUCF) – CO2 Not a problem	The Party reported in its NIR (eg. p.326) that it uses the emission factor from the Swedish NIR for CO2 emissions from the drainage of organic soils. The ERT noted that the Swedish EFs are themselves weighted averages of default IPCC EFs from the 2013 Wetland Supplement (p 2.11), weighted by the shares of boreal/poor, boreal/rich and temperate forest soils in Sweden or similar weightings for other land uses. The ERT thinks that the applicability of these Swedish EFs to Estonia are not justified because Estonia lies entirely in the temperate zone according to the maps in the 2006 IPCC guidance (p 3.47).	KL.7, in the draft 2022 report	This observation has been marked as "not a problem".		

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
	During the review, the Party clarified that its experts considered that using the default EFs from the IPCC 2006 guidelines for the temperate zone would be appropriate. The ERT agrees that this is indeed a possibility although using the more recent and more detailed default EFs from the IPCC 2013 Wetland supplement would likely improve accuracy. The Party resubmitted its CRF tables, using the default EFs from the IPCC 2006 guidelines for the temperate zone for all drained organic soils. The ERT agrees with the Party that this resubmission complies with the KP accounting rules. The ERT nevertheless encourages Estonia to consider the use of more accurate EFs from the 2013 Wetland supplement for its next inventory submission.				
5. General (waste) – CO2 (W.7, 2020) Convention reporting adherence	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 NIR annex 4 (p.92) but as “NO” in CRF table 5.A. The ERT considers that the recommendation has not yet been fully addressed.	W.2, in the draft 2022 report	Correction has been made in the 2021 submissions CRF and Annex 4.		CRF 5.A.1.a, 5.C.1.1, 5.C.2.1; 2021 NIR Annex 4, page 107; 2022 NIR Annex 4, page 92
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 they are accounted for in the calculations of CH4 emissions for this category.	W.4, in the draft 2022 report	Explanation will be added 2023 NIR		NIR 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 provides 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.	W.5, in the draft 2022 report	Correction has been made in CRF.		CRF 5.A.1.a
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 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.	W.6, in the draft 2022 report	Climate zone information will be added in 2023 NIR.		2023 NIR Chapter 7.2.2

CRT category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Reason for non- implementation	Chapter/section in the NIR
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 MSW composted. During the review, the Party clarified that for 2003, 2014 and 2017, a waste management company reported composted waste with a MSW code, which is not common practice, and therefore the Party will switch to using the amount of waste from the waste management company 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.	W.8, in the draft 2022 report	Additional information will be added in 2023 NIR		2023 NIR Chapter 7.3.2
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.	W.7, in the draft 2022 report	It is correct, that IPCC 2006 Guidelines waste DOC content is used for GHG emission calculation and 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.		CRF 5.A NIR Chapter 7.2.2; Table 7.7; Table 7.9

REFERENCES

General

Estonia's Seventh National Communication under the UN Framework Convention on Climate Change. Ministry of the Environment. Estonian Environmental Research Centre. Tallinn, 2013.

IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. [Eggelston. S., Buendia. L., Miwa. K., Ngara. T., Tanabe. K (eds)]. Hayama: Institute of Global Environmental Strategies (IGES).

European Commission. The EU Emissions Trading System (EU ETS). [www] https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en (27.02.2023).

WMO Statement on the State of the Global Climate in 2021. [www] https://library.wmo.int/doc_num.php?explnum_id=11178 (27.02.2023)

Energy

Arro, H., Pihu, T., Prikk. A. (2006). Calculation of CO_2 emissions from CFB Boilers of Oil Shale Power Plants. Oil Shale, Vol. No. 4, p. 356-365.

Eesti Statistikaameti andmebaas. [www]. https://andmed.stat.ee/et (14.03.2023)

EMEP/EEA air pollutant emission inventory guidebook – 2019. [www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion

EMEP/EEA air pollutant emission inventory guidebook – 2019 1.A.3.b.i-iv 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

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

Greenhouse Gas Emissions in Finland 1990–2021. National Inventory Report under the UNFCCC and the Kyoto Protocol, 15 April 2021. https://unfccc.int/

H. Aatola, M. Larmi, T. Sarjovaara. (2008). Hydrotreated Vegetable Oil (HVO) as a Renewable Diesel Fuel: Trade-off between NOx, Particulate Emission, and Fuel Consumption of a Heavy Duty Engine

Handbook Emission Factors for Transport. [www] https://www.hbefa.net/e/index.html (10.09.2021)

Kattai, V., Saarde, T., Savitski, T. (2000). Estonian Oil Shale. Bull. of the Geological Survey of Estonia. Tallinn, Estonia (in Estonian).

