REPUBLIC OF ESTONIA
MINISTRY OF THE ENVIRONMENT

GREENHOUSE GAS EMISSIONS IN ESTONIA 1990-2020
NATIONAL INVENTORY REPORT

SUBMISSION TO THE UNFCCC SECRETARIAT

Common Reporting Formats (CRF) 1990–2020

Estonia 2022

PREFACE

Estonia's National Inventory Report (NIR) under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol contains the following parts:

Part I. 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 1990–2020 is included as well as the description of current emission trends.

Part II. Supplementary information required under Article 7, paragraph 1 of the Kyoto Protocol.

The Estonian Environmental Research Centre (Ms Hanna-Lii Kupri, Ms Sirly-Ann Meriküll, Ms Kelly Joa, Ms Kadi Meltz, Ms Kristin Puusepp, and Mr Stanislav Štõkov) and the Estonian Environment Agency (Ms Helen Karu, Ms Eve Suursild, Mr Allan Sims 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 Hanna-Lii Kupri and Mr Marek Maasikmets 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.

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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 Article 7 of Regulation (EU) 525/2013 on the European Parliament and of the Council on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change (hereafter referred to as MMR) will continue to apply for greenhouse gas inventory until 2022. The implementation of the MMR is further specified in the Commission Implementing Regulation (EU) No 749/2014 and the Commission Delegated Regulation (EU) No 666/2014.

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

ES.1.3 Background information on supplementary information required under Article 7, paragraph 1, on the Kyoto Protocol

Estonia, as an Annex I Party that is also part of the Kyoto Protocol is required to report supplementary information in accordance with Article 7, paragraph 1, of the Kyoto Protocol. The required information is specified in the Annex of Decision 15/CMP.1.

Part II of this report includes information related to Article 3, paragraph 3 (Afforestation, Reforestation, Deforestation) and paragraph 4 (Forest Management) in Chapter 11 and information related to Article 3, paragraph 14 (information on minimization of adverse impacts of climate change) in Chapter 15.

A summary information on accounting of Kyoto units is presented in Chapter 12. Information related to changes in national system and in the national registry are provided in Chapter 13 and Chapter 14 accordingly.

ES.2. Summary of national emission and removal-related trends

ES.2.1 GHG inventory

In 2020, the total emissions of GHGs (with indirect CO2), measured as CO2 eq., were 12 853.1 kt, and without LULUCF 11 555.8 kt. From 1990 to 2020 emissions with LULUCF decreased by 65%. Table ES. 1 shows the trend in total emissions without LULUCF during the period 1990–2020. shows greenhouse gas emissions trends in CO_2 eq.

In 2020, the most important GHG in Estonia was carbon dioxide (CO_2), contributing 80.9% to total national GHG emissions expressed in CO_2 eq. (including indirect CO_2), followed by methane (CH_4), 9.5%, and nitrous oxide (N_2O), 8.0%. Fluorocarbons (so-called ‘F-gases’)

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[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)

account for about 1.6% of total emissions (see Table ES.2). The Energy sector accounted for 81.9 % of total GHG emissions, followed by Agriculture (13.1%), Industrial processes and product use (2.6%) (including indirect CO_2) and Waste (2.5%).

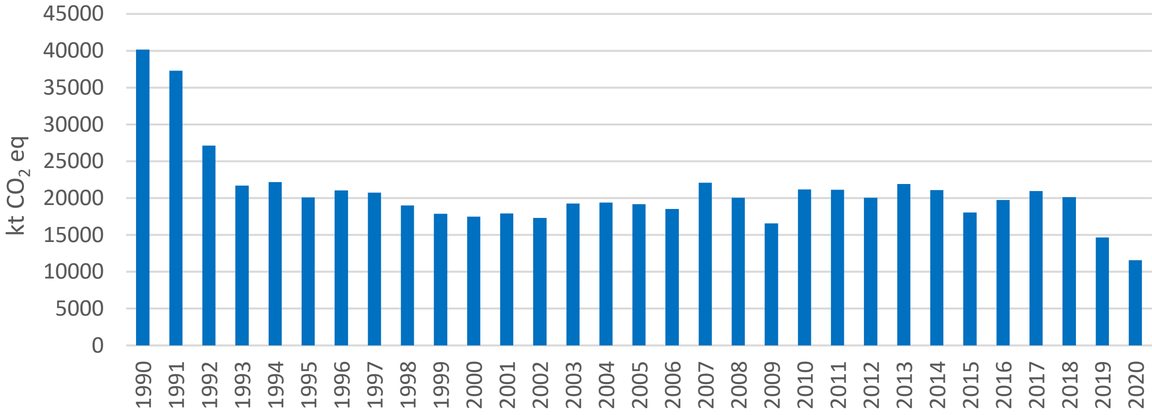

Figure ES.1. Estonia's greenhouse gas emissions in 1990–2020 (with indirect CO_2), without LULUCF, kt CO_2 eq.

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	Change from base to latest reported year
	kt CO_2 equivalent								%
CO_2 emissions without net CO_2 from LULUCF	36922.21	18066.41	15500.38	17109.78	19002.52	17935.07	12380.19	9343.01	-74.70
Indirect CO2 (from NMVOCs reported under IPPU 2.D.3 Solvent use and road paving with asphalt) *	18.5	17.4	16.5	18.5	11.3	18.4	20.8	24.7	34. 13
CH_4 emissions without CH_4 from LULUCF	1912.52	1284.38	1259.91	1239.50	1253.87	1093.14	1098.30	1095.46	-42.72
N_2O emissions without N_2O from LULUCF	1340.45	698.21	637.47	672.16	746.47	862.50	928.46	929.68	-30.64
HFCs	NO	28.45	79.15	134.96	176.11	232.36	226.33	184.74	100.00
PFCs	NO	NO	NO	NO,NA	NO	NO	NO	NO	0.00
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	0.00
SF_6	NO	3.07	2.61	1.08	1.83	2.67	2.84	2.92	100.00
NF_3	NO	NO	NO	NO	NO	NO	NO	NO	0.00
Total (without LULUCF)	40175.17	20080.53	17479.52	19157.48	21180.81	20125.74	14636.12	11555.81	-71.24
Total (with LULUCF)	37015.28	17281.14	13274.54	17881.75	16345.42	18687.44	14301.56	12853.08	-65.28
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**Base year (1990)**	**1995**	**2000**	**2005**	**2010**	**2018**	**2019**	**2020**	**Change from base to latest reported year**
	kt CO_2 equivalent								**%**
1. Energy	36213.16	17697.15	15098.87	16742.41	18899.50	17770.83	12210.92	9461.45	-73.87
2. Industrial processes and product use	963.74	635.29	695.97	727.83	539.51	628.54	621.35	295.47	-69.34
3. Agriculture	2628.34	1350.11	1122.23	1172.06	1253.80	1417.62	1501.48	1508.38	-42.61
4. Land use, land-use change and forestry	-3159.90	-2799.39	-4204.98	-1275.73	-4835.38	-1438.30	-334.56	1297.27	-141.05
5. Waste	369.93	397.97	562.45	515.18	488.00	308.74	302.38	290.51	-21.47

*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 4.4.3.2 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	36922.21	1912.515	1340.446	NO	NO	40175.17
	%	91.90%	4.76%	3.34%			100%
1995	kt	18066.41	1284.38	698.2075	28.4544	3.074369	20080.53
	%	89.97%	6.40%	3.48%	0.14%	0.02%	100%
2000	kt	15500.38	1259.908	637.4722	79.14731	2.612363	17479.52
	%	88.68%	7.21%	3.65%	0.45%	0.01%	100%
2005	kt	17109.78	1239.497	672.1646	134.9583	1.079591	19157.48
	%	89.31%	6.40%	3.80%	0.70%	0.01%	100%
2010	kt	19002.52	1253.873	746.4746	176.1103	1.831974	21180.81
	%	89.72%	5.92%	3.52%	0.83%	0.01%	100%
2018	kt	17935.07	1093.135	862.5032	232.355	2.669071	20125.74
	%	89.12%	5.43%	4.29%	1.15%	0.01%	100%
2019	kt	12380.19	1098.3	928.4571	226.3338	2.840394	14636.12
	%	84.59%	7.50%	6.34%	1.55%	0.02%	100%
2020	kt	9343.01	1095.455	929.6807	184.7401	2.922969	11555.81
	%	80.85%	9.48%	8.05%	1.60%	0.03%	100%

ES.2.2 KP-LULUCF activities

Under Article 3, paragraph 3 of the Kyoto Protocol (KP), Estonia reports emissions and removals from Afforestation (A), Reforestation (R) and Deforestation (D). From Article 3, paragraph 4 Forest management (FM) is reported.

Estimates of emissions and removals from Article 3.3 and Article 3.4 activities are presented in Table ES.3. In 2020, net emissions from Article 3.3 activities were 290.90 kt CO_2 eq. Uptake from Afforestation and reforestation activities including non-CO_2 emissions from drained forest and emissions from wildfires were estimated at -187.29 kt CO_2 eq. Deforestation resulted in a net emission of 478.20 kt CO_2 eq. Areas subject to AR and D were 56.70 kha and 34.11 kha, respectively by the end of the 2020. Annual rates of Afforestation have declined continuously from 0.89 kha to 0.19 kha during the period 2013–2020. Deforestation annual areas have also declined compared to 2013, when D area was 1.56 kha per year. In 2020, it was 0.96 kha per year.

For Forest management under Article 3.4 activities overview of CO_2 emissions and removals are presented in Table ES.3. In 2020 FM contributed to the total GHG balance with an uptake of -365.38 CO_2 eq. and without HWP FM emitted 546.74 kt CO_2 eq. Total area of FM was 2 386.83 kha.

Table ES.3. Net CO_2 emissions/removals in the KP LULUCF sector, kt CO_2 eq.

Greenhouse gas sources and sink activities	**Net kt CO_2 eq. emissions/removals**								**Total**
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
A. Article 3.3 activities	262.01	305.81	348.46	425.86	443.61	428.92	345.43	290.90	**2 851.02**
A.1. Afforestation and Reforestation	-292.73	-292.28	-268.57	-253.37	-235.86	-218.85	-202.73	-187.29	**-1 941.68**
A.1.1. Units of land not harvested since the beginning of the commitment period	-296.70	-286.31	-272.64	-257.45	-240.02	-223.16	-206.99	-191.62	-
A.1.1. Drained organic soils	3.97	4.03	4.06	4.07	4.14	4.20	4.27	4.33	-
A.1.1. Biomass burning	0.0003	0.001	0.01	0.01	0.02	0.11	0.0000	NO	-
A.1.2. Units of land harvested since the beginning of the commitment period	NA	NA	NA	NA	NA	NA	NA	NA	-
A.2. Deforestation	554.74	588.09	617.03	679.23	679.47	647.76	548.16	478.20	**4 792.69**
A.2.1 N mineralization	6.04	6.62	7.23	7.89	8.46	8.99	9.40	9.70	-
A.2.1 Biomass burning	NO	NO	NO	NO	NO	NO	NO	NO	-
B. Article 3.4 activities	-3 484.03	-3 000.67	-3 659.37	-3 505.08	-2 973.21	-3 430.89	-2 135.12	-365.38	**-22 553.76**
B.1. Forest management	-2 822.31	-2 267.04	-2 779.33	-2 538.81	-1 949.56	-2 365.12	-1 182.45	546.74	-
B.1. Drained organic soils	327.90	327.84	327.81	327.80	327.74	327.67	327.61	327.54	-

Greenhouse gas sources and sink activities	Net kt CO_2 eq. emissions/removals								Total
	2013	2014	2015	2016	2017	2018	2019	2020	
B.1. Biomass burning	0.002	0.04	0.34	0.50	0.13	2.80	0.11	0.17	-
4(KP) Carbon stock changes in the HWP	-661.72	-733.64	-880.04	-966.27	-1 023.64	-1 065.77	-952.67	-912.12	-

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.

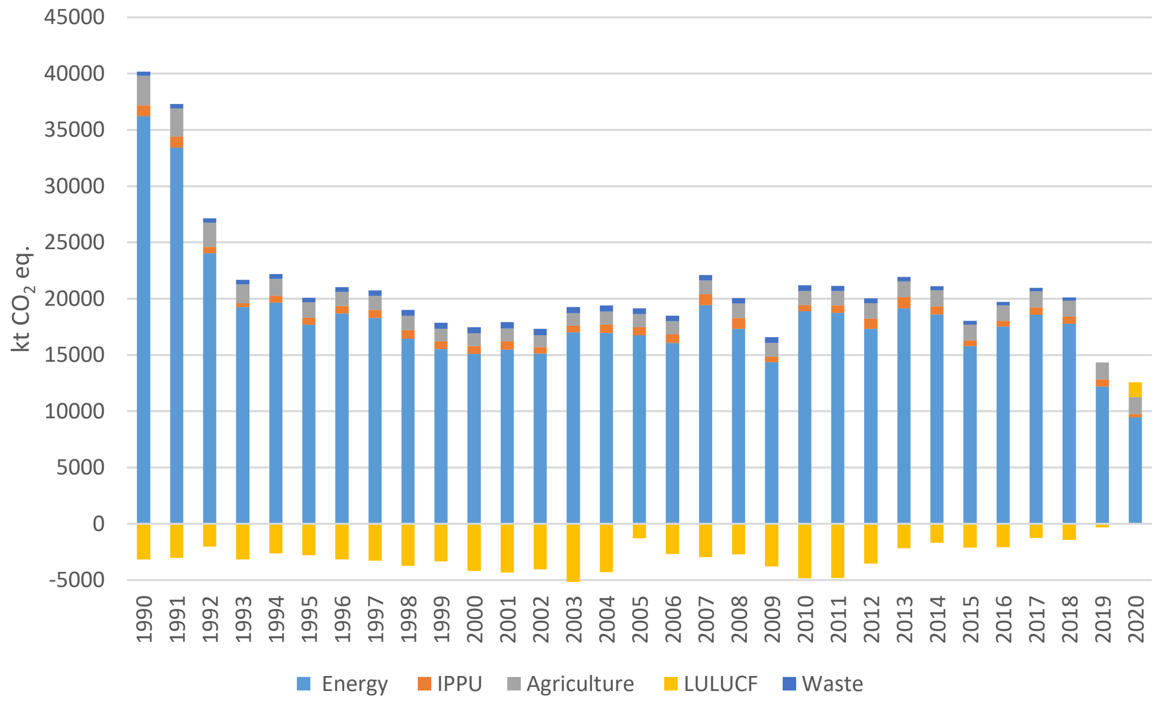

Figure ES. 2. Greenhouse gas emissions trends by sector, kt CO_2 eq.

The Energy sector is the most significant source of greenhouse gas emissions in Estonia with 81.9% share of the total emissions in 2020. Since the base year, total GHG emissions from Energy sector in Estonia have decreased by 73.9%. The key driver for the fall in emissions is the transition from a planned economy to a market economy. The GHG emission decrease in 2020 comparing to previous year was mainly from the energy industries, because of the increase of the EU ETS emission allowance price.

Agriculture is the second most significant source of greenhouse gas emissions in Estonia. In 2020 the agriculture sector contributed 13.1% of the total emissions. Since the base year emissions have decreased by 42.6%, mostly due to the decreasing livestock population and quantities of synthetic fertilizers and manure applied to agricultural fields.

In 2020 Industrial processes and product use greenhouse gas emissions contributed 2.6% of the total greenhouse gas emissions in Estonia. Emissions have decreased by 69.3% between 1990 and 2020 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.

The Waste sector contributed 2.5% of the total greenhouse gas emissions in 2020. The total emissions in CO_2 eq. from the Waste sector decreased by 21.5% compared to the base year.

In 2020, the LULUCF sector acted as a CO_2 source, totaling with emissions 1297.3 kt CO_2 eq. Since 1990, net removals have decreased by 141.1%.

ES.3.2. KP-LULUCF activities

Estonia reports activities under Article 3, paragraph 3 and Forest management under Article 3, paragraph 4, of the Kyoto Protocol. Estonia has chosen to account for the KP-LULUCF activities at the end of commitment period.

The total emissions related to Afforestation/Reforestation and Deforestation activities were estimated at 290.90 kt CO_2 eq. in 2020. Afforestation/reforestation amounted a net uptake of -187.29 kt CO_2 eq. and Deforestation a net emission of 478.20 kt CO_2 eq. Areas of AR and D were 56.70 and 34.11 kha, respectively. In 2020 FM contributed to the total GHG balance with an uptake of -365.38 CO_2 eq. (with HWP). Total area of FM was 2 386.83 kha.

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 (WMO Statement on the State of the Global Climate in 2020[3]) the global mean temperature for 2020 was 1.2±0.1 °C above pre-industrial levels. Global mean temperature in 2020 is on course to be one of the three warmest on record. The past six years are the six warmest on record, and the past decade, 2011–2020, is also the warmest 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 2020. [www] https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate (13.01.2021)

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 2020. 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. The CRF tables are produced with the CRF Reporter software (version 6.0.8). The methodology used in

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

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 20202. Chapters 3–8 give information of GHG emission trends from the base year 1990 to year 2020 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 summarised. Chapter 11 provides description of KP-LULUCF, Chapter 12 information on accounting of Kyoto units, Chapter 13 information on changes in national system and Chapter 14 information on changes in national registry. Chapter 15 gives information on minimisation of adverse impacts in accordance with Article 3, paragraph 14 of KP. Annex 1 contains key category reporting tables and Annex 2 the assessment of uncertainty. Annex 3 gives information on detailed methodological descriptions for individual source or sink categories. Assessment of completeness of inventory estimates is presented in Annex 4. Annex 5 contains the Standard Independent Assessment Report.

1.1.3. Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

Estonia, as an Annex I Party that is also part of the Kyoto Protocol is required to report supplementary information in accordance with Article 7, paragraph 1, of the Kyoto Protocol. The required information is specified in the Annex of Decision 15/CMP.1.

Part II of this report includes information related to Article 3, paragraph 3 (Afforestation, Reforestation, Deforestation) and paragraph 4 (Forest management) in Chapter 11 and information related to Article 3, paragraph 14 (information on minimization of adverse impacts of climate change) in Chapter 15. A summary of information on accounting of Kyoto units is presented in Chapter 12 and more detailed information is presented in Standard Electronic Tables (SEF). Information related to changes in national system and in the national registry are provided in Chapter 13 and Chapter 14 accordingly.

Estonia has chosen to report greenhouse gas emission removals from activities under Article 3.3 (i.e., Afforestation, Reforestation and Deforestation) and Article 3.4 (Forest management) for the second commitment period (CP).

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 and KP 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

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

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.

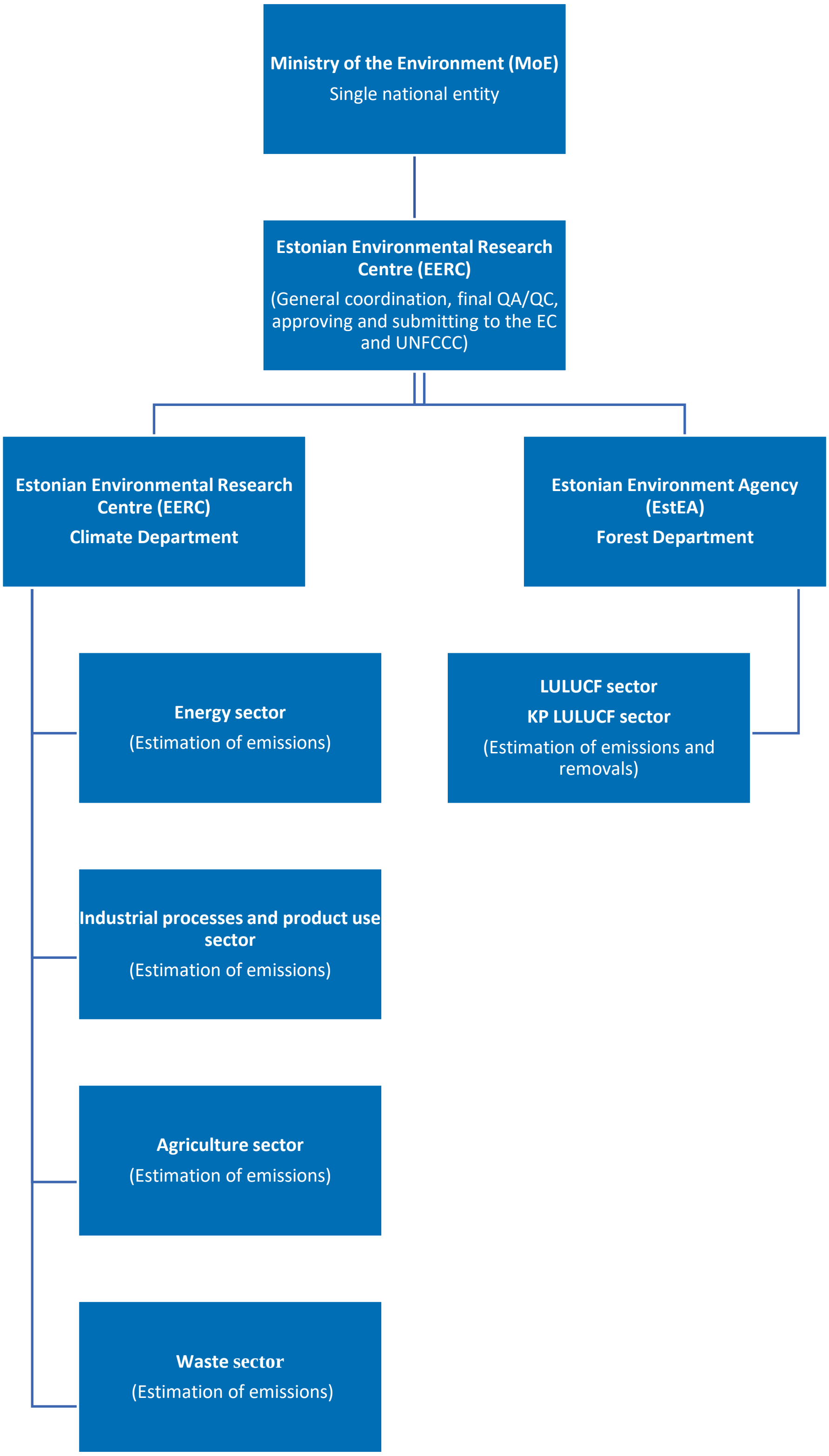

Figure 1.1. National System for GHG inventory in Estonia

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. 15*
Sectoral experts´ complete data entry to the CRF Reporter and notify the EERC	EERC, EstEA	Dec. 14
QC checks are carried out (CRF Reporter) and documented by inventory coordinator (EERC) and sent to the sectoral experts	EERC	Dec. 18
Sectoral experts send the necessary data for uncertainty analysis to EERC	EERC, EstEA	Dec. 28

Activity	Responsible	Deadline
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
Independent experts will carry out the QA for the CRF tables and submit the documented results to EERC. EERC submits the results to sectoral experts	Independent experts	Jan. 5
EERC performs the key category analysis and uncertainty analysis and sends the results to the sectoral experts and independent experts	EERC, EstEA	Jan. 5
MoE provides the chapters on accounting of Kyoto units, information on changes in national registry to the EERC	MoE	Jan. 7
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 draft 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
Draft NIR is sent to different departments of MoE and other relevant insitutions for approval	EERC	Jan. 18
The draft 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. 16
EERC submits the results of the MoE and other relevant institutions QA to the sectoral experts and independent expert	EERC	Febr. 16
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. 22
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	Febr -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.

All information required pursuant to Article 7 of the Kyoto Protocol has been integrated within the reporting processes.

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 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 2021 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.

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

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 2020 submission was carried out as a centralized review from 2 to 7 November 2020.

The GHG inventories submitted by Member States in 2016–2021 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 2017–2021 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 the certain parts of the GHG inventories. Comparison of EU ETS emissions with emissions reported in national GHG inventory was carried out for year 2020 (please see Annex 6.3. Consistency of reported emissions with data from the ETS).

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

[7] European Commission. The EU Emissions Trading System (EU ETS). [www] https://ec.europa.eu/clima/policies/ets_en (13.01.2021).

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.

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, the Kyoto Protocol, and the European Union (EU) greenhouse gas monitoring legislation 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 2022 submission contains estimates for the years 1990–2020.

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. Starting from 2023 the reporting will be done under the EU Governance Regulation.

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, Agriculture, 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:

- EU ETS from the Environmental Board – data on production and consumption of oil shale, semi-coke gas and generator gas.
- Eesti Energia AS (Estonian Energy 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.
- Narva Oil Plant AS (at the Estonian Power Plant) – Oil shale consumption for shale oil production, shale oil and semi-coke gas production data.
- Viru Keemia Grupp AS (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 V model for calculation of emissions from Transport.
- EstEA – activity data on Road transport fossil and biofuel consumption in Estonia from COPERT V model.
- EstEA – number of vehicles and road traffic mileage in Road transport.
- The 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 1990–2020.

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 Road 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:

- 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

Activity data used in the estimates is obtained mainly from National Forest Inventory (NFI). Data gained from NFI comprises:

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

Activity data of wildfires is obtained from Estonian Rescue Service. In 2012, the Estonian Environment Agency started annual fieldwork to record wildfire locations, determining the precise area and biomass burned. Storm damaged forest area is obtained from Statistics Estonia and Estonian Environment Agency (NFI). 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), Agricultural Research Centre and Estonian Crop Research Institute. 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 EstEA's Tableau. 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 EstEA's 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 EstEA's 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 the EstEA's Water Bureau is responsible for collecting the data. 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 the EstEA's 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); EU ETS data from Estonian Enviromental 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, waste fuel 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 of energy companies; EU ETS data from Estonian Enviromental 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; data on waste fuels 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 V 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 from statistical database
2. Industrial processes and product use	IPCC 2006	IPCC 2006	EU ETS data from Estonian 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

IPCC category	Methodology	Emission factor	Activity data
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	CS	National and international companies, Statistics Estonia, Eurostat
3. Agriculture	IPCC 2006	IPCC 2006	Statistics Estonia, National Forest Inventory, EstEA, plant specific data, Estonian Agricultural Board, Estonian Animal Recording Centre
A. Enteric fermentation	T1, T2	D, CS, OTH	Statistics Estonia, Estonian Animal Recording Centre, EstEA
B. Manure management	T1, T2	D, CS	Statistics Estonia, Estonian Animal Recording Centre, EstEA
D. Agricultural soils	T1	D	Statistics Estonia, EstEA; EstEA
G. Liming	T1	D	Statistics Estonia, Estonian Agricultural Board
H. Urea application	T1	D	Statistics Estonia, plant specific data, Estonian Agricultural Board
4. LULUCF	IPCC 2006	IPCC 2006	National Forest Inventory (EstEA); Statistics Estonia; Estonian Rescue Service; Land Parcel Identification System; Estonian Crop Research Institute; Agricultural Research Centre; 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; Estonian Crop Research Institute; Agricultural Research Centre
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; Statistics Estonia, FAOSTAT
A. Solid waste disposal	T2	D	EstEA; Statistics Estonia
B. Biological treatment of solid waste	T1	D	EstEA
C. Incineration and open burning of waste	T1, T2a	D	EstEA

IPCC category	Methodology	Emission factor	Activity data
D. Wastewater treatment and discharge	T1	D	EstEA; 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

1.4.2. KP-LULUCF inventory

Estonia implements *Reporting Method 1, approach 2* based on the National Forest Inventory sampling grid for tracking land-use changes and land subject to activities under Article 3.3 and FM under Article 3.4. The area of Estonia is not divided into regions.

Information on the IPCC land use and land-use change categories for each sample plot is presented in the forest inventory database. The annual land-use change areas were calculated for 1990–2020. Land-use matrix was developed by adding and subtracting the transition areas to and from land-use category areas.

Area and the volume of growing stock and deadwood of ARD activities is obtained from the NFI. The area of deforestation is also based on NFI data and is equivalent to the area of forest land converted to other land uses under the UNFCCC reporting. CO_2 emissions due to biomass loss related to deforestation are estimated assuming that the volume of growing stock on deforested area is the same as under the forest land remaining forest land category in the UNFCCC reporting.

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 2019), the trend of emissions (change between 1990 and 2019) 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 and in Annex 1.

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

		TIER 1						TIER 2					
		Criteria identification (without LULUCF)			Criteria identification with LULUCF			Criteria identification without LULUCF			Criteria identification with LULUCF		
		Level 1990	Level 2019	Trend	Level 1990	Level 2019	Trend	Level 1990	Level 2019	Trend	Level 1990	Level 2019	Trend
1.A.1.a Energy Industries/Public Electricity and Heat Production - Liquid Fuels	CO_2	x	x	x	x	x	x	x		x	x		x
1.A.1.a Energy Industries/Public Electricity and Heat Production - Solid Fuels	CO_2	x	x	x	x	x	x	x	x	x	x	x	x
1.A.1.a Energy Industries/Public Electricity and Heat Production - Gaseous Fuels	CO_2	x	x	x	x	x	x	x					
1.A.1.a Energy Industries/Public Electricity and Heat Production - Peat	CO_2	x	x	x	x	x	x						
1.A.1.a Energy Industries/Public Electricity and Heat Production - Other Fuels (Waste)	CO_2		x	x		x	x		x	x	x	x	x
1.A.1.c Energy Industries/Manufacture of Solid Fuels and Other Energy Industries - Solid Fuels	CO_2		x	x		x	x		x	x	x	x	x
1.A.2.c Manufacturing Industries and Construction/Chemicals - Liquid Fuels	CO_2	x		x	x		x						
1.A.2.c Manufacturing Industries and Construction/Chemicals - Gaseous Fuels	CO_2	x		x	x		x						
1.A.2.d Manufacturing Industries and Construction/Pulp, Paper and Print - Liquid Fuels	CO_2	x		x			x						
1.A.2.d Manufacturing Industries and Construction/Pulp, Paper and Print - Gaseous Fuels	CO_2		x	x		x	x						
1.A.2.e Manufacturing Industries and Construction/Food Processing, Beverages and Tobacco - Liquid Fuels	CO_2	x	x	x	x		x						
1.A.2.e Manufacturing Industries and Construction/Food Processing, Beverages and Tobacco - Gaseous Fuels	CO_2		x	x		x	x						
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Liquid Fuels	CO_2	x		x	x		x						
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Solid Fuels	CO_2	x		x	x			x		x			x
1.A.2.f Manufacturing Industries and Construction/Non-metallic Minerals - Other Fuels	CO_2		x	x		x	x		x		x	x	

		TIER 1						TIER 2					
		Criteria identification (without LULUCF)			**Criteria identification with LULUCF**			**Criteria identification without LULUCF**			**Criteria identification with LULUCF**		
		Level 1990	**Level 2019**	**Trend**	**Level 1990**	**Level 2019**	**Trend**	**Level 1990**	**Level 2019**	**Trend**	**Level 1990**	**Level 2019**	**Trend**
1.A.2.g Manufacturing Industries and Construction/Other - Liquid Fuels	CO_2	x	x	x	x	x	x						
1.A.2.g Manufacturing Industries and Construction/Other - Solid Fuels	CO_2	x		x	x			x		x			x
1.A.2.g Manufacturing Industries and Construction/Other - Gaseous Fuels	CO_2	x	x		x	x	x				x		
1.A.3.b Transport/Road Transportation - Liquid Fuels	CO_2	x	x	x	x	x	x	x	x	x	x	x	x
1.A.3.c Transport/Railways - Liquid Fuels	CO_2		x			x							
1.A.4.a Other Sectors/Commercial/Institutional - Liquid Fuels	CO_2		x	x		x							
1.A.4.a Other Sectors/Commercial/Institutional - Gaseous Fuels	CO_2		x	x		x	x						
1.A.4.b Other Sectors/Residential - Liquid Fuels	CO_2	x	x	x	x	x	x				x		
1.A.4.b Other Sectors/Residential - Solid Fuels	CO_2	x		x	x			x		x			x
1.A.4.b Other Sectors/Residential - Gaseous Fuels	CO_2		x	x		x	x						
1.A.4.b Other Sectors/Residential - Peat	CO_2	x		x	x		x	x		x			x
1.A.4.b Other Sectors/Residential - Biomass	CH_4		x	x		x	x	x	x	x		x	x
1.A.4.c.i Other Sectors/Agriculture/Forestry/Fishing/Stationary - Liquid Fuels	CO_2	x	x	x	x	x	x				x		
1.A.4.c.ii Other Sectors/Agriculture/Forestry/Fishing/Off-road vehicles and other machinery - Liquid Fuels	CO_2		x	x		x	x						
2.A.1 Cement production	CO_2	x		x	x		x						
2.A.2 Lime production	CO_2		x			x							
2.B.1 Ammonia production	CO_2	x		x	x								
2.F.1.a Commercial Refrigeration	HFC		x	x		x	x						
2.F.1.c Industrial Refrigeration	HFC		x	x		x	x						
2.F.1.d Refrigerated Vehicles	HFC			x									
3.A.1 Enteric Fermentation - Dairy Cattle	CH_4	x	x	x	x	x	x	x	x	x		x	x

		TIER 1						TIER 2					
		Criteria identification (without LULUCF)			Criteria identification with LULUCF			Criteria identification without LULUCF			Criteria identification with LULUCF		
		Level 1990	Level 2019	Trend	Level 1990	Level 2019	Trend	Level 1990	Level 2019	Trend	Level 1990	Level 2019	Trend
3.A.1 Enteric Fermentation - Non-Dairy Cattle	CH_4	x	x	x	x	x		x	x	x		x	
3.B.1.1 Manure Management - Dairy Cattle	CH_4		x	x		x	x		x	x	x	x	x
3.B.1.1 Manure Management -Non-Dairy Cattle	CH_4		x	x		x	x			x	x		
3.B.1.3 Manure Management - Swine	CH_4		x			x		x			x		
3.B.2.1 Manure Management - Dairy Cattle	N_2O								x	x		x	
3.B.2.1 Manure Management -Non-Dairy Cattle	N_2O									x			
3.B.2.5 Indirect N2O Emissions from Manure Management	N_2O							x	x	x		x	x
3.D.1.1 Direct Soil Emissions - Inorganic N Fertilizers	N_2O	x	x	x	x	x	x	x	x	x		x	x
3.D.1.2a Direct Soil Emissions - Animal Manure Applied to Soils	N_2O		x	x		x		x	x	x		x	x
3.D.1.3 Direct Soil Emissions Urine and Dung Deposited by Grazing Animals	N_2O							x				x	x
3.D.1.4 Direct Soil Emissions - Crop Residue	N_2O	x	x	x	x	x	x	x	x	x		x	x
3.D.1.6 Direct Soil Emissions - Cultivation of Organic Soils	N_2O		x	x		x	x	x	x	x		x	x
3.D.2.1 Indirect Emissions - Atmospheric Deposition	N_2O		x			x		x	x	x		x	x
3.D.2.2 Indirect Emissions - Nitrogen Leaching and Run-off	N_2O	x	x	x	x	x	x	x	x	x		x	x
4.A.1. Forest Land remaining Forest Land - living biomass	CO_2				x	x	x				x	x	x
4.A.1. Forest Land remaining Forest Land - dead wood	CO_2				x	x	x				x		
4.A.1. Forest Land remaining Forest Land - mineral soils	CO_2				x	x	x				x	x	x
4.A.1. Forest Land remaining Forest Land - organic soils	CO_2				x	x	x				x	x	x
4.A.2.1. Cropland converted to Forest Land - living biomass	CO_2					x	x					x	x
4.A.2.2. Grassland converted to Forest Land - living biomass	CO_2					x	x				x	x	x
4.A.2.2. Grassland converted to Forest Land - litter	CO_2					x	x						

		TIER 1						TIER 2					
		Criteria identification (without LULUCF)			**Criteria identification with LULUCF**			**Criteria identification without LULUCF**			**Criteria identification with LULUCF**		
		Level 1990	**Level 2019**	**Trend**	**Level 1990**	**Level 2019**	**Trend**	**Level 1990**	**Level 2019**	**Trend**	**Level 1990**	**Level 2019**	**Trend**
4.A.2.3 Wetlands converted to Forest Land - living biomass	CO_2					x	x						x
4.D Forest Land 4(II) Emissions and removals from drainage and rewetting	N_2O				x	x	x					x	x
4.D Forest Land 4(II) Emissions and removals from drainage and rewetting	CH_4					x	x				x	x	x
4.B.1 Cropland remaining Cropland - mineral soils	CO_2					x	x					x	x
4.B.1 Cropland remaining Cropland - organic soils	CO_2				x	x	x					x	x
4.B.2.2 Grassland converted to Cropland - mineral soils	CO_2					x	x				x		
4.B.2.2 Grassland converted to Cropland - organic soils	CO_2					x	x				x		
4.C.1 Grassland remaining Grassland – organic soils	CO_2					x							
4.C.2.1 Forest Land converted to Grassland - living biomass	CO_2					x	x				x	x	
4.C.2 Land converted to Grassland – mineral soils	CO_2					x	x				x		x
4.D.1.1 Peat extraction remaining Peat extraction - organic soils	CO_2				x	x	x					x	x
4.E.2.1 Forest Land converted to Settlements – living biomass	CO_2					x	x					x	x
4.E.2.1 Forest Land converted to Settlements – litter	CO_2					x							
4.E.2.1 Forest Land converted to Settlements (min+org soils)	CO_2					x	x					x	x
4.E.2.2 Cropland converted to Settlements - soils	CO_2					x	x					x	
4.F.2.1 Forest land converted to Other land – living biomass	CO_2					x	x						
Wood panels and sawnwood	CO_2				x	x	x					x	x
5.A Solid waste disposal	CH_4	x	x	x	x	x	x	x	x	x		x	x
5.D.1 Domestic wastewater	CH_4		x			x	x	x	x	x		x	
5.D.1 Domestic wastewater	N_2O		x			x	x		x	x		x	

1.5.2. KP-LULUCF inventory

Key category analysis for KP-LULUCF was performed according to chapter 2.3.6 of the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. The basis for the assessment of key categories under Article 3.3 and Article 3.4 of the KP is the same as the assessment made for the UNFCCC inventory. The key categories are CO_2 removals due to Afforestation/reforestation, CO_2 emissions from Deforestation and CO_2 removals due to Forest management.

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 2.

The uncertainty estimate of the 2022 inventory submission to the UNFCCC 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 and time series. Estonia acknowledges the observation by ERT (FCCC/ARR/2020/EST/G.5) and UNFCCC Annex I inventory reporting guidelines requirement, however because of lack of activity data there is no separate information available for calculating separate uncertainty percentages for the base year. 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. In some categories Estonia is also using country specific / emission source specific uncertainty information that is unfortunately not representative for 1990. We are looking into possibilities of getting sufficient activity data for the base year estimations.

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 2020 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 2022 inventory submission

	Combined as % of total national emissions in 2020	Introduced into the trend in total national emissions in 2020
	Uncertainty [%]	
Without LULUCF	8.54	1.99
With LULUCF	23.53	5.25

1.6.2. KP-LULUCF inventory

Tier 1 was implemented for estimating uncertainty rates related to activity data and emission factors employed in the estimates under Article 3.3. and Article 3.4 activities (Chapter 11.3.1.5).

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 4.

The geographical coverage of the inventory is complete.

1.7.2. KP-LULUCF inventory

Estonia provides C stock change estimates for all required carbon pools: above- and below-ground biomass, litter, deadwood, mineral and organic soils for ARD and FM activities, HWP pool is estimated under FM. Non-CO_2 emissions from drained organic forest soils and biomass burning are estimated for AR and FM, and N_2O emissions from N mineralization are reported only under D.

Estonia does not separate gains and losses (a net change is reported) for living biomass estimates since it is not feasible due to the stock-difference method used.

[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 1990–2020.

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 40 175.17 kt CO_2 eq. in 1990 to 11 555.8 kt CO_2 eq. in 2020 (Figure 2.1). From 1990 to 2020 emissions without LULUCF decreased by 71.24%. This decrease was predominantly caused by the transition from a planned economy to a market economy and the successful implementation of the necessary reforms.

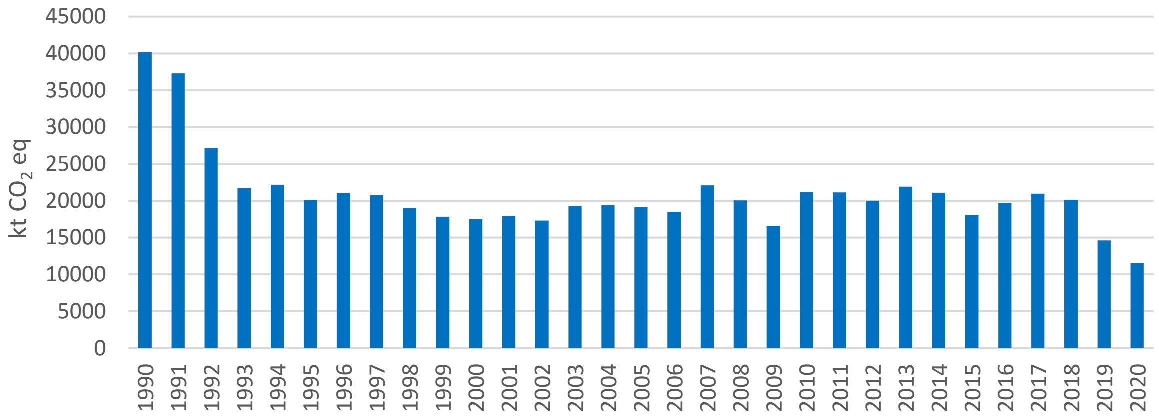

Figure 2.1. Overall development of greenhouse gases in Estonia (with indirect CO_2), without LULUCF, kt CO_2 eq.