Martins. A. (2007). Analysis of calculation methods for determining the emissions of pollutants of ambient air. A study of the Research Laboratory of Multiphase Media Physics. Tallinn University of Technology. Tallinn. Estonia (in Estonian).

Metrosert AS report: Uncertainty Estimation of CO_2 emission in the Estonian National Greenhouse Gas Inventory, April 2007, Tallinn, Estonia (in Estonian).

Ots, A. Oil Shale Fuel Combustion. (2004). Tallinn: Tallinna Raamatutrükikoda, page 833.

Riigi Teataja. Gaasituru toimimise võrgueeskiri. [www] https://www.riigiteataja.ee/akt/129122020033 (10.03.2022)

Riigi Teataja. Vedelkütuse seadus. [www] https://www.riigiteataja.ee/akt/VKS (08.03.2023)

Riigi Teataja. Välisõhku väljutatava süsinikdioksiidi heite arvutusliku määramise meetodid. [www] https://www.riigiteataja.ee/akt/129122016063?leiaKehtiv (04.03.2023).

SE, 2022. The national database of Statistics Estonia. [www] https://www.stat.ee/en

Sempos, I. (2019) Note on fossil carbon content in biofuels.

Statistics Estonia. Estonian economy grew by 5.2% compared to the pre-pandemic level. [www] https://www.stat.ee/en/node/258605 (02.03.2023)

Soone, J., Doilov, S. (2003). Sustainable utilisation of oil shale resources and comparison of contemporary technologies used for oil shale processing // Oil Shale. 2003.Vol. 20. No.3S. P. 311–323.

Tallinn University of Technology. Emissions of CO_2 from CFB Boilers of Oil Shale Power Plants. Research Report of the Department of Thermal Engineering. (2006). Tallinn (in Estonian).

Industrial Processes and Product Use

2002 report of the refrigeration, air conditioning and heat pumps technical options committee (RTOC). [www] http://wedocs.unep.org/handle/20.500.11822/7796, (22.02.2023).

AS Metrosert (Estonian Central Office of Metrology) (2007). Uncertainty estimation of CO2 emission in Estonian national greenhouse gas inventory in 2004. Report

EAA air pollutant inventory emission guidebook 2019, page 61:

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 (22.02.2023)

Eurostat database https://ec.europa.eu/eurostat/data/database; (22.02.23).

http://eippcb.jrc.ec.europa.eu/reference/, (22.02.2023).

https://jvis.agri.ee/jvis/login.html (22.02.2023).

https://kotkas.envir.ee/, (22.02.2023).

https://www.riigiteataja.ee/, (22.02.2023).

https://www.worldcargonews.com/in-depth/in-depth/lessors-maintain-a-positive-mood (22.02.2023).

IPCC 2000 Good Practice Guidance and Uncertainty Management, Chapter 3, table 3.23, page 3.110.

IPCC 2000 Good Practice Guidance, Chapter 3, page 3.106, table 3.22.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. [Eggelston. S., Buendia. L., Miwa. K., Ngara. T., Tanabe. K (eds)]. Hayama: Institute of Global Environmental Strategies (IGES).

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).

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.

Schwarz, W., Rhiemeier, J. M. (2007). The analysis of the emissions of fluorinated greenhouse gases from refrigeration and air conditioning equipment used in the transport sector other than road transport and options for reducing these emissions: Maritime, Rail, and Aircraft Sector (07010401/2006/445124/MAR/C4). Prepared for the European Commission.

Wartmann, S; Harnisch, J. (2005). Reduction of SF_6 emissions from high and medium voltage electrical equipment in Europe. Report to CAPIEL. [www] https://www.tandfonline.com/doi/pdf/10.1080/15693430500402234 (22.02.2023).

Yang,L., Franco,V et al. 2015. NOx control technologies for Euro 6 diesel passenger cars. [www] https://www.theicct.org/sites/default/files/publications/ICCT_NOx-control-tech_revised%2009152015.pdf, (22.02.2023).

Agriculture

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. Kaasik, A., Leming, R., Remmel, T. (2002). Toitainete (N, P, K) kadu veise- ja seakasvatuses. Agraarteadus, nr 13 (4), pages 201–211.

DIAS. Standard Values for Farm Manure. [www] https://dcapub.au.dk/djfpublikation/djfpdf/djfhd7.pdf (24.12.2021).

EARC. Eesti Jõudluskontrolli aastaraamatud. [www] https://www.jkkeskus.ee/jkk/piimaveised/statistika/j%C3%B5udluskontrolli-aastaraamatud/ (10.01.2022).

EstEA. Estonian Weather Service. [www] http://www.ilmateenistus.ee/ (20.12.2021)

Estonian Environment Agency. Estonian Informative Inventory Report 1990–2019, Ch. 5 Agriculture (NFR 3). Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture. IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, pages 4.53, 4.70, 4.89. IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.1–10.87. IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, pages 11.1–11.54.

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 (16.12.2021).

Estonian University of Life Sciences. (2011). Maaelu arengu aruanne. Tartu: AS Ecoprint, page 86.

Estonian Universtity of Life Sciences. (2011). Maaelu arengu aruanne. Tartu: AS Ecoprint, page 86.

ESTONICA. Encyclopedia about Estonia. Laansalu, A. Crisis in agriculture in the 1990s. [www] http://www.estonica.org/en/The_rural_economy_in_Estonia_until_2001/Crisis_in_agriculture_in_the_1990s/ (20.12.2021).

ESTONICA. Encyclopedia about Estonia. Laansalu, A. Livestock farming. [www] http://www.estonica.org/en/The_rural_economy_in_Estonia_until_2001/Livestock_farming/ (20.12.2021).

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 (10.01.2022).

FAO. FAOSTAT data. Crops and livestock products. [www] https://www.fao.org/faostat/en/#data/QCL (31.12.2021).

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 (24.01.2022).

Fur Institute of Canada. Fox farming. [www] https://fur.ca/fur-farming/fox-farming/ (15.01.2022).

Home page of Härma Küülikud. Küülikute hooldamisest ja pidamisest. [www] http://www.rabbitfarm.planet.ee/kasulikinfo.html (24.01.2022).

IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management

IPCC 2006 Guidelines, Volume 4, Chapter 11: N2O emissions from managed soils, and CO2 emissions from lime and urea application

Järvan, M. (2005). Põldude lupjamine. Saku: Maalehe Kirjastus, page 6.

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 (22.12.2022).
Kaasik, A. (2020). Report of the project ”Kariloomade söödaplaanide uuring (1990–2020)”, pages 18-20.

Kaasik, A., Möls, M. Loomakasvatusest eralduvate saasteainete heitkoguste inventuurimetoodikate täiendamine ja heite vähendamistehnoloogiate kaardistamine. [www] https://envir.ee/media/5276/download (10.01.2022).

Kalamees, K. Eesti Maakari. [www] https://www.etll.ee/?ARETUS/Piimaveised/EK (24.01.2022).

Keskkonnaministeerium. Algab sõnnikukäitluse inventuur. [www] https://envir.ee/uudised/algab-sonnikukaitluse-inventuur (16.02.2021).

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 (2), p. 95–108.

KOTKAS, [www] https://kotkas.envir.ee/ (07.12.2021).

Lehtsalu, S., Kaart, T., Kiiman, H. (2010). Lehmvasikate kasvatamine sündimisest seemendamiseni. Agraarteadus, 21 (1), lk 14–23.

Linnasmägi, M.-L., (2021). Ülevaade Eestis toodetud jäätmekompostidest. Bachelor thesis, page 53.

Loide, V. (2019). Põllumuldade kaltsiumisisaldusest ja lupjamisest. Presentation, 10th World Soil Day, Tartu, Estonia.

Milieu Ltd, WRc, RPA. Environmental, economic and social impacts of the use of sewage sludge on land. [www] https://ec.europa.eu/environment/archives/waste/sludge/pdf/part_i_report.pdf (24.01.2022).