In 2020 the most important GHG in Estonia was carbon dioxide (CO_2), contributing 80.9% to total national GHG emissions expressed in CO_2 eq. (including indirect CO_2), followed by methane (CH_4), 9.5%, and nitrous oxide (N_2O), 8.0%. Fluorocarbons (so-called 'F-gases') account for about 1.6% of total emissions (Figure 2.2).

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

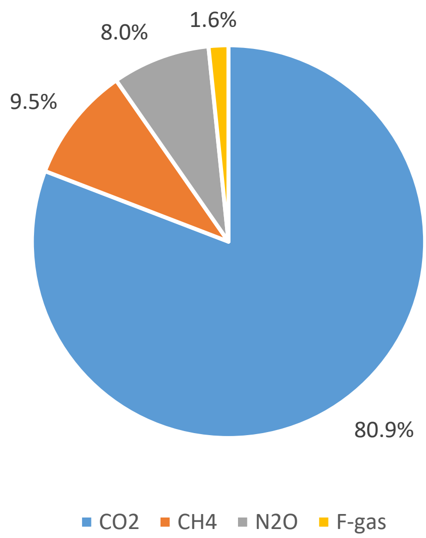

Figure 2.2. GHG emissions by gas in 2020, %

Figure 2.3 shows GHG emission trends by gas in 1990 to 2020. CO_2 emissions (with indirect CO_2) decreased by 74.7% from 36 922.2 kt in 1990 to 9 343.0 kt in 2020, 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 42.7% from 1 912.5 kt CO_2 eq. in 1990 to 1 095.5 kt CO_2 eq. in 2020, 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 29.3% from 1 340.4 kt CO_2 eq. in 1990 to 929.7 kt CO_2 eq. in 2020, 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 187.7 kt CO_2 eq. in 2020, 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 2017–2020 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 2020 was 184.7 kt CO_2 eq. and SF_6 emissions 2.9 kt CO_2 eq.

NF_3 emissions do not occur in Estonia.

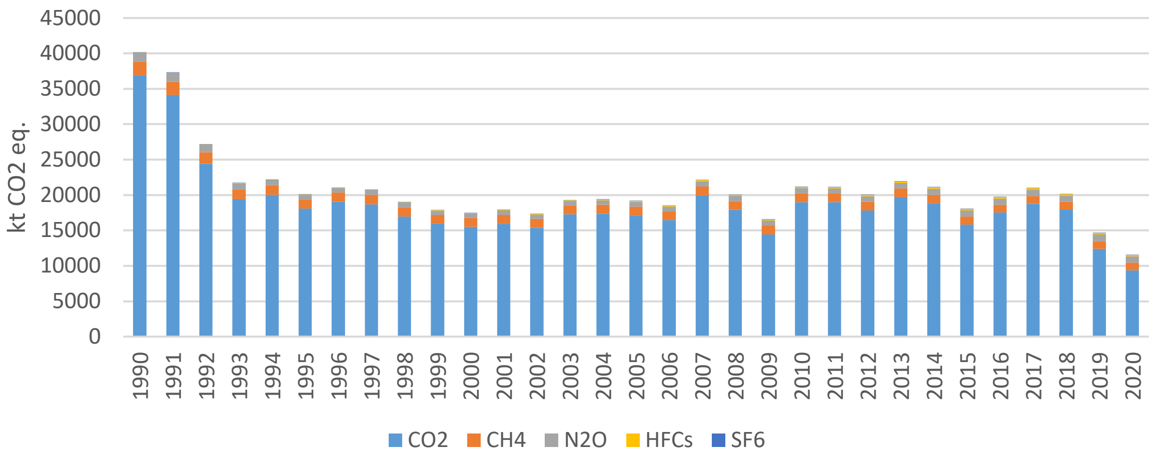

Figure 2.3. Estonia's greenhouse gas emissions by gas 1990–2020 (without LULUCF), kt CO_2 eq.

Air pollutant emissions reported in the CRF are based on the data reported in UNECE/CLRTAP inventories by the Estonian Environment Agency. 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 2020.

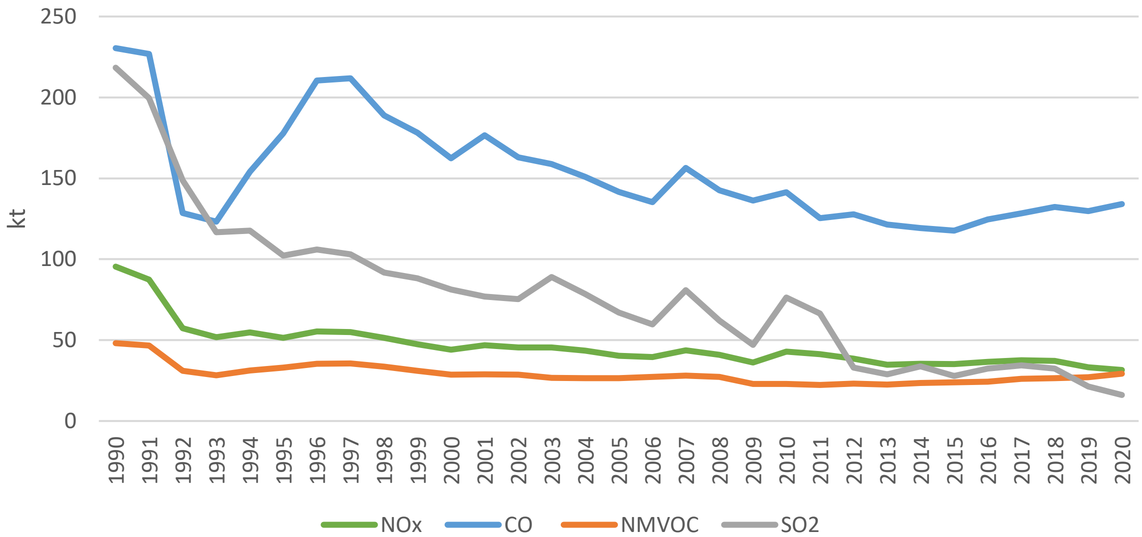

Figure 2.4. Indirect GHG emission trends in 1990 to 2020.

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 81.9% of total greenhouse gas emissions in 2020 (excl. LULUCF). The second largest sector is Agriculture, which accounted for 13.1% of the total emissions in 2020 followed by the Industrial processes and product use and the Waste sectors accounted for 2.6% and 2.5% of total emissions in 2020.

Over the period 1990–2020 (Figure 2.5), emissions from the Energy sector decreased by 73.9%, emissions from the Industrial processes and product use sector decreased by 69.3% and emissions from the Agriculture sector decreased by 42.6%. Emissions from the Waste sector decreased by 21.5%. In 2020, the LULUCF sector acted as a CO_2 source, totaling with emissions 1297.3 kt CO_2 eq. Since 1990, net removals have decreased by 141.1%.

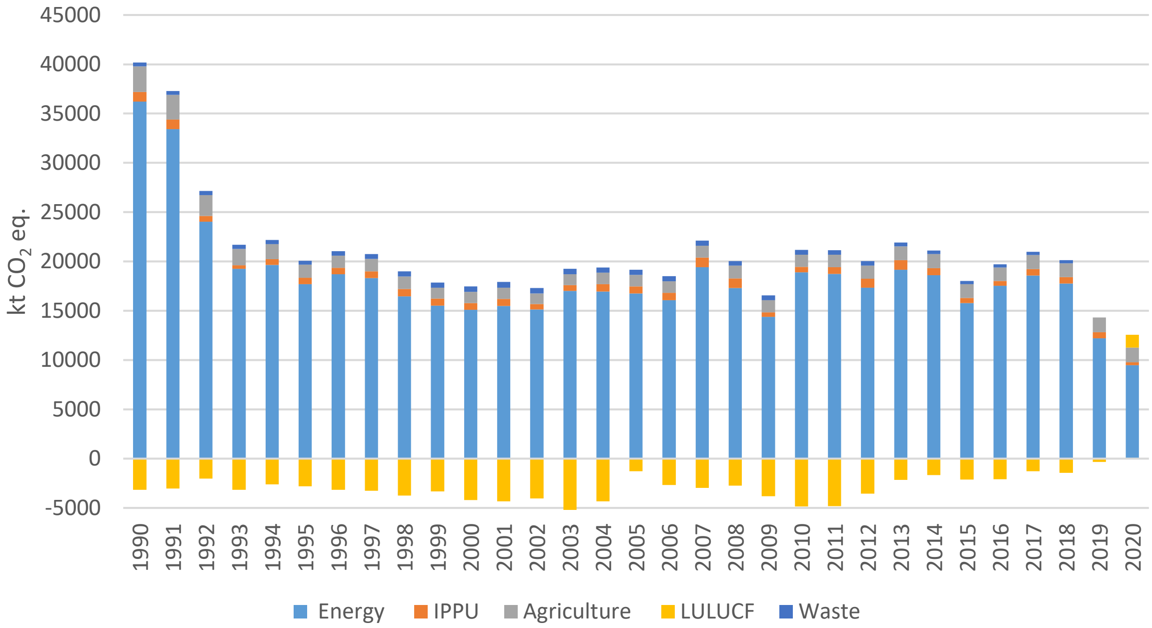

Figure 2.5. Greenhouse gas emission trends, by sectors, kt CO_2 eq.

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

2.2.1. Trends in Energy (CRF 1)

Estonia’s emissions from the Energy sector are divided into the following categories: Fuel combustion, including 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 81.9% of all emissions in 2020, totalling 9461.45 kt CO_2 eq. 99.8% of emissions originate from fuel combustion, and only 0.2% from fugitive emissions. Energy-related CO_2 emissions varied 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 after Estonia regained its independence from the Soviet Union. 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.

Emissions from the Energy sector decreased by 73.9% compared to 1990 (incl. Energy industries – 79.3%; Manufacturing industries and construction – 85.3%; Transport – 10.0%; Other sectors – 55.3%; and Fugitive emissions – 70.9%). 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 after 1991 when Estonia regained independence. The overall progression of GHG emissions in the Energy is presented in Figure 2.6. The GHG emission decrease in 2020 compared to the previous year was mainly in the energy industries, because of the EU ETS emission allowance price increase and lower electricity prices.

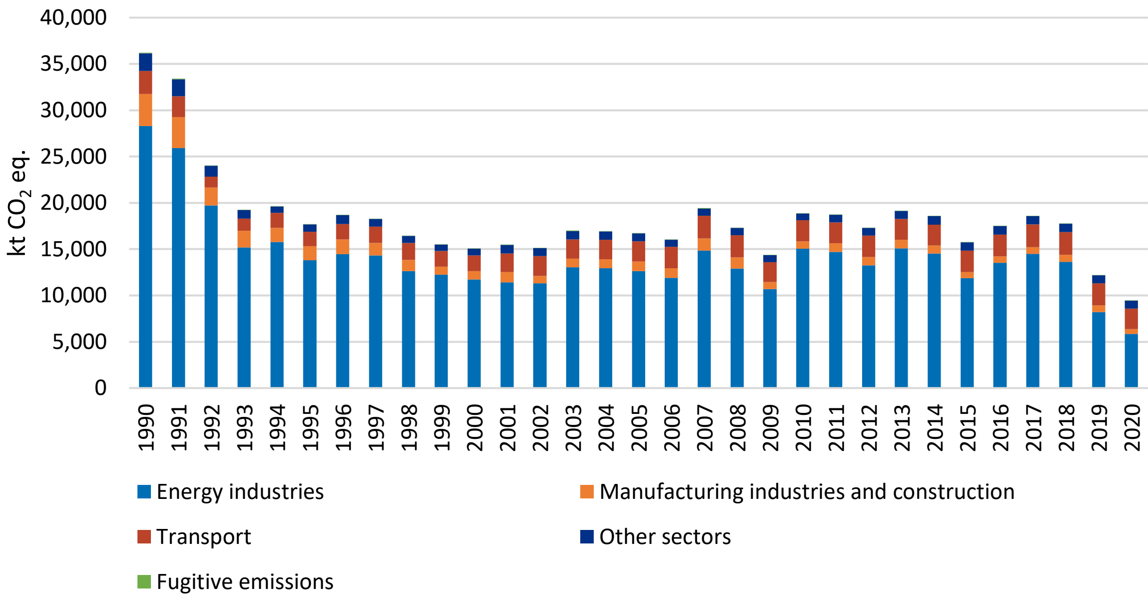

Figure 2.6. Trend in emissions from Energy sector 1990–2020, kt CO_2 eq.

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 2020 the Industrial processes and product use sector contributed 2.56% of all GHG emissions in Estonia, totalling 295.47 kt CO_2 eq. with indirect CO_2 and 270.73 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 60.05% of total emissions from the sector (with indirect CO_2). Compared to 2019, the emissions from Industrial processes and product use (with indirect CO_2) decreased by 52.45% in 2020.This is because of closure of clinker production in cement plant in March 2020 and decreased F-gas emissions. The F-gas emissions decreased because of bans of the Regulation (EU) No 517/2014 that were implemented in 2020.

Industrial CO_2 emissions have fluctuated strongly during years 1990–2020.

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.

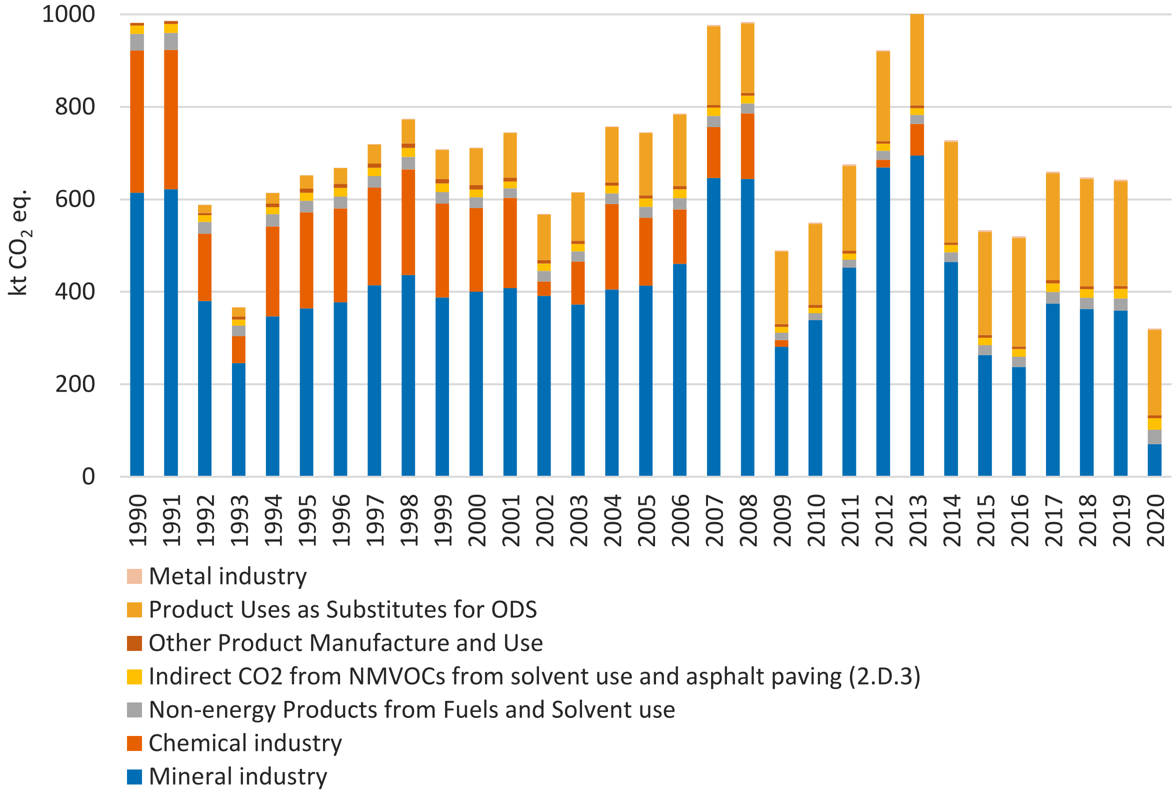

Figure 2.7. Trend in emissions from Industrial processes and product use sector, 1990–2020, kt CO_2 eq.

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 1 508.38 kt CO_2 eq. in 2020. The sector contributed about 13% to the total CO_2 eq. emissions in Estonia. In 2020, the emissions from Enteric fermentation decreased by 0.6% compared to the previous year while the emissions from Manure management increased by 4.2%. The dairy industry has suffered a decline in production due to economic sanctions imposed by Russia on the EU starting from August 2014. Consequently, the number of dairy cattle in 2020 fell by 11.8% in comparison with 2014. The number of swine has fallen by 11.5% in 2020 compared to 2014 in Estonia because of the outbreak of African swine fever in the region in 2015. However, compared to 2018, the number of swine increased by 8.3% in 2020. The increase in the number of livestock is caused by the improved economic situation. Also, a high demand for pork in both inland and foreign markets as pork being the most popular meat in Estonia has helped, to some extent, to recover the number of swine after the low point that started after the African swine fever in 2015.

Emissions from Agricultural soils and Enteric fermentation of livestock were the major contributors to the total emissions recorded in the sector – 49% and 35%, respectively.

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 produce. 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 42.5% in 2020 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 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 overall progression of GHG emissions in the Agriculture sector is presented in Figure 2.8.

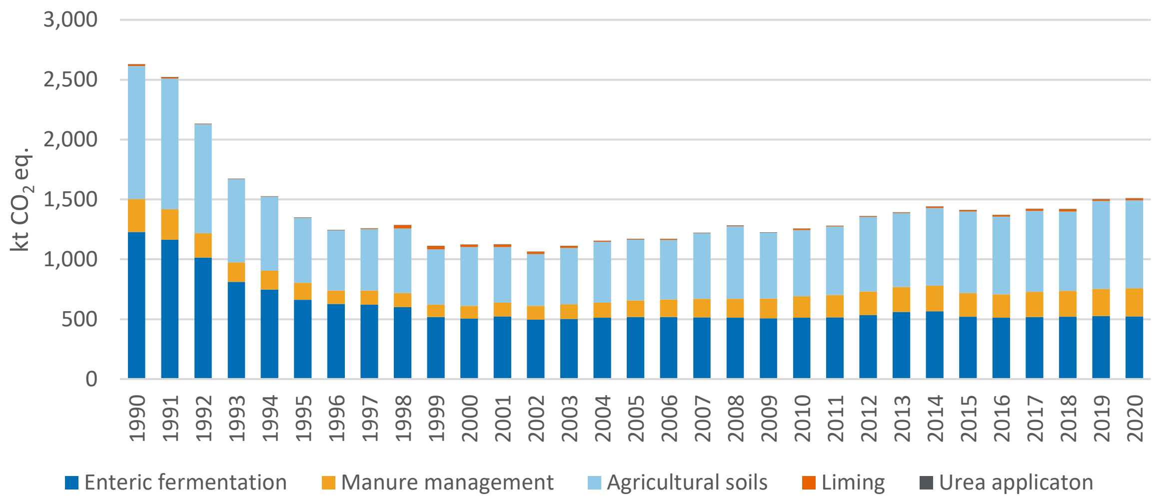

Figure 2.8. Trend in emissions from the Agriculture sector, 1990–2020, kt CO_2 eq.

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 1990–2020 is presented in Figure 2.9. In 2020 net emissions from the LULUCF sector

[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/ (20.12.2021).

[11] Estonian Universtity of Life Sciences. (2011). *Maaelu arengu aruanne.*

equalled 1 297.27 kt CO_2 equivalent. Compared to the base year (1990), uptake of CO_2 in the LULUCF sector has decreased by 141.1% and compared to the previous year (2019), by 487.7%. The LULUCF sector sink is mainly affected by the age structure of managed forests, management practices in forestry and agriculture, usage of peat soils and horticultural peat, and C sequestration in HWP.

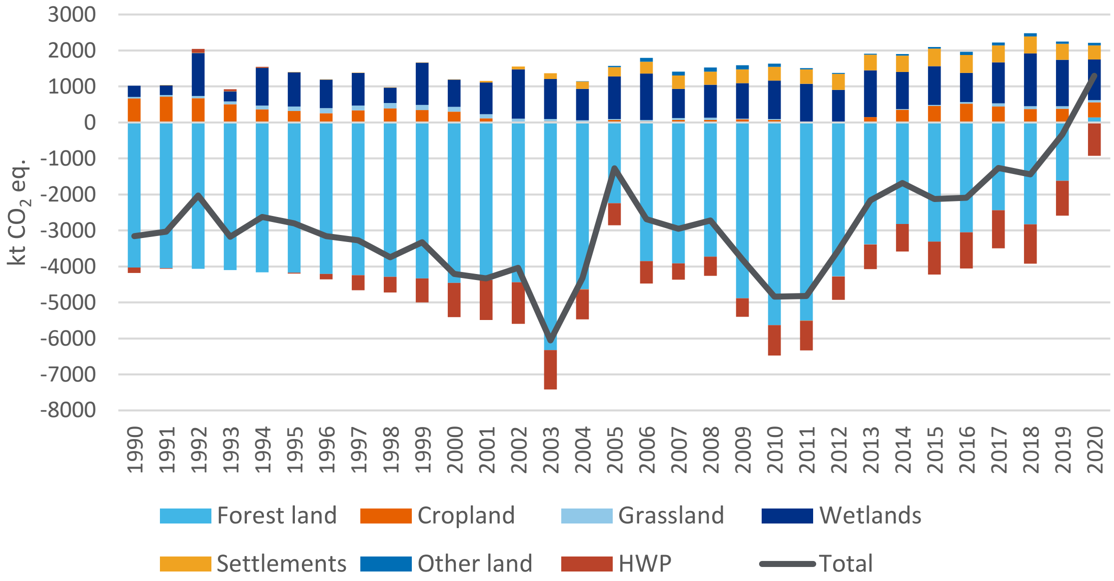

Figure 2.9. Trend in emissions from land use, land-use change and forestry sector 1990–2020, kt CO_2 eq.

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), the capacity of carbon sequestration in biomass has decreased in recent years. In addition, the annual increase in conversion from other land categories to Forest land (afforestation and reforestation) has been slowing – particularly in Cropland and Grassland conversion to Forest land, 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.

In the period 1990–2002, the area of Forest land remaining forest land category decreased due to the 20-year transition period (the total forest land area increased). However, C sequestration increased due to the rapid increase in forest growing stock. In 2004–2008, C sequestration decreased as the felling volume increased strongly in the previous few years. Felling volumes in 2004–2011 were lower compared to the previous period.

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 290.5 kt in 2020 2.5% of total GHG emissions in 2020. Total CO_2 eq. emissions from the Waste sector (Table 7.2) in 2020 decreased by 3.9% compared to 2019. In recent years, total emissions have followed a declining trend. Compared to the base year of 1990, the amount of CO_2 eq. emissions in 2020 were 21.5% smaller. Compared to the base year, CO_2 eq. emissions from Solid waste disposal (SWD) have decreased by 18.6%, CO_2 eq. emissions from Waste incineration and Open burning of waste by 78.9%, and from Wastewater treatment and discharge by 44.1%. On the other hand, CO_2 eq. emissions from Biological treatment of solid waste have, compared to the base year of 1990, increased by 2586.3%.

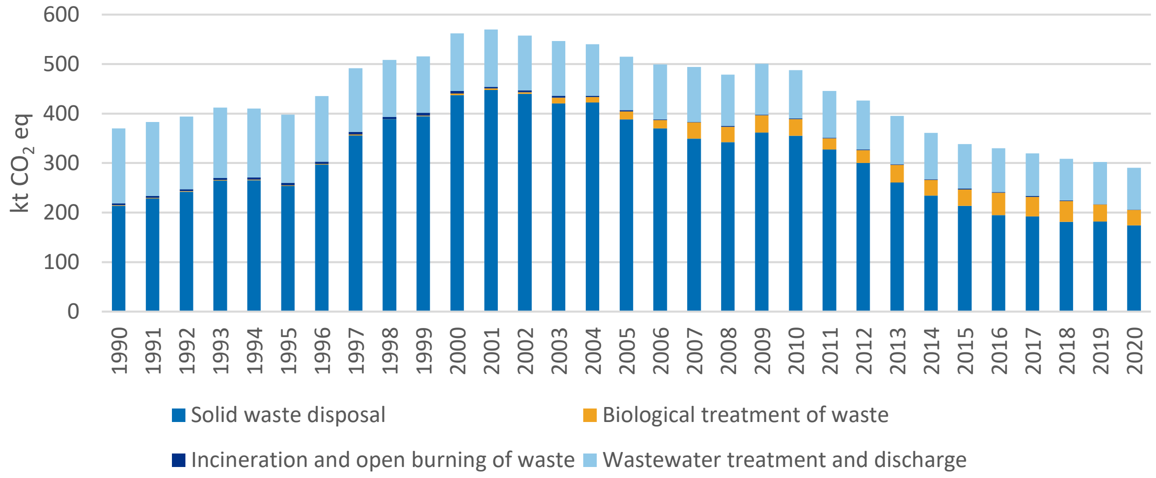

Figure 2.10. Trend in emissions from waste sector by source categories in 1990–2020, kt CO_2 eq.

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

The lowest CO_2 eq. emissions occurred in 2020, which was mainly connected to the decreasing amount of waste deposited in landfills. 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 prepared 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 reduced consumption habits and waste generation. Also, opening the Iru waste incineration plant in 2013 had a decreasing effect on the amount of deposited waste trend since 2010.

2.2.6. Description and interpretation of emission trends for KP-LULUCF inventory in aggregated and by activity, and by gas

In 2020, Article 3.3 activities were a net source in Estonia. The total net emissions were estimated at 290.90 kt CO_2 eq. Uptake from Afforestation and reforestation activities including non-CO_2 emissions from drained forest and emissions from wildfires were estimated at -187.29 kt CO_2 eq. Net emissions from Deforestation were 478.20 kt CO_2 eq. (Table 2.1). Areas subject to AR and D were 56.70 kha and 34.11 kha, respectively by the end of 2020. Forest management, under Article 3.4, was a net sink with total uptake of -365.38 kt CO_2 eq. (with HWP).

CH_4 and N_2O emissions from drained organic soils and wildfires are estimated on AR and FM areas (Table 2.1). CO_2 emissions from fires are included in the biomass estimates due to the stock-difference method used. On D areas, emissions from wildfires are not provided since all biomass present on forest land before deforestation is assumed to be lost after the land-use change. N_2O emissions from N mineralization occur only on D areas due to the losses in mineral soil C stocks (Table 2.1).

Table 2.1 KP-LULUCF areas and emissions by gas

KP activity	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Afforestation/reforestation								
Area, kha	54.16	54.85	55.27	55.78	56.11	56.33	56.52	56.70
CO_2, kt	-296.70	-286.31	-272.64	-257.45	-240.02	-223.16	-206.99	-191.62
CH_4 and N_2O emissions from drained organic soil								
Area, kha	5.62	5.77	5.84	5.87	5.93	5.99	6.06	6.12
CH_4, kt	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07
N_2O, kt	0.008	0.008	0.008	0.008	0.008	0.008	0.009	0.009
kt CO_2 eq.	3.97	4.03	4.06	4.07	4.14	4.20	4.27	4.33
AR biomass burning								
Area, ha	0.99	3.17	0.50	1.24	4.49	23.99	0.84	NO
CH_4, kt	1.19E-05	1.83E-05	2.99E-04	3.68E-04	8.34E-04	3.88E-04	1.41E-06	NO
N_2O, kt	1.17E-07	1.80E-07	2.95E-06	3.62E-06	8.21E-06	3.81E-06	1.39E-08	NO
kt CO_2 eq.	0.0003	0.0005	0.008	0.01	0.02	0.12	0.00004	NO
AR total kt CO_2 eq.	-292.73	-282.28	-268.57	-253.37	-235.86	-218.85	-202.73	-187.29
Deforestation								
Area, kha	23.23	24.86	26.55	28.41	30.24	31.90	33.15	34.11
CO_2, kt	548.70	581.47	609.80	671.34	671.01	638.77	538.76	468.50
N_2O emissions from N mineralization, kt	0.020	0.022	0.024	0.026	0.028	0.030	0.032	0.033
kt CO_2 eq.	6.04	6.62	7.23	7.89	8.46	8.99	9.40	9.70
D total kt CO_2 eq.	554.74	588.09	617.03	679.23	679.47	647.76	548.16	478.20
ARD TOTAL kt CO_2 eq.	**262.01**	**305.81**	**348.46**	**425.86**	**443.61**	**428.92**	**345.43**	**290.90**
Forest management								
Area, kha	2389.99	2390.02	2389.96	2389.42	2388.63	2387.90	2387.32	2386.83
kt CO_2	-3150.21	-2594.92	-3107.48	-2867.11	-2277.43	-2695.59	-1510.16	219.03
CH_4 and N_2O emissions from drained organic soil								
Area, kha	277.06	276.91	276.84	276.81	276.75	276.68	276.62	276.56
CH_4, kt	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
N_2O, kt	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
kt CO_2 eq.	327.90	327.84	327.81	327.80	327.74	327.67	327.61	327.54
FM biomass burning								
Area, ha	31.86	52.25	43.78	102.19	23.47	302.95	44.58	85.49
CH_4, kt	7.64E-05	1.51E-03	0.0121	0.0180	4.50E-03	0.1003	0.0039	0.0061
N_2O, kt	7.51E-07	1.48E-05	1.19E-04	1.77E-04	4.43E-05	9.87E-05	3.80E-05	6.04E-05

KP activity	2013	2014	2015	2016	2017	2018	2019	2020
kt CO_2 eq.	0.002	0.04	0.35	0.50	0.13	2.80	0.11	0.17
Harvested wood products, kt	-661.72	-733.64	-880.04	-966.27	-1023.64	-1 065.77	-952.67	-912.12
FM TOTAL kt CO_2 eq.	**-3 484.03**	**-3 000.67**	**-3 659.37**	**-3 505.08**	**-2 973.21**	**-3 430.89**	**-2 135.12**	**-365.38**

3. ENERGY (CRF 1)

3.1. Overview of the sector

The Energy sector is the main source of greenhouse gas emissions in Estonia. In 2020 the Energy sector contributed about 81.9% of total emissions, totalling 9461.45 kt CO_2 equivalent (Figure 3.1). Compared to the base year 1990 (36 213.16 kt CO_2 eq.), the emissions have decreased about 73.9%. 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.

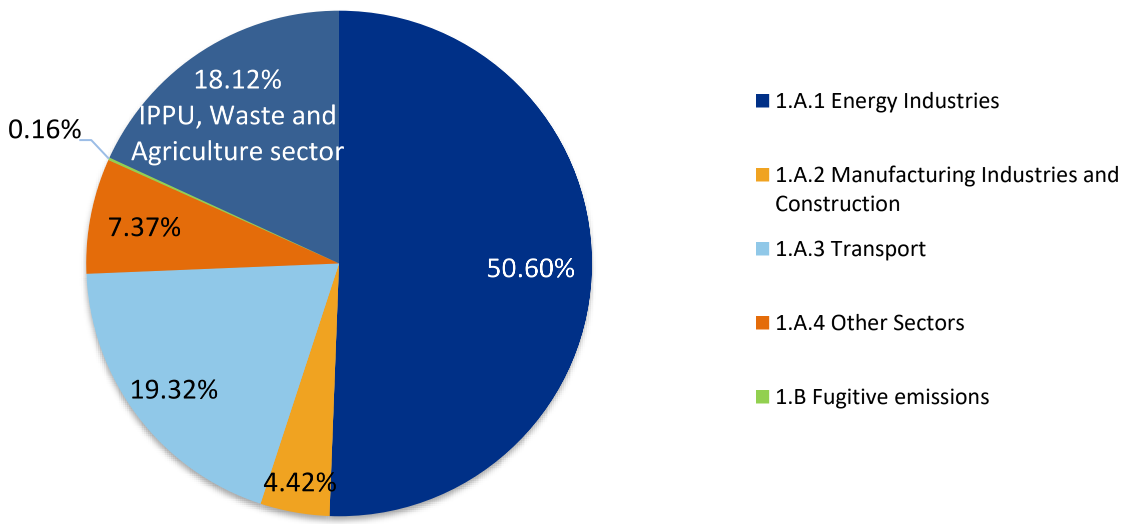

Figure 3.1. Emissions from the Energy sector compared to the total emissions in 2020, %

The share of domestic fuels is large in Estonia's 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.

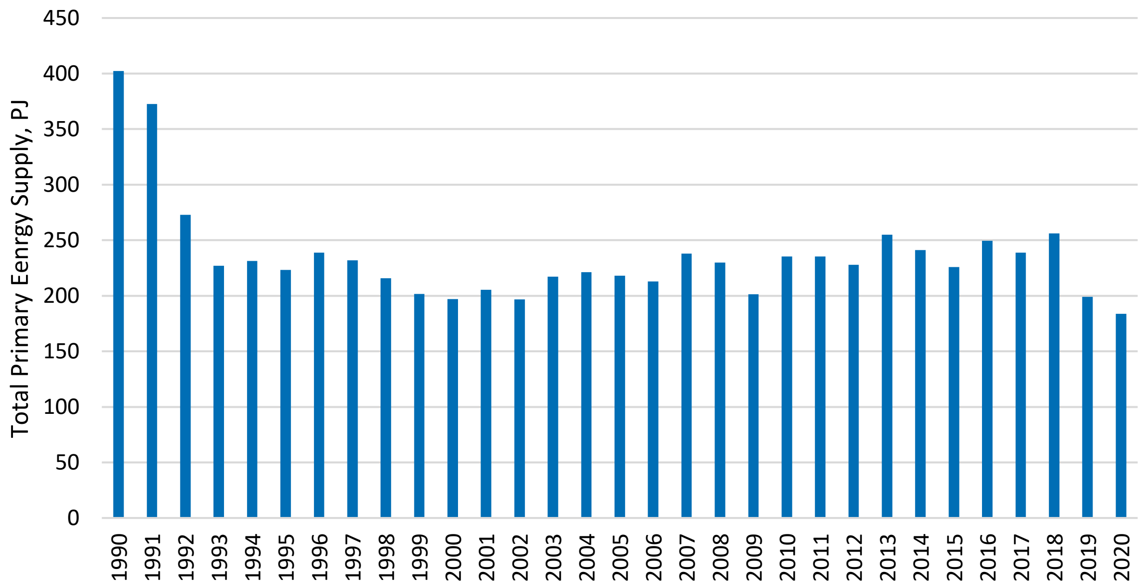

Figure 3.2. Development of total primary energy supply in Estonia in 1990–2020, PJ (Source: Statistics Estonia)

In 2020 the primary energy supply was 183.8 PJ, of which oil shale 62.8% and wood and municipal wastes 28.4%. Other fuels had smaller shares – natural gas 8.2%, peat 0.6%, and coal 2.4%. The primary energy supply decreased about 7.7% in 2020 compared to the previous year (see Figure 3.2). The main reason for the decrease was the increase of the EU ETS emission allowance prices and lower 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 2020.

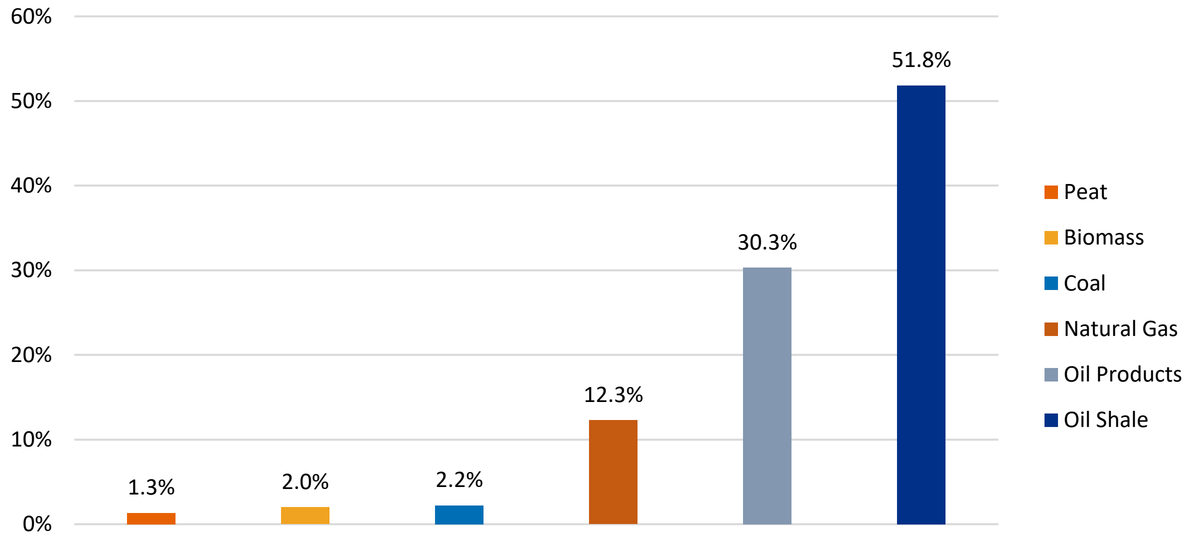

Figure 3.3. Structure of primary energy supply in Estonia in 1990, %

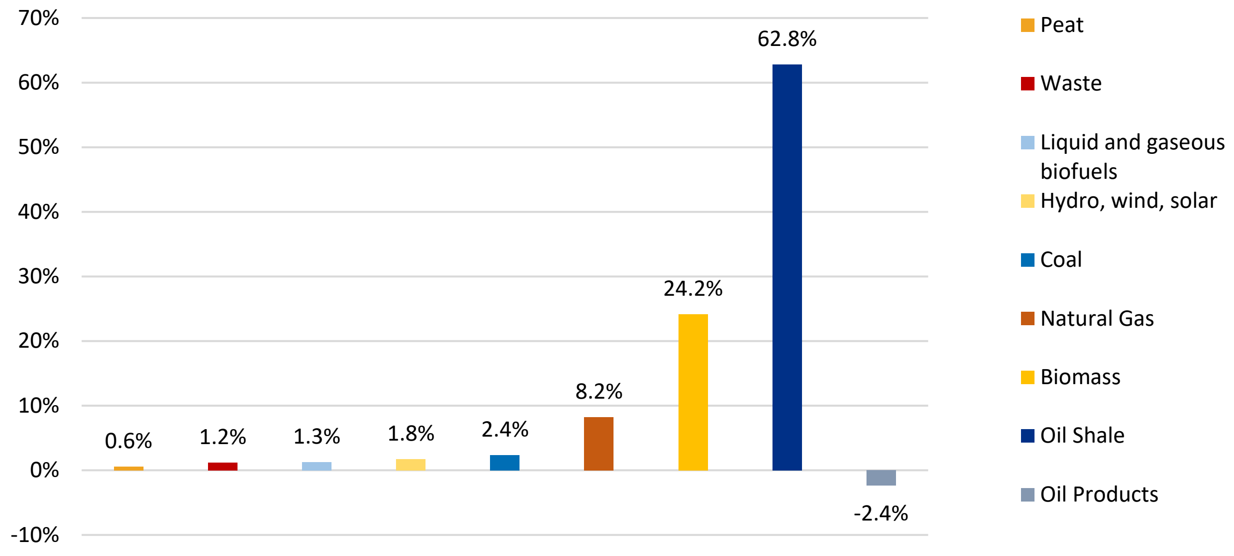

Figure 3.4. Structure of primary energy supply in Estonia in 2020, %

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. Also, the primary energy supply decreased by 7.7% compared to 2019.

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 3.4).

The GHG emission and fuel consumption decreased compared to the previous year primarily in the energy industries, as the EU ETS emission allowance prices increased. Emissions from the Energy sector by subcategories in 1990–2020 are presented in Figure 3.5.

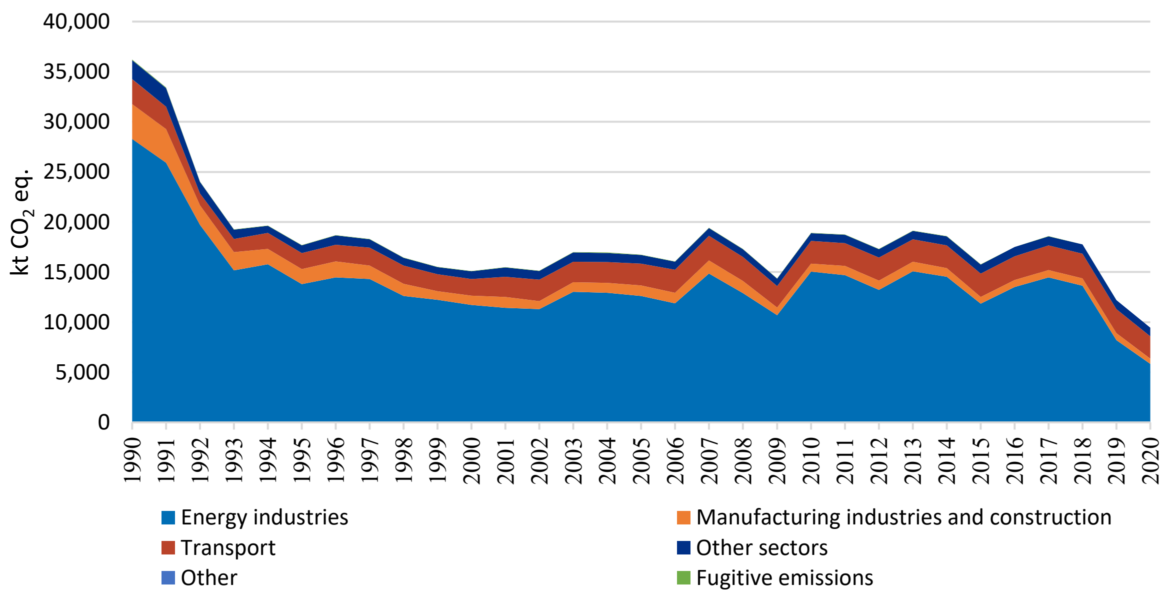

Figure 3.5. Emissions from the Energy sector by subcategory in 1990–2020, kt CO_2 eq.

The trend of fuel consumption in Energy sector in 1990–2020 is presented in Figure 3.6.

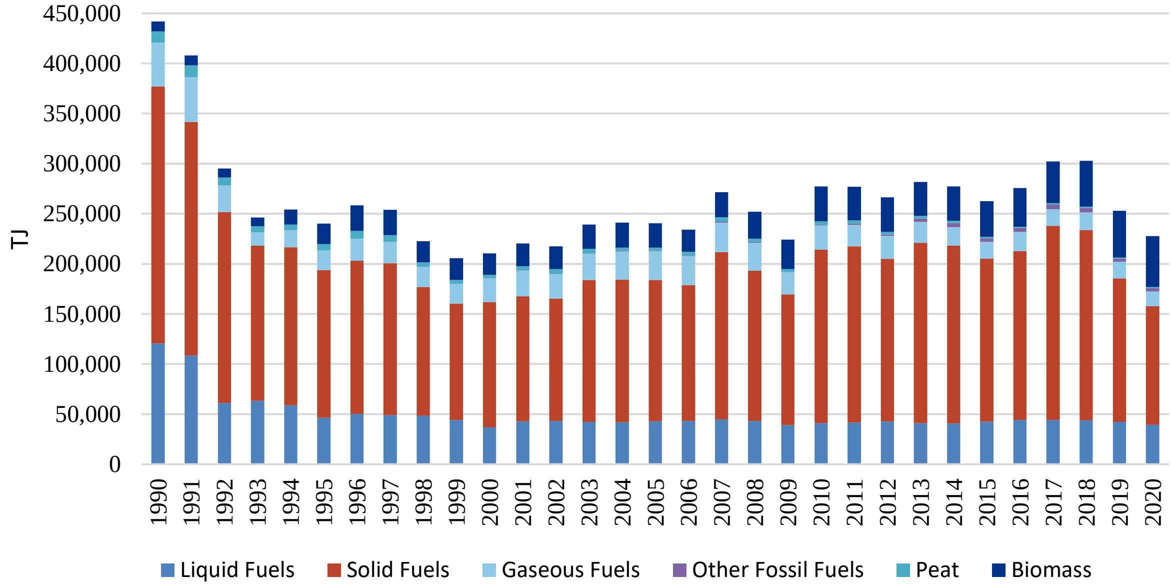

Figure 3.6. Fuel consumption in Energy sector in 1990–2020, TJ

The greenhouse gases which are 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 Fuel combustion (CRF 1.A) and Fugitive emissions (CRF 1.B). Emissions from the Energy sector in 1990–2020 by greenhouse gas are presented in Table 3.1.

Table 3.1. Emissions from the Energy sector in 1990, 1995, 2000, 2005, 2010, and 2015–2020 by greenhouse gas, kt

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1 Energy Total, CO_2 eq.	36 213.16	17 697.15	15 113.80	16 742.41	18 899.50	15773.44	17 519.24	18 585.32	17 770.83	12 210.92	9 461.45
1.A Fuel Combustion Total, CO_2 eq.	36 148.99	17 666.58	15 078.63	16 700.15	18 869.40	15752.71	17 495.40	18 564.41	17 748.31	12 189.96	9 442.75
1.A Fuel Combustion, CO_2	35 948.46	17 461.42	14 886.28	16 514.62	18 635.80	15549.83	17 281.71	18 342.76	17 524.65	11 974.94	9 221.91
1.A Fuel Combustion, CH_4	5.11	5.89	5.26	4.72	6.16	5.28	5.58	5.72	5.75	5.58	5.80
1.A Fuel Combustion, N_2O	0.24	0.19	0.20	0.23	0.27	0.24	0.25	0.26	0.27	0.25	0.25
1.B Fugitive Emissions, CO_2 eq.	64.17	30.58	35.17	42.26	30.10	20.74	23.84	20.91	22.52	20.96	18.70

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

The emissions from Fuel combustion include point sources, transport, and other fuel combustion. Direct and indirect GHGs (CO_2, CH_4, N_2O, CO, NMVOC, NO_x), as well as SO_2 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 (including Commercial, Residential/institutional, and Agriculture/forestry/fishing sectors);

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 for the subcategory 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 (9221.91 kt) accounted for 97.5% of the Energy sector's total CO_2 eq. emissions and 79.8% of total CO_2 eq. emissions in 2020. The share of CH_4 emissions from Fuel combustion (144.96 kt CO_2 eq.) was 1.25% of total 2020 CO_2 eq. emissions, mainly from incomplete combustion of wood fuels (small combustion). N_2O emissions are relatively small (75.88 kt CO_2 eq.) accounting for about 0.66% of total 2020 CO_2 eq. and 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 2015–2020, kt

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1.A Fuel Combustion Total, CO_2 eq.	36 148.99	17 666.58	15 078.63	16 700.15	18 869.40	15752.71	17 495.40	18 564.41	17 748.31	12 189.96	9 442.75
1.A.1 Energy Industries, CO_2 eq.	28 288.34	13 800.21	11 727.31	12 625.27	15 038.58	11862.68	13 512.41	14 483.00	13 639.33	8 203.31	5 847.70
1.A.2 Manufacturing Industries and Construction, CO_2 eq.	3 475.23	1 507.55	913.07	1 036.76	792.61	658.11	696.16	734.05	740.19	716.38	511.27
1.A.3 Transport, CO_2 eq.	2 481.91	1 586.83	1 684.86	2 169.22	2 288.39	2318.49	2 365.86	2 450.68	2 468.41	2 401.82	2 232.54
1.A.4 Other Sectors, CO_2 eq.	1 903.52	772.00	753.39	868.90	749.82	913.42	920.96	896.67	900.38	868.45	851.23

Methods

Emissions from Fuel combustion (CRF 1.A.1–1.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.

Calculations of all emissions from Fuel combustion are done in Excel Work Tables created by the Energy sector expert.

Key categories

The key categories in 2020 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3 and Annex 1.

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 2022 inventory submission, the difference in CO_2 emissions in 2020 between RA and Sectoral approach (SA) was 29.6%. 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.

3.2.2. International bunker fuels

International bunkers cover International aviation and Navigation according to the IPCC 2006 Guidelines.

In 2020 GHG emissions from International bunkering were 982.62 kt CO_2 eq., including Marine bunkers 909.90 kt CO_2 eq. and Aviation bunkers 72.72 kt of CO_2 eq.

GHG emissions from International 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. In 2019 emissions from Marine bunkering fell 40.7% next to 2018 due to substituting diesel oil with LNG and a decrease in passenger traffic. In 2020 emissions from Marine bunkering increased 37.8% compared to 2019 due to an increase in fuel stocks. 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.

The emissions trend in International aviation has been quite stable, slight increases in 2007 and 2008 were caused by lower bunker fuel prices in Estonia. In 2020 emissions from International aviation decreased 65.7% compared to 2019 because of a severly reduced international air traffic due to COVID-19 pandemic.

Figure 3.7. presents the trend of GHG emissions from International bunker fuels. It can be seen from the figure that fuel consumption has been increasing in aviation bunkering, but fell

abruptly in 2020, caused by a decline in international flights. Marine bunkering saw an increase in GHG emissions.

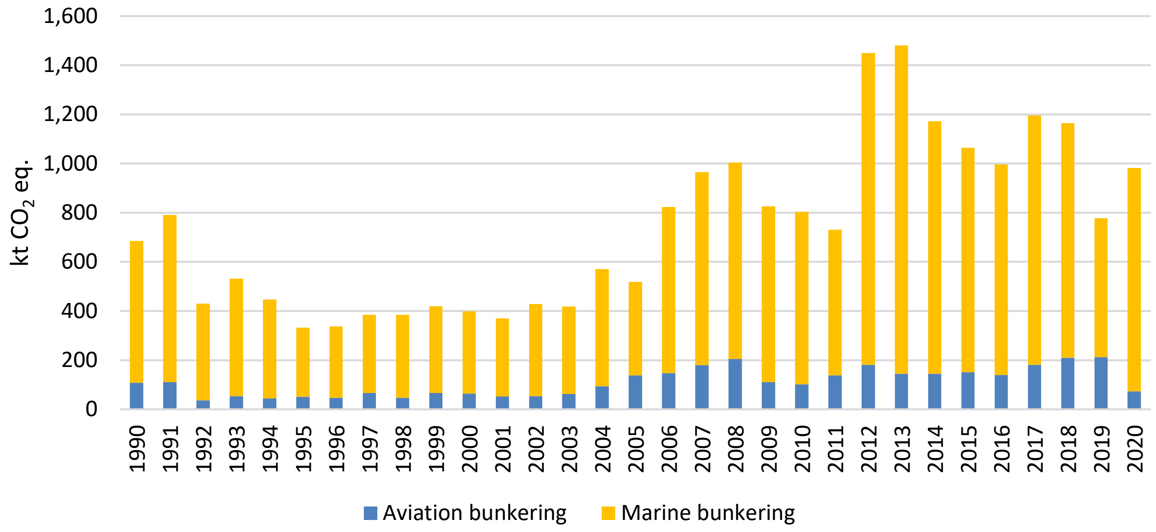

Figure 3.7. Emissions from International bunkers in 1990–2020, kt CO_2 eq.

The emissions are calculated using the IPCC 2006 methodology and country-specific emission factors. Fuel consumption data on Marine bunkering is obtained from the energy statistics and it includes fuel sales to ships abroad. Statistics Estonia obtains this data from the international trade database according to the relevant merchandise code. Activity data for the calculations in Domestic and International aviation (landing and take-off cycles, fuel consumption) is obtained from the Estonian Environment Agency.

Category-specific recalculations

Emissions from Marine bunkering were recalculated due to using updated Joint Questionnaire dataset made by Statistics Estonia, which is sent to Eurostat and IEA databases.

Table 3.4 Differences between 2021 and 2022 submissions, kt CO_2 eq.

Year	Marine bunkering
2019	21.42
2018	27.81
2017	40.78
2016	37.28
2015	41.55
2014	67.24
2013	87.87
2012	69.35
2011	34.05
2010	40.50
2009	43.61
2008	45.80
2007	44.56
2006	36.58
2005	17.51

Year	Marine bunkering
2004	22.96
2003	16.03
2002	16.51
2001	13.15
2000	14.45
1999	16.85
1998	17.02
1997	15.66
1996	13.06
1995	11.54
1994	16.18
1993	19.91
1992	19.21
1991	39.71
1990	33.84

3.2.3. Feedstocks and Non-energy use of fuels

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

Activity data on lubricants and bitumen consumption is received from Joint Questionnaire that Statistics Estonia annually sends to IEA. Natural gas data for the category Non-energy use is acquired from the national energy balance sheet. 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.

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

3.2.4.1. Category description

Energy industries (CRF 1.A.1) and Manufacturing industries and construction (CRF 1.A.2) include emissions from fuel combustion in point sources in energy production and industrial sectors (power plants, boilers, and industrial plants with boilers, and/or other combustion).

In 2020 Energy industries (1.A.1) contributed 61.8% of Energy sector emissions, totalling 5847.70 kt CO_2 eq. (Table 3.5) and 50.6% of total GHG emissions. Compared to the base year 1990, the emissions were 79.3% lower (28 288.34 kt CO_2 eq.). The decrease of 28.7% in the Energy industries compared to the previous year was mainly because of the EU ETS emission allowance price increase.

The emissions from Energy industries by relevant subcategories and gases in 1990–2020 are presented in Table 3.5. Figure 3.8 presents the trend of GHG emissions from Energy industries by relevant subcategories from 1990 to 2020.

In general the trend of GHG emissions in Energy industries follows the trend of fuel consumption. The decrease of GHG emissions in the public electricity and heat production sub-sector in 2020 compared to 1990 was 79.3%. 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 fuels in Energy industries (closing factories, decrease of electricity import, etc.). At the same time, the GHG emissions from Other energy industries (1.A.1.c) 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. Whereas these emissions can be observed from Other fuels in Energy industries sector. In 2020 Iru waste incineration plant emitted 143.39 kt CO_2 eq.

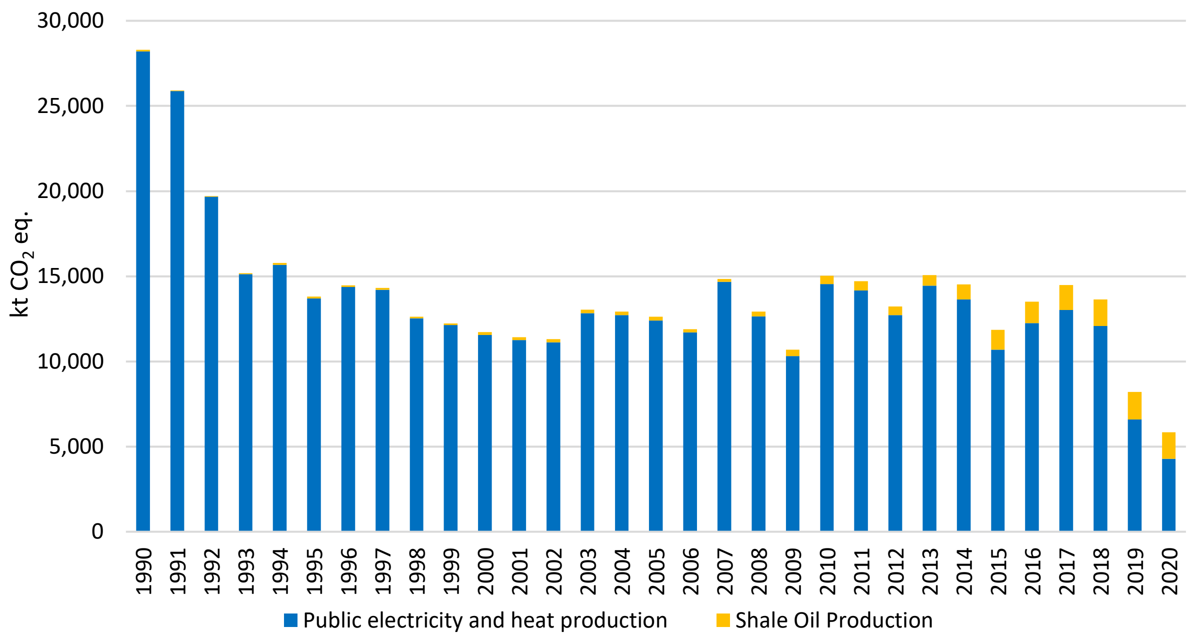

Figure 3.8. Trend of GHG emissions from Energy industries by relevant sub-categories in 1990–2020, kt CO_2 eq.

In 2020 the gross electricity production was 5 956 GWh – about 23.2% lower compared to 2019 (7 616 GWh). The electricity export increased from 2 704 GWh in 2019 to 3 723 GWh in 2020 (about 27.4%). The electricity import increased from 4 861 GWh in 2019 to 7 367 GWh in 2020 (34%).

Renewable energy is generated from wind and biomass and in small hydroelectric plants in Estonia While electricity generation in wind parks has increased rapidly the proportion of renewable energy in energy production intensified. In 2020 the production of electricity from wind energy increased about 18.6% compared to 2019 due to good wind conditions.

In 2020 the heat production fell around 3% compared to 2019. Roughly 39% of heat was produced in heating plants and power plants produced about 61% of heat.

Estonia imported coal, wood, natural gas, and liquid fuels in 2020. Natural gas imports decreased about 7.7% compared to 2019. Motor gasoline and diesel imports grew about 20% compared to the previous year. Coal imports decreased about 80.5% compared to 2019.

In 2020 the Manufacturing industries and construction contributed about 5.4% of Energy sector emissions, totalling 511.27 kt CO_2 eq., and about 4.4 % of total GHG emissions.

Table 3.6 and Figure 3.9 represent the emissions from Manufacturing industries and construction by relevant subcategories and GHGs in 1990-2020. Compared to 1990, the emissions have decreased by 85.3% in 2020. Emissions decreased in the Manufacturing industries and construction sector by 28.6% compared to 2019, mainly from the cement production due to the increase of the EU ETS emission allowance price in 2020. The structural changes in the economy after regaining independency in 1991 caused the relevant decrease from 1992.

According to the structure of CRF tables, all 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.

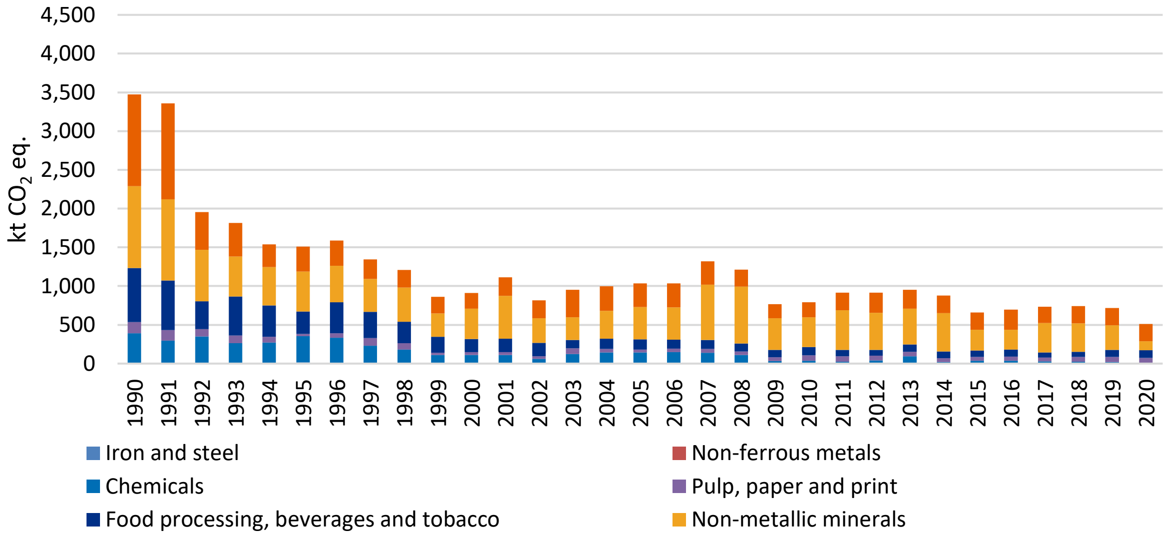

Figure 3.9. Trend of GHG emissions from Manufacturing industries and construction by relevant sub-categories in 1990–2020, kt CO_2 eq.

In Estonia the share of the CRF sub-category **1.A.2.a Iron and steel** is very small. The category 1.A.2.a Iron and steel 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.

The trend of GHG emissions from the CRF category 1.A.2.a Iron and steel in 1990–2020 is presented in Figure 3.10.

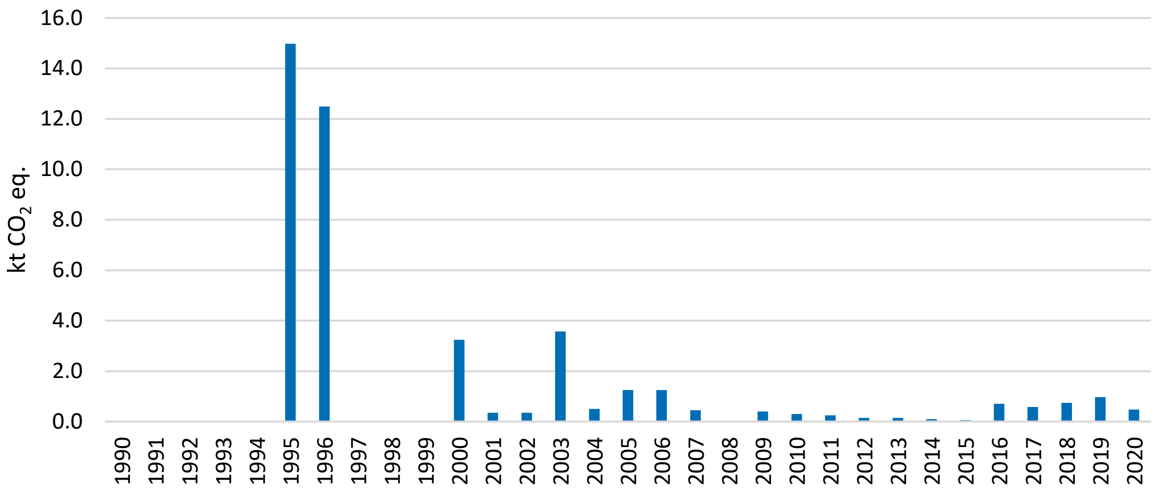

Figure 3.10. Trend of GHG emissions from Iron and steel in 1990–2020, kt CO_2 eq.

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 2020 the emissions from Non-ferrous metals were 1.2 kt CO_2 eq., because the biggest company in the sub-sector was restructured and changed its field to sorting materials. The GHG emission trend matches the trend of fuel consumption in this sub-category.

Figure 3.11. presents the trend of GHG emissions of the CRF category 1.A.2.b Non-ferrous metals in 1990–2020.

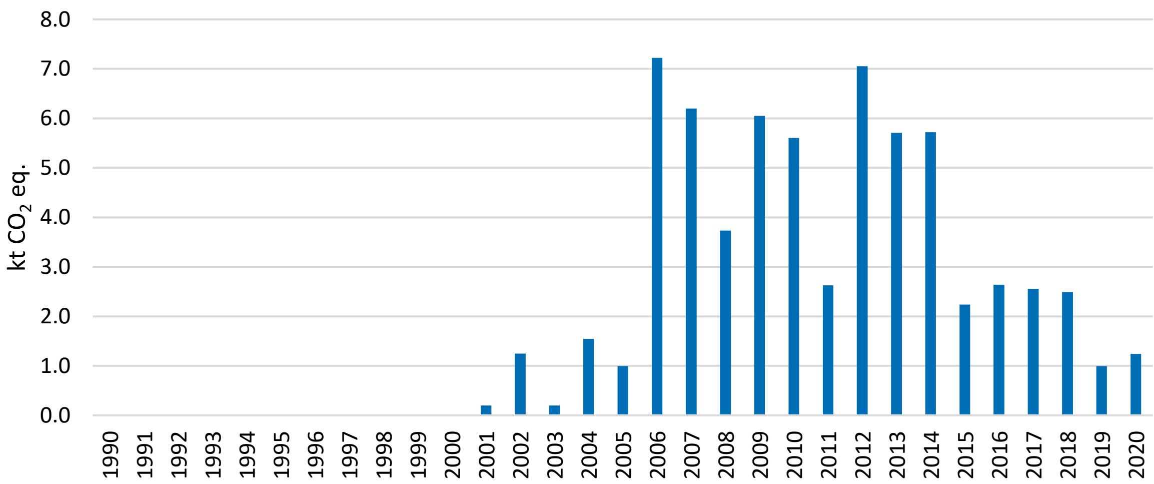

Figure 3.11. Trend of GHG emissions from Non-ferrous metals in 1990–2020, kt CO_2 eq.

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 forms about 2.1% of the Manufacturing industries and construction GHG emissions in 2020.

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 of the CRF category 1.A.2.c Chemicals in 1990–2020.

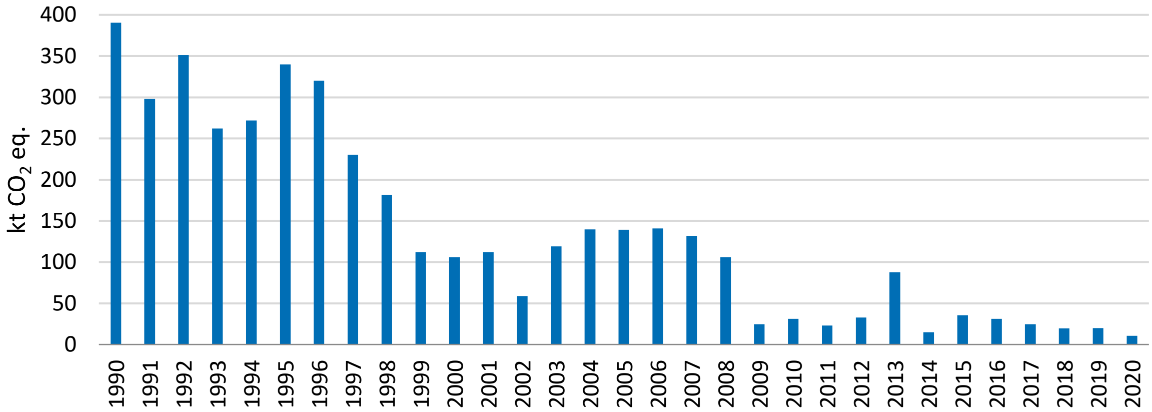

Figure 3.12. Trend of GHG emissions from Chemicals in 1990–2020, kt CO_2 eq.

The CRF sub-category **1.A.2.d Pulp, paper, and print** formed about 12.3% of the Manufacturing industries GHG emissions in 2020.

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 commissioned.

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 11.9% 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 2020 GHG emissions increased 1.3% compared to 2019.

The above-described factors characterise the GHG emission trend.

The trend of GHG emissions of the CRF category Pulp, paper and print in 1990–2020 is presented in Figure 3.13.

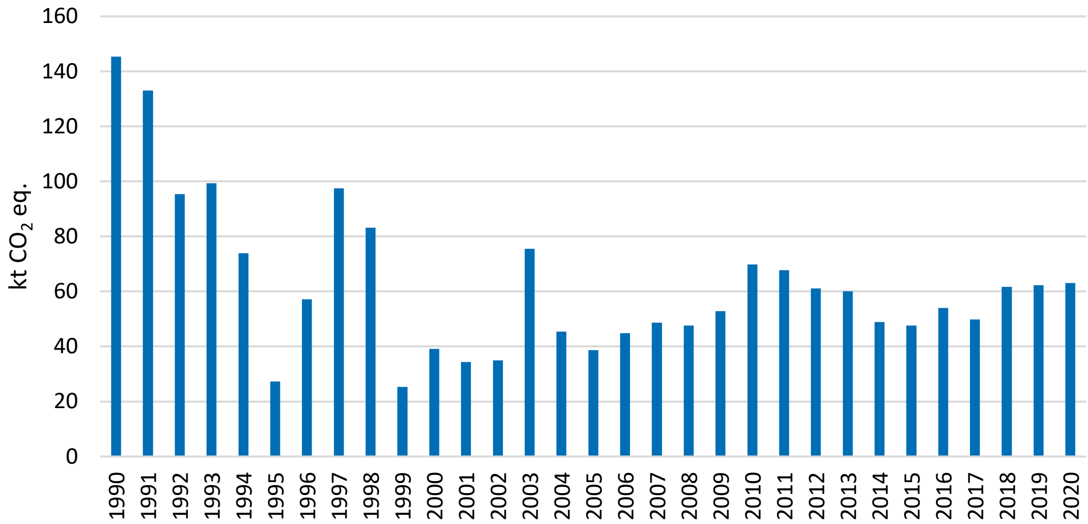

Figure 3.13. Trend of GHG emissions from Pulp, paper and print in 1990–2020, kt CO_2 eq.

The share of the CRF sub-category **1.A.2.e Food processing, beverage, and tobacco** forms about 19.2% of the Manufacturing industries and construction GHG emissions in 2020.

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 did not affect this sector that much.

Figure 3.14. describes GHG emissions trend in CRF category Food processing, beverages, and tobacco in 1990–2020.

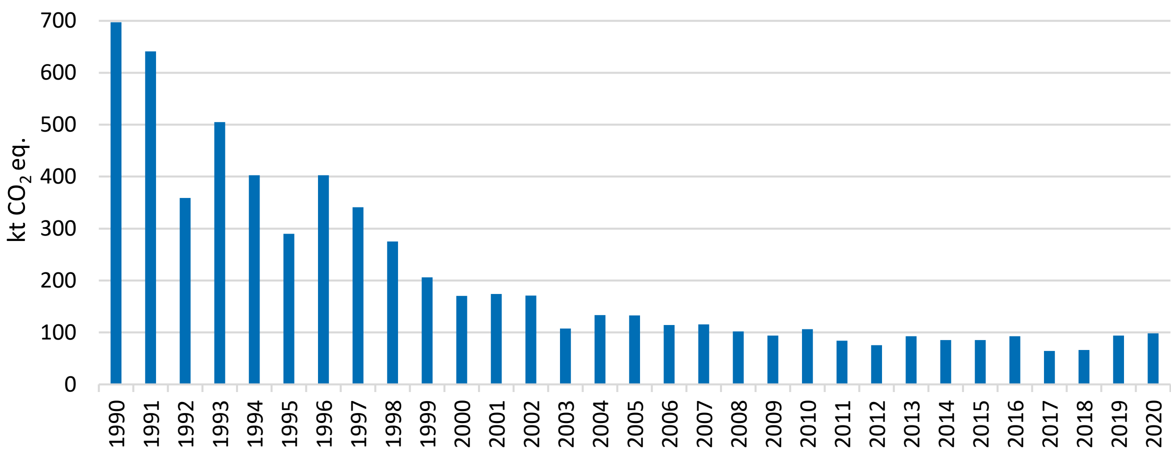

Figure 3.14. Trend of GHG emissions from Food processing, beverages, and tobacco in 1990–2020, kt CO_2 eq.

The share of CRF sub-category **1.A.2.f Non-metallic minerals** is the second largest in Manufacturing industries and construction with 23% in 2020. 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.

The trend of GHG emissions of CRF category 1.A.2.f Non-metallic minerals in 1990–2020 is presented in Figure 3.15.

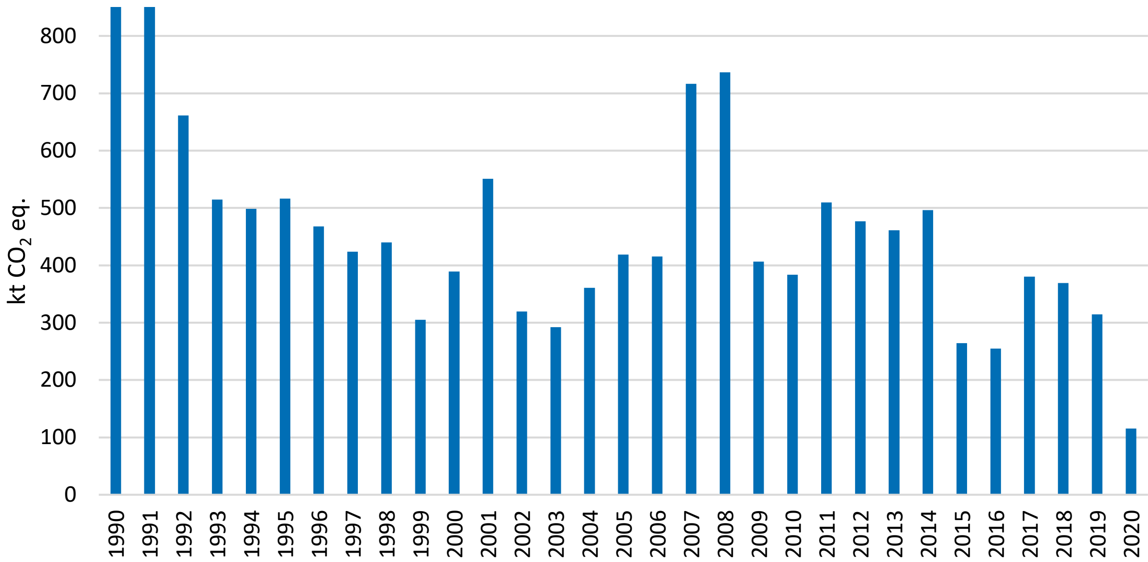

Figure 3.15. Trend of GHG emissions from Non-metallic minerals in 1990–2020, kt CO_2 eq.

The share of the CRF sub-category **1.A.2.g Other** is the biggest sub-sector in Manufacturing industries and construction sector with close to 43.4% in 2020.

In Estonia the Manufacturing industries and construction sector's sub-category 1.A.2.g Other includes following sub-sectors: 'Production of transport equipment'; 'Machinery'; 'Mining and quarrying'; 'Production of wood and wood products construction'; 'Textile, leather and clothing industry', 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 12.4% compared to 2010 because of overall economic upturn. In 2020 emissions decreased 0.6% next to the previous year. This decrease resulted from lower usage of solid and gaseous fuels.

Figure 3.16. presents the trend of GHG emissions of CRF category Other in 1990–2020.

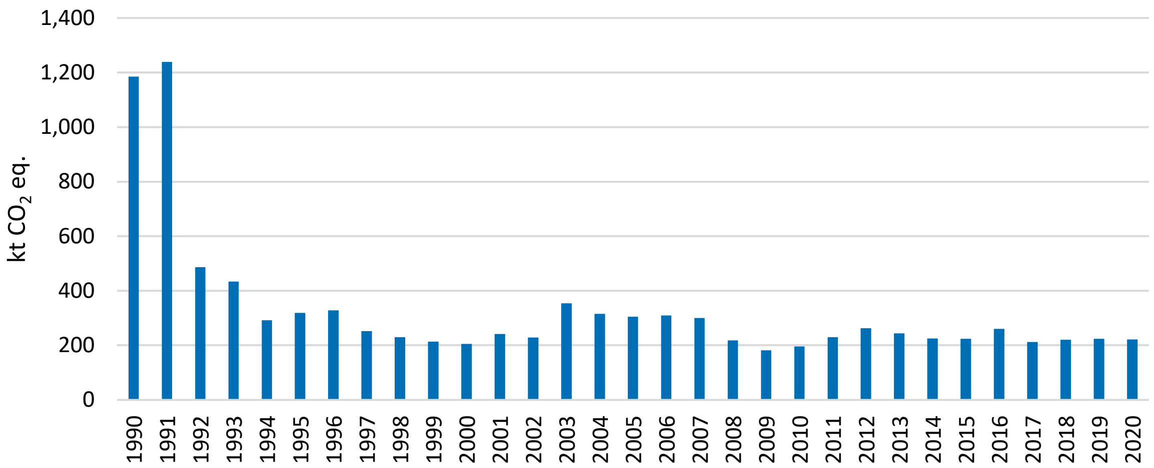

Figure 3.16. Trend of GHG emissions from Other in 1990–2020, kt CO_2 eq.

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 and gases, kt

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
1.A.1 Energy Industries Total, CO_2 eq.	28 288.34	13 800.21	11 727.31	12 625.27	15 038.58	11 862.68	13 512.41	14 483.00	13 639.33	8 203.31	5 847.70
1.A.1 Energy Industries, CO_2	28 270.64	13 792.87	11 721.04	12 613.15	15 013.80	11 834.64	13 479.92	14 447.31	13 602.24	8 166.44	5 808.56
1.A.1 Energy Industries, CH_4	0.12	0.06	0.07	0.06	0.26	0.31	0.35	0.40	0.42	0.47	0.52
1.A.1 Energy Industries, N_2O	0.05	0.02	0.02	0.04	0.06	0.07	0.08	0.09	0.09	0.08	0.09
1.A.1.a Public Electricity and Heat Production Total, CO_2 eq.	28 209.78	13 702.83	11 557.34	12 397.08	14 536.63	10 684.05	12 243.76	13 013.06	12 072.43	6 590.73	4 284.74
1.A.1.c Manufacture of Solid Fuels and Other Energy Industries Total, CO_2 eq.	78.56	97.38	169.97	228.19	501.95	1 178.63	1 268.65	1 469.94	1 566.90	1 612.57	1 562.96

Table 3.6. GHG emissions from Manufacturing industries and construction by relevant subcategories and gases, kt

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
1.A.2 Manufacturing Industries and Construction Total, CO_2 eq.	3 475.23	1 507.55	913.07	1 036.76	792.61	658.11	696.16	734.05	740.19	716.38	511.27
1.A.2.a Iron and Steel, CO_2 eq.	0.00	14.98	3.24	1.24	0.30	0.05	0.70	0.58	0.75	0.97	0.48
1.A.2.b Non-Ferrous metals, CO_2 eq.	0.00	0.00	0.00	1.00	5.60	2.24	2.64	2.56	2.49	1.00	1.24
1.A.2.c Chemicals, CO_2 eq.	390.54	339.95	106.01	139.44	31.31	35.31	31.34	24.46	19.34	20.00	10.77
1.A.2.d Pulp, Paper and Print, CO_2 eq.	145.36	27.24	39.11	38.60	69.83	47.61	54.05	49.87	61.72	62.21	63.03
1.A.2.e Food Processing, Beverages and Tobacco, CO_2 eq.	697.09	290.06	170.39	132.55	106.58	85.05	92.50	64.62	66.55	94.11	98.12
1.A.2.f Non-Metallic Minerals, CO_2 eq.	1 057.43	516.40	389.18	418.48	383.64	264.41	254.60	380.02	368.96	314.58	115.53
1.A.2.g Other, CO_2 eq.	1 184.81	318.91	205.13	305.44	195.35	223.43	260.33	211.94	220.39	223.51	222.11

3.2.4.2. Methodological issues

Emissions from Fuel combustion 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[12].

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[12].

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[12].

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.

[12] 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**[13]

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

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' was updated. According to the Annex 2, 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.

[13] Ministry of the Environment of Estonia (2019). Välisõhku väljutatava süsinikdioksiidi heite arvutusliku määramise meetodid.

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[14]. 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 °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[14] and the rest to the ash hill.

In 2020 80.53 PJ of oil shale was consumed for shale oil production in total and processing of 59 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	Gas generators		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**

[14] J. Soone. S. Doilov (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	Gas generators		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**

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	Gas generators		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**
2016	4.08	4.44	NO	8.52	0.54	0.85	1.39	**9.91**

Year	Solid Heat Carrier			Total	Gas generators		Total	Total
	Narva	VKG	Kiviõli	in SHC	VKG	Kiviõli	in gas generators	Oil shale gas
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	0.00	11.12	2.11	1.14	3.25	**14.37**
2020	5.86	5.24	0.00	11.10	1.67	0.94	2.61	**13.71**

NO – no production occured

CO_2 emissions from the combustion of different oil shale gases are calculated separately and included into CRF category 1.A.1.a Public electricity and heat production/Solid fuels (see Annex 3).

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. The cement is made in a wet process. Limestone and clay are used for raw material and shale oil is the main fuel source.

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.

CO_2 emission factors and other parameters

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

Table 3.9. Carbon emission factors, oxidation factors, and net calorific values for 2020

Fuels	NCV average	Unit	CEF, tC/TJ	Oxidation factor	Source of emission factor
Liquid fuels					
LPG	45.5	GJ/t	17.39	1	CS (Estonia)
Gasoline (for non-road transport)	44	GJ/t	19.22	1	CS (Estonia)
Light fuel oil	42.5	GJ/t	20.23	1	CS (Estonia)
Shale oil (heavy fraction)	39.22	GJ/t	21.1	1	CS (Estonia), MoE 2017
Shale oil (light fraction)	42.3	GJ/t	20.2	1	CS (Estonia), MoE 2017
Diesel oil	42.3	GJ/t	19.94	1	CS (Estonia)
Residual fuel oil (heavy fuel oil)	40.15	GJ/t	20.74	1	CS (Estonia)

Fuels	NCV average	Unit	CEF, tC/TJ	Oxidation factor	Source of emission factor
Solid fuels					
Coal	22.00	GJ/t	25.76	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 peat	9.7	GJ/t	28.9	1	D, IPCC 2006
Sod peat[15]	12	GJ/t	27.82	1	FI (Finland)
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)*	16	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 (CRF 1.A.1.a)	9.0	GJ/t	17.94	1	PS, Iru incineration plant
Gaseous fuels					
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
Black liquor	13.4	GJ/t	26	1	D, IPCC 2006
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

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

CH_4 and N_2O emission factors for Energy industries and 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
Gasoline	3	0.6	3	0.6	D, IPCC 2006
Gas oil (light fuel oil)	3	0.6	3	0.6	D, IPCC 2006
Gas oil (for non-road use)	3/0.003*	0.6/0.17*	3/0.003*	0.6/0.17*	D, IPCC 2006/CS[16]
Shale oil	3	0.6	3	0.6	D, IPCC 2006
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[16]
Recycled 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 $_{PC}$[12]	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 peat	1/1.7*	1.5/2.5*	2/1.7*	1.5/2.5*	D, IPCC 2006/CS[16]
Sod peat	1/1.7*	1.5/2.5*	2/1.7*	1.5/2.5*	D, IPCC 2006/CS[16]
Peat briquette	1/1.7*	1.5/2.5*	2/1.7*	1.5/2.5*	D, IPCC 2006/CS[16]
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[16]
Gaseous fuels					
Natural gas	1/0.003*	0.1/0.12*	1/0.003*	0.1/0.12*	D, IPCC 2006/ CS[16]
Biomass fuels					
Solid biomass (solid, includes e.g. firewood, bark, chips, sawdust, and other industrial wood	30/0.29*	4/0.21*	30/0.29*	4/0.21*	D, IPCC 2006/CS[16]

[16]Country specific emission factors for 1-50MW 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.