Monni, S., Syri, S. (2003). Uncertainties in the Finnish 2001 Greenhouse Gas Emission Inventory. VTT Research Notes, no. 2209. Espoo: Otamedia Oy, p. 55–56. Espoo.

Muldade lupjamise mõtte ja lupjamistööde arengust Eestis. Agraarteadus, nr 11 (2), pages 117–131.

Oll, Ü., Nigul, L. (1991). Sigade söötmine. Tallinn: Valgus, page 267.

Petrova, A. Eesti Holsteini tõugu lehmade piimajõudlus, sigimine ja aretus kõrgetoodangulises karjas 21. Sajandi esimesel kümnendil. [www] http://ph.emu.ee/~ktanel/magVLI_APetrova_2012.pdf (24.01.2022).

Piirsalu, P. Hõbe- ja sinirebaste värvusmutandid ja nende kasvatamine. [www] http://www.eau.ee/~alo/karusloomad/rebased/?Rebased (15.01.2022).

Piirsalu, P. Minkide värvusmutandid ja nende kasvatamine. [www] http://www.eau.ee/~alo/karusloomad/mingid/?Minkide_sigimine/Poegimine (15.01.2022).

Riigi Teataja. Atmosfääriõhu kaitse seadus. [www] https://www.riigiteataja.ee/akt/A%C3%95KS (15.12.2021).

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# (24.01.2022).

Riigi Teataja. Maa heas põllumajandus- ja keskkonnaseisundis hoidmise nõuded. [www] https://www.riigiteataja.ee/akt/116012015006?leiaKehtiv (15.02.2021). Riigi Teataja. Põllumajandusliku keskkonnatoetuse saamise täpsemad nõuded ning toetuse taotlemise, taotluse menetlemise ja toetuse maksmise täpsem kord. [www] https://www.riigiteataja.ee/akt/960819 (15.02.2021).

Riigi Teataja. Nõuded karuslooma pidamise ja selleks ettenähtud ruumi või ehitise kohta. [www] https://www.riigiteataja.ee/akt/13356899?leiaKehtiv (20.12.2021).

Riigi Teataja. Põllumajandusliku keskkonnatoetuse saamise täpsemad nõuded ning toetuse taotlemise, taotluse menetlemise ja toetuse maksmise täpsem kord. [www] https://www.riigiteataja.ee/akt/960819 (24.01.2022)

Riigi Teataja. Ühtse pindalatoetuse, põllukultuuri kasvatamise ja põllumajanduskultuuri täiendava otsetoetuse saamise nõuded ning toetuse taotlemise ja taotluse menetlemise täpsem kord. [www] https://www.riigiteataja.ee/akt/12821418 (15.02.2021).

Rypdal, K., Winiwarter, W. (2001). Uncertainties in greenhouses gas emission inventories – evaluation, comparability and implications. Environmental Science and Policy, no.4, p. 107–116.

Saveli, O. (2004). Fur farming of Estonia. Animal Breeding in Estonia. Tartu: Paar OÜ.

SE. (1991). Eesti statistika 1990, page 445.

SE. Põllumajandus 1994 – Põllumajandus 2005. Tallinn.

SE. Statistical database. [www] https://andmed.stat.ee/en/stat (20.12.2021)

Standard Values for Farm Manure. [www] https://dcapub.au.dk/djfpublikation/djfpdf/djfhd7.pdf (15.12.2021).

Statistics Estonia. Agricultural land and crops by county. [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__taimekasvatussaaduste-tootmine/PM0281 (27.12.2021)

Statistics Estonia. Agricultural production in Estonia increased last year. [www] https://www.stat.ee/en/uudised/moodunud-aastal-eesti-pollumajandustoodang-taas-suurenes (27.12.202)

Statistics Estonia. Livestock and poltry by county (quarters) [www] https://andmed.stat.ee/en/stat/majandus__pellumajandus__pellumajandussaaduste-tootmine__loomakasvatussaaduste-tootmine/PM09 (31.12.2021); FAO. FAOSTAT data. [www] www.fao.org/faostat/en/#data (31.12.2021).