Fuels	Energy industries		Manufacturing industries and construction		Source
	CH_4	N_2O	CH_4	N_2O	
residues, pellets, and briquettes)					
Black liquors	3	2	–	–	D, IPCC 2006
Biogas (landfill gas and biogas from wastewater treatment)	1/0.0025*	0.1/0.12*	–	–	D, IPCC 2006/CS[16]

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

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 emission factor is used, if not, the EMEP/EEA Guidebook 2019 is used. 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 received from the Energy Department of Statistics Estonia (Joint Questionnaire). This data is also presented in the SE database and added to the *Estonian National Inventory Report 1990–2020 (Annex 3)*. 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) 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. Fuel consumption in Energy industries (CRF 1.A.1) and Manufacturing industries and construction (CRF 1.A.2) in 1990–2020 is presented in Figure 3.17, Figure 3.18, and Table 3.14.

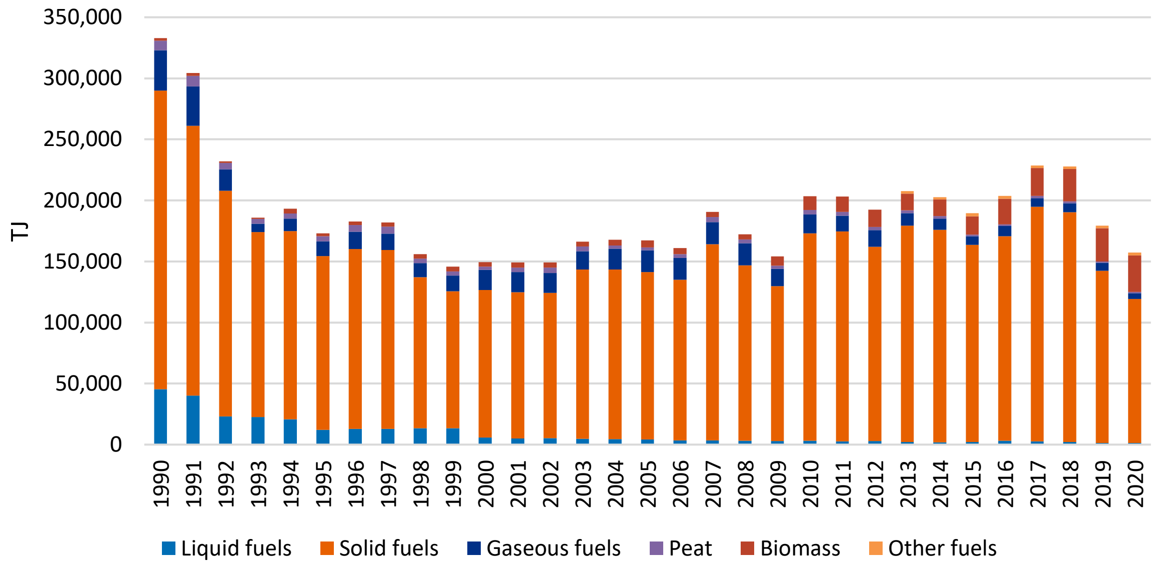

Figure 3.17. Trend of fuel consumption in Energy industries, TJ

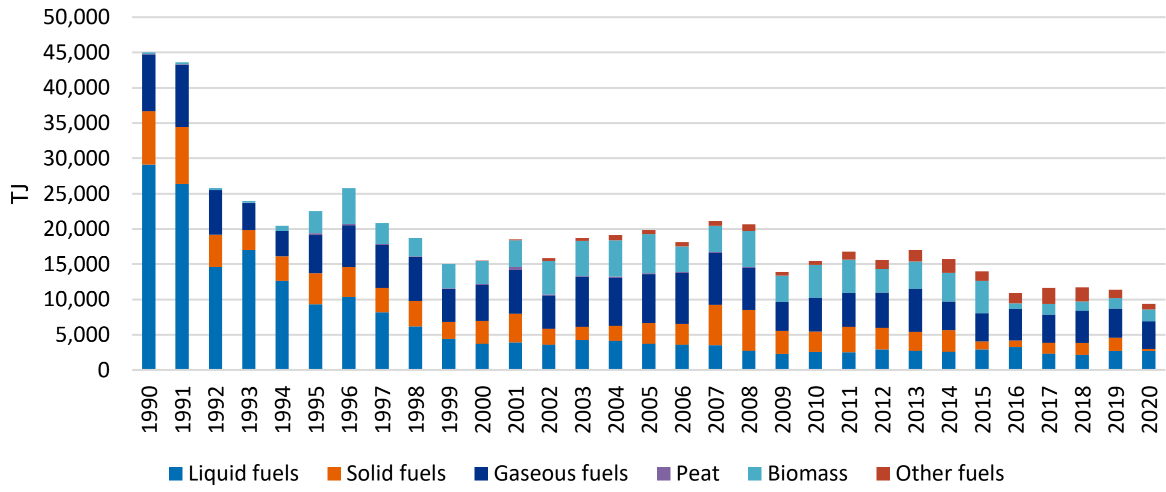

Figure 3.18 Trend of fuel consumption in Manufacturing industries and construction, TJ

Table 3.14. Fuel consumption in Energy industries and Manufacturing industries and construction in 1990, 1995, 2000, 2005, 2010, and 2015–2020, TJ

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1.A.1 Energy industries	**332 999**	**173 004**	**149 563**	**167 239**	**203 393**	**189 427**	**203 723**	**228 673**	**227 865**	**179 201**	**157 324**
Liquid fuels	45 263	12 073	5 866	4 342	3 255	2 243	3 060	2 711	2 239	1 390	1 442
Solid fuels	244 766	142 405	120 724	136 935	169 840	161 225	167 574	192 135	188 055	141 022	117 848
Gaseous fuels	32 852	11 952	16 502	17 810	15 362	7 247	8 465	7 108	7 446	6 521	4 673
Peat	7 940	4 315	2 806	2 509	3 636	1 345	1 366	1 641	1 420	965	1 196
Biomass	2 179	2 259	3 666	5 642	11 300	14 970	20 950	22 860	26 475	27 362	29 769
Other fuels[17]	0	0	0	0	0	2 397	2 309	2 218	2 229	1 941	2 397

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1.A.2 Manufacturing industries and construction	**45 027**	**22 506**	**15 275**	**19 835**	**15 401**	**13 957**	**10 876**	**11 640**	**11 712**	**11 373**	**9 409**
Liquid fuels	29 085	9 292	3 513	3 751	2 547	2 896	3 240	2 337	2 170	2 672	2 699
Solid fuels	7 585	4 409	3 253	2 884	2 927	1 174	939	1 523	1 669	1 902	260
Gaseous fuels	8 004	5 408	5 099	6 934	4 783	3 948	4 459	3 996	4 564	4 165	3 962
Peat	90	236	83	148	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
Other fuels[18]	0	0	8	610	467	1 313	1 437	2 304	1 976	1 220	840

[17] Municipal solid waste combusted in Iru waste incinerator since 2013
[18] Waste oils, Other fossil based waste (MSW), and Plastics combusted in Kunda Nordic Cement plant since 2000

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 2020. The data availability allows the estimation of uncertainty by a fuel type rather than by a sector in fuel combustion[19].

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[20]

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

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[21]

$$U_E = 2 \times u_E$$

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.

[19] Metrosert AS report: Uncertainty Estimation of CO_2 emission in the Estonian National Greenhouse Gas Inventory, April 2007, Tallinn, Estonia.
[20] IPCC 2006 Guidelines, Volume 1, Chapter 3; Uncertainties, page 3.28, equation 3.1
[21] 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 3.15. The largest uncertainty contribution 60% is caused by incomplete data of the emission factor of other fuels (waste fuels).

Table 3.15. Estimated relative uncertainties of CO_2 emission due to Fuel combustion in Estonia in 2020[22]

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 3.16).

Table 3.16. 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[23]
Biomass	CH_4	5%	60%	**U_A –** IPCC GPG, Table 2.6, p. 2.41 **U_E –** Finnish[23]
	N_2O	5%	60%	**U_A –** IPCC GPG, Table 2.6, p. 2.41 **U_E –** Finnish[23]

[22] IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories.
[23] Finnish NIR 1990–2018.

Source and Sink	GHG	Activity data uncertainty U_A	Emission factor uncertainty U_E	Reference U_A, U_E
1.A.2 Manufacturing industries and constructions				
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[23]
Biomass	CH_4	5%	60%	**U_A** – IPCC GPG, Table 2.6, p. 2.41 **U_E** – Finnish[23]
	N_2O	5%	60%	**U_A –** IPCC GPG, Table 2.6, p. 2.41 **U_E –** Finnish[23]
Other fuels	CH_4	5%	60%	**U_A –** IPCC GPG, Table 2.6, p. 2.41 **U_E –** Finnish[23]
	N_2O	5%	60%	**U_A** – IPCC GPG, Table 2.6, p. 2.41 **U_E –** Finnish[23]
1.A.3 Transport				
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[23]
	N_2O	5%	150%	**U_A** – IPCC GPG, Table 2.6, p. 2.41 **U_E** – Finnish[23]
1.A.4 Other sectors				
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[23]
Liquid fuels	N_2O	5%	75%	**U_A** – IPCC GPG, Table 2.6, p. 2.41 **U_E** – Finnish[23]
Biomass	CH_4	10%	150%	**U_A** – IPCC GPG, Table 2.6, p. 2.41 **U_E** – Finnish[23]
	N_2O	10%	150%	**U_A** – IPCC GPG, Table 2.6, p. 2.41 **U_E** – Finnish[23]
1.B Fugitive emissions from fuels				
1.B.2.b Natural gas	CH_4	10%	25%	IPCC GPG, p. 2.92

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 2016 national inventory.

Detailed uncertainty estimations by categories are presented in Annex 2.

3.2.4.4. Category-specific QA/QC and verification

There are several QC procedures. The most resource-demanding is checking the fuel consumption data 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 2022 inventory submission Energy sector CO_2 emissions were compared against the emissions of European Union Emission Trading Scheme (EU ETS) enterprises (for the year 2020). 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

1.A.1.a Heat and power production and 1.A.2 Manufacturing industries and construction category emissions were recalculated using updated Joint Questionnaire dataset managed by Statistics Estonia, which is sent to Eurostat and IEA databases, including off-road vehicles in 1.A.2.g Other emission calculations and using country specific CH_4 and N_2O emission factors for 1-50 MW combustion plants instead of default values in 1.A.1.a and 1.A.2 all subsectors.

Table 3.17 Differences between 2022 and 2021 submissions, kt CO_2 eq.

Year	1.A.1.a	1.A.2.a	1.A.2.b	1.A.2.c	1.A.2.d	1.A.2.e	1.A.2.f	1.A.2.g
1990	-23.58	–	–	-0.62	-0.35	-0.75	598.24	-1348.13
1991	-22.51	-	–	-0.51	-0.32	-0.65	312.60	-1.86
1992	-13.96	-0.02	–	-0.40	-0.19	-0.33	61.27	-1.14
1993	-11.49	–	–	-0.40	-0.23	-0.39	24.13	-1.15
1994	-16.40	–	–	-0.44	-0.17	-0.26	5.69	-1.61
1995	-10.56	–	–	-0.51	-0.06	-0.34	-157.11	-5.44
1996	-12.34	-0.002	–	-0.45	-3.24	-0.81	-125.20	-4.96
1997	-13.54	-0.002	–	-0.24	-1.48	-0.58	28.79	-9.25
1998	-13.33	-0.002	–	-0.06	-0.71	-0.52	8.76	-8.48
1999	-13.32	–	–	-0.04	-1.02	-0.43	26.14	-48.47
2000	-11.01	–	-0.002	-0.04	-1.18	-0.34	2.49	-20.00
2001	-12.43	–	-0.002	-0.04	-1.10	-0.31	13.72	-6.02
2002	-12.99	–	-0.002	-0.02	-1.12	-0.33	11.81	-6.69
2003	-11.69	–	–	-0.19	-0.13	-0.13	21.91	-7.96
2004	-15.43	–	–	-0.08	-0.16	-0.21	-42.54	-8.12
2005	-20.44	–	–	-0.10	-0.18	-0.20	-61.80	-8.79
2006	-19.77	–	-0.009	-0.06	-0.22	-0.18	-53.54	-6.24
2007	-18.59	-0.002	-0.001	-0.13	-0.33	-0.21	-62.43	-5.59
2008	-18.58	-0.002	-0.001	-0.09	-0.29	-0.13	-55.33	-8.02

Year	1.A.1.a	1.A.2.a	1.A.2.b	1.A.2.c	1.A.2.d	1.A.2.e	1.A.2.f	1.A.2.g
2009	-23.33	-0.002	-0.001	-0.02	-0.38	-0.12	-56.72	-5.81
2010	-31.64	–	-0.001	-0.03	-0.52	-0.10	-7.66	-7.09
2011	-33.64	–	–	-0.01	-0.44	-0.10	-106.73	-7.54
2012	-35.28	–	-0.001	-0.01	-0.39	-0.09	-45.83	-5.56
2013	-39.87	–	-0.002	-0.03	-0.32	-0.08	-38.82	-6.37
2014	-38.82	–	-0.001	-0.01	-0.36	-0.09	-13.09	-6.14
2015	-42.38	–	-0.001	-0.02	-0.37	-0.10	-7.70	-7.54
2016	-56.05	–	-0.001	-0.01	-0.02	-0.06	-0.30	-0.55
2017	-71.53	–	-0.07	-0.28	-1.81	-1.60	-5.96	-2.45
2018	-66.56	–	-0.001	-0.01	-0.40	-0.07	-28.07	-0.55
2019	-64.24	–	–	-0.005	-0.31	-0.09	-30.28	-0.41

3.2.4.6. Category-specific planned improvements

There are no planned category-specific improvements.

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 2020 the number of registered vehicles increased, railway passengers rose, and goods transported by rail reduced. While passengers travelling by sea decreased, the number of goods transported increased.

3.2.5.1. Category description

In 2020 the greenhouse gas emissions from Transport sector amounted for 2232.54 kt CO_2 eq. The share of the Transport sector in the Energy sector was 23.6% and approximately 19.3% of the total greenhouse gas emissions in 2020. Emissions from Transport include all domestic transport sectors (see Table 3.18):

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

Table 3.18. 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 transport	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 locomotives in 1990–1998.

CRF category	Description	Remarks
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.

CO_2 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 with 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 9.2% 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 7.0% compared to the previous year. The drop was primarily caused by decreased fuel consumption in Road transport.

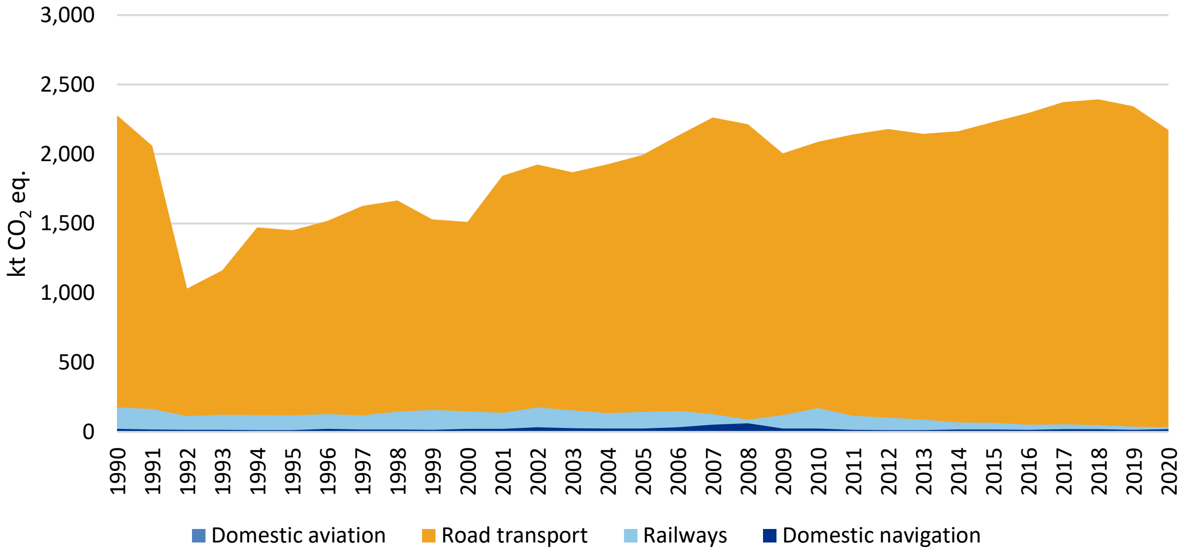

Figure 3.19. Emissions from Transport sector by subcategory in 1990–2020, kt CO_2 eq.

Road transportation is an essential emission source in the Transport sector covering 97.4% of the sector's emissions (see Figure 3.19). The fuel consumption and the emissions from the Transport sector are presented in Table 3.19 and Table 3.20.

Table 3.19. Emissions from the Transport sector by subcategories, kt

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1.A.3 Transport Total, CO_2 eq.	2 481.91	1 586.83	1 684.86	2 169.22	2 288.39	2 318.49	2 365.86	2 450.68	2 468.41	2 401.82	2 232.54
1.A.3.a Domestic Aviation, CO_2	5.52	3.24	2.40	4.67	2.78	4.12	3.36	3.55	4.04	3.88	3.56
1.A.3.b Road Transport, CO_2	2 234.91	1 424.13	1 482.02	1 964.70	2 065.04	2 206.99	2 271.62	2 348.87	2 368.96	2 319.23	2 150.66
1.A.3.c Railways, CO_2	159.35	107.14	133.44	129.93	154.98	58.70	46.28	48.27	45.32	33.63	31.08
1.A.3.d Domestic Navigation, CO_2	21.65	12.41	21.72	24.75	24.80	18.54	15.43	20.25	19.88	16.43	19.82
1.A.3 Transport Total, CH_4	0.88	0.49	0.46	0.39	0.25	0.16	0.16	0.15	0.15	0.15	0.12
1.A.3 Transport Total, N_2O	0.13	0.09	0.11	0.12	0.12	0.09	0.08	0.09	0.09	0.08	0.08

Table 3.20. Fuel consumption in Transport sector, TJ

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1.A.3.a Domestic aviation											
Aviation gasoline	78	46	34	66	39	58	47	50	57	55	50
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
Diesel oil	9 473	8 935	8 487	14 709	16 269	20 046	20 338	20 773	20 991	20 416	20 170
LPG	9	16	32	62	95	228	256	306	369	440	423
CNG	NO	NO	NO	NO	2	116	173	191	172	197	365
1.A.3.c Railways											
Coal	179	50	NO	NO	NO	NO	NO	NO	NO	NO	NO
Diesel oil	1 946	1 396	1 819	1 777	2 115	804	635	660	619	462	425
1.A.3.d Domestic navigation											
Diesel oil	296	169	296	338	338	254	212	277	272	226	271

NO - no consumption occurred

3.2.5.2. Domestic aviation

The number of passengers, who passed through airports in 2020 decreased in comparison to 2019. The passenger traffic volume of Estonian airports was over 0.89 million people, which is 73.1% less than in 2019. Almost 0.87 million passengers were transported on international flights and over 33 thousand passengers were transported on domestic flights (50% less than in 2019). In 2020 compared to 2019, cargo and mail services through airports decreased 15.6%, amounting to 9190 tonnes.

At the end of 2020 the Register of Estonian Civil Aircraft included 215 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 0.16% with 3.59 kt CO_2 eq. in 2020. The decrease compared with the previous year was on account of a decrease in cargo and mail services. The corresponding emissions were 5.57 kt CO_2 equivalent in 1990.

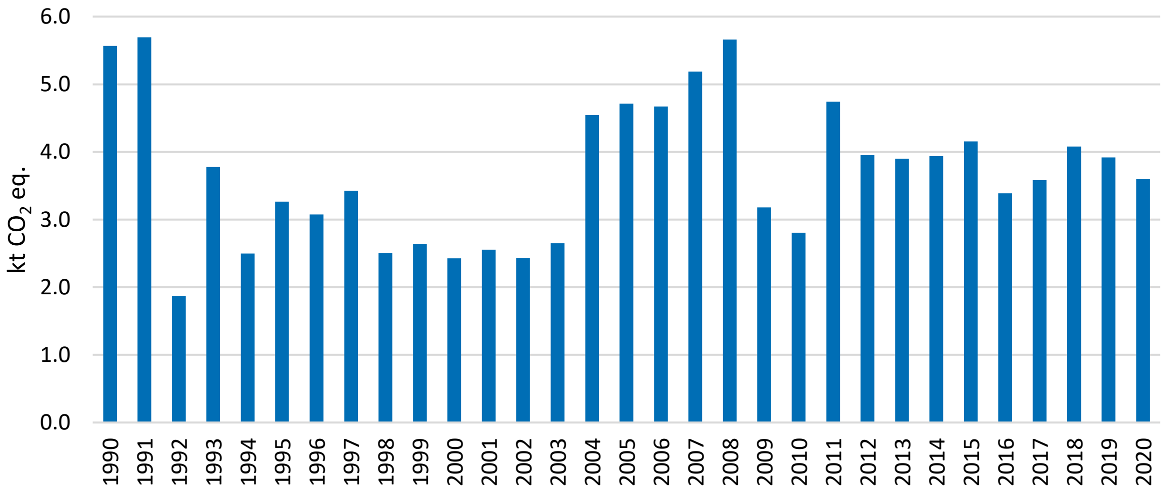

Figure 3.20. GHG emissions from Domestic aviation in 1990–2020, kt CO_2 eq.

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[24]

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

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

Equation 3.5[25]

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

Equation 3.6[26]

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[27]

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

Equation 3.8[28]

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

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 1992–2020. An extrapolation has been made for 1990 and 1991 (see Table 3.21).

[25] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.3.
[26] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.5.
[27] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.4.
[28] IPCC 2006 Guidelines, Volume 2, Chapter 3; Mobile Combustion, page 3.59, equation 3.6.5.

Table 3.21. 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

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 aquired 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 (chapter: 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 (chapter: 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 2020 emission calculations are presented in Table 3.22.

Table 3.22. 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[29]	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 per ton of aviation gasoline are converted to kg/TJ using net average calorific value of aviation gasoline. The results for 2020 are presented in Table 3.23.

Table 3.23. 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 2 174.16 kt CO_2 eq. in 2020 is about 97.4% of total Transport sector emissions and 22.9% of the Energy sector. In 2020 the GHG emissions of the Road transport sector were about 4.6% lower than in 1990 (2 278.23 kt CO_2 eq.).
The trend of CO_2 emissions follows, in general, the fuel consumption trend in the Road transportation 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 road transportation due to the state of emergency established by the Government of Estonia.

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

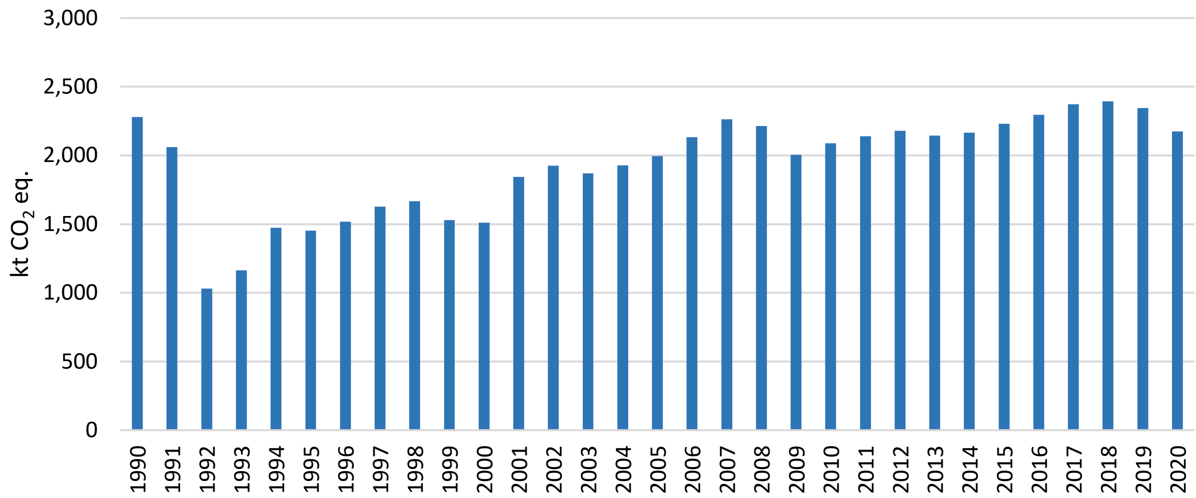

Figure 3.21. Emissions from the Road transport in 1990–2020, kt CO_2 eq.

Methods

Emissions from Road transport are estimated using the IPCC 2006 *Tier 2* methodology for CO_2 emissions and the COPERT model in accordance with the IPCC 2006 *Tier 3* methodology for CH_4 and N_2O emissions. COPERT model is also used for calculation of SO_2, CO, NO_x, and NMVOC emissions. CH_4 and N_2O emissions from LPG in Road transport are calculated using the IPCC *Tier 1* methodology since the COPERT model does not include LPG. CO_2 emissions from CNG in Road transport are calculated using the IPCC *Tier 2* method.

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[30]

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

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).

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

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

Equation 3.10[31]

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

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).

N_2O and CH_4 emissions are calculated separately for gasoline and diesel vehicles. 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. Calculations are made in COPERT 5 model, which is based on EMEP/EEA air pollutant emission inventory guidebook 2019 sector 1.A.3.b Road transport[32]. The COPERT model is located in the Estonian Environment Agency. Also, a validation of fuel and mileage statistics is performed and data is adjusted, if necessary.

COPERT 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 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.

QA/QC input data collection of COPERT model include vehicle data and annual mileage per vehicle and is collected from the Estonian Road Administration. Meteorological data is provided by Estonian Weather Service and fuel consumption by Statistics Estonia. QA/QC plan consists of six parts:

1) stakeholder engagement (stakeholders – e.g. data suppliers, reviewers, recipients);
2) data collection, including activity data; before using the data, common statistical quality checking related to the assesment of trends is carried out;
3) data manipulation (common statistical quality chekcing);

[31] IPCC 2006 Guidelines, Volume 2, Chaper 3; Mobile Combustion, page 3.15, equation 3.2.5.
[32] 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

4) inventory compilation;
5) reporting;
6) archiving.

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

Activity data

The activity data for calculating the CO_2 emissions is based on the amount of fuel consumed in road traffic. This 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 Road Administration.

There has been a small amount of biofuels used as a blend in Estonia until 2017 (less than 1%), taking into account the energy content. The biofuels production and inland consumption data is received 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. Information regarding the types of bioethanol and biodiesel is currently not collected. According to the Estonian Liquid Fuel Act since the 1st of July 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. The biofuel consumption is reported in Table 3.24.

Table 3.24. Consumption of bioethanol, biodiesel, biomethane in Estonia in 2005–2020, TJ

	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
2019	308.87	838.00	188.24
2020	259.08	1370.73	285.85

NO – no consumption occured

In the 2022 inventory the emissions from bioethanol and biodiesel use are reported separately from fossil-based diesel oil and gasoline emissions. Bioethanol is 100% bio-origin, but as all biodiesel is assumed to be FAME (caloric value 36.5 MJ/kg) it is also assumed that 5.4% of FAME is fossil origin. In 2020 the fossil CO_2, CH_4, and N_2O emissions from transportation biofuels totalled 5.84 kt CO_2 eq., constituting 0.05% of Estonia's total GHG emissions.

The use of LPG in road transport in Estonia is very small and is not included into COPERT model. The emissions are calculated separately based on activity data obtained from annual energy statistics. LPG vehicles run on biofuel 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 model to ensure the accounting of the emissions from the second fuel.

The activity data for CNG is taken from Joint Questionnaire by Statistics Estonia and CH_4 and N_2O emissions are estimated using IPCC *Tier 3* method.

In Table 3.25 the number of vehicles and in Table 3.26 road traffic mileage are presented following COPERT model.

Table 3.25. 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**

Table 3.26. 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	**8 032**
1991	5721	671	1200	5	**7 598**
1992	2352	352	793	5	**3 503**
1993	2733	383	845	5	**3 966**
1994	4170	416	833	5	**5 424**
1995	3877	444	836	8	**5 165**
1996	4101	487	837	11	**5 435**
1997	4392	552	917	13	**5 872**
1998	4161	477	1075	15	**5 728**
1999	4017	509	896	16	**5 438**
2000	4134	503	893	16	**5 546**
2001	5301	726	1004	16	**7 048**
2002	5203	868	1045	17	**7 133**
2003	5246	821	933	20	**7 020**
2004	5448	954	934	24	**7 360**
2005	5822	954	892	29	**7 697**
2006	6481	948	935	43	**8 406**
2007	7008	974	955	54	**8 991**
2008	6871	961	989	65	**8 886**
2009	6574	724	813	55	**8 165**
2010	6446	753	967	54	**8 219**
2011	6490	800	1036	50	**8 376**
2012	6620	846	1029	59	**8 554**
2013	6665	842	955	69	**8 532**
2014	6891	874	927	67	**8 759**
2015	7388	814	915	65	**9 181**
2016	7676	1007	852	76	**9 611**
2017	7986	1093	846	77	**10 003**
2018	8354	1236	824	81	**10 494**
2019	8495	1252	796	65	**10 608**
2020	8122	1252	719	53	**10 146**

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

CO_2 emission factors of gasoline, LPG, and diesel oil for Road transport are presented in Table 3.27. 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 3.27. 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	1.00	0.10
1991	19.50	38.85	2.40	20.01	7.31	2.46	17.72	1.00	0.10
1992	19.50	35.84	2.19	20.01	7.42	2.52	17.72	1.00	0.10
1993	19.50	36.17	2.30	20.01	7.45	2.34	17.72	1.00	0.10
1994	19.50	38.68	2.63	20.00	7.35	2.22	17.72	1.00	0.10
1995	19.51	39.21	2.90	20.02	7.46	2.34	17.83	1.00	0.10
1996	19.49	38.78	3.01	20.01	7.37	2.45	17.83	1.00	0.10
1997	19.52	37.76	2.96	20.01	7.21	2.42	17.79	1.00	0.10
1998	19.60	37.81	2.93	20.01	7.46	2.56	17.77	1.00	0.10
1999	19.55	35.97	3.03	20.01	7.30	2.31	17.75	1.00	0.10
2000	19.27	32.11	3.46	20.01	7.16	2.18	17.72	1.00	0.10
2001	19.34	31.00	3.70	19.97	6.84	1.88	17.75	1.00	0.10
2002	19.71	28.32	3.76	19.96	6.64	1.81	17.76	1.00	0.10
2003	19.79	25.81	3.64	19.97	6.44	1.62	17.76	1.00	0.10
2004	19.79	23.30	3.68	19.95	6.20	1.65	17.75	1.00	0.10
2005	19.27	22.89	3.51	19.95	6.06	1.59	17.75	1.00	0.10
2006	19.03	21.19	2.50	19.94	5.37	1.65	17.73	1.00	0.10
2007	19.06	19.30	2.31	19.94	4.66	1.73	17.62	1.00	0.10
2008	19.19	16.95	2.15	19.95	4.57	1.81	17.52	1.00	0.10
2009	19.40	16.00	2.06	19.91	3.91	1.84	17.56	1.00	0.10
2010	19.77	15.08	1.96	19.89	3.65	1.88	17.47	1.00	0.10
2011	19.78	14.10	1.86	19.92	3.34	1.97	17.29	1.00	0.10
2012	19.61	13.00	1.71	19.96	2.84	2.12	17.59	1.00	0.10
2013	19.80	12.26	1.54	19.94	2.46	2.27	17.30	1.00	0.10
2014	19.88	11.03	1.35	19.95	2.17	2.37	17.31	1.00	0.10
2015	19.85	11.30	1.36	19.92	1.89	2.49	17.30	1.00	0.10
2016	19.82	10.90	1.24	19.89	1.61	2.58	17.41	1.00	0.10
2017	19.81	10.08	1.07	19.94	1.40	2.65	17.24	1.00	0.10
2018	19.37	9.71	0.96	19.96	1.20	2.80	17.36	1.00	0.10
2019	19.09	9.81	0.97	19.87	1.13	2.85	17.73	1.00	0.10
2020	19.22	9.68	0.94	19.94	0.99	2.98	17.39	1.00	0.10

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[33] (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 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. 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[34], 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[35] of the Minister of Economic Affairs and Infrastructure biomethane used in transport must meet the quality requirements of natural gas. Table 3.28 presents the CEF-s, CH_4 and N_2O emission factors for CNG and biomethane.

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

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

[33]Handbook Emission Factors for Transport. [www] https://www.hbefa.net/e/index.html (10.09.2021).
[34]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).
[35]Riigi Teataja. Gaasituru toimimise võrgueeskiri. [www] https://www.riigiteataja.ee/akt/129122020033 (10.03.2022).

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
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

The amounts of fuels imported in 2020 are presented in Table 3.29.

Table 3.29. Imported fuel amounts in 2020 by country

Country	Gasoline, kg	Diesel, kg	LPG, kg
Finland	238824039	164787318	–
Germany	10997895	946097	5730
Ireland	–	–	159
Latvia	30030	10560054	495921
Lithuania	259372049	320429206	633083
Cyprus	–	–	353357
Poland	10535	207024	2567
Russia	172865713	80448406	6215139
Sweden	125132	1981	22354
Uzbekistan	2316945	–	–
Belarus	–	20003008	–
Belgium	–	382813	15
Netherlands	–	8002799	2297
Czech Republic	–	–	2744
Denmark	–	–	1919460
Greece	–	–	417
Spain	–	–	708
Italy	–	–	4816
Norway	–	–	1132246
United Kingdom	–	–	1780264

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 2020 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
Belarus	–	19.55	–
Belgium	–	20.20	17.20
Czech Republic	–	–	17.97
Cyprus	–	–	17.20

Country	Gasoline	Diesel	LPG
Denmark	–	–	17.21
Ireland	–	–	17.37
Finland	19.50	20.00	17.70
France	–	–	17.21
Germany	20.53	20.19	17.97
Greece	–	–	17.20
Italy	–	–	17.20
Latvia	18.91	20.40	17.13
Lithuania	19.13	19.85	18.22
Netherlands	–	19.78	18.19
Norway	–	–	17.75
Poland	19.19	19.76	17.04
Sweden	19.64	20.25	17.75
Russia	18.90	20.21	17.21
United Kingdom	–	–	17.42
Uzbekistan	18.90	–	–

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

For bioethanol and biodiesel, the CH_4 and N_2O emission factors are 3 kg/TJ and 0.6 kg/TJ (IPCC 2006 emission factors for gasoline and diesel). CH_4 and N_2O emissions are calculated using COPERT model. CH_4 and N_2O emission factors in COPERT are described in the EMEP/EEA air pollutant emission inventory guidebook 2019, Chapter 1.A.3.b Road transport GB2019. 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.

3.2.5.4. Off-road vehicles

Off-road vehicles are used in industry, agriculture, forestry, and for household purposes (see Table 3.31).

Table 3.31 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 Households	Other miscellaenous equipment (e.g. ATV-s, forklifts, cranes, etc.)	Fuel conusmption and emissions are included in 1.A.4.b Households
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 2020 emissions from off-road vehicles accounted for 208.47 kt CO_2 eq., which is an 8.1% decrease compared to the previous year. Emissions off-road mobile equipment in 1990-2020 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.

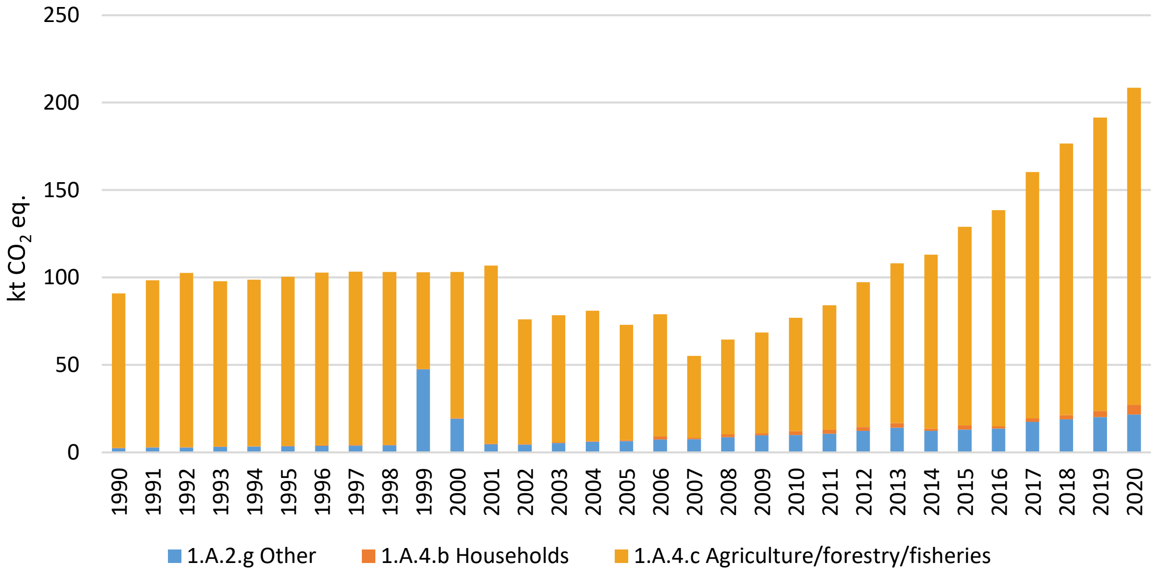

Figure 3.22 Emissions from off-road vehicles in Estonia in 1990-2020, kt CO_2 eq.

Diesel oil and gasoline is used as fuels 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.

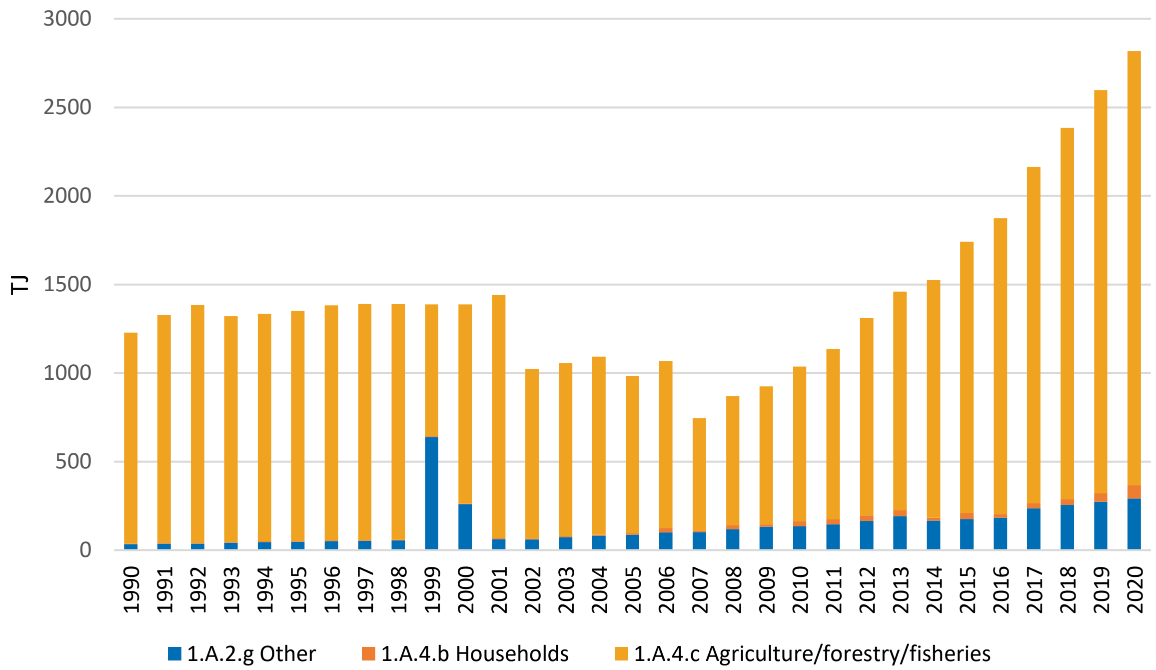

Figure 3.23 Fuel consumption of off-road vehicles in Estonia in 1990-2020

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[36] 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 2010-2020 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 2010-2020. In Table 3.24 number of vehicles by vehicle type is presented[37].

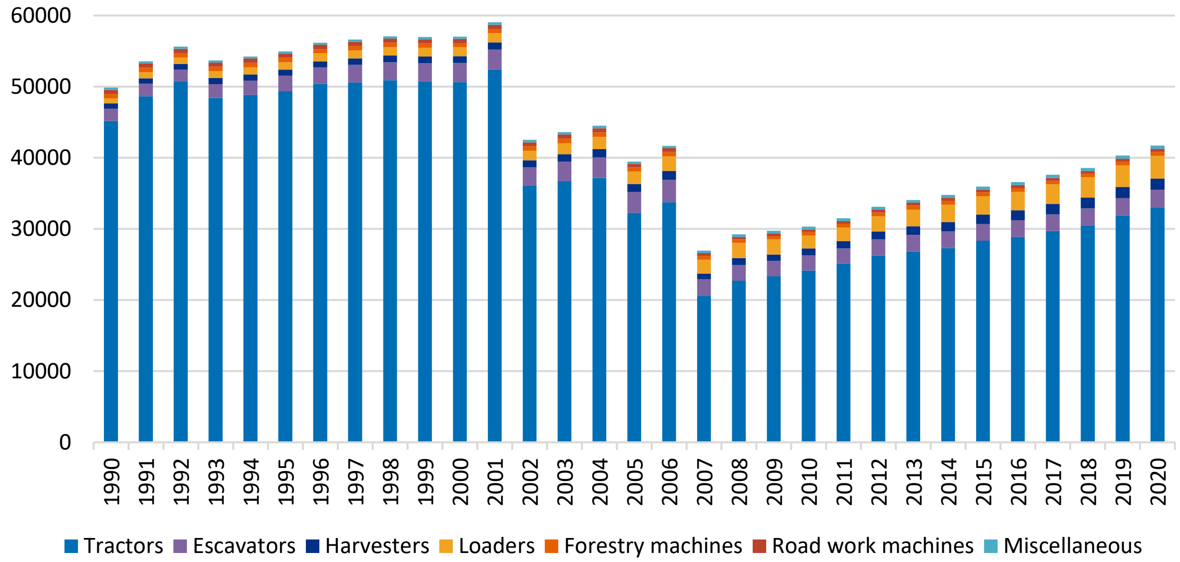

Figure 3.24 Number of off-road vehicles in 1990-2020

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

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[36] 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

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

Table 3.32 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	1003	18
2011	1101	18
2012	1278	17
2013	1427	18
2014	1508	16
2015	1710	17
2016	1857	17
2017	2140	23
2018	2350	34
2019	2532	51
2020	2709	67

Emission factors and other parameters

Carbon emission factors for gasoline and diesel oil for off-road vehicles are presented in Table 3.33. 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.

Table 3.33. 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
1992	19.50	20.01
1993	19.50	20.01
1994	19.50	20.00

Year	Gasoline	Diesel
	CEF	CEF
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

CH_4 emission factors by vehicle type used in calculations are presented in Table 3.34 and N_2O emission factors in Table 3.35.

Table 3.34 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
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

Year	Gasoline		Diesel						
	Tractors	Other	Tractors	Excavators	Harvesters	Loaders	Forestry	Other	Road work
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

Table 3.35 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
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

Year	Gasoline		Diesel						
	Tractors	Other	Tractors	Excavators	Harvesters	Loaders	Forestry	Other	Road work
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

Emission 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[38].

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 2020. 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 15.8 million tonnes of goods in 2020. 8.8 million tonnes of transit goods were delivered by rail, of which 0.73 million tonnes were refined oil products and over 7.6 million tonnes were chemical products.

Railway transportation in Estonia has a small share of emissions in the Transport sector. The emissions were 34.75 kt CO_2 eq. in 2020 with the share of 1.6% in the Transport sector. In 1990 the corresponding figure was 176.23 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.

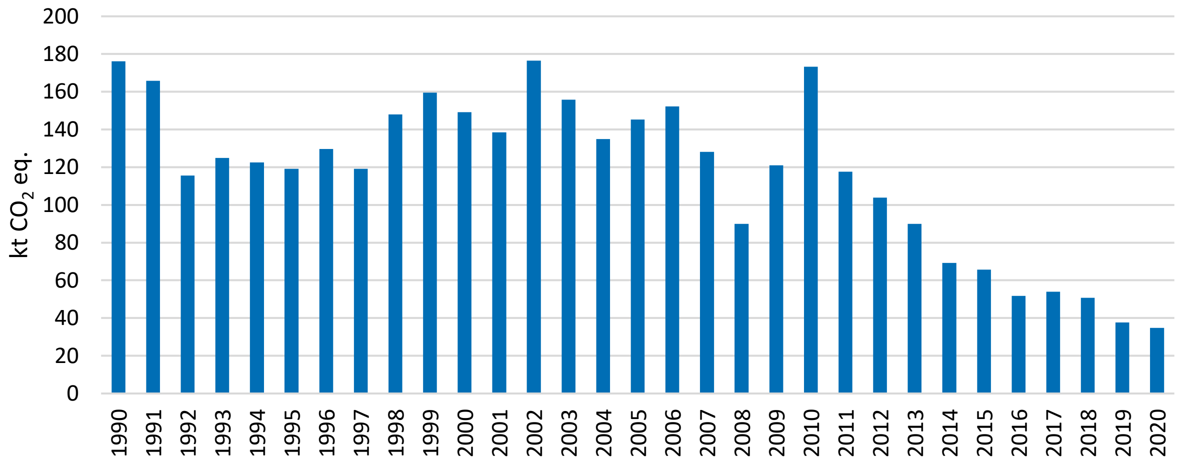

Figure 3.25. Emissions from Railways in 1990–2020, kt CO_2 eq.

[38]Emission factors are based on "Revision of calculation principles for emissions from other mobile sources". The report is available upon request.

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.

Methods

Emissions from Railways are calculated by multiplying the estimated fuel consumption with a country specific emission factor (IPCC 2006 *Tier 2*).

Activity data

The activity data on fuel consumption used in Railways is obtained from Statistics Estonia and is presented in Table 3.20.

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 3.36.

Table 3.36. Emission factors used in the calculation of emissions from Railways

Fuel	GHG	EF	Source
Diesel Oil	CO_2	19.94 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	25.76 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 Ships Register listed 109 seagoing ships (gross weight 100 tons or more) and 30 inland ships at the end of 2020. In addition, 10 merchant ships were listed in the register of bareboat character ships.

Domestic navigation in Estonia is also a minor emission source in Transport sector. The emissions of Domestic navigation were 20.03 kt CO_2 eq. in 2020 (0.9% of Transport sector emissions). The increase comparing to the previous year was due to a increase in diesel oil consumption. In 1990 the corresponding figure was 21.88 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. In 2006, 2007, and 2008 there was a growth in the emissions from Domestic navigation because of a sharp increase of passenger traffic of sea transport enterprises.

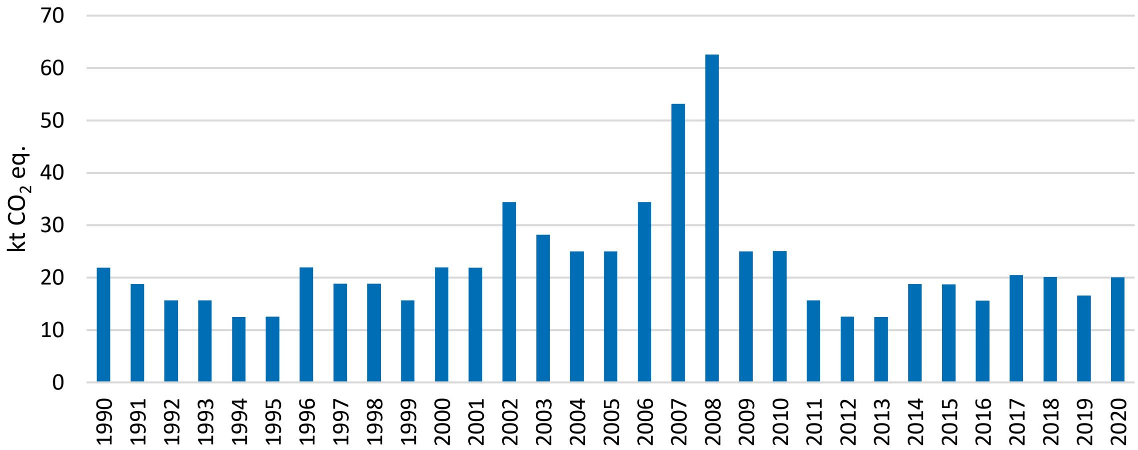

Figure 3.26. Emissions from Domestic navigation in 1990–2020, kt CO_2 eq.

Methods

Emissions in Domestic navigation are calculated by multiplying the estimated fuel (diesel oil) consumption with a country specific emission factor (IPCC 2006 *Tier 2*).

Activity data

The activity data on fuel consumption used in Domestic navigation is gained from the Statistics Estonia and presented in Table 3.20.

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 of 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, SO_2 EF is country specific. All emission factors are presented in Table 3.37.

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

Fuel	GHG	EF	Source
Diesel Oil	CO_2	19.94 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. Category-specific recalculations

Emissions in the 1.A.3 categories were recalculated due to using updated Joint Questionnaire dataset from Statistics Estonia (sent to Eurostat and IEA), updated COPERT data, and using country specific CH_4 and N_2O emission factors for CNG and biomethane passenger cars and buses.

Table 3.38 Differences between 2022 and 2021 submissions, kt CO_2 eq.

Year	1.A.3.a	1.A.3.b	1.A.3.c	1.A.3.d
1990	–	8.93	–	–
1991	–	-1.57	–	–
1992	–	4.09	–	–
1993	–	16.75	–	–
1994	–	9.24	–	–
1995	–	11.20	–	–
1996	–	33.20	–	–
1997	–	18.91	–	–
1998	–	23.23	–	–
1999	–	22.74	–	–
2000	–	17.92	–	–
2001	–	22.99	–	–
2002	–	22.74	–	–
2003	–	22.10	–	–
2004	–	17.66	–	–
2005	–	14.62	–	–
2006	–	3.53	–	–
2007	–	5.30	–	–
2008	–	68.52	–	–
2009	–	6.12	–	–
2010	–	13.82	–	–
2011	–	-3.97	–	–
2012	–	-8.14	–	–
2013	–	-2.99	–	–
2014	–	-13.66	–	–

Year	1.A.3.a	1.A.3.b	1.A.3.c	1.A.3.d
2015	–	-7.71	–	–
2016	–	-8.41	–	–
2017	–	3.19	–	–
2018	–	15.97	–	–
2019	–	16.77	–	–

– - no differences in recalculations

The notable change in 2008 recalculations in 1.A.3.b occurred because NCV-s used in updated COPERT version were updated and unified for all years and it caused a change in TJ-s.

3.2.5.8. Category-specific planned improvements

No category-specific improvements are 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, and fishing boats.

In 2020 emissions in CRF 1.A.4 Other sectors were 851.23 kt CO_2 eq., about 9.0% of the Energy sector's emissions and 7.4% of total GHG emissions in Estonia. Corresponding emissions in 1990 were 1903.52 kt CO_2 equivalent (see Figure 3.27 and CS – country specific; * - country specific

Table 3.40).

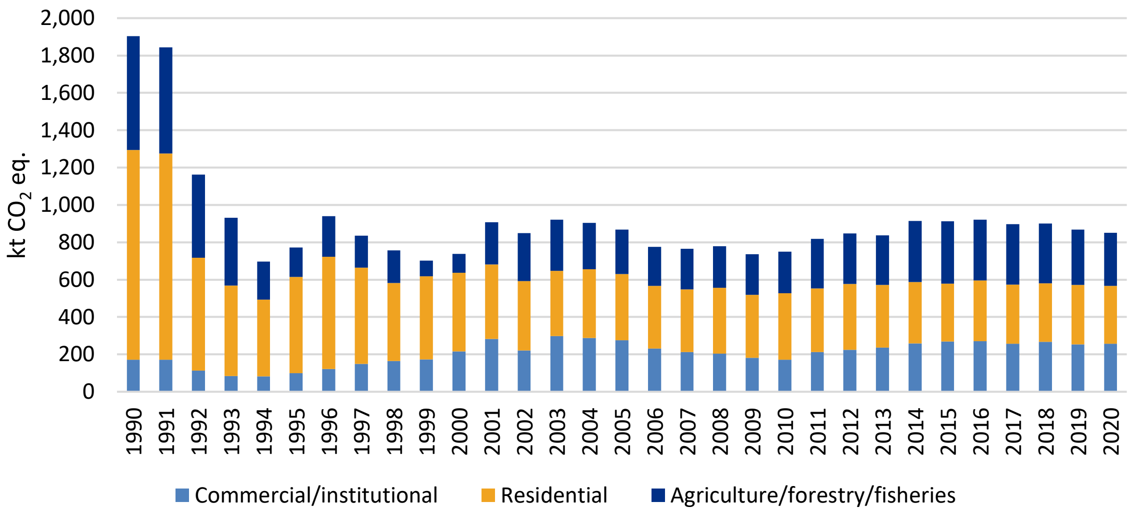

Figure 3.27. Trend of GHG emissions from Other sectors, kt CO_2 eq.

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.

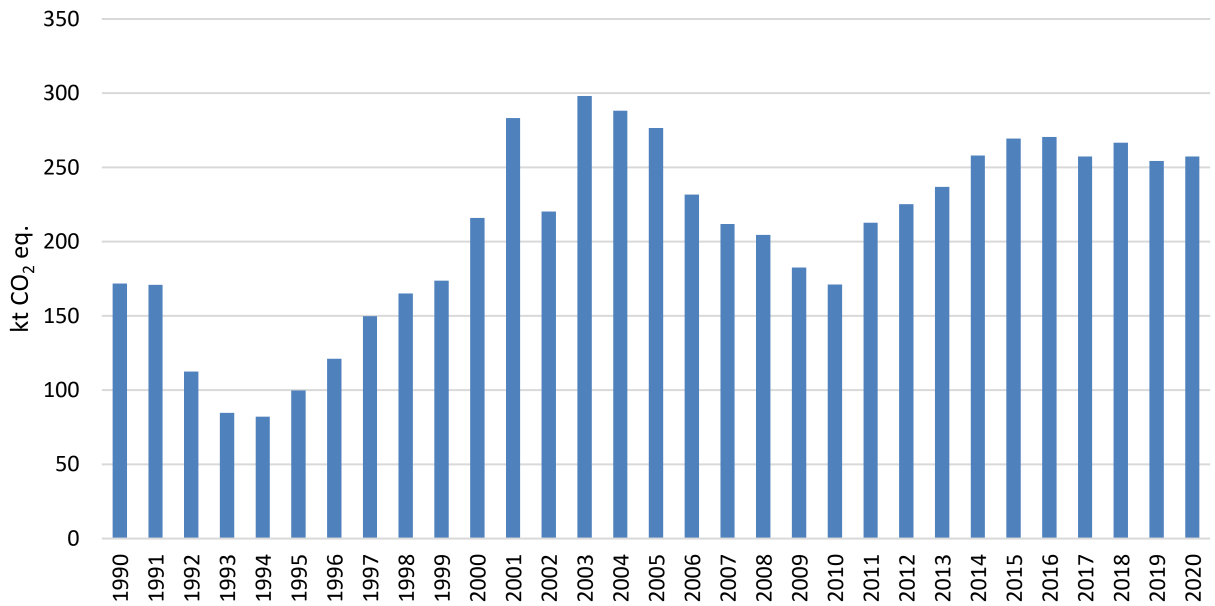

Figure 3.28. Trend of GHG emissions from Commercial and institutional sector, kt CO_2 eq.

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 1.2% compared to 2019 following a growing natural gas consumption.

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, 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 increased in 2020 more than three times in comparison with 1990/1991 (see Figure 3.33).

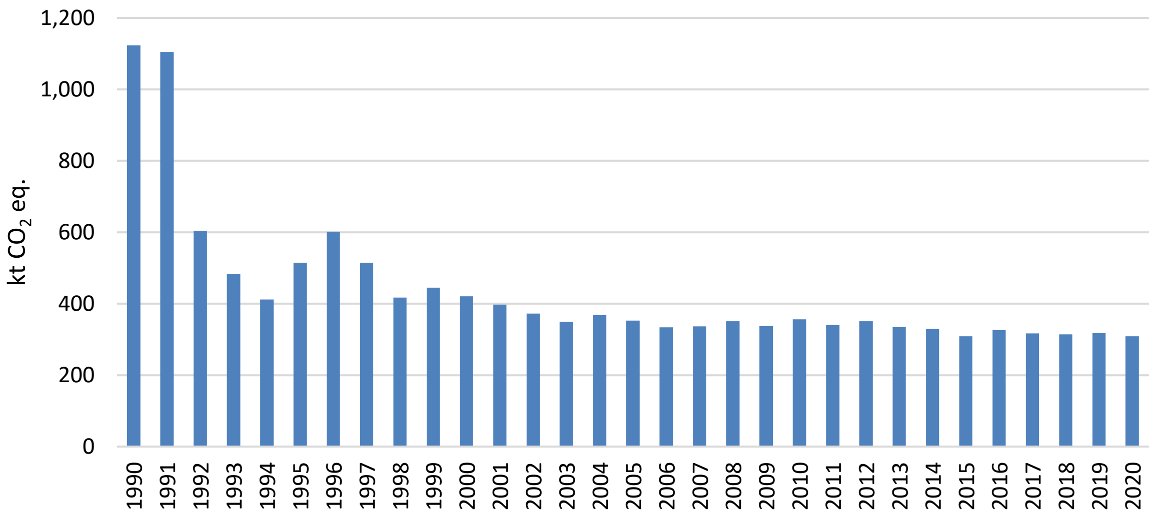

Figure 3.29. Trend of GHG emissions from Residential sector, kt CO_2 eq.

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 tarctors, 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. 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.

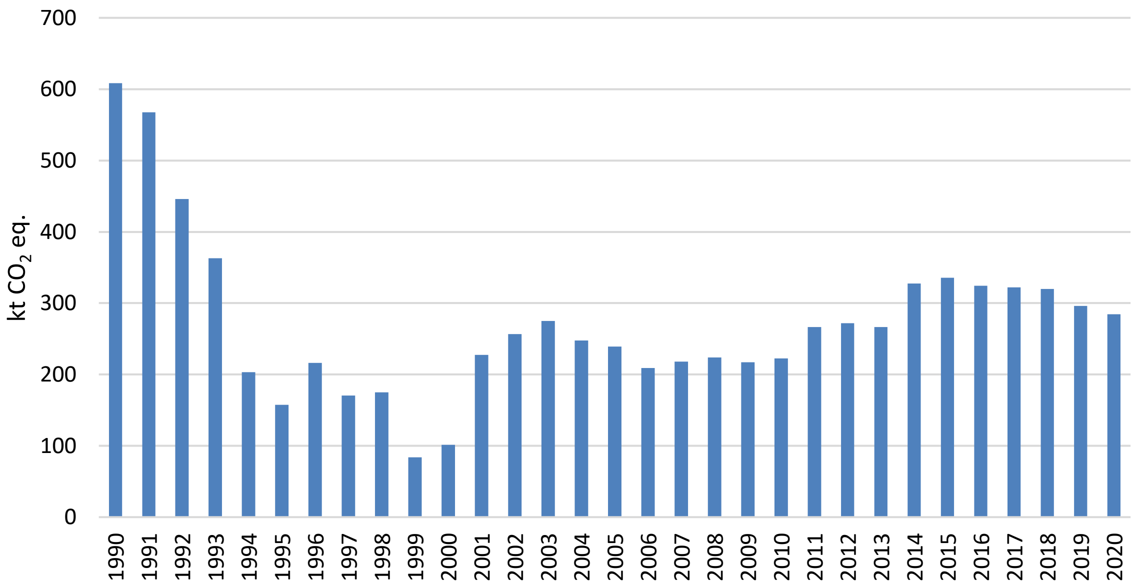

Figure 3.30. Trend of GHG emissions from Agriculture/forestry/fisheries sector, kt CO_2 eq.

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 by Statistics Estonia. It covers fuels used in Commercial/institutional and 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.

The fuel consumption data by main fuel groups is presented in Table 3.41 and Figure 3.31.

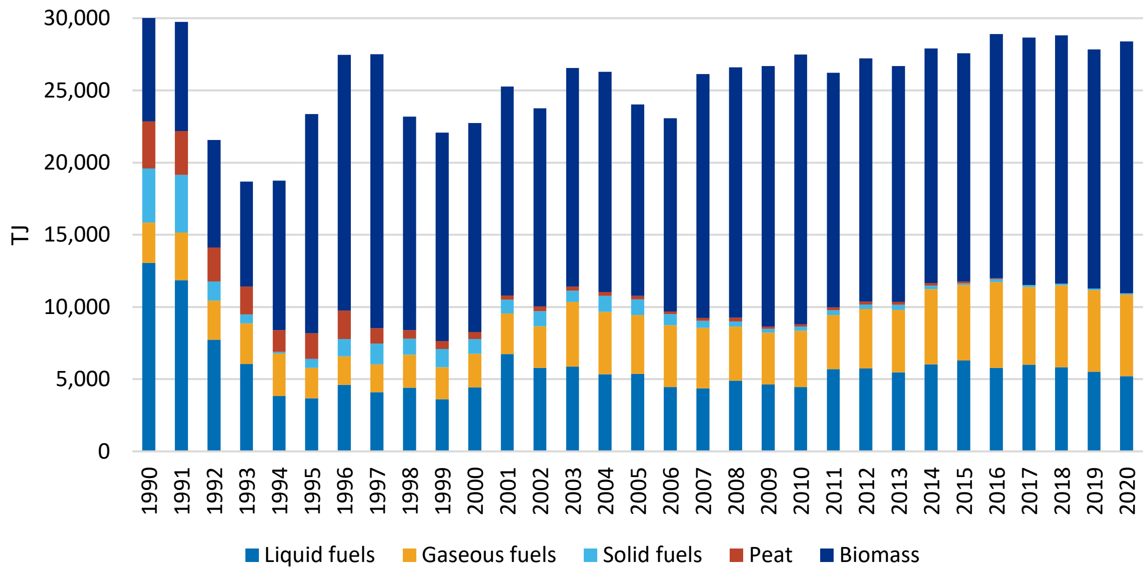

Figure 3.31. Fuel consumption in CRF 1.A.4 Other sectors, TJ

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 as steady, some fluctuations are in the liquid fuel consumption trend in 1992, 2001, and 2002 (see Figure 3.32).

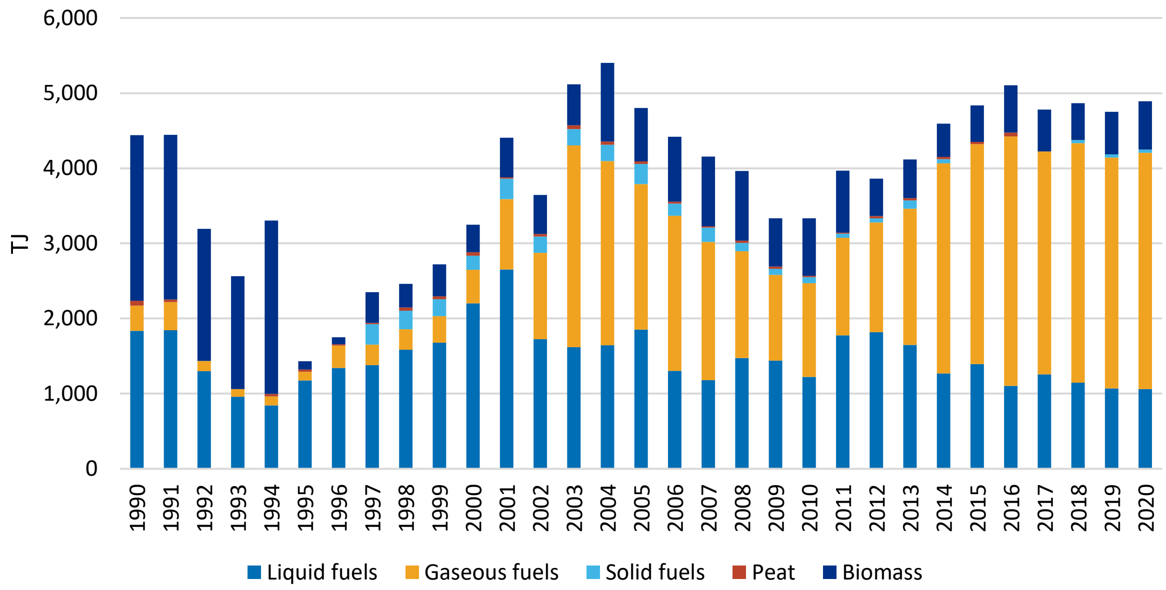

Figure 3.32. Fuel consumption in Commercial/institutional sector, TJ

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 SE 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. The increase in 2020 GHG emissions comparing to the previous year were due to increased consumption of wood fuels.

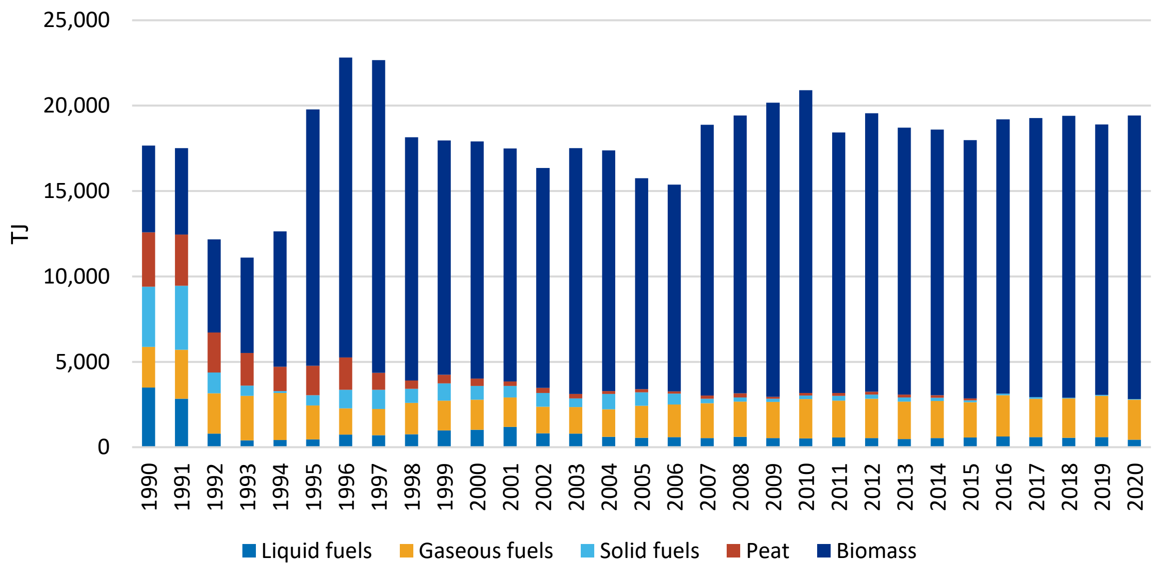

Figure 3.33. Fuel consumption in Residential sector, TJ

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 and the consumption has been rather stable since 2001. The use of liquid fuels decreased since 1990 up to 1999 almost 60%, 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.

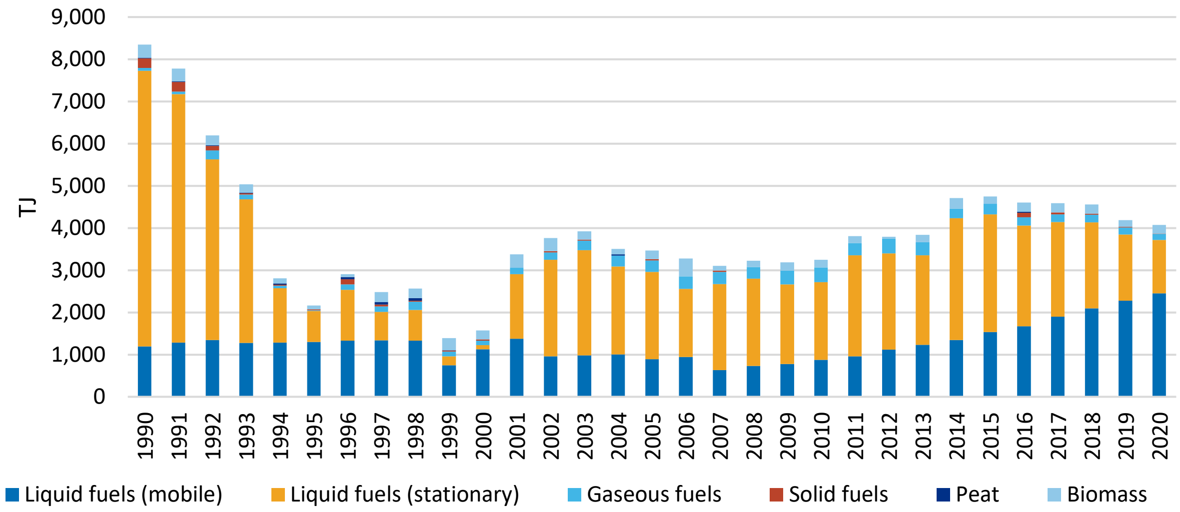

Figure 3.34. Fuel consumption in Agriculture/forestry/fisheries sector, TJ

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. For CH_4 and N_2O emission calculations country specific and IPCC 2006 default emission factors are used (Table 3.39**)**.

Table 3.39. CH_4 and N_2O emission factors for small combustion of fuels, kg/TJ

Fuel	CH_4	N_2O	Source
Light fuel oil, residual fuel oil	10/0.003*	0.6/0.17*	IPCC 2006/CS[16]
LPG	5	0.1	IPCC 2006
Natural gas	5/0.003*	0.1/0.12*	IPCC 2006/CS[16]
Coal (commercial)	10	1.5	IPCC 2006
Coal (residential, agriculture)	300	1.5	IPCC 2006
Oil shale (commercial)	10	1.5	IPCC 2006

Fuel	CH_4	N_2O	Source
Oil shale	300	1.5	IPCC 2006
Peat/peat briquette (commercial)	10/1.72*	1.4/2.45*	IPCC 2006/CS[16]
Peat/peat briquette (residential, agriculture)	300/1.72*	1.4/2.45*	IPCC 2006/CS[16]
Wood	300/0.29*	4/0.21*	IPCC 2006/CS[16]

CS – country specific; * - country specific

Table 3.40. Emissions from Other sectors (incl. Commercial/institutional, Residential, and Agriculture/forestry/fisheries), kt

Sector	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1.A.4 Other sectors total, CO_2 eq.	**1 903.52**	**772.00**	**738.47**	**868.90**	**749.82**	**913.42**	**920.96**	**896.67**	**900.38**	**868.45**	**851.23**
1.A.4.a Commercial/ institutional, CO_2 eq.	171.77	99.84	216.07	276.62	171.17	269.44	270.56	257.30	266.64	254.29	257.43
1.A.4.b Residential, CO_2 eq.	1 123.29	514.91	421.09	352.97	356.14	308.56	325.99	317.15	313.77	318.15	309.20
1.A.4.c Agriculture/ forestry/ fisheries, CO_2 eq.	608.46	157.24	101.31	239.31	222.52	335.43	324.41	322.22	319.96	296.01	284.60

Table 3.41. Fuel consumption in CRF 1.A.4 Other sectors, TJ

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1.A.4 Other Sectors Total	**30 451**	**23 370**	**22 731**	**24 023**	**27 480**	**27 564**	**28 902**	**28 649**	**28 819**	**27 840**	**28 391**
Liquid fuels	13 051	3 668	4 439	5 359	4 459	6 283	5 786	5 995	5 830	5 508	5 209
Solid fuels	3 749	624	1 014	1 086	299	109	190	132	110	103	89
Gaseous fuels	2 786	2 121	2 322	4 089	3 885	5 248	5 937	5 400	5 671	5 662	5 649
Peat	3 264	1 753	487	227	160	137	71	0	0	0	0
Biomass	7 601	15 203	14 470	13 263	18 677	15 787	16 918	17 122	17 207	16 567	17 444

In 1.A.4.c Agriculture/forestry/fisheries mobile emissions from off-road agricultural 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 3.33 the carbon emission factors of motor fuels used for off-road vehicles are presented, in Table 3.34 CH_4 emission factors and Table 3.35 N_2O emission factors of motor fuels used for off-road transportation are presented.

3.2.6.3. Category-specific recalculations

Emissions in 1.A.4.a Commercial/institutional, 1.A.4.b Households, and 1.A.4.c Agriculture/forestry/fishing were recalculated due to using updated Joint Questionnaire from Statistics Estonia, which is sent to Eurostat and IEA, including off-road vehicles in calculations in 1.A.4.b and 1.A.4.c, and using country-specific emission factors for CH_4 and N_2O for natural gas, LFO, residual fuel oil, peat, and biomass for 1-50 MW combustion plants in 1.A.4.a and 1.A.4.c instead of default values.

Table 3.42. Differences between 2022 and 2021 submissions, kt CO_2 eq.

Year	1.A.4.a	1.A.4.b	1.A.4.c
1990	-12.87	-0.03	-41.79
1991	-12.78	0.14	-40.06
1992	-10.22	-1.28	-30.25
1993	-8.73	-7.21	-27.09
1994	-13.20	-5.76	-14.53
1995	-0.95	-2.18	-11.26
1996	-0.91	-1.35	-13.37
1997	-2.73	-2.03	-13.52
1998	-2.23	-2.78	-13.19
1999	-2.86	-4.52	-6.08
2000	-2.70	-4.83	-8.86
2001	-3.78	-3.61	-21.00
2002	-3.46	-2.91	-23.76
2003	-3.65	-2.85	-25.87
2004	-6.59	-3.70	-22.49
2005	-4.38	-2.61	-22.15
2006	-5.20	-3.60	-18.64
2007	-5.38	-2.66	-19.52
2008	-5.52	-3.43	-19.38
2009	-3.77	-1.63	-19.31
2010	-4.55	-4.30	-19.37
2011	-4.90	-3.69	-23.40
2012	-3.41	-4.10	-23.70
2013	-2.79	-3.80	-24.28
2014	-2.54	-3.58	-31.36
2015	-3.13	-4.01	-29.62
2016	-2.61	-3.57	-29.35
2017	-7.74	-6.88	-30.10
2018	-2.80	-3.12	-30.34
2019	-3.28	14.34	-26.11

3.2.6.4. Category-specific planned improvements

There is an ongoing project (2020-2023) on developing country specific emission factors for heating appliances in households in sub-sector 1.A.4.b. Results are planned to be used in future submissions.

3.2.7. Other (CRF 1.A.5)

Emissions from 1.A.5 Other are included in 1.A.4.a Commercial/institutional because of the Joint Questionnaire dataset.

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

3.3.1. Solid Fuels (CRF 1.B.1)

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

Unlike coal mines, there are no CH_4 emissions 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 3).

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 and during system upsets, and accidents. Liquid fossil fuels and natural gas is mainly imported.

Table 3.43. Reported emissions, calculation methods, and type of emission factors for the subcategory Fugitive Emissions in the Estonian GHG inventory.

CRF	Source	Emissions	Method	Emission factor
1.B.2	Oil and Natural Gas	CO_2	T1	D
		CH_4	T1	D

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 transmission, distribution, and venting. Natural gas is imported into Estonia from Russia and the Inchukalns 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.

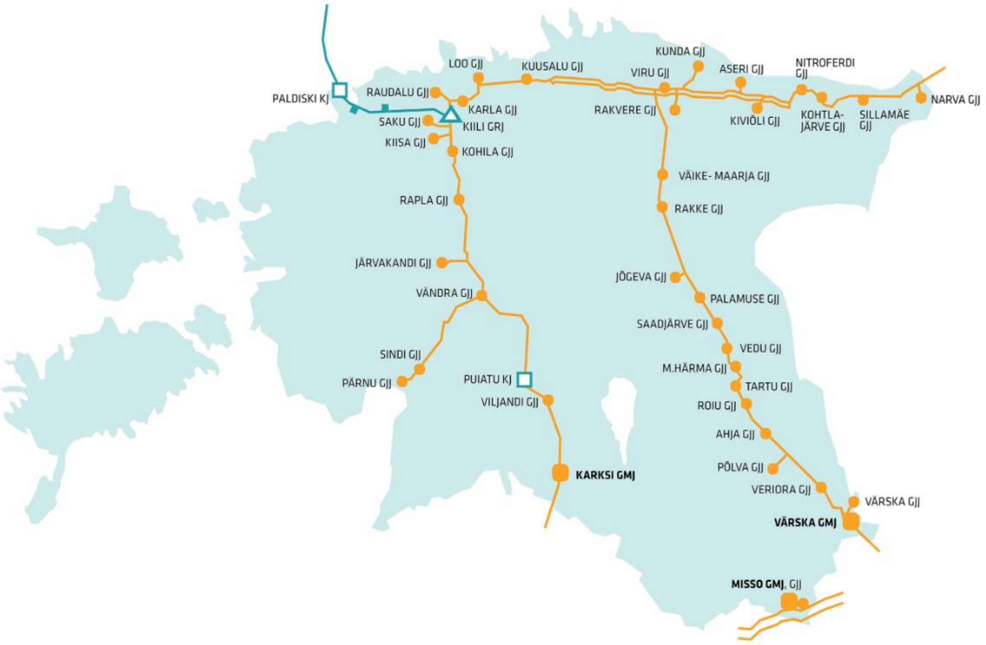

Figure 3.35. Natural gas distribution network in Estonia

In 2020 fugitive emissions from oil and natural gas were 0.03 kt CO_2 and 0.75 kt CH_4 (18.70 kt CO_2 eq.). It is about 0.20% of the Energy sector's emissions and 0.16% of total GHG emissions in Estonia. Corresponding emissions were 64.17 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[39]

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

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 sub-category CRF 1.B.2 is acquired from the Joint Questionnaire dataset made by Statistics Estonia.

[39] 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 distribution, transmission, and venting emissions are taken from the IPCC 2006 Guidelines (developed countries and economies in transition).

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

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

3.3.2.3. Quantitative overview

Table 3.44 includes CO_2 and CH_4 emissions from natural gas distribution. Table 3.45 shows CO_2 and CH_4 emissions from natural gas transmission. Table 3.46 includes CO_2 and CH_4 emissions from natural gas venting. Table 3.47 present the CO_2 and CH_4 emissions from oil and gas activities.

Table 3.44. CO_2 and CH_4 emissions from natural gas distribution

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
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
Natural gas distribution CH_4, kt	1.95	0.93	1.07	1.28	0.91	0.63	0.72	0.63	0.68	0.64	0.57
Natural gas distribution total, kt CO_2 eq.	48.76	23.24	26.73	32.11	22.87	15.76	18.12	15.89	17.11	15.93	14.21

Table 3.45. CO_2 and CH_4 emissions from natural gas transmission

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
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
Natural gas transmission CH_4, kt	0.29	0.14	0.16	0.19	0.14	0.09	0.11	0.10	0.10	0.10	0.09
Natural gas transmission total, kt CO_2 eq.	7.35	3.50	4.03	4.84	3.45	2.37	2.73	2.39	2.58	2.40	2.14

Table 3.46. CO_2 and CH_4 emissions from natural gas venting

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
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
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

Natural Gas Venting Total, kt CO_2 eq.	8.06	3.84	4.42	5.31	3.78	2.60	2.99	2.63	2.83	2.63	2.35

Table 3.47. CO_2 and CH_4 emissions from oil and gas activities

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Natural gas transmission and distribution total, kt CO_2 eq.	64.17	30.58	35.17	42.26	30.10	20.74	23.84	20.91	22.52	20.96	18.70

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 recalculations

There were no category-specific recalculations.

3.3.2.6. Category-specific planned improvements

There are currently no category-specific planned improvements.

3.4. CO_2 transport and storage (CRF 1.C)

Up to 2020 no CO_2 transport and storage has been used in Estonia.

4. INDUSTRIAL PROCESSES AND PRODUCT USE (CRF 2)

4.1. Overview of the sector

Greenhouse gas emissions from the Industrial processes and product use sector contributed 2.56% to the total anthropogenic greenhouse gas emissions in 2020 (Figure 4.1), totalling 295.47 kt CO_2 eq. with indirect CO_2 and 270.73 kt CO_2 eq. without indirect CO_2.

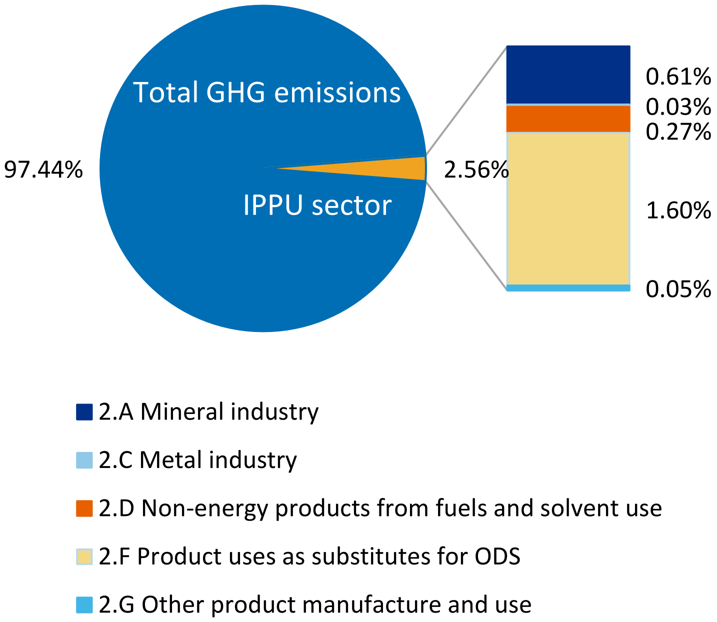

Figure 4.1. Emissions from Industrial processes and product use compared with total emissions in 2020, %

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, 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; and
- 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 1990–2020

	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)	T2,PS				
2.C.5 Lead production	T3/PS				
2.D.1 Lubricant use	T1/D				
2.D.2 Paraffin wax use	T1/D				
2.D.3 Other (Urea based catalysts for motor vehicles)	T2/D				
2.D.3 Solvent use					T1/D
2.D.3 Road paving with asphalt					T1/D
2.F.1 Refrigeration and air conditioning		T2/CS			
2.F.2 Foam blowing agents		T2/CS			
2.F.3 Fire protection		T2/CS			
2.F.4 Aerosols		T2/CS			
2.G.1 Electrical equipment				T3/CS	
2.G.2 SF_6 and PFCs from other product use				T2,T3/CS	
2.G.3 N_2O from product uses			T2/CS		

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

Compared to 2019, the emissions from the Industrial processes and product use sector (with indirect CO2) decreased by 52.45% in 2020. The decrease is mainly caused by closure of clinker burning part in cement plant in March 2020 and reduced F-gas emissions. The F-gas emissions decrease can be related to the Regulation (EU) No 517/2014 that was implemented in 2020.