Tikk, H., Tikk, V., Piirsalu, M., Hämmal, J. (2007). Linnukasvatus I. Tartu: OÜ Tartumaa Trükikoda, lk 32.Turbas, E. (2000).

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.

LULUCF

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.

Aosaar, J., Varik, M., Lõhmus, K., Ostonen, I., Becker, H., Uri, V. (2013). Long-term study of above- and below-ground biomass production in relation to nitrogen and carbon accumulation dynamics in a grey alder (*Alnus incana* (L.) Moench) plantation on former agricultural land. European Journal of Forest Research, 126, 495–506.

Eesti Statistikaamet (1991). Eesti statistika aastaraamat 1990. Tallinn: Olion.

Eesti Statistikaamet (1992). Statistika aastaraamat 1992. Tallinn.

Estonian Environment Agency (2022). NFI 2021. [www] https://keskkonnaportaal.ee/sites/default/files/Teemad/Mets/SMI2021_tulemused_0.pdf (08.02.2023).

Estonian Fire Safety Act (RT I 2010, 24, 116).

Estonian Forest Act (RT I 2006, 30, 232).

FAO (2018). Terms and definitions FRA 2020. Forest resources assessment working paper 118. [www] https://www.fao.org/3/I8661EN/i8661en.pdf (08.02.2023)

Forest Europe, UNECE & FAO (2011). State of Europe's forests 2011. Status and trends in sustainable forest management in Europe. Oslo: Ministerial Conference on the Protection of Forests in Europe, Forest Europe Liaison Unit.

IPCC (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry. [Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia , L., Miwa, K., Ngara, T., Tanabe, K. and Wagner, F. (eds.)]. Hayama: IPCC & IGES.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. [Eggelston. S., Buendia. L., Miwa. K., Ngara. T., Tanabe. K (eds)]. Hayama: IGES.

IPCC (2014a). 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. [Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M., Troxler, T.G. (eds)]. Published: IPCC, Switzerland.

IPCC (2014b). 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M., Troxler, T.G. (eds). Published: IPCC, Switzerland.

KE0230: Energy balance sheet by type of fuel or energy (Eurostat methodology). Statistical database, Statistics Estonia. [www] https://andmed.stat.ee/en/stat/majandus__energeetika__energia-tarbimine-ja-tootmine__aastastatistika/KE0230 (03.02.2023).

KK501: Extraction of mineral resources by county (1992–2010). Statistical database, Statistics Estonia. [www] https://andmed.stat.ee/en/stat/Lepetatud_tabelid__Keskkond.%20Arhiiv__Loodusvarad%20ja%20nende%20kasutamine.%20Arhiiv/KK501 (03.02.2023).

KK91: Used domestic extraction by type of raw material. Statistical database, Statistics Estonia. [www] https://andmed.stat.ee/en/stat/keskkond__keskonna-arvepidamine__materjalivoo-arvepidamine/KK91 (03.02.2023)..

Kõlli, E., Ellermäe, O. (2003). Humus status of postlithogenic arable mineral soils. Agronomy Research, 1, 161–174.

Kõlli, R., Asi, E., Köster, T. (2004). Organic carbon pools in Estonian forest soils. Baltic Forestry 10, 19–26.

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.

Kõlli, R., Köster, T., Kauer, K. (2007). Organic matter of Estonian grassland soils. Agronomy Research 5, 109–122.

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.

Köster, K., Metslaid, M., Engelhart, J., Köster E. (2015). Deadwood basic density, and conventration of carbon and nitrogen for main tree species in managed hemiboreal forests. Forest Ecology and Management, 354, 35–42.

Lamlom, H. S., Savidge, A.R. (2003). A reassessment of carbon content in wood: variation within and between 41 North American species. Biomass and Bioenergy, 25, 381-388.

Lutter, R., Tullus, A., Kanal, A., Tullus, T., Tullus, H. (2016). The impact of former land-use type to above- and below-ground C and N pools in short-rotation hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) plantations in hemiboreal conditions. Forest Ecology and Management, 378, 79–90.

Metsaruum OÜ (2012). Põllumajandusmaadel kasvava puitse biomassi määramine. Report, unpublished.

NIR Sweden (2022). National Inventory Report Sweden 2022. Greenhouse Gas Emission Inventories 1990–2020. Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Swedish Environmental Protection Agency

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 (03.02.2023).