Regarding chemical industry (2.B) – ammonia production has completely ceased since 2014 and the plant is going to be dismantled. Industrial CO2 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 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 CO2 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 CO2 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. CO2 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 CO2 emissions from 2014 to 2016.

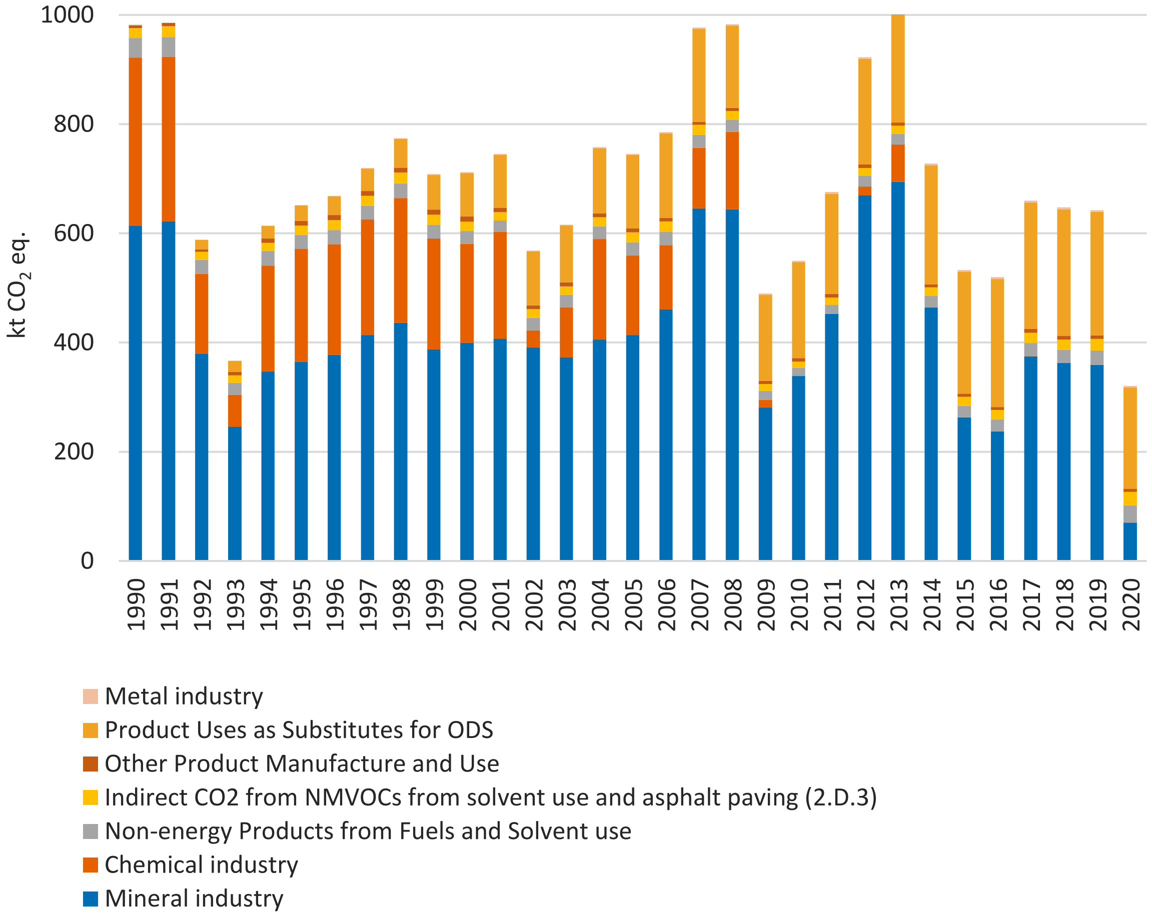

Figure 4.2. Emissions from Industrial processes and product use in 1990–2020 (with indirect CO_2), kt CO_2 eq.

Table 4.2. Trend in the greenhouse gas emissions from Industrial processes and product use in 1990–2020, kt CO_2 equivalent

	1990	1995	2000	2005	2010	2015	2018	2019	2020
CO_2									
Mineral industry	614.0	364.4	399.9	413.6	338.5	262.8	363.0	359.2	70.3
Chemical industry	307.7	207.8	180.8	146.4	NO	NO	NO	NO	NO
Metal industry	0.8	0.7	1.1	1.5	2.5	3.0	3.4	3.3	2.9
Non-energy products from fuels and solvent use (without indirect CO_2)	17.4	7.5	7.4	5.1	4.2	5.5	5.6	5.8	6.8
Indirect CO_2 from solvent use and road paving with asphalt	18.5	17.4	16.5	18.5	11.3	16.1	18.4	20.8	24.7
N_2O									
Other product manufacture and use	5.5	6.0	8.1	6.8	5.1	3.9	3.1	3.1	3.1
HFCs	NO*	28.5	79.2	135.0	175.5	223.4	232.4	226.3	184.7
PFCs	NO**	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	NO**	3.07	2.61	1.08	1.83	2.35	2.67	2.84	2.92
Total (with indirect CO_2)	**963.7**	**635.3**	**696.0**	**727.8**	**539.5**	**517.0**	**628.5**	**621.3**	**295.5**
Total (without indirect CO_2)	**945.3**	**617.9**	**679.4**	**709.3**	**528.26**	**500.9**	**610.1**	**600.6**	**270.7**

*The use of HFC-s started in 1992 in Estonia
**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 2020 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3 and Annex 1.

4.2. Mineral industry (CRF 2.A)

In this category Estonia reports non-fuel emissions from:

- Cement production (2.A.1) – until March 2020;
- 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) – which was 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 and 2015–2016). 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. 2020 year´s 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, the 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 –2020; emissions from it are accounted under the Energy sector.

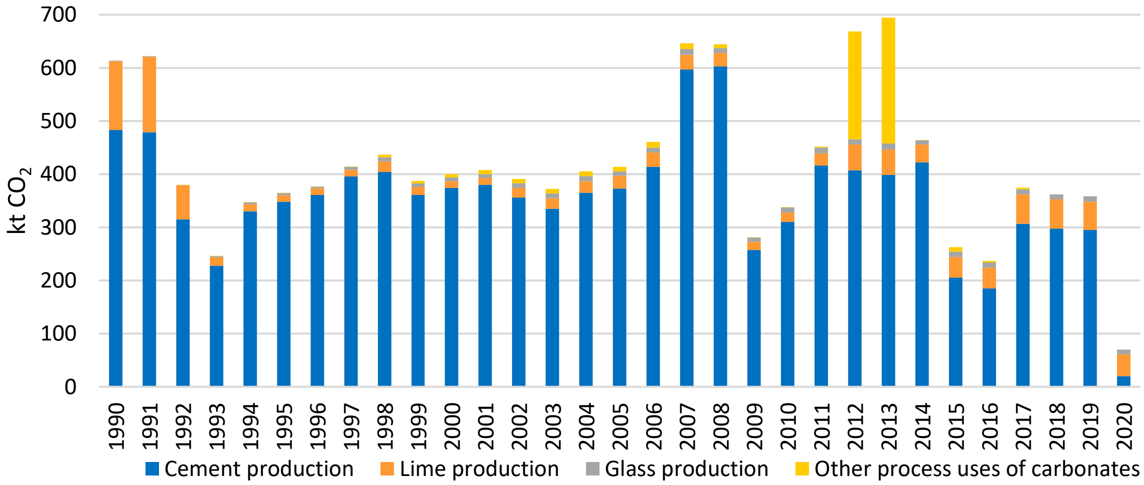

Figure 4.3. CO_2 emissions from Mineral industry in 1990–2020, kt

Table 4.3. CO_2 emissions from Mineral industry in 1990–2020, kt

	1990	1995	2000	2005	2010	2015	2017	2018	2019	2020
2.A.1 Cement production	483.0	347.9	373.7	372.9	310.4	205.6	306.8	297.8	295.5	20.1
2.A.2 Lime production	129.7	12.4	12.8	24.1	17.7	38.7	55.4	54.7	52.8	40.6
2.A.3 Glass production	1.2	4.0	7.4	8.1	9.7	10.0	9.8	9.6	10.4	9.0
2.A.4.a Ceramics	NA	0.05	6.0	8.5	0.7	1.0	0.7	0.95	0.53	0.51
2.A.4.b Soda ash use	IE[40]	IE	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	2.0	NO	NO	NO
Total	**614.0**	**364.4**	**399.9**	**413.6**	**338.5**	**262.8**	**374.7**	**363.0**	**359.2**	**70.3**

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 2020. In 2020 the clinker burning took place only for the first 3 months and was ceased thereafter. Clinker production with wet process was not economically feasible anymore as CO_2 quota prices rose rapidly in 2019 and in 2020.

The 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[41]).

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[42].

Equation 4.1

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

Activity data, emission factor and cement kiln dust (CKD) correction factor was given by the cement plant. All measurements and calculations were done according to Regulation (EU) 2018/2066[43] 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

[40] All emissions previously reported under 2.A.4.b are now included into emissions reported under 2.C.5
[41] https://kotkas.envir.ee/, (03.12.2021)
[42] IPCC 2006 Guidelines, Volume 3, Chapter 2: Mineral Industry, page 2.9, equation 2.2.
[43] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018R2066 (15.12.2021)

software (Cement CO_2 and Energy Protocol software from the World Business Council for Sustainable Development[44]).

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.

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 throughout the time series. 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[45].

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[46] and European Commission's best available techniques (BAT) reference document[47] to reduce emissions and continuously to improve the dust control technology of the production. BAT reference document nor any legal act specify how much kiln dust should be recycled. The plant has 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 1990–2020

2.A.1 Cement production	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Clinker production, kt	790.3	571.3	619.5	635.4	536.7	356.3	318.5	517.9	505.4	503.6	35.0
$EF_{clinker}$, t/t	0.549	0.547	0.538	0.547	0.549	0.558	0.547	0.554	0.556	0.556	0.555
CKD correction factor	1.113	1.113	1.121	1.073	1.054	1.034	1.063	1.069	1.060	1.055	1.037
CO_2 emissions kt	483.0	347.9	373.7	372.9	310.4	205.6	185.2	306.8	297.8	295.5	20.1

[44] http://apki.net/wp-content/uploads/2013/05/WBCSD-CO2-Energy-Accounting-Reporting-Standard-for-The-Cement-Industry.pdf, (03.12.2021)
[45] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.13, equation 2.5.
[46] https://www.riigiteataja.ee/en/eli/ee/510012019010/consolide/current, (14.12.2021)
[47] https://ec.europa.eu/jrc/en/publication/reference-reports/best-available-techniques-bat-reference-document-production-cement-lime-and-magnesium-oxide, (16.12.2021)

4.2.1.3. Uncertainties and time-series consistency

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

For overall uncertainty of EF uncertainties of EF-s of clinker and kiln dust were combined by addition[48]. 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 additional information how uncertainty is calculated[49]. 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 environmental minister of Estonia.

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.

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[41]).

The emissions of 2005–2020 have been compared with the EU ETS data. Differences were zero to 0.00009 % 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).

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 the lime production are due to calcination of calcium and magnesium carbonates at high temperatures. In Estonia there are currently three lime production plants,

[48] IPCC 2006 Guidelines, Volume 1, Chapter 3, page 3.28, equation 3.2
[49] FCCC/ARR/2020/EST/I.1

from which one is small (contributes ca 0.05% of the total lime production) and the other two produced each ca 50% of the total production in 2020.

4.2.2.2. Methodological issues

Methods

Emissions from the lime production are calculated by multiplying emission factors with activity data. Activity data are collected mainly 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[50].

Equation 4.2

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

Where:

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

Emission factors

Four different 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. Two plants that must submit their EU-ETS reports are calculating emission factors: 1) based on chemical analyses of carbonate content or 2) 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[51] stipulates the emission factor 0.7857. This emission factor is appropriate for producing lime from Estonian limestone, which has high calcium content and contains maximally 3% of magnesium oxide.

   From one of the bigger plants' emission factors based on actual CaO and MgO content has been available since 2005. As this emission factor differs strongly from the default emission factor, emission factors for 1990–2004 are established as a mean value from the emission factors in 2005–2008.

3. Third, smallest lime plant has been estimating their emission factor since 1994.

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[50] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.21, equation 2.6.
[51] https://www.riigiteataja.ee/akt/108032019006?leiaKehtiv, (16.12.2021)

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

The operator of one of the bigger plants explained that all products that leave the kiln (including kiln dust) are sold and these products have already 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[52]) 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[53]. 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 other bigger 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)[54]:

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.

Data on lime production as well as emission factors between 1990–2019 are available in Table 4.5.

Table 4.5. Activity data, emission factors and CO_2 emissions for lime production in 1990–2020

2.A.2 Lime	1990	1995	2000	2005	2010	2014	2015	2016	2017	2018	2019	2020
Lime production, kt	185.0	16.8	19.9	37.2	26.9	48.8	54.5	55.4	78.0	76.3	73.1	54.8
IEF_{lime}, t/t	0.70	0.74	0.64	0.65	0.66	0.70	0.71	0.71	0.71	0.72	0.72	0.74

[52] 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, (06.12.2021).
[53] https://eippcb.jrc.ec.europa.eu/reference, (06.12.2021).
[54] 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	2018	2019	2020
CO_2 emissions kt	129.7	12.4	12.8	24.1	17.7	34.1	38.7	39.3	55.4	54.7	52.8	40.7

4.2.2.3. Uncertainties and time-series consistency

The uncertainty of tonnes of produced lime is 0.31%. This is combined uncertainty of two largest lime producer´s output.

The default value of EF uncertainty 2%, is used for lime production[55].

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[41]), 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 2005-2020. 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.

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.

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

1. For flat glass production Tier 1 method according to the IPCC 2006 Guidelines[56] 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[57] 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 (1993–2020) 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.

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 2006–2020. 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[58] and are based on stoichiometric ratios. The emission factor for limestone is then (Equation 4.6):

Equation 4.6

[56] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.28, equation 2.10.
[57] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.28, equation 2.12.
[58] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.

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

Where:

part of $CaCO_3$ = 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[59]. 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 are 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 1990–2020 are available in Table 4.6.

Table 4.6. Activity data and emission factors and emissions from container and glass production in 1990–2020

2.A.3 Glass	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**2019**	**2020**
Container glass production, kt	NO	27.9	59.1	62.1	81.6	88.0	86.2	86.7	76.7
Limestone consumption, kt	NO	3.86	8.99	8.64	11.17	11.35	11.02	11.98	10.50
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	11.23	12.13	10.55
$EF_{default}$, 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	24.40	27.27	24.51
IEF, t/t	NA	3.667	3.667	3.667	3.667	3.192	3.190	3.190	3.190
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	9.6	10.4	9.0

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[60].

[59] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.29, equation 2.13.
[60] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.31.

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[41]) 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 2022 submission was 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 desulphurisation
- Emissions from 2.A.4.b Other uses of soda ash have been relocated and included to emissions from 2.C.5 Lead production.

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

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 a 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* methodology from the IPCC 2006 Guidelines[61]. In the case of the large production plant emissions arise only from limestone filler. The emissions are calculated based on $CaCO_3$ content of the filler. 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;
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[62]. 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.

[61] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34, equations 2.14-2.15.
[62] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.

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 are calculated based on limestone filler, which is in line with the method used by the plant calculating the emissions. For calculation based on limestone filler, the exact $CaCO_3$ content of the limestone filler used is provided by the plant. 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.

The total mass of carbonates on which CO_2 emissions are calculated are presented in Table 4.7. This includes the precise amounts of the limestone filler used by one producer and amounts that are estimated by the *Tier 1* method for other producers.

Data on the amount of clay and limestone filler used in brick production were directly collected from the plants in 1992 to 2020. 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%[63] 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[64].

For the years 1992–2020 data about bricks production was directly collected from the plants. 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 1990–2020 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 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 1990–2020

	1990	1995	2000	2005	2010	2015	2018	2019	2020
2.A.4.a Ceramics									
Production of ceramics, kt including:	251.1	28.8	119.6	184.6	38.3	33.4	32.9	35.0	36.9
Production of bricks and tiles, kt	251.1	28.8	32.7	69.0	38.3	33.4	32.9	35.0	36.9
Emissions from bricks and roof tile production, kt	NA	0.051	0.014	0.653	0.705	0.952	0.953	0.527	0.509

63 IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34
64 IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.36.

	1990	1995	2000	2005	2010	2015	2018	2019	2020
EF of bricks and roof tiles, t CO_2/t products	NA	0.002	$4 \cdot 10^{-4}$	0.008	0.018	0.028	0.029	0.015	0.014
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	2.17	1.20	1.16
$EF_{default}$ 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	0.0004	0.0003	0.0002
$EF_{default}$ 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[41]) 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 2009–2020, 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)[65]. 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[66]. 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[67].

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%.

[65] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.34, equation 2.14.
[66] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.
[67] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.36.

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[41]) 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 2020 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[68].

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

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[69]. 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")[70].

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%.

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[71].

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).

[69] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1.
[70] https://www.riigiteataja.ee/akt/108032019006?leiaKehtiv, (15.12.2021).
[71] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.39.

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 2014–2020, no NH_3 production took place at this plant. The plant operator states that the plant will be finally shut down and will be dismantled 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 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 energy balance. In the energy balance data 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)[72].

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 the inventory compilers. The amount of gas feedstock was provided by 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 been 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

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

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 1990–2020 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 1990–2020

2.B.1	1990	1995	2000	2005	2010–2011	2012	2013	2014–2020
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 2014-2020, 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 UNFCCC Review Team asked to provide background data sources that inform estimates of natural gas used as fuel in ammonia plants[73]. 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 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 energy balance from Statistics Estonia[74]. The differences in gas feedstock AD that Statistics Estonia used in the energy balance 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.

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

[73] ARR2016/ Table 5. I.8 IPPU
[74] ARR2016/ Table 5. I.9 IPPU

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 2020 emissions from the category 2.C were 2.90 kt CO_2.

Methods

Estonia uses the *Tier 3*[75] 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.

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)[76]. 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:

[75] IPCC 2006 Guidelines, Volume 3, Chapter 4, page 4.73
[76] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.35

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[77]. 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	2017	2018	2019	2020
Anthracite use kt	NO	NO	NO	0.309	0.657	0.624	0.753	0.762	0.764	0.668
Soda ash and ammonium bicarbonate use, kt	1.87	1.56	3.74	1.48	1.26	2.88	2.91	2.68	2.52	2.26

4.4.1.3. Uncertainties and time-series consistency

The uncertainty of activity data is default value for *Tier 3* method ±5%[78]. Uncertainty of emission factor is also 5% – the default value for *Tier 3*.

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[41]). 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.

[77] IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.7, table 2.1
[78] IPCC 2006 Guidelines, Volume 3, Chapter 4, page 4.76, table 4.23

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[77]) 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

$$\boldsymbol{La_2(CO_3)_3 = La_2O_3 + 3CO_2}$$

Emission factors

The emission factor of soda ash is 0.41492[77]. 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

$$\frac{\boldsymbol{44(M_{CO2}) * 3(stoich.coeffiecient) * 0.5\ (50\%\ of\ carbonates\ are\ calcined)}}{\boldsymbol{79\ \left(M_{NH4(HCO3)}\right) * 6(stoich.coefficient)}}$$

where M is molecular mass.

Activity data

The quantities of soda ash used by the plant in 1998, 2002-2020 (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 2006-2020 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 2004-2020 are from reports on air pollution and quantities in 1990-2006 are from old newspapers (e.g., Äripäev, 1995[79], Äripäev, 1998[80])

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[81]. 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[41]). No significant differences were found.

4.4.2.5. Category-specific recalculations

In comparison to the previous submission the emissions from ammonium bicarbonate used for precipitation of rare earth carbonates and neutralization of acid gases, also emissions from calcination of rare earth carbonates have now been accounted.

The quantities of rare earth carbonates that were calcined are confidential. Therefore, only emissions are shown in the Table 4.10.

Table 4.10. Recalculation of emissions from rare earth metal compounds industry in 1990-2019

	2022 submission		2021 submission	2022 submission	2021 submission	difference
Year	Emissions from $NH_4(HCO_3)$, kt CO_2	Emissions from REE compound calcination, kt CO_2	Emissions from $NH_4(HCO_3)$ and REE compound calcination, kt CO_2	Emissions from 2.C.5 subsector, kt CO_2	Emissions from 2.C.5 subsector, kt CO_2	kt CO_2
2019	0.5577	0.2789	0	3.2926	2.4560	0.8366
2018	0.5980	0.2990	0	3.3508	2.4538	0.8970
2017	0.6547	0.3273	0	3.4231	2.4411	0.9820
2016	0.7072	0.3536	0	3.4771	2.4162	1.0609

79 Äripäev, 1995 https://www.aripaev.ee/uudised/1995/12/03/silmet-otsib-uusi-partnereid. (01.11.2021).
80 Äripäev, 1998 https://www.aripaev.ee/uudised/1998/11/19/silmet-ootab-kasumit. (01.11.2021).
81 IPCC 2006 Guidelines, Volume 3, Chapter 2, page 2.39, section 2.5.2.2.

	2022 submission		2021 submission	2022 submission	2021 submission	difference
Year	Emissions from $NH_4(HCO_3)$, kt CO_2	Emissions from REE compound calcination, kt CO_2	Emissions from $NH_4(HCO_3)$ and REE compound calcination, kt CO_2	Emissions from 2.C.5 subsector, kt CO_2	Emissions from 2.C.5 subsector, kt CO_2	kt CO_2
2015	0.6728	0.3364	0	3.0304	2.0212	1.0092
2014	0.6621	0.3311	0	3.0418	2.0486	0.9932
2013	0.5800	0.2900	0	3.1013	2.2313	0.8700
2012	0.6483	0.3242	0	3.3706	2.3982	0.9725
2011	0.4487	0.2243	0	3.1525	2.4795	0.6730
2010	0.2540	0.1270	0	2.4508	2.0698	0.3810
2009	0.4649	0.2325	0	2.3897	1.6923	0.6974
2008	0.4805	0.2402	0	2.4911	1.7704	0.7207
2007	0.4184	0.2092	0	2.4469	1.8192	0.6277
2006	0.3710	0.1855	0	2.3725	1.8159	0.5566
2005	0.1639	0.0819	0	1.5213	1.2755	0.2458
2004	0.1339	0.0670	0	1.6493	1.4484	0.2009
2003	0.1228	0.0614	0	0.6823	0.4981	0.1842
2002	0.3026	0.1513	0	1.3915	0.9376	0.4539
2001	0.3248	0.1624	0	1.4530	0.9657	0.4873
2000	0.2886	0.1443	0	1.5531	1.1202	0.4329
1999	0.2886	0.1443	0	1.3234	0.8905	0.4329
1998	0.2886	0.1443	0	1.4570	1.0241	0.4329
1997	0.2886	0.1443	0	1.0167	0.5837	0.4329
1996	0.2886	0.1443	0	0.7131	0.2802	0.4329
1995	0.2626	0.1313	0	0.6489	0.2550	0.3940
1994	0.2705	0.1353	0	0.6684	0.2626	0.4058
1993	0.0920	0.0460	0	0.2273	0.0893	0.1380
1992	0.1380	0.0690	0	0.3409	0.1339	0.2069
1991	0.2621	0.1311	0	0.6477	0.2545	0.3932
1990	0.3146	0.1392	0	0.7592	0.3058	0.4538

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.

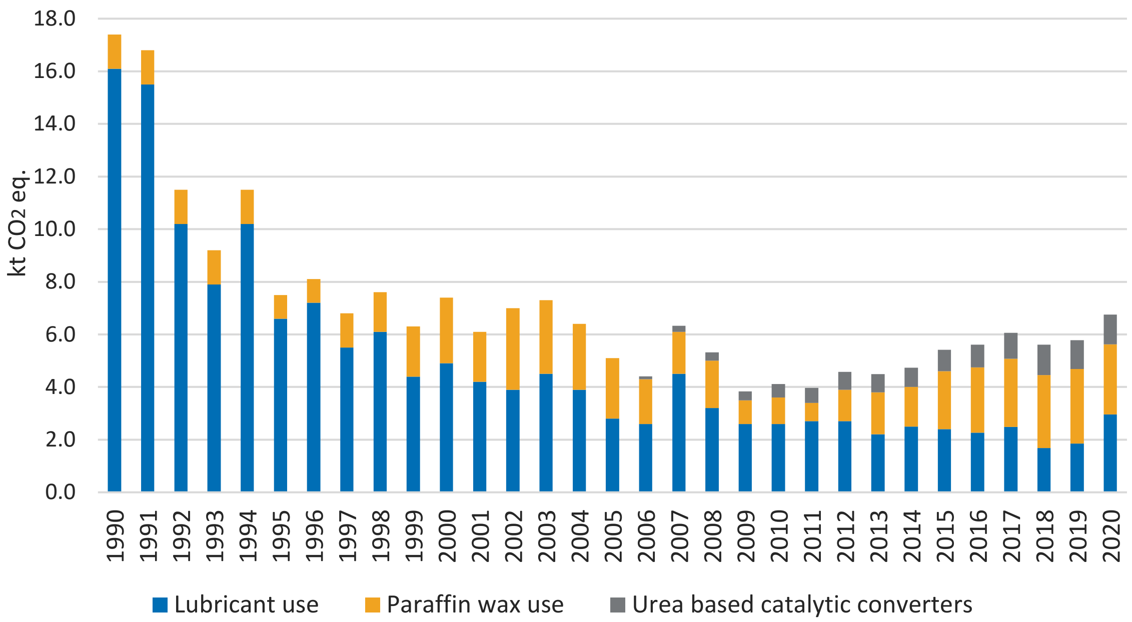

Figure 4.4. CO_2 emissions from non-energy products from fuels and solvent use in 1990–2020, kt

Table 4.11. 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**	**2017**	**2018**	**2019**	**2020**
2.D.1 Lubricant use, kt	27.3	11.2	8.4	4.8	4.5	4.3	4.1	4.2	2.9	3.1	5.0
Lubricant use, TJ	1 098	449	336	191	180	172	165	170	115	126	202
CO_2 emission, kt	16.1	6.6	4.9	2.8	2.6	2.5	2.4	2.5	1.7	1.9	3.0
$EF_{lubricants}$, 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	4.4	4.72	4.8	4.5
Paraffin wax use, TJ	88	63	167	154	71	100	153	176	190	194	182
CO_2 emission, kt	1.3	0.9	2.5	2.3	1.0	1.5	2.2	2.6	2.8	2.8	2.7
$EF_{paraffin\ waxes}$, 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	4.1	4.8	4.6	4.8
CO_2 emission, kt	NO	NO	NO	NO	0.5	0.7	0.8	1.0	1.2	1.1	1.1
$EF_{catalytic\ converters}$, t/t	0.2383 for all years										
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	6.1	5.6	5.8	6.8

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)[82]. 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[83].

Equation 4.14

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

Where:

CO_2 emissions	=	CO_2 emissions from lubricants, tonne CO_2;
LC	=	total lubricant consumption, TJ;
$CC_{Lubricant}$	=	carbon content of lubricants (default), tonne C/TJ (= kg C/GJ);
$ODU_{Lubricant}$	=	ODU factor (based on default composition of oil and grease), fraction;
44/12	=	mass ratio of CO_2/C.

In 2020 the apparent consumption of lubricants was 5.03 kt and the CO_2 emission from this category (2.D.1) was 2.96 kt.

Activity Data

Data on production of lubricants in 1990–2020 was provided by Statistics Estonia. No production of motor and industrial oils was present in Estonia during 1990–2020 according to Statistics Estonia and the Eurostat database[84].

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

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[85].

Activity data on lubricants are presented in Table 4.11.

[82] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.7, equation 5.2.
[83] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.9, section 5.2.2.2.
[84] https://ec.europa.eu/eurostat/web/main/data/database, (17.02.2022)
[85] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.18, table 1.2.

Emission factors

According to Tier 1 the weighted average ODU factor 0.2 for lubricants is used[86].

The default carbon content for lubricants 20.0 t C/TJ was applied[87].

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 Road 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 Road Administration. It was concluded that the use of lubricants in 2-stroke engines is marginal.

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 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.

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[86] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.9, table 5.2.

[87] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.21, table 1.3.

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)[88], because no sufficient data on oxidation factors of different paraffin wax products were found.

Total consumption of paraffin waxes (TJ) is multiplied with the emission factor.

Equation 4.15[88]

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

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 2020, the apparent consumption of paraffin waxes (including candles) was 4.52 kt and the CO_2 emission from this category (2.D.2) was 2.66 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 2006–2020 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 1995–2020 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[89].

Activity data on paraffin waxes are presented in Table 4.11.

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[90].

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[88] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.11, equation 5.4.
[89] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.18, table 1.2.
[90] IPCC 2006 Guidelines, Volume 2, Chapter 1, page 1.21, table 1.3.

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 2007–2020[91]. 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

2016-2019 years´ emissions have been recalculated because errors of aggregation of statistical data were corrected and because statistical data in Eurostat database were retrospectively corrected. The recalculations are in the Table 4.12

Table 4.12. Recalculations of consumed paraffin waxes and emissions from them in 2016-2019

Year	2022 submission; Consumption of paraffin waxes kt	2022 submission; Emission from paraffin waxes kt CO_2	2021 submission; Consumption of paraffin waxes kt	2021 submission; Emission from paraffin waxes kt CO_2
2016	3.90518	2.30249	4.19647	2.47424
2017	4.38407	2.58485	4.10347	2.41941
2018	4.71547	2.78024	4.35814	2.56956
2019	4.81381	2.83822	4.61248	2.71952

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.

[91] IPCC 2006 Guidelines, Volume 3, Chapter 5, page 5.13 section 5.3.3.2.

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 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[92]. 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[93].

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[94].

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.

(As) 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 2020, the consumption of urea-based DEF (AdBlue) was 4.75 kt and the CO_2 emission from this category (2.D.3) was 1.13 kt. The main reason for having slightly larger emission compared to 2019, is the growing number of new (Euro 6 complying) passenger cars. AdBlue consumption of light commercial vehicles, heavy trucks and buses did not increase much in comparison with 2019.

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[92] 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, (15.12.2021)

[93] 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, (15.12.2021).

[94] IPCC 2006 Guidelines, Volume 2, Chapter 3 page 3.12.

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.

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 Road 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[95] 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%[96]. Assuming that the average value is somewhere in 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

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

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.

4.5.3.1.5. Category-specific recalculations

No category-specific recalculations were done.

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 have to be reported according to the NEC Directive and the UNECE CLRTAP (United Nations Economic Commission for Europe’s Convention on Long-Range Transboundary Air Pollution). Both reports must be submitted by 15.02.2022 and are compiled by the Estonian Environmental Agency. For this reason, the data of 2019 is used for 2020. New data will be provided by the 15th of March submission.

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 4.13).

The NMVOC and indirect CO_2 emissions from solvents by the EMEP/EEA Air pollutant emission inventory NRF code are shown in Table 4.13. 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 2020 (Table 4.14).

Table 4.13. Reported emissions from Solvent use in 2020

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, manufacture, 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. Especially large increase in NMVOC emissions has been in paint application (industrial and domestic) and in 2020 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 (due to coronavirus) and antifreezes (this could be because of increased consumption of solar cells[84]). 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[132] they should remain constant during time series. In real life it could be that the emission factors might have decreased as effect ofRegulation (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 in the period 1990–2020 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).

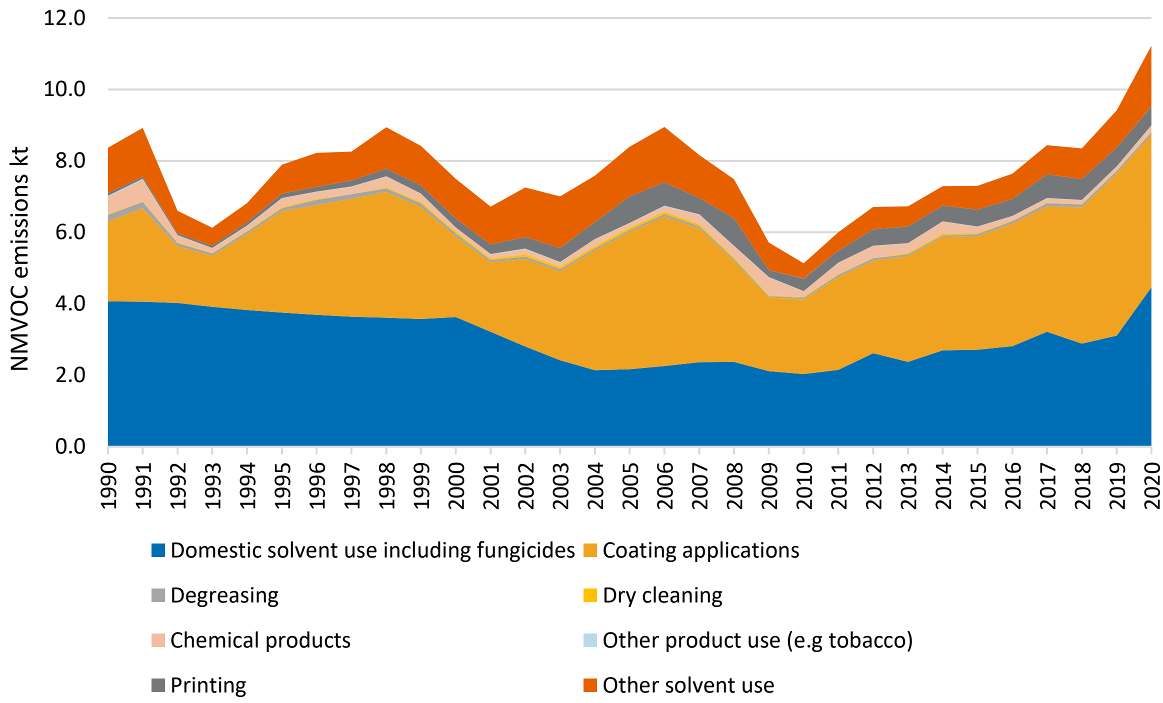

Figure 4.5. Total NMVOC emissions from Solvent use in 1990–2020, kt

Table 4.14. Emissions from Solvent use and Road paving with asphalt in 1990–2020, kt

Emissions from Solvent use and Road paving with asphalt, kt		**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**2019**	**2020**
2D3a	NMVOC emissions from Domestic solvent use (e.g., fungicides), kt	4.07	3.75	3.63	2.17	2. 03	2.71	2.88	3.11	4.46
2D3d	NMVOC emissions from Coating applications (e.g., paint), kt	2.24	2.85	2.26	3.84	2.09	3.18	3.82	4.55	4.28
2D3e	NMVOC emissions from Degreasing, kt	0.18	0.08	0.08	0.05	0.05	0.06	0.09	0.07	0.07
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	0.11	0.17
2D3h	NMVOC emissions from Printing, kt	0.08	0.13	0.25	0.74	0.35	0.47	0.58	0.53	0.53
2D3i	NMVOC emissions from Other solvent use, kt	1.26	0.81	1.11	1.38	0.42	0.66	0.86	1.04	1.71
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**	**7.30**	**8.35**	**9.42**	**9.41**
Indirect CO_2 emissions from NMVOCs from Solvent use, kt		**18.40**	**17.37**	**16.50**	**18.46**	**11.29**	**16.07**	**18.37**	**20.71**	**20.72**
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**
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**	**0.04**	**0.05**

Emissions from Solvent use and Road paving with asphalt, kt	1990	1995	2000	2005	2010	2015	2018	2019	2020
Total indirect CO_2 emissions from Solvent use and Road paving with ashphalt, kt	**18.45**	**17.39**	**16.52**	**18.50**	**11.32**	**16.11**	**18.41**	**20.76**	**24.74**

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)[97]. 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[98]).

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.

[97] IPCC 2006 Guidelines, Volume 1, Chapter 7, page 7.6, box 7.2.
[98] 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 2017, 2018 and 2019. Recalculations of 2017-2018 emissions were done because of correction of activity data. Recalculation of 2019 emissions was subtraction of NMVOCs from subcategory 2G Other; lubricant use because emissions from lubricants are already accounted under the category 2.D.1.

Table 4.15. Recalculations of 2017-2019 emissions of NMVOCs from solvent use

Year	Difference in NMVOC emissions from 2D3h Printing industry, 2022 - 2021 submission, kt	Difference in NMVOC emissions from 2D3a Domestic Solvent use, 2022 - 2021 submission, kt	Difference in NMVOC emissions from 2D3d Paint application, 2022 - 2021 submission, kt	Difference in NMVOC emissions from subcategory 2G, 2022 - 2021 sub-mission, kt	Difference in indirect CO_2 emissions in 2021 submission, kt
2017	–	0.008573	–	–	-0.01886
2018	0.004244	-0.005768	0.000269	–	0.00276094
2019	–	–	–	0.04295	0.094489

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 2020.

Indirect CO_2 emissions from road paving with asphalt: 0.05 kt.

NMVOC and indirect CO_2 emissions in 1990–2020 are shown in Table 4.14.

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 1990–2020.

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[99].

The uncertainty of the average carbon content of NMVOCs is 10%. The combined emission factor of indirect CO_2 is $\sqrt{(100^2 \cdot 10^2)}$=101%.

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 2020 greenhouse gas emissions under the category CRF 2.F Product uses as substitutes for ODS amounted to 184.74 kt CO_2 equivalent, which was about 1.59% 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).

[99] 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[100]). In addition, wholesalers have bought more HFC-s from other EU countries. An exemption is the high-GWP R-404A which sale has decreased more than twofold in comparison to 2018. 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 2008, one-component polyurethane foams with R-134a were banned by Regulation (EU) No 842/2006[101] 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[100] 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)

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.

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[100] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014R0517&from=en, (17.12.2021)
[101] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32006R0842&from=EN, (22.12.2021)

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 18%.

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

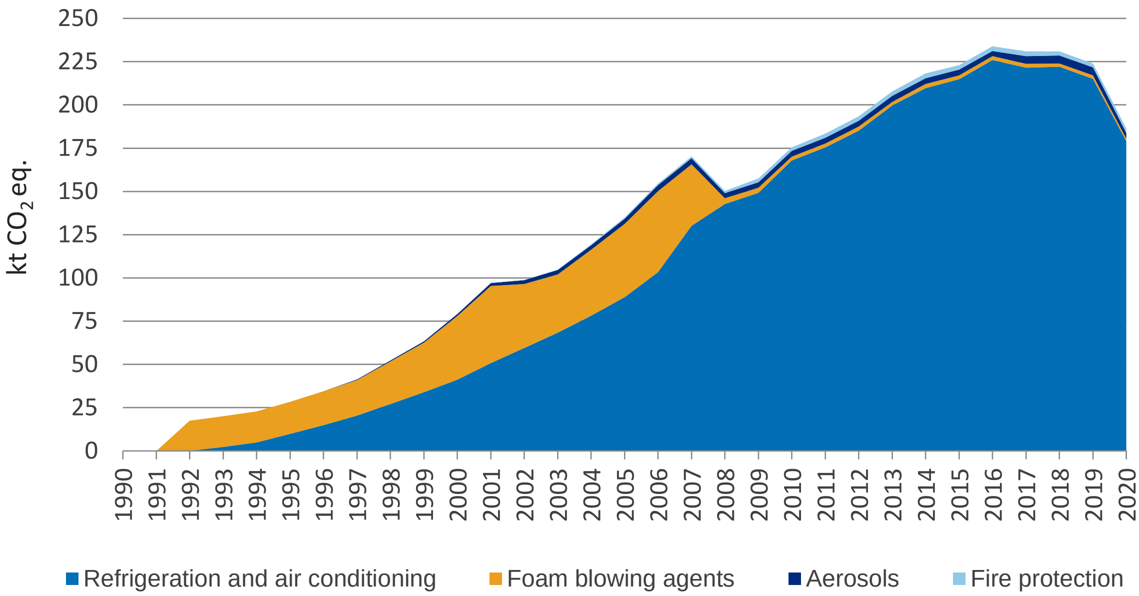

Figure 4.6. Actual emissions of HFCs by subcategory in 1990–2020, kt CO_2 equivalent

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 Road Administration, Maritime 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 96.0% of the Estonian F-gas emissions (177.42 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 sub sector, 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 87% of the 2020 HFC stock (mostly used in supermarket systems), R-134a – about 7% mainly used in vending machines, small shops and restaurants) and R-407F – 2.8% (substitute for R-404A). Little new equipment with R-404A was installed in 2020 since supermarket chains are aware of the bans on equipment with R-404A stipulated in Regulation (EU) No 517/2014[102].