Repola. J, Ojansuu, R. and Kukkola, M. (2007). Biomass functions for Scots pine, Norway spruce and birch in Finland. Working Papers of the Finnish Forest Research Institute, 53.

Report of the individual review of the annual submission of Estonia submitted in 2012. 25.02.2013. United Nations, Framework Convention on Climate Change. FCCC/ARR/2012/EST.

Report of the individual review of the annual submission of Estonia submitted in 2013. 22.01.2014. United Nations, Framework Convention on Climate Change. FCCC/ARR/2013/EST.

Report of the individual review of the annual submission of Estonia submitted in 2014. 10.04.2015. United Nations, Framework Convention on Climate Change. FCCC/ARR/2014/EST.

Report on the individual review of the annual submission of Estonia submitted in 2016. 22.03.2017. United Nations, Framework Convention on Climate Change. FCCC/ARR/2016/EST.

Report on the individual review of the annual submission of Estonia submitted in 2018. 16.01.2019. United Nations, Framework Convention on Climate Change. FCCC/ARR/2018/EST.

Report on the individual review of the annual submission of Estonia submitted in 2020. 14.04.2021. United Nations, Framework Convention on Climate Change. FCCC/ARR/2020/EST.

Roosalu, R. (2022). Eesti Vabariigi 2021. aasta maavaravarude koondbilansid (seisuga 31.12.2021. a.). Tallinn: Maa-amet. [www] https://geoportaal.maaamet.ee/docs/geoloogia/koondbilanss_2021_seletuskiri.pdf (31.01.2023).

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.

Statistical Office of Estonia (1995). Agriculture 1994. Tallinn.

Statistical Office of Estonia (1999). Agriculture 1998. Tallinn.

Statistical Office of Estonia (2004). Agriculture 2003. Tallinn.

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.

Uri, V. (2020). Riigihanke 191205 „Eesti puistute biomassi mudelite väljatöötamine“ lõpparuanne. [Elaboration of country specific biomass models for Estonian forests.] Estonian University of Life Sciences. Report. [www] https://keskkonnaportaal.ee/et/kasvuhoonegaaside-heitkoguste-inventuuri-uuringud-riikliku-aruandluse-t%C3%A4itmiseks (08.02.2023).

Varik, M., Kukumägi, M., Aosaar, J., Becker, H., Ostonen, I., Lõhmus, K., Uri, V. (2015). Carbon budgets in fertile Silver birch (*Betula pendula* Roth) chronosequence stands. Ecological Engineering, 77, 284–296.

Waste

EMEP/EEA air pollutant emission inventory guidebook – 2019. [www] https://www.eea.europa.eu//publications/emep-eea-guidebook-2019 (02.03.2023).

Infragate. (2014). Hajaasustuse reovee kohtkäitlussüsteemide inventuuri aruanne.

The Information Technology Centre of the Ministry of the Environment. Waste data visualizing system (Tableau). [www] https://public.tableau.com/app/profile/keskkonnaagentuur (02.03.2023).

MoE. (2014). Riigi jäätmekava 2014-2020. [www] https://envir.ee/ringmajandus/jaatmed/riigi-jaatmekava (02.03.2023).

REN. (2013). IEA- Eurostat-UNECE. Energy Questionnaire- Renewables and Wastes

SEI. (2008). Eestis tekkinud olmejäätmete (sh eraldi pakendijäätmete ja biolagunevate jäätmete) koostise ja koguste analüüs. Segaolmejäätmete sortimisuuring. [www] https://envir.ee/media/5317/download (02.03.2023).

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 (02.03.2023).

SEI. (2013). Uuringu lõpparuanne – 2013 Eestis tekkinud segaolmejäätmete, eraldi kogutud paberi- ja pakendijäätmete ning elektroonikaromu koostise uuring. [www] https://envir.ee/media/5291/download (02.03.2023).

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 (02.03.2023).

Vaania. (2000). Olmejäätmete koostise valikuline uurimine Eesti erinevates piirkondades. Uuringu aruanne.

FAOSTAT New food Balances database [www] http://www.fao.org/faostat/en/#data/FBS (02.03.2023)