Stock of R-404A in supermarkets has decreased by another 8 tonnes in 2020 in comparison to 2019. The reason for the emissions decrease is that in another 30 supermarkets the old R-404A equipment was replaced with CO_2-systems at the end of 2020. In the end of 2020 about 26% of supermarkets had CO_2 equipment and ca 4% had switched to low-GWP refrigerants.

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[102] https://eur-lex.europa.eu/legal-content/ET/TXT/?uri=celex%3A32014R0517 (07.01.2022).

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 2020 stock data (67.68 t of HFC) had to be completed by the estimation of the stock by supplementary 4.38 t which makes a total sum of 72.03 t of HFC or 72.30 t of HFC blends. 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 72.30 t for the 2020 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 8 tonnes lower than in the previous submission for the year 2020. The main reason for this decrease is the phaseout of R-404A-based supermarket equipment, following the EU-wide use ban of virgin HFCs refrigerants with a GWP 2500 or higher that came in force in 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 4 000 possible clients (with on average three devices with a refrigerant charge of 350 g/device), resulting in about 4.29 t of HFC- and HC-refrigerants. Estonian experts estimated that R-404A constituted 30% (1.29 t) and R-134a 33% (1.40 t) in this subcategory. The share of other HFC refrigerants (R-422A, R-422D, R-452A) is ca 4%. The rest of the stock (1.44 t) is consisting of HC-refrigerants

The number of vending machines in Estonia (ca 15 000 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 2.77 t of R-134a and 0.32 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 2005 (15 years ago) was decommissioned according to 15 years lifetime in 2020.

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 supplied by 10 service companies, 4 companies did not provide refilling data and in case of 2 of them 2019 year´s refilling data was used. 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 11.6% is used as operating emission factor. This is lower as in previous years (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 1st January 2020 and that is why only minimal amounts of (recycled) R-404A were refilled.

An EF_{op} of 11.6% 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)[103].

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[104].

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}: 11.6% (vending machines: 1.5%);
- Country specific disposal emission factor EF_{disp}: 50%.

In 2020, the total quantity of HFCs filled into new commercial refrigeration equipment was 0.46 t (without non-HFC components). The manufacturing emissions from this filling were 0.002 t. The HFC stock amounted to 77.97 t (66.71 of R-404A, 6.89 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 8.80 t. R-404A (7.75 t) and HFC-134a (0.32 t), constituted the largest part of them.

The amount of R-404A, R-134a and R-407C filled in new equipment in 2005 was decommissioned according to 15 years lifetime in 2020.

In 2020, the amount of HFC refrigerant remaining in products at decommissioning amounted to 3.67 t of R-404A, 0.63 t of R-134a and a small amount of other refrigerants – 4.33 t of HFCs

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

total. The emissions from disposal were in total 2.17 t (1.84 t of R-404A, 0.32 t of R-134a and small amount of other refrigerants).

Total HFC emissions from commercial refrigeration in 2020 amounted to 10.99 t (39.88 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 ± 10.3% (0.10) which is in the same magnitude as in the previous submission. The reviews of the 2018 and 2020 submissions gave recommendation to improve accuracy and completeness of data collected for 2.F.1 subsector (I.7, 2020 and I.7,2018) and 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 2018 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 17 service companies. The amounts of R-407F, R-448A and R-449A sold in Estonia in 2020 were ca 5 tonnes more than filled into equipment according to the inventory. Possibly this could be an underestimation because of poor quality reports of the 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 17 service companies was used, only 10 of them gave refilling data and the refilling data of the rest contributed to the uncertainty. The uncertainty of EF is 30.8%.

The combination of the uncertainty of activity data 10.3% with the respective emission factor (± 30.6%) results in the UN of manufacturing, operating and disposal HFC emissions of ± ~32.5%.

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 and 2020 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 626 000 households in Estonia in 2020. The number of domestic refrigerators was estimated at 620 992 and the number of newly imported fridges/freezers at 69 802 (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 2020 which in turn is estimated via lifetime. The average lifetime of fridges/freezers was estimated to be 9 years in 2020. 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 2019-2020 there was no more HCFC. low. 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 2020. 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[105].

The number of refrigerators decommissioned per annum can be calculated (based on 9 years average lifetime) at 61 243 out of which 40 002 were collected by recycling companies and sent for treatment to foreign countries. The remaining 21 241 are disposed of without refrigerant

[105] IPCC 2006 Guidelines, Volume 3, Chapter 7, table 7.9, page 7.52.

recovery. EES Ringlus assumed that (i) *ca* 30% 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 0.29 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 2020 amount of R-134a emissions in this subcategory was 0.76 t (stock emissions: 0.011 t, end-of-life emissions: 0.75 t) representing 1.09 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.

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

The lifetime of HC-containing fridges was lowered to 8 years (it was estimated to be 5-8 years by the main producer responsibility organization EES Ringlus) and the average lifetime was gradually lowered to 9 years in 2018-2020. The stock in 2010-2019, number of units decommissioned in 2016-2019 and HFC-134a in decommissioned equipment in 2006-2019 have been recalculated and therefore the emissions too. The recalculations were done because the companies removing HFC-134a from the refrigerators reported that ca 26% of the fridges disposed are with HFC-134a (before learning this the calculation model gave as result that there are no or very little HFC-134a containing fridges). The recalculations are in Table 4.16.

Table 4.16. Recalculation of stock and decommissioned equipment and emissions from domestic refrigeration

	2022 submission						2021 submission						
	Units of equipment in stock	Units with HFC-134a in stock	HFC-134a emissions from stock, t	Units decommissioned illegally	Units with HFC-134a decommissioned illegally	HFC-134a emissions from decommissioning, t	Units of equipment in stock	Units with HFC-134a in stock	HFC-134a emissions from stock, t	Units decommissioned illegally	Units with HFC-134a decommissioned illegally	HFC-134a emissions from decommissioning, t	Difference in emissions between 2022 and 2021 emissions, CO2 eq. kt
2006	564799	66000	0.0396	11396	3419	0.4821	564799	66000	0.0396	33920	11396	0.141	0.4877
2007	574945	62400	0.0374	11397	3419	0.4821	574945	62400	0.0374	34040	11397	0.1177	0.521
2008	575240	58467	0.0351	11398	3419	0.4821	575240	58467	0.0351	33948	11398	0.1006	0.5456
2009	575733	53987	0.0324	11399	3420	0.4822	575733	53987	0.0324	35587	9300	0.0656	0.5958
2010	575142	46738	0.028	11400	3420	0.4822	575142	48088	0.0289	34500	11400	0.0804	0.5735
2011	576422	46722	0.028	13000	3900	0.5499	576422	47913	0.0287	35051	13000	0.0917	0.6543
2012	591726	44139	0.0265	13600	4080	0.5753	591726	25924	0.0156	35604	13600	0.1918	0.5641
2013	584888	41556	0.0249	13534	4060	0.5725	584888	19320	0.0116	37659	13534	0.3817	0.292
2014	576762	36241	0.0217	14198	4259	0.6006	576762	1367	0.0113	39788	14198	0.6006	0.015
2015	576054	34283	0.0206	13976	4193	0.5912	576054	10140	0.0061	42351	13976	0.5912	0.0207
2016	583296	34828	0.0209	18934	5680	0.8009	583296	9837	0.0059	42633	15058	0.637	0.2559
2017	593018	27123	0.0163	24270	7281	1.0266	593018	9581	0.0057	43601	15549	0.6577	0.5425
2018	597779	23508	0.0141	26592	6648	0.9374	597779	2557	0.0015	42801	12325	0.3476	0.8614
2019	612461	19892	0.0119	24619	6155	0.8678	612461	152	0.0001	43285	10191	0.2874	0.847

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 79.7% of the stock. HFC-134a makes up 9.0% 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 stock of R-404A has decreased by 7.5 tonnes in 2020 compared to 2017.

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 10 service companies who cover most of the market and in case of 3 companies previous years' data was used. Basic data about the Estonian food industry can be found in the statistics of the Veterinary and Food Board (VTA[106]) as companies handling foodstuff shall be approved by the VTA and the data is available online.

As the refrigerant stock based on the data from service companies and the national VTA 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 8.23% or 6.62 t of the total HFC stock of 80.38 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 2005 was decommissioned in 2020.

Emissions: Activity data (stock, new installations in 2020, 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

[106] https://jvis.agri.ee/jvis/avalik.html#/toitKaitlemisettevotedparing, (03.12.2021).

missing from FOKA database).

The results of the surveys in 2020 showed that the refilling ratios of the individual companies range from 2 to 19%. The average refilling rate was 9.1% 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[107] 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 2020 amounted to 0.37 t (0.26 t of R-448A, 0.11 t of R-134a, 0.02 R-404A, 0.02 t of R-407F, 0.05 t of R-452A). The manufacturing emissions from filling were 0.002 t of HFCs (0.004 kt CO_2 eq).

The HFC stock amounted to 80.13 t (7.24 t of R-134a, 63.84 t of R-404A, 2.56 t of R-407C, 2.90 t of R-407F, 1.06 t of R-410A, 0.87 t of R-448A and small volumes of R-452A, R-422A, R-422D, R-417A). The emissions from stock totalled 7.31 t of HFCs (25.51 kt CO_2 eq).

The amount of refrigerants left in products at decommissioning amounted to 3.27 t (0.05 t of R-134a, 3.12 t of R-404A, 0.10 t of R-407C). The disposal emissions totalled 1.63 t of HFCs (6.24 kt CO_2 eq).

In 2020, total HFC emissions from industrial refrigeration amounted to 8.94 t (31.75 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 ± 91% which is in the same magnitude than in previous submission The uncertainty results from estimations in the determination of the total HFC stock. The reviews of the 2018 and 2020 submissions gave recommendation to improve accuracy and completeness of data collected for 2.F.1 subsector (I.7,2020 and I.7,2018) and in industrial refrigeration subsector. The collected activity data was more complete than for 2018 and therefore the estimated HFC quantity was smaller. The estimated stock comprises mainly from difference of the number of industries

[107] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

present (e.g in Food and Veterinary Board´s database) and the number of those which HFC amount is known. Low-GWP refrigerants were reported by 8 of 16 service companies. The amounts of R-407F, R-448A and R-449A sold in Estonia in 2020 were ca 5 tonnes more than filled into equipment according to the inventory. Possibly this could be an underestimation because of poor quality reports of the service companies.

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.

The uncertainty of the EF is not improved in comparison with previous submission. Only 10 service companies gave data on refilling but activity data from 16 service companies was used. The refilling data of the rest contributed to the uncertainty. The uncertainty of EF is 22.8%. The combination of this value with the UN of the respective emission factor (± 15%) results in the UN of emissions of ± 24.6%.

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

Stock and new equipment in 2019 have been recalculated. Some equipment was registered in the national database for F-gas equipment (FOKA) in 2020 and year of their installation year was 2019. The recalculations are in Table 4.17.

Table 4.17. Recalculation of 2019 year´s stock, new equipment, and emissions of industrial refrigeration

Submission	HFC-134a filled into new equipment, kt	HFC-134a in stock, kt	Emissions from HFC-134a filled into new equipment, kt	Emissions from HFC-134a in stock, kt	Emissions from HFC-134a filled into new equipment and from stock CO_2 eq. kt
2022	1.20	4.98	0.005995	0.74760	1.07764
2021	0.02	2.45	0.000100	0.36780	0.526097

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 and 2020 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 31.12.2020, 1 097 refrigerated vans and trucks and 1 790 refrigerated trailers were registered in Estonia. The number of trucks has decreased by 40% in comparison to 2019. The reason is that freight transport by road in 2020 was 18% less than in 2019[108]. 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 Road Administration provided a list of all vehicles registered at the end of 2019, subdivided into weight classes (N1, N2, and N3 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 N1 and half of class N2 according to 2001/16/EC) run R-134a and R-452A systems (average charge 2.0 kg/unit), bigger trucks (half of class N2 and class N3) 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[109]. 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.

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[108] Statistics Estonia
https://andmed.stat.ee/et/stat/majandus__transport__maanteetransport/TS51/table/tableViewLayout2
(06.12.2021)
[109] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

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 N1 and half N2: 2.0 kg; N3 and half weight class N2: 5.8 kg; trailers: 8.0 kg;
- Country-specific manufacturing emission factor: 1%;
- Country-specific operating emission factor: 30%;
- Country-specific disposal emission factor: 30%.

The total 2020 quantity of HFCs filled in the equipment of newly registered refrigerated vehicles in Estonia amounted 107.90 kg of R-404A, 319.55 kg of R-452A and 4.5 kg of R-134a. The 'manufacturing' emissions of these first fills were 1.08kg of 404A, 3.20 kg of R-452A and 0.045 kg of R-134a. The HFC stock in refrigerated vehicles amounted to 0.49 t of R-134a, 19.84 t of R-404A and 2.68 t of R-452A. The emissions from stock were 0.15 t of R-134a, 5.95 t of R-404A and 0.81 t of R-452A. The amount of refrigerant left in products at decommissioning amounted to 1.42 t of R-404A and 0.13 t of R-134a. The disposal emissions were 0.04 t of R-134a and 0.43 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 7.14 t (27.01 kt CO_2 eq.) in 2020.

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 0.097% in 2020, thus Estonian reefer containers constituted 0.097% 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[110];
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%[111]. 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[112]. 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 2020 the HFC stock in reefer containers amounted to 7.16 t of R-134a and 1.406 t of R-404A. The 2020 HFC stock emissions from reefer containers attributable to Estonia were 0.72 t of R-134a and 0.14 t of R-404A. In 2020, 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 1.01 t (1.847 kt CO_2 eq.) in 2020.

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%).

[110] https://www.worldcargonews.com/in-depth/in-depth/lessors-maintain-a-positive-mood (16.11.2021).
[111] 2002 report of the refrigeration, air conditioning and heat pump technical options committee (RTOC). https://wedocs.unep.org/handle/20.500.11822/7796, (22.12.2020).
[112] IPCC 2006 Guidelines, Volume 3, Chapter 7.5.2.2 "Choice of emission factors" and 7.5.2.3 "Choice of activity data"

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%.

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 emissions for the years 2017-2019 have been recalculated because more accurate source data – number of reefer containers – became available. The recalculations are in Table 4.18.

Table 4.18. Recalculation of 2017-2019 years´ emission from reefer containers

Emissions and year	2021 submission	2022 submission	Difference between 2022 and 2021 submissions
2017; emissions of R-404A from reefers	0.1374	0.1383	0.0035
2017; emissions of R-134a from reefers	0.6304	0.6359	0.0079
2017; emissions from Transport refrigeration, CO_2 eq. kt	25.6809	25. 6923	0.0114
2018; emissions of R-404A from reefers	0.1318	0.1368	0.0051
2018; emissions of R-134a from reefers	0.5850	0.6154	0.0304
2018; emissions from Transport refrigeration, CO_2 eq. kt	29. 2960	29.3594	-0.0634
2019; emissions of R-404A from reefers	0.14068	0.14860	0.0079
2019; emissions of R-134a from reefers	0.6272	0.67670	0.0495
2019; emissions from Transport refrigeration, CO_2 eq. kt	29.2454	29.3472	0.1018

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 2020, there were 624 614 passenger cars in the traffic register kept by Estonian Road 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 M1 and N1 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 HFC-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 HFC-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 Road Administration provided a list of all passenger cars registered at the end of 2020, subdivided into production years (dating back to 1994 and beyond). In 2020 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 review of 2020 submission asked in question I.6 if such time series with German data until 2015 and Estonian data in 2016-2018 is consistent. 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)[113], 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.[114]

The method used for calculations is the Tier 2 according to the IPCC 2006 Guidelines[115] 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 80.05 t in the year 2020. The HFC-134a emissions from the Estonian passenger car fleet in 2020 totalled 8.00 t (10%) (11.45 kt CO_2 eq.).

The amount of HFC-134a in the passenger cars MACs disposed in 2020 was estimated at 6.16 t (8.81 kt CO_2 eq). Disposal emissions from the Estonian passenger car fleet in 2020 totalled 3.08 t (EF=50%), the CO_2 equivalent of which was 4.40 kt.

Total MAC HFC emissions from passenger cars in 2020 amounted to 11.08 t (15.85 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 ± 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.

[113] 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.
[114] 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.
[115] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

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 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 2020, there were about 104 915 trucks of the weight classes (according to 2002/16/EC) N1, N2, and N3 in the national vehicles' registry of Estonia (including vehicles with suspended registry entry), more than a half of which are newer than 12 years (their approximate lifetime). In comparison to 2019 the number of trucks has decreased by 20%. The reason is that freight transport by road has decreased by 30% in the first half in 2020[116] which was probably caused by restrictions due to the coronavirus.

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 Road Administration provided a list of all trucks registered at the end of 2020, subdivided into weight classes (N1, N2, and N3), 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 N1, N2, and N3 trucks in the country. The same truck models as in Germany were identified in the Estonian truck park for each weight category (N1, N2, N3). 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 N1, N2 and N3 trucks in Estonia result from the

[116] https://www.logistikauudised.ee/uudised/2020/12/04/kaubaveod-maanteedel-vahenesid-esimesel-poolaastal-ligi-kolmandiku (10.01.2022)

extrapolation of model values according to the share that these models have in the total Estonian fleet, by the three different weight classes N1, N2 and N3.

In 2020, Estonian specific data on A/C charges and quota of N2 and N3 category vehicles was collected from Estonian truck sellers and used in calculation. None of the N1 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 N1: 0.77 kg; weight class N2: 0.91 kg; and weight class N3: 0.91 kg.
- Emission factors (Schwarz, 2007)[117]: weight class N1: 10%; weight classes N2 and N3: 15%, which are likewise in accordance with the IPCC 2006 Guidelines and the IPCC Good Practice Guidance[118].
- 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[119] estimates of recovery efficiency and estimates from service companies.

In 2020, the total R-134a stock in truck MACs in Estonia amounted to 23.24 t and R-134a emissions from the Estonian truck fleet totalled 2.83 t (4.04 kt CO_2 eq.).

The amount of R-134a in the truck MACs disposed of in Estonia in 2020 was estimated at 1.79 t. Disposal emissions from the Estonian truck fleet in 2020 totalled 0.89 t (EF=50%), the CO_2 equivalent of which is 1.28 kt.

Total MAC HFC emissions from trucks in 2020 amounted to 3.72 t (5.32 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.

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[117] 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).

[118] IPCC 2000 Good Practice Guidance and Uncertainty Management, Chapter 3, table 3.23, page 3.110.

[119] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

Category-specific recalculations

No category-specific recalculations have been done.

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.1.5.3. Buses

Source category description

In 2020, 5 235 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 Road Administration provided a list of all buses registered at the end of 2019 (M3 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)[117] in consequence of the extensive importation of second-hand vehicles from there.

Method according to the IPCC 2006 Guidelines[120]: *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.

[120] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.52, table 7.9.

- 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 13.93 t in the year 2020. The operating emissions from the Estonian bus fleet in 2020 totalled 2.49 t of R-134a, the CO_2 equivalent of which was about 3.56 kt).

The amount of HFC-134a in the bus MACs disposed of in 2020 was estimated at 1.07 t. Disposal emissions from the Estonian bus fleet in 2020 totalled 0.54 t (EF=50%), the CO_2 equivalent of which is 0.77 kt.

Total MAC HFC emissions from buses in 2020 amounted to 3.03 t (4.33 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 ± 8.7%, 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 2020 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 13. 30 t (12.73 t of HFC-s), thereof 4.30 t of R-134a; 3.01 t of R-407F; 1.95 t of R-507A, 1.5 t of R-442A, 1.58 t of R-407C, 0.66 t of R-404A 0.1 t of R-434A, 0.38 t R-438A, 0.02 t of R-427A, 0.08 t of R-417A.
- Country-specific stock emissions (refills) totalled 3.97 t, which is 30% 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 2020 there was no decommissioning.

In 2020, the total MAC HFC emissions from ships amounted to 3.78 t (8.57 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 2020, there were 183 railcars and engines in the Estonian fleet equipped with a working air conditioner. All railcars were purchased as new in 2013–2017. All were for domestic transport.

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 all three local rail operators involved in passenger transport were interviewed in 2020. Dining cars, sleeping cars and coaches of international trains (historically) had much higher refrigerant charges (30 kg) than standard cars (average 11.09 kg). The average charge in engines MAC is 1.30–1.67 kg. An old MAC system can release 20 grams of refrigerant per operating hour, but the refilling rate of newer cars is much lower.

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 1.30–1.67 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 0.31% for all railcars in 2020, which is in accordance with the IPCC Good Practice Guidance[121].

The total HFC-134a stock in railcar MACs in Estonia amounted to 1.42 t in 2020.

Total MAC HFC emissions from railcars in 2020 amounted to 4.4 kg (0.006 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 2020 (± 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.

[121] IPCC 2006 Good Practice Guidance, Chapter 3, page 3.110, table 3.23.

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 2020, there were 26 775 wheel-tractors and 8 719 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.

Methodological issues

The Estonian Road Administration provided a list of all wheel tractors and mobile machinery registered at the end of 2020. 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 2020. 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/year, roadwork machines 1.0 kg/year, wheel tractors 1.25 kg/year, forestry machines 2.3 kg/year and combine harvesters: 2.2 kg/year.
- 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 2020, the total HFC-134a stock in tractor and mobile machinery MACs in Estonia amounted to 16.36 t. The HFC-134a emissions from the entire Estonian fleet totalled 3.45 t (21.07%), the CO_2 equivalent of which is about 4.93 kt.

The amount of HFC-134a in the tractor/mobile machinery MACs disposed of in 2020 was estimated at 1.45 t. Disposal emissions from the respective Estonian fleet totalled 0.29 t (EF=20%), the CO_2 equivalent of which is 0.42 kt.

In 2020, the total MAC HFC emissions from wheel tractors and mobile machinery amounted to 3.74 t (5.35 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

No category-specific recalculations have been done.

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 2020, 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 2020. 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 2020, the stock of installed heat pumps in Estonia amounted to approximately 180 114 systems (18 335 ground, 13 947 water, 146 800 air and 1032 other heat pumps) out of which 14 594 were installed in 2020. 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[122] and the IPCC Good Practice Guidance[123]. 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 2020, no heat pumps were manufactured and filled with refrigerant in Estonia. In 2020, operating stock amounted to 38.73 t of R-407C (ground and other HP), 146.54 t of R-410A and 28.16 t of R-32 (air HP). Respective operating emissions totalled 0.97 t of R-407C, 3.66 t of R-410A and 0.50 t of R-32. The amount of refrigerant in HP at decommissioning was 0.88 t of R-407C and 0.70 t of R-410A. Disposal emissions in 2020 totalled 0.34 t of R-407C and 0.45 t of R-410A.

Total HFC emissions from heat pumps in 2020 amounted to 5.78 t (10.66 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%.

[122] IPCC 2006 Guidelines, Volume 3, chapter 7, page 7.52, table 7.9.
[123] 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

2020 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 2020 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: 1 826 chillers, 6 295 ventilation systems and 28 505 split systems. The EF_{manu} (first filling loss) was established at 20g/system for chillers (0.019%) and 40g/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[124]. 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.

[124] 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 2020 were: 0.006 t of R-134a, 0.02 t of R-32 and 0.06 t of R-125.

The operating stock in 2020 amounted to 138.45 t of R-134a, 72.61 t of R-32 and 60.91 t of R-125 and operating emissions were: 3.22 t of R-134a, 3.95 t of R-32 and 3.96 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 2020 were: 1.57 t of R-134a, 0.50 t of HFC-32 and 0.54 t of HFC-125.

Total HFC emissions from stationary and room air-conditioning in 2020 amounted to 13.76 t (25.77 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 2020, 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%[125].

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[126] 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 2020 Estonian HFC-134a bank in PU insulation panels amounted to 14.33 tons, the annual use-phase emissions were 0.07 tons (0.10 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.

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[125] 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.

[126] 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[127]. 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 2020, the stock constituted of 0.29 t of HFC-365mfc, 0.04 t of HFC-227ea and 0.03 t of HFC-134a. Stock emissions were: 2.87 kg HFC-365mfc, 0.35 kg HFC-227ea and 0.28 kg HFC-134a.

Total HFC emissions from Spray and injection PU foam in 2020 amounted to 0.0035 t (0.0038 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 2017-2019 have been recalculated because new data on HFC-containing spray foam sold in Estonia was obtained from a survey. Amounts of HFC-365mfc and HFC-227ea and emissions are in the Table 4.19.

Table 4.19. Recalculation of amounts of HFC-s containing in spray foams sold in Estonia in 2017-2019 and emissions from them.

	2017	**2018**	**2019**
HFC-365mfc in new products, 2021 submission, t	-	-	-
HFC-365mfc in new products, 2022 submission, t	0.05394	0.05394	0.05394
HFC-227ea in new products, 2021 submission, t	-	-	-
HFC-227ea in new products, 2022 submission, t	0.00174	0.00174	0.00174
HFC-365mfc in stocks, 2021 submission, t	0.252434	0.24991	0.247411
HFC-365mfc in stocks, 2022 submission, t	0.295586	0.293062	0.290131

[127] 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).

	2017	2018	2019
HFC-227ea in stock, 2021 submission, t	0.031915	0.031596	0.03128
HFC-227ea in stock, 2022 submission, t	0.033307	0.03438	0.035428
Emissions from HFC-365 mfc and HFC-227ea containing spray foams CO2 eq. kt, 2021 submission	0.003032	0.003002	0.002972
Emissions from HFC-365 mfc and HFC-227ea containing spray foams CO2 eq. kt, 2022 submission	0.012718	0.01312	0.013131

Category-specific planned improvements

There are no planned category-specific improvements.

4.6.2.1.3. XPS insulation foam

Source category description

The 2020 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%;
- 2020 HFC-134a bank: 7.90 t;
- 2020 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 *ca* 5 million of 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: 1.55 t of R-152a (0.19 kt CO_2 eq.);
- Stock = use-phase emissions: 8.77 t of HFC-152a (1.09 kt CO_2 eq.).

Total HFC emissions from One component PU foams in 2020 amounted to 10.33 t (1.28 t CO_2 eq.). This is ca 30% less than in 2019 because Estonian consumers preferred HFC free foams.

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[41] 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 2010–2020, 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[128]. 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.

[128] IPCC 2006 Guidelines, Volume 3, Chapter 7, page 7.33.

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 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 choicefor 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 2020 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 2020 quantity of F-gases in installed firefighting systems amounted to 32.94 t (24.49 t of HFC-227ea, 2.88 t of HFC-23 and 6.05 t of R-866 (FS49C2), the latter containing 8% CO_2 in mixture with HFC-134a and HFC-125). The emissions from this stock are calculated with 2%: 0.057 t of R-23, 0.01 t of R-125, 0.10 t of R-134a and 0.490 t of R-227ea.

Total HFC emissions from Fire protection in 2020 amounted to 0.66 t (2.61 kt CO_2 eq.).

4.6.3.3. Uncertainties and time-series consistency

In Estonia, the total 2020 quantity of F-gases in installed firefighting systems amounted to 32.35 t (23. 90 t of HFC-227ea, 2.88 t of HFC-23 and 6.05 t of R-866 (FS49C2), the latter containing 8% CO_2 in mixture with HFC-134a and HFC-125). The emissions from this stock are calculated with 2%: 0.048 t of R-23, 0.01 t of R-125, 0.10 t of R-134a and 0.490 t of R-227ea.

Total HFC emissions from Fire protection in 2020 amounted to 0.59 t (2.58 kt CO_2 eq.).

4.6.3.4. 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.

4.6.3.5. Category-specific recalculations

Quantities in stock in 2013-2019 have been recalculated because two service companies reported equipment previously not known. This equipment came to their service in 2013-2019 but were not newly installed. There is no information when this equipment was installed but it is known in which year the equipment came to the service. The recalculations are in Table 4.20.

Table 4.20. Recalculations of fire protection F-gases and emissions in 2013-2019

Year	HFC-227ea stock in 2021 submission t	HFC-227ea stock in 2022 submission t	HFC-23 stock in 2021 submission t	HFC-23 stock in 2022 submission t	R-866 (GWP 1522.6) stock in 2021 submission t	R-866 (GWP 1522.6) stock in 2022 submission t	Emissions from stock (2%) in 2021 submission CO_2 kt	Emission from stocks (2%) in 2022 submission CO_2 kt	Difference in emissions CO_2 kt
2019	21.952	25.426	2.401	3.108	5.467	6.246	2.2910	2.7476	0.4567
2018	25.640	27.137	2.287	3.163	5.528	6.946	2.4965	2.8953	0.3989
2017	25.714	27.211	2.994	3.163	6.453	7.846	2.7386	2.9275	0.1889
2016	25.381	26.561	3.055	3.227	6.571	7.225	2.7388	2.8859	0.1468
2015	25.768	26.815	3.117	3.246	6.705	7.359	2.7862	2.9118	0.1255
2014	24.496	24.496	3.117	3.246	6.705	7.115	2.7044	2.7550	0.0507
2013	23.626	24.535	2.885	2.885	6.45	6.860	2.5719	2.6430	0.0710

4.6.3.6. 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 2018). Use-phase emissions: The number of MDIs for both anti-asthma and natural medicines sold to the domestic market–in 2020 (production + import - export) is the stock of the same year 2020. 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 2020 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 2020 the amount of HFC-134a used in domestic production was 1.15 t , of which 3% were manufacturing emissions (0.04 t or 0.05 CO_2 eq. kt). 100% of the products (1.12 kt of HFC) was sold to the domestic market, resulting in use-phase emissions of the same amount (1.60 kt CO_2 eq).
- Anti-Asthma MDIs: The 2020 domestic market was 1.14 t of HFC-134a with the same quantities of emissions. The emissions of CO_2 eq. are 1.63 kt. There were no HFC-227ea containing MDI-s on Estonian market in 2020 and that is reason why emissions are ca 30% lower than in 2019.

Total HFC emissions from Metered-dose inhalers in 2020 amounted to 2.29 t (3.28 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

No category-specific recalculations have been done.

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 tyres (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.

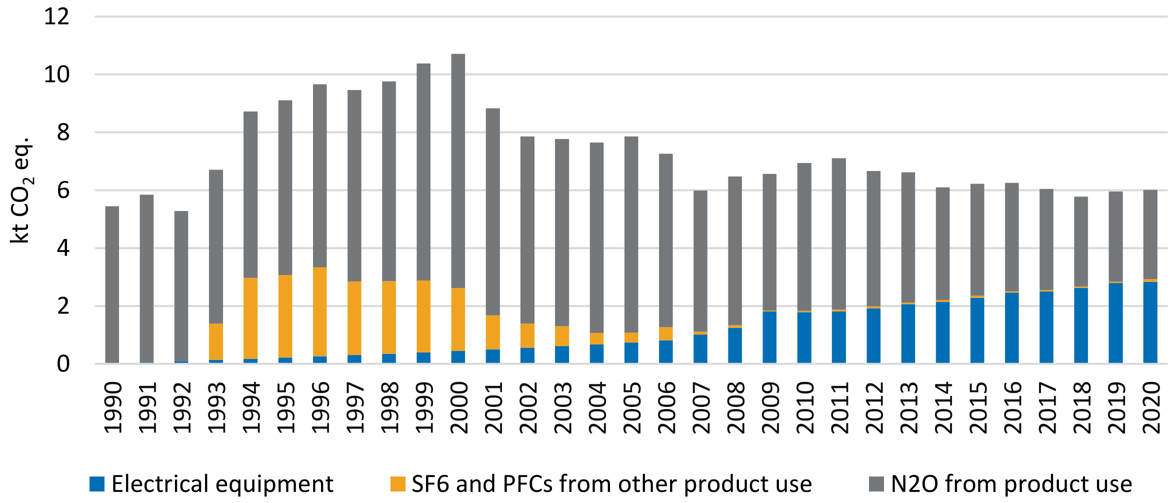

Figure 4.7. Emissions from Other product manufacture and use in Estonia in 1990–2020, kt CO_2 eq.

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) 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[129].

In 2020, total stock in operating systems amounted to 30.63 t of SF_6. Manufacturing emissions amounted to 0.333 kg. Total emissions from stock were 0.12 t. 0.080 t of SF_6 was disposed and emissions from it were 0.0016 t in 2020.

Total emissions from switchgear in 2020 were 0.13 t of SF_6 which is 2 837.86 t (or 2.84 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

[129] 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)

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

One of electrical network operators (owner of medium-voltage equipment) has applied a new method accounting SF_6 in their equipment. The amounts of SF_6 in stock (specifically medium-voltage switchgear) have been recalculated from 1999 to 2019. Also, the amounts of SF_6 filled into (medium voltage) new equipment have been recalculated from 1998-2007. The emission factors for 2008-2009 were found to be different from the rest on the time series in the previous submission and in this submission the emissions were recalculated with the same EF-s as before and after these years.

The recalculations are in Table 4.21.

Table 4.21. Recalculations of SF_6 in medium-voltage equipment and filled into new equipment in 1998-2019.

Year	SF_6 stock in MV equipment, kt 2021 submission	SF_6 stock in MV equipment, kt 2022 submission	Emissions from MV equipment CO_2 eq. kt 2021 submission	Emissions from MV equipment CO_2 eq. kt 2022 submission	SF_6 filled into new equipment, t 2021 submission	SF_6 filled into new equipment, t 2022 submission	Emission from filling into new equipment, CO_2 kt 2021 submission	Emission from filling into new equipment, CO_2 kt 2022 submission	Total SF_6 emissions CO_2 eq. t 2021 submission	Total SF_6 emissions CO_2 eq. t 2022 submission
1998	0.0000	0.0000	0.0000	0.0000	0.2642	0.6642	0.0060	0.0151	0.3433	0.3525
1999	0.0028	0.0040	0.0062	0.0091	0.5319	0.3142	0.0121	0.0072	0.3977	0.3958
2000	0.0055	0.0085	0.0122	0.0194	0.5319	0.3142	0.0121	0.0072	0.4460	0.4482
2001	0.0083	0.1350	0.0183	0.0308	0.5319	0.3311	0.0121	0.0075	0.4942	0.5021
2002	0.0112	0.0192	0.0255	0.0437	0.5319	0.2973	0.0121	0.0068	0.5436	0.5565
2003	0.0139	0.0252	0.0317	0.0574	0.5319	0.4621	0.0121	0.0105	0.5920	0.6161
2004	0.0167	0.0332	0.0380	0.0756	0.5319	0.3061	0.0121	0.0070	0.6404	0.6729
2005	0.0199	0.0416	0.0452	0.0947	0.5319	0.3061	0.0121	0.0070	0.6898	0.7342
2006	0.0220	0.0495	0.0502	0.1129	0.5276	0.8924	0.0120	0.0203	0.7368	0.8079
2007	0.0249	0.0577	0.0749	0.1316	0.5947	2.7318	0.0136	0.0623	0.8946	1.0073
2008	0.0307	0.0688	0.3504	0.1569	2.3144	2.3144	0.0528	0.0528	1.2499	1.4057
2009	0.0365	0.0772	0.4164	0.1761	1.3508	1.3508	0.0308	0.0308	1.3388	1.4551
2010	0.0393	0.0855	0.0900	0.1949	1.6236	1.6236	0.0370	0.0370	1.6826	1.7880
2011	0.0441	0.0903	0.1000	0.2058	0.3820	0.3820	0.0087	0.0087	1.7035	1.8089
2012	0.0508	0.0970	0.1160	0.2211	1.0208	1.0208	0.0233	0.0233	1.8188	1.9242
2013	0.0532	0.0995	0.1210	0.2267	0.8340	0.8340	0.0190	0.0190	1.9533	2.0587
2014	0.0571	0.0104	0.1302	0.2361	0.4800	0.4800	0.0109	0.0109	2.0361	2.1420
2015	0.0641	0.0111	0.1460	0.2520	0.7670	0.7670	0.0175	0.0175	2.1804	2.2862
2016	0.0711	0.1205	0.1620	0.2748	1.0190	1.0190	0.0232	0.0232	2.4854	2.5982
2017	0.0796	0.1261	0.1815	0.2874	0.2430	0.2430	0.0055	0.0055	2.3998	2.5057
2018	0.0850	0.1314	0.1938	0.2996	0.4590	0.4590	0.0105	0.0105	2.5203	2.6262
2019	0.0979	0.1426	0.2230	0.3251	0.6350	0.6350	0.0145	0.0145	2.6956	2.7975

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 2020 stock of SF_6 totalled 36.6 kg, with 2020 operating emissions of 3.71 kg. There were no emissions from disposal, as no equipment was decommissioned in 2020.

Emissions from accelerators totalled 3.71 kg (or 0.085 kt) CO_2 equivalent in 2020.

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

No recalculations were made.

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[130] 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%).

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.

[130] IPCC 2006 Guidelines, Volume 3, Chapter 8, page 8.31.

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 2020. Activity data for 1990–1991 were 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[131], 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 2020 was 8.52 t (2.54 kt CO_2 eq.).

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.

4.7.3.1.5. Category-specific recalculations

No category-specific recalculations have been done.

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.

[131] IPCC 2006 Guidelines, Volume 3, Chapter 8, page 8.36.

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 2007–2020. The total quantity of N_2O supplied to the Estonian market was asked from the distributors of N_2O products. In 2020, 127 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 2020 was 0.00185 kt (0.552 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 are 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 March 2022 submission emissions are based on the data reported in NEC/CLRTAP inventories by the Estonian Environment Agency (EstEA). Since the NEC/CLRTAP inventories must be submitted by 15.02.2022 the emissions for 15th January GHG inventory submission were calculated by EERC. 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.[132]

Activity data for the years 1990–1994 is obtained from the annual proceeding of Statistics Estonia ‘Industry’ and for the years 1995–2020 from the electronic database on the website of Statistics Estonia.

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.

[132] EMEP/EEA air pollutant emission inventory guidebook 2019. [www] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019 (06.12.2021).

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 were 1 508.38 kt CO_2 eq. in 2020 in Estonia. The sector contributed about 13.1%[133] to the total CO_2 eq. emissions in Estonia (Figure 5.1). In 2020 the emissions from Enteric fermentation decreased by 0.6% compared to the previous year while the emissions from Manure management increased by 4.4%, mostly due to the growing share of cattle and swine manure stored in liquid systems. 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. However, compared to 2018 the number of swine increased by 8.3% in 2020. The increase in the number of livestock is caused by the improved economic situation. Also, a high demand for pork as the most popular meat in Estonia has helped, to some extent, to recover the number of swine after the low point that started after the African swine fever in 2015.

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).

[133] GHG emissions related to the LULUCF sector are not included.

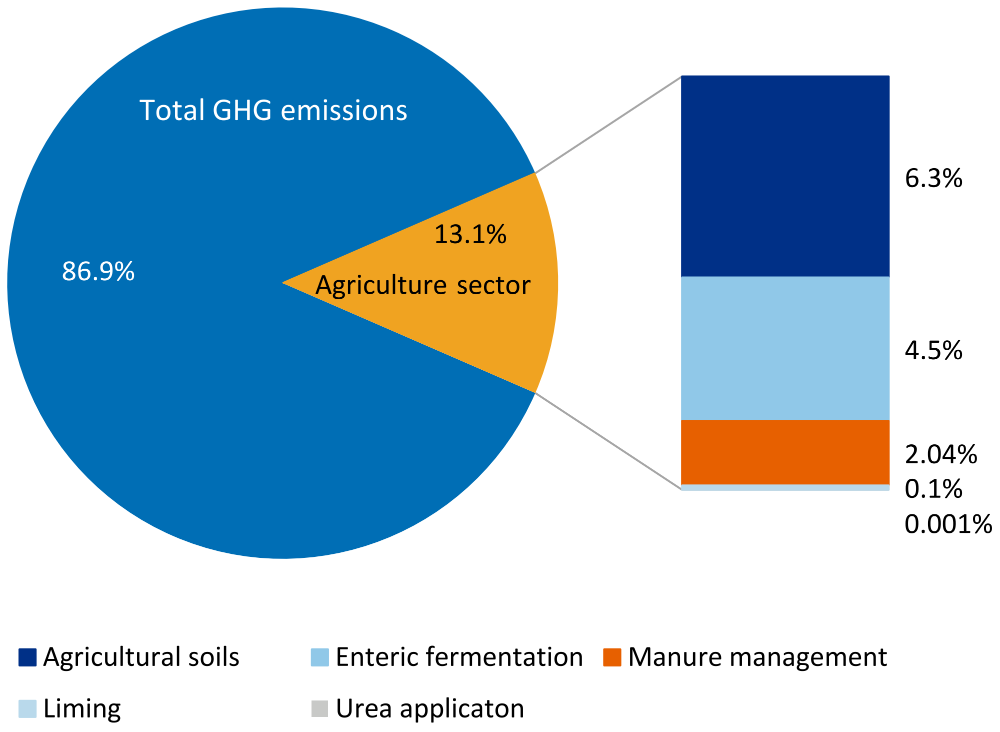

Figure 5.1. Emissions from the Agriculture sector compared to the total CO_2 eq. emissions in 2020, %

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. 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%[134].

[134] 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).

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[135]. 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 4% in 2020 compared with the base year (i.e. 1990), mostly due to a decrease in the livestock population and quantities of synthetic fertilizers and manure applied to agricultural fields.

Table 5.1. Estonia's agricultural GHG emissions by sources in 1990–2020, kt

Year	Enteric fermen-tation	Manure management		Agricultural soils	Liming	Urea application	Total GHG emissions			Total CO_2 eq. emissions
	CH_4	CH_4	N_2O[136]	N_2O[137]	CO_2	CO_2	CH_4	N_2O	CO_2	CO_2 eq.
1990	49.11	6.58	0.37	3.73	12.11	1.00	55.69	4.10	13.11	2 628.34
1995	26.53	3.33	0.20	1.82	3.59	0.64	29.86	2.01	4.23	1 350.11
2000	20.16	2.43	0.15	1.65	19.41	0.43	22.59	1.8	19.85	1 122.23
2005	20.68	3.43	0.18	1.70	7.22	1.41	24.11	1.88	8.63	1 172.06
2010	20.45	4.67	0.21	1.86	9.37	0.01	25.12	2.07	9.37	1 253.80
2011	20.63	4.92	0.21	1.92	3.93	0.01	25.55	2.13	3.94	1 277.57
2012	21.37	5.31	0.21	2.09	6.98	0.03	26.67	2.3	7.01	1 359.61
2013	22.47	5.68	0.22	2.07	6.11	0.37	28.15	2.29	6.47	1 391.84
2014	22.65	5.97	0.22	2.18	8.64	0.02	28.62	2.4	8.67	1 437.90
2015	20.8	5.28	0.22	2.29	9.04	0.03	26.08	2.51	9.07	1 408.52
2016	20.48	5.25	0.22	2.17	14	0.03	25.72	2.39	14.03	1 369.13
2017	20.76	5.7	0.23	2.27	16.3	0.10	26.45	2.49	16.4	1 420.76
2018	20.79	5.98	0.23	2.22	19.27	0.13	26.77	2.45	19.41	1 417.62
2019	21.07	6.22	0.24	2.46	15.46	0.13	27.29	2.7	15.6	1 501.48
2020	20.94	6.52	0.24	2.46	15.73	0.13	27.46	2.7	15.86	1 508.38

[135] Estonian Universtity of Life Sciences. (2011). Maaelu arengu aruanne. Tartu: AS Ecoprint, lk 86.
[136] N_2O emissions include Indirect N_2O emissions from the Manure management category.
[137] N_2O emissions include Indirect N_2O emissions from the Agricultural soils category.

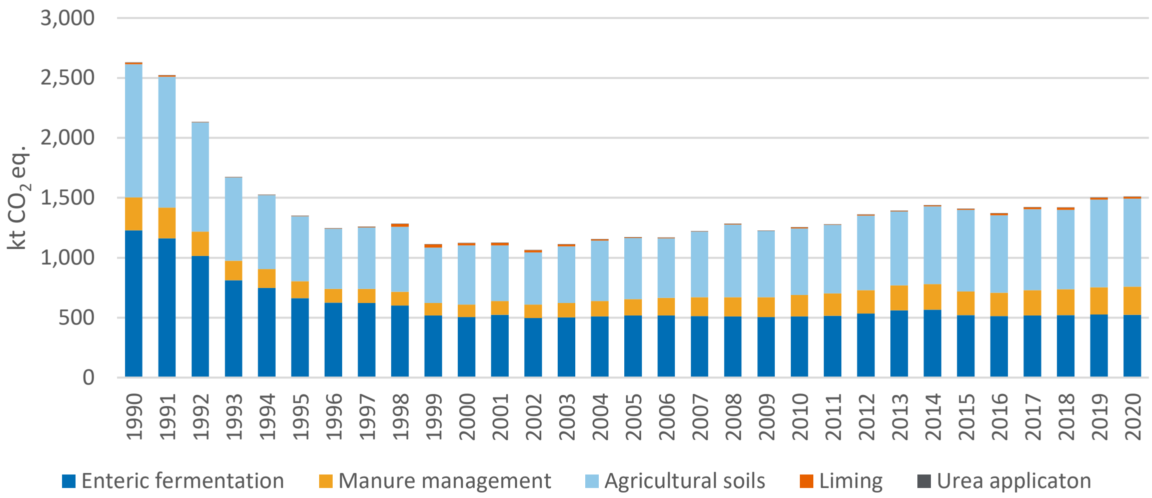

Figure 5.2. Trends in emissions by categories in Estonia in 1990–2020, kt CO_2 eq.

The following is a short overview of the results in the nitrogen balance in Estonia in 2020. The total amount of nitrogen excreted with manure was 21 901 tonnes in 2020. The total nitrogen that volatilized from manure management as NH_3 and NO_3 was 4 021 tonnes. The total nitrogen from nitrogen leaching and run-off from manure management was 48 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 41 486 tonnes and from crop residues 33 497 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 8 299 tonnes. The total nitrogen from nitrogen leaching and run-off from agricultural soils were 28 721 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 and swine;
- CH_4 emissions from manure management of cattle and swine;
- N_2O emissions from manure management of cattle, swine and sheep;
- 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 2020 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3 and Annex 1.

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).
	www.stat.ee	- collection and reporting of data on livestock population;

References	Link	Data, activity
Statistics Estonia – Agricultural Statistics (SE)		- 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.
Estonian Agricultural Board	http://www.pma.agri.ee	- sales records of urea and lime fertilizers
Nitrofert Ltd.	-	- plant-specific activity data on urea fertilizers produced in Estonia

5.1.2. Livestock characterization

Livestock population decreased by 2020 in comparison with the base year (Figure 5.3): the number of dairy cattle decreased by 70%, i.e. from 280.7 thousand heads to 84.3 thousand heads (Figure 5.3, Figure 5.4), the number of non-dairy cattle decreased from 475.2 thousand heads in 1990 to 169 thousand heads in 2020 (Figure 5.3, Figure 5.5). The total number of swine decreased by 63%, i.e. from 859.9 thousand heads in 1990 to 316.8 thousand heads in 2020 (Figure 5.3, Figure 5.6). The number of horses decreased from 8.6 thousand heads in 1990 to 5.7 thousand heads in 2020 – by 34%. The number of sheep decreased by 53% – from 158.5 thousand heads in 1990 to 75.3 thousand heads in 2020 (Figure 5.3). However, the population of goats increased from 2.1 thousand heads to 5.0 thousand from 1990 to 2020 (Figure 5.3). The poultry population decreased 55% by 2020 compared to the base year – from 5 597.2 thousand heads in 1990 to 2 536.8 thousand heads in 2020.

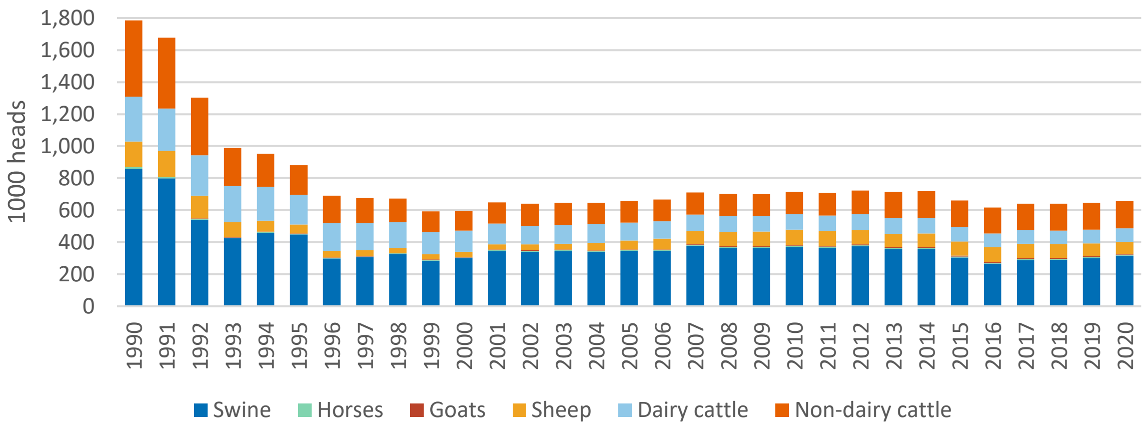

Figure 5.3. Population of livestock in Estonia in 1990–2020 (December 31st), 1000 heads

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 was reported by SE (bovine animals, mature males, and 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 5.5. The number of non-dairy cattle reported in the CRF tables (Figure 5.5, Annex A.3.2_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.

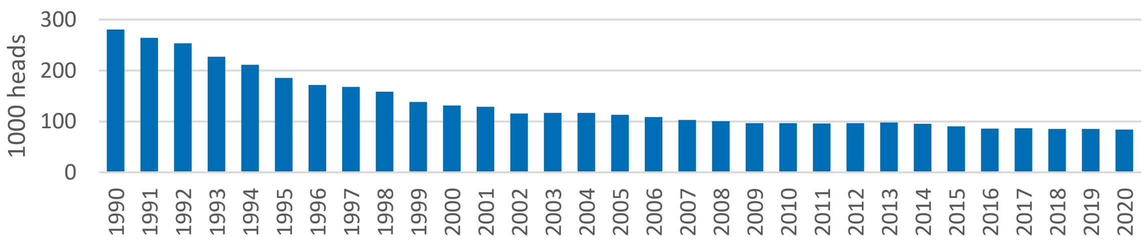

Figure 5.4. Population of dairy cattle in Estonia in 1990–2020 (December 31st), 1000 heads

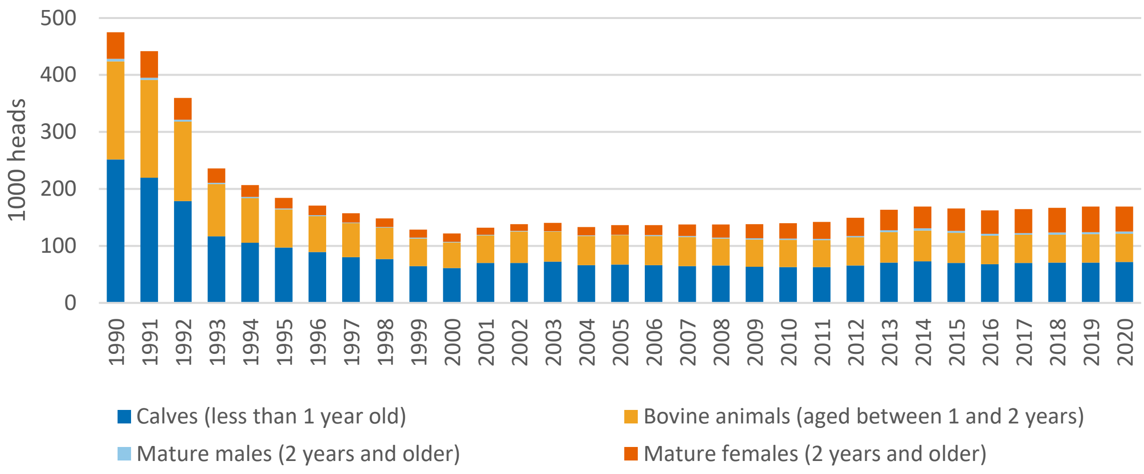

Figure 5.5. Population of non-dairy cattle in Estonia in 1990–2020 (December 31st), 1000

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 5.6, Annex A.3.2_I.2).

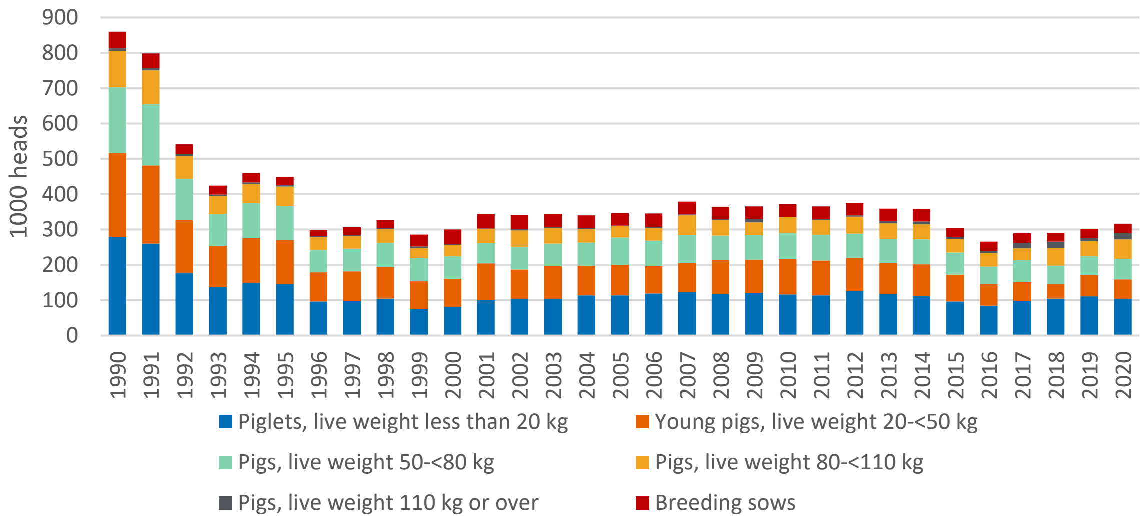

Figure 5.6. Population of swine in Estonia in 1990–2020 (December 31st), 1000 heads

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.[138]. During

[138] Saveli, O. (2004). Fur farming of Estonia. Animal Breeding in Estonia. Tartu: Paar OÜ.

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[139]. Nowadays, a major share of the production of Estonian fur farming is exported[140]. Fur farming will be banned in Estonia by 2026.

The activity data used in the estimations in the 2020 submission 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 2022 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[141]. 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.

The annual average livestock populations reported in the CRF tables, and their trends are provided in Table 5.4.

[139] Riigi Teataja. Nõuded karuslooma pidamise ja selleks ettenähtud ruumi või ehitise kohta. [www] https://www.riigiteataja.ee/akt/13356899?leiaKehtiv (20.12.2021).
[140] 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).
[141] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, p 10.8.

Table 5.4. The number of livestock population in Estonia in 1992–2020, in accordance with SE (as of 31 December) and FAO datasets, 1000 heads[142]

Year	Cattle		Pigs		Sheep		Goats		Horses		Poultry	
	SE	**FAO**	**SE**	**FAO**	**SE**	**FAO**	**SE**	**FAO**	**SE**	**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
2011	238.3	236.3	365.7	371.7	83.9	78.6	4.3	4.1	6.5	6.5	2 032.9	2 033
2012	246	238.3	375.1	365.7	76.8	83.9	4.6	4.3	6.2	6.5	2 170.9	2 005
2013	261.4	246	358.7	375.1	81.8	76.8	5	4.6	6.3	6.2	2 139.2	2 133
2014	264.7	261.4	357.9	358.7	85.2	81.8	4.6	5	6.3	6.3	2 339.6	2 084
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	5.7	NA	2 150.9	2 080
2020	253.3	253.3	316.8	316.6	75.32	NA	4.98	NA	5.7	NA	2 536.8	2 055

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 2007–2020. The data used in the calculations of the average yearly population of sheep and goats are presented in Annex A.3.2_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].

[142] 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. Crops and livestock products. [www] https://www.fao.org/faostat/en/#data/QCL (31.12.2021).

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[143] 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.3.2_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[144]. 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[145]. The average fertility rate for Ltd. Balti Kasrusnahk in 2005 was 3.8/litter[146]. 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.3.2_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 2020 another one was carried out. The mentioned surveys have covered only the number of breeding females in compliance with the EU regulation 2018/1091[147] or the respective earlier regulations.

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[143] Tikk, H., Tikk, V., Piirsalu, M., Hämmal, J. (2007). Linnukasvatus I. Tartu: OÜ Tartumaa Trükikoda, lk 32.
[144] Piirsalu, P. Minkide värvusmutandid ja nende kasvatamine. [www] http://www.eau.ee/~alo/karusloomad/mingid/?Minkide_sigimine/Poegimine (15.01.2022).
[145] Fur Institute of Canada. Fox farming. [www] https://fur.ca/fur-farming/fox-farming/ (15.01.2022).
[146] Piirsalu, P. Hõbe- ja sinirebaste värvusmutandid ja nende kasvatamine. [www] http://www.eau.ee/~alo/karusloomad/rebased/?Rebased (15.01.2022).
[147] 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[148]. 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 1990–2020, compiled by the EstEA. In the Agriculture sector, NO_x emission from Agricultural soils and NMVOC emissions from Manure management decreased by 45% and 54%, 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[149].

Table 5.5. NMVOC and NO_x emissions originating from the Agriculture sector in 1990–2020, kt

Year	NO_x	NMVOC
1990	4.53	10
1995	1.60	4.76
2000	1.55	3.42
2005	1.52	3.91
2010	1.92	3.94
2011	1.94	4.06
2012	2.13	4.18
2013	2.16	4.2
2014	2.25	4.44
2015	2.29	4.51
2016	2.30	4.17
2017	2.33	4.58
2018	2.39	4.71
2019	2.50	4.43
2020	2.49	4.57

148 Home page of Härma Küülikud. Küülikute hooldamisest ja pidamisest. [www] http://www.rabbitfarm.planet.ee/kasulikinfo.html (24.01.2022).
149 Estonian Environment Agency. Estonian Informative Inventory Report 1990–2019, Ch. 5 Agriculture (NFR 3).

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 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 2020 (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 2015–2020 compared to 2014 is the result of Russia's economic sanctions against the EU. The growth in CH_4 emissions in the recent years is the result of increased milk production per cow and the growing number of beef cattle. The number of the total CO_2 eq. emissions from enteric fermentation of Estonian livestock made up 35% of the total CO_2 eq. emissions from the Agricultural sector in Estonia in 2020. CH_4 emissions from enteric fermentation in 2020 were 57% lower than the emissions of the base year due to the decrease in the number of the livestock population (Table 5.6, Figure 5.7).

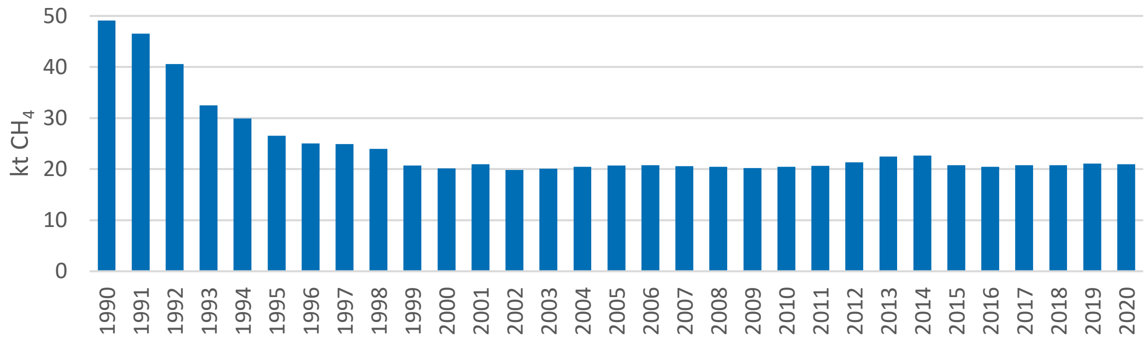

Figure 5.7. Enteric fermentation CH_4 emissions from Estonian livestock in 1990–2020, kt

Table 5.6. CH_4 emissions from Enteric fermentation by animal type in 1990–2020 in Estonia, kt

Year	Cattle	Swine	Sheep	Goats	Horses	Poultry	Rabbits	Fur animals	Total CH_4, kt
1990	46.77	0.89	1.27	0.01	0.15	NE	NE	0.02	49.11
1995	25.52	0.46	0.44	0.01	0.08	NE	NE	0.01	26.53
2000	19.46	0.34	0.27	0.02	0.08	NE	NE	0.01	20.16
2005	19.76	0.37	0.44	0.02	0.09	NE	NE	0.01	20.68
2010	19.13	0.40	0.77	0.02	0.12	NE	NE	0.01	20.45
2011	19.33	0.39	0.75	0.02	0.12	NE	NE	0.01	20.63
2012	20.09	0.40	0.73	0.03	0.11	NE	NE	0.01	21.37
2013	21.27	0.39	0.66	0.03	0.11	NE	NE	0.01	22.47
2014	21.42	0.39	0.69	0.02	0.11	NE	NE	0.01	22.65
2015	19.61	0.33	0.71	0.03	0.11	NE	NE	0.01	20.8

Year	Cattle	Swine	Sheep	Goats	Horses	Poultry	Rabbits	Fur animals	Total CH_4, kt
2016	19.32	0.29	0.73	0.03	0.10	NE	NE	0.01	20.48
2017	19.58	0.32	0.72	0.03	0.10	NE	NE	0.01	20.76
2018	19.64	0.33	0.69	0.03	0.10	NE	NE	0.0041	20.79
2019	19.97	0.32	0.65	0.03	0.10	NE	NE	0.0004	21.07
2020	19.85	0.36	0.60	0.02	0.10	NE	NE	0.0003	20.94

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 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. 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[150]

$$NE_{mj} = C_{f\ j} \times (weight_j)^{0.75}$$

Where:

NE_{mji} = net energy for maintenance by *j* category of cattle; MJ/head/day;
Weight = live weight of *j* category of cattle, kg.

[150] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.15, equation 10.3.

Equation 5.4[151]

$$Cf\ (in\ cold)\ = Cf_i +\ 0.0048 \times (20 - °C)$$

Where:

Cf = coefficient for calculating NE_m (Table 5.7);
°C = mean daily temperature during the winter season.

Table 5.7. C_f coefficient[152]

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[153]

$$NE_{aj} = C_a \times NE_{mj}$$

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[154]

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.

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151 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.13, equation 10.2.
152 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.16, table 10.4.
153 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.16, equation 10.4.
154 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.17, table 10.5.

Equation 5.6[155]

$$NE_g = 22.02 \times (\frac{BW}{C \times MW})^{0.75} \times WG^{1.097}$$

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;
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[156]

$$Ne_{li} = kg\_of\_milk/day_i \times (1.47 + 0.40 \times Fat_i)$$

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[157]

$$NE_{pregnancy} = C_{pregnancy} \times NE_m$$

Where:

$NE_{pregnancy}$ = net energy required for pregnancy, MJ/head/day;
$C_{pregnancy}$= pregnancy coefficient = 0.1[(158)];
NE_m= net energy required by the animal for maintenance, MJ/head/day.

155 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.17, equation 10.6.
156 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.18, equation 10.8.
157 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, equation 10.13.
158 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, table 10.7.

Ratio of net energy available in a diet for maintenance to digestible energy consumed

Equation 5.9[159]

$$REM = 1.123 - \left(4.092 \times 10^{-3} \times DE_{ji}\%\right) + \left(1.126 \times 10^{-5} \times \left(DE_{ji}\%\right)^2\right) - 25.4/DE_{ji}\%$$

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[160]

$$REG = 1.164 - \left(5.160 \times 10^{-3} \times DE_{ji}\%\right) + \left(1.308 \times 10^{-5} \times \left(DE_{ji}\%\right)^2\right) - 37.4/DE_{ji}\%$$

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[161]

$$GE = \frac{\left(NE_{mji} + NE_{feedji} + NE_{l} + NE_{workji} + NE_{pregnancyj}\right) \times \left(\frac{100}{DE_{ji}\%}\right)}{(NE/DE)_{ji} + \left(NE_{gji}/\{NE_g/DE\}_{ji}\right)}$$

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[162], 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, %.

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[159] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.20, equation 10.14.

[160] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.21, equation 10.15.

[161] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.21, equation 10.16.

[162] Net energy for work was not calculated.

Methane emission factor from the livestock category

Equation 5.12 [163]

$$EF = [GE \times Y_m \times (365 days/yr)]/[55.65 MJ/CH_4 kg]$$

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.3.2_III.1);

Milk production per day, kg/day – a source of data is SE (Annexes A.3.2_II.1-2);

Fat content of milk, % – data were obtained from EARC (Annexes A.3.2_II.3-4);

Percentage of cows that give birth in a year, % – data were employed from EARC (Annex A.3.2_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, %[164]

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[165], which

[163] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.31, equation 10.21..

[164] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.30, table 10.12.

[165] 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-

stipulate markedly lower methane emissions. Additionally, the consumption of milk (only) assumes zero methane emissions from the rumen[166]. 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[167]. 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 mean 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 2020, 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
Mature females (2 years and over)	58
Bovine animals (aged between 1 and 2 years)	63
Calves (6–12 months)	19
Calves (0–6 months)	3

The values of CH_4 EF have increased in the period of 1990–2020, mainly due to the increased milk production per cow (Table 5.11). Figure 5.8 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 1990–2020 (Annexes A.3.2_II.1–4, A.3.2_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	103
1995	559.2	4.08	3 588	236	98
2000	574.1	4.29	4 660	267	111
2005	588.7	4.21	5 886	300	125
2010	604.0	4.11	7 021	329	137
2011	607.1	4.10	7 168	333	139
2012	610.3	4.04	7 526	341	143
2013	613.4	4.00	7 990	353	147
2014	616.5	4.00	8 233	359	150
2015	619.5	3.98	8 442	341	143
2016	622.5	4.00	8 878	352	147
2017	625.5	3.94	9 159	358	150
2018	629.3	3.91	9 287	360	151

convention/greenhouse-gas-inventories/submissions-of-annual-greenhouse-gas-inventories-for-2017/submissions-of-annual-ghg-inventories-2012 (24.01.2022).

[166] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.30.

[167] Lehtsalu, S., Kaart, T., Kiiman, H. (2010). Lehmvasikate kasvatamine sündimisest seemendamiseni. Agraarteadus, 21 (1), lk 14–23.

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
2019	632.6	3.89	9 633	368	154
2020	635.9	3.89	9 943	367	153
IPCC default					
EE[168]	550[169]		2 555[169]		99[170]
WE	600		5 986		117

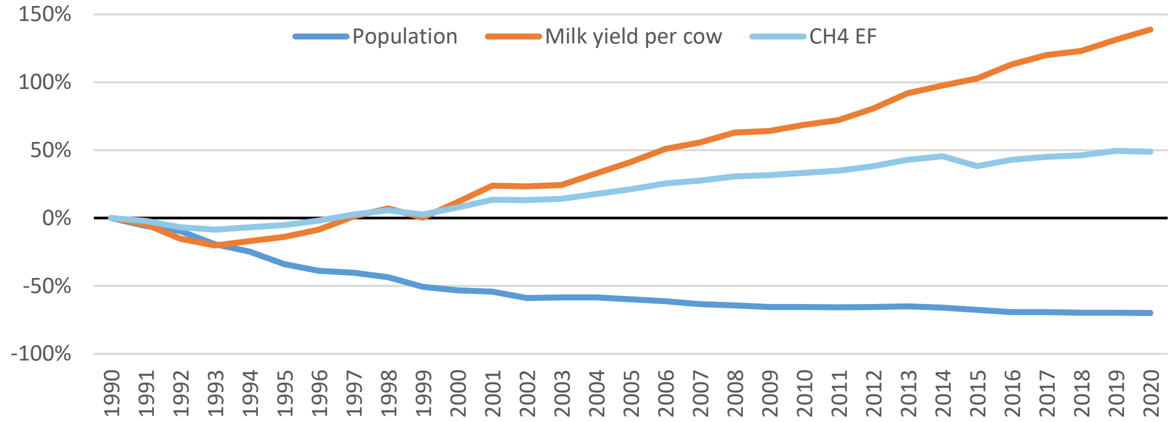

Figure 5.8. Changes in dairy cattle population, milk yield per cow and CH_4 EF in the period of 1990–2020 in relation to the base year (1990), %

5.2.2.2. Quantitative overview – CH_4 emissions from enteric fermentation of cattle in 2020

Total CH_4 emissions from cattle enteric fermentation were 19.85 kt in 2020. Dairy cattle livestock was the main contributor to CH_4 emissions from cattle enteric fermentation in Estonia in 2020 (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. The influence was apparent also in 2020. Consequently, the number of dairy cattle has dropped by 11.1% since 2014. 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 2nd place next to Denmark in Europe. CH_4 emissions from cattle enteric fermentation decreased by 57.6% in 2020 compared with the base year.

[168] EE – Eastern Europe, WE – Western Europe.
[169] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.72, table 10A.1.
[170] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.29, table 10.11.

Table 5.12. CH_4 emissions from Enteric fermentation of cattle in 1990–2020 in Estonia, kt

Year	Cattle[171]			Total, CH_4, kt
	Dairy cattle	Other mature cattle	Growing cattle	
1990	29.32	3.28	14.16	46.77
1995	18.65	1.31	5.56	25.52
2000	14.92	0.98	3.55	19.46
2005	14.43	1.06	4.27	19.76
2010	13.54	1.81	3.78	19.13
2011	13.67	1.95	3.72	19.33
2012	14.09	2.09	3.91	20.09
2013	14.71	2.36	4.20	21.27
2014	14.64	2.53	4.25	21.42
2015	13.17	2.53	3.91	19.61
2016	12.93	2.64	3.75	19.32
2017	13.17	2.68	3.73	19.58
2018	13.09	2.82	3.74	19.64
2019	13.34	2.87	3.76	19.97
2020	13.17	2.81	3.87	19.85

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 taken from the 2006 IPCC Guidelines; ratios of feed digestibility were obtained from a study by A. Kaasik[172].

Gross energy intake by swine

Equation 5.13[173]

$$GE_j = ME_j/(DE_j - Ym - UE)$$

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[174];

[171] 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.
[172] Kaasik, A. Report of the projekt „Kariloomade söödaplaanide uuring 1990–2020".
[173] 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.
[174] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.35, table A-4.

UE = urinary energy excretion, 2% for swine[175].

Equation 5.14[176]

$$ME_j = 2.0 \times w_j^{0.63}$$

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[177]

$$CH_4 Emission = EF_j \times population_j / (10^6 kg/Gg)$$

Where:

CH_4 Emission$_j$ = methane emissions from Enteric fermentation from *j* category of swine, kt CH_4/year.

Equation 5.16[178]

$$EF = [GE \times Y_m \times (365 days/yr)]/[55.65 MJ/CH_4 kg]$$

Where:

GE = gross energy intake, MJ/head/day;
Y_m = methane conversion rate, which is the factor of gross energy in feed converted to methane.

Table 5.13 demonstrates CH_4 emission factors for each category of swine and the IPCC default EF for swine recommended for developed countries. Implied emission factors for swine enteric fermentation for the entire time series are presented in Figure 5.9.

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[179]
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	

[175] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.42.
[176] 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..
[177] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, equation 10.19.
[178] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.31, equation 10.21.
[179] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, table 10.10.

Swine category	Emission factor, kg CH_4/head/year	
	Calculated	IPCC default[179]
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	

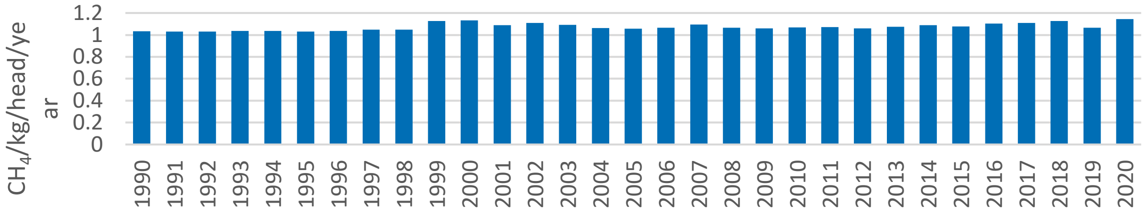

Figure 5.9. Implied emission factor (IEF) of swine enteric fermentation in 1990–2020, CH_4 kg/head/year

5.2.3.2. Quantitative overview – CH_4 emissions from enteric fermentation of swine in 2020

The total CH_4 emissions from swine enteric fermentation were 0.36 kt in 2020. The emissions decreased by 60% since the base year due to the decreasing population of swine (Figure 5.10). The main reason for this is the decline in pork production in Estonia compared to the base year. 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 11% in 2020 compared to 2014 in Estonia because of the outbreak of African swine fever in the region in 2015. In 2020, pork production constituted only 48% of the production in 1990.

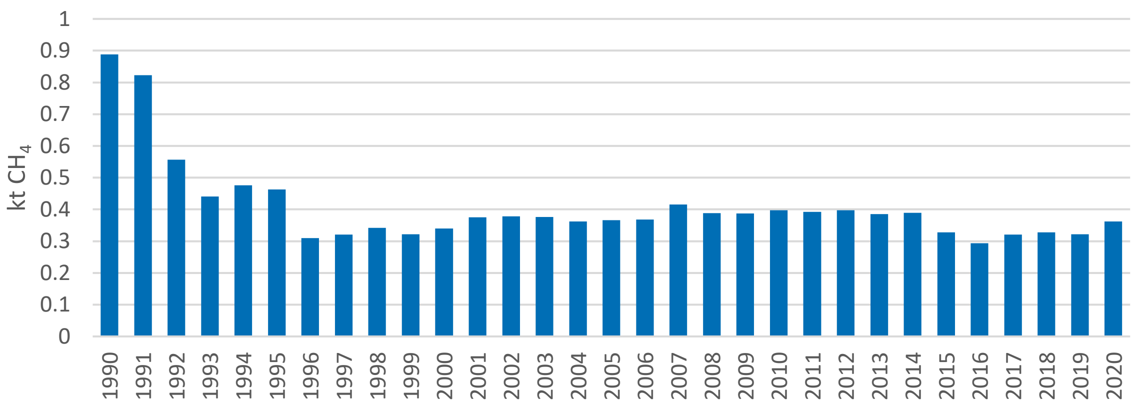

Figure 5.10. CH_4 emissions from Enteric fermentation of swine in 1990–2020 in Estonia, kt

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[180]

$$CH_4 Emission = EF_j \times population_j / (10^6 kg/Gg)$$

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[181]

Livestock category	Emission factor, kg CH_4/head/year
Sheep	8
Goats	5
Horses	18
Poultry	Not estimated
Fur animals	0.1[182]
Rabbits	Not estimated

5.2.4.2. Quantitative overview – CH_4 emissions from enteric fermentation of other livestock categories in 2020

The total CH_4 emissions from Enteric fermentation of other livestock were 0.73 kt in 2020. CH_4 emissions declined by 50% in 2020 compared with the base year due to a decrease in the number of other livestock population (Figure 5.11).

[180] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, equation 10.19.

[181] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.28, table 10.10 (developed countries).

[182] 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.

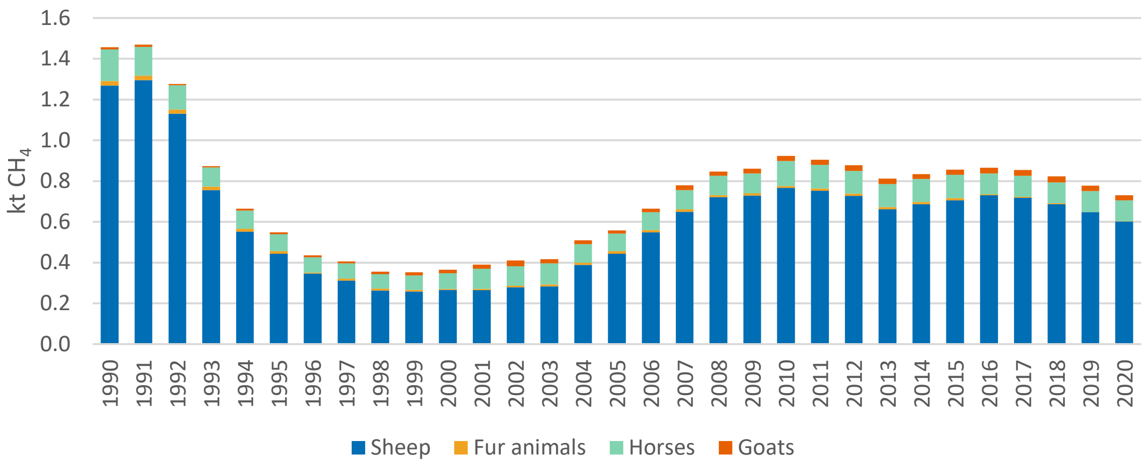

Figure 5.11. CH_4 emissions from Enteric fermentation of other livestock categories in 1990–2020, kt

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%[183].

Despite 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

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

183 IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.33.

Input	Uncertainty	References
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[184]. 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

Percentage of cows that gave birth in a year

The methodology for calculating the percentage of cows which gave birth in a year was updated for the 2022 submission for 1990-2019.

According to the previous methodology, the number of dairy cattle populations was divided with the number of calves population. According to an expert opinion[185] and IPPC 2006 guidelines, the correct and more accurate method is to divide the number of births given in a year with the number of cows (AAP), as shown in Equation 5.18:

Equation 5.18

$$Percentage\ of\ cows\ that\ gave\ birth = Number\ of\ births\ given/AAP$$

Where:

Percentage of cows that gave birth = percentage of cows that gave birth in a year, head;
Number of births given = number of births given by cows in a year, head;
AAP = annual average population of cows, head.

The comparison of the changed values of the percentage of cows which gave birth in a year due to the updated data in the 2022 submission compared to the 2021 submission is shown in Table 5.16.

[184] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.33-10.34.
[185] Allan Kaasik, docent at the Chair of Animal Nutrition, Estonian University of Life Sciences.

Table 5.16. Comparison of the reported percentage of cows which gave birth in a year in 1990–2019 and the updated values in 2022 submissions, %

Year	2021 submission	2022 submission
1990	80	74
1995	80	100
2000	76.9	99
2005	84	98
2010	94	100
2011	88.8	100
2012	90.2	100
2013	94.8	100
2014	95.2	100
2015	95.7	100
2016	95.8	100
2017	93.6	100
2018	96.7	100
2019	95.3	100

CH_4 emission factor for enteric fermentation for calves aged 0-6 months and 6-12 months

Methane emission factor for enteric fermentation for calves aged 0-6 months and calves aged 6-12 months were recalculated for 1990-2019 due to a calculation error.

Equation 5.16[178], as stated in the paragraph 5.2.3.1, is used to calculate the methane conversion factor for calves.

As stated in IPCC Guidelines, Volume 4, Chapter 10, page 10.31, this emission factor equation assumes that the emission factors are being developed for an animal category for an entire year (365 days). "While a full year emission factor is typically used, in some circumstances the animal category may be defined for a shorter period (e.g., for the wet season of the year or for a 150-day feedlot feeding period). In this case, the emission factor would be estimated for the specific period (e.g., the wet season) and the 365 days would be replaced by the number of days in the period." Young calves (aged 0-6 and 6-12 months) are only in these categories for 6 months or 183 days, therefore the correct methodology is to multiply the daily intake of feed with 183 days instead of 365 days.

The comparison of the changed values of the amounts of CH_4 emission factors of calves aged 0-6 months and calves aged 6-12 months due to the recalculations in the 2022 submission compared to the 2021 submission are shown in Table 5.17.

Table 5.17. Reported CH_4 emission factors of Enteric fermentation of calves in the 2021 submission and updated values for 2022 submission, kg CH_4/head/year

Age group	Enteric fermentation	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Calves, aged 0-6 months	2022 submission	3.5	3.5	3.5	3.4	3.3	3.6	3.6	3.6	3.6	3.6
Calves, aged 0-6 months	2021 submission	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Calves, aged 6-12 months	2022 submission	21.7	21.7	21.7	21.7	20.6	19.6	19.6	19.6	19.6	19.6

Age group	Enteric fermentation	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Calves, aged 6-12 months	2021 submission	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6

Weight of sheep

The liveweight of sheep was updated for 2022 submission for 1990-2019 due to an expert opinion[186].

The liveweight of sheep used in previous submissions was overrated. In Estonia, out of all sheep, approximately 22% are Estonian Dark-Faced breed (ET) and 20% are Estonian White-Faced breed (EV). The average liveweight of ET ewes is 76 kg and of EV ewes is 67 kg. For grossbreed and other breeds the previously used value of 65 kg for liveweight can be used.

Therefore, the following equation was used to find the average liveweight of sheep:

Equation 5.19

$$Average\ weight\ of\ sheep = \frac{((\text{share of ET} \times \text{weight of ET} + share\ of\ EV \times weight\ of\ EV + share\ of\ grossbreed\ and\ other \times weight\ of\ grossbreed\ and\ other) + (lambs\ per\ ewe \times weight\ of\ lambs))}{2.8}$$

Where:

Average weight of sheep =	average liveweight of sheep, kg;
Share of ET =	share of Estonian Dark-Faced breed ewes, %;
Weight of ET =	average bodyweight of Estonian Dark-Faced breed ewes, kg;
Share of EV =	share of Estonian White-Faced breed ewes, %;
Weight of EV =	average bodyweight of Estonian White-Faced breed ewes, kg;
Share of crossbreed and other =	share of crossbreed and other breeds of ewes, %;
Weight of crossbreed and other =	average bodyweight of crossbreed and other breeds of ewes, kg;
Lambs per ewe =	average number of lambs per ewe, heads;
Weight of lambs =	average bodyweight of lambs, kg.

The comparison of the changed values for liveweight of sheep in 1990-2019 due to the updates made in the 2022 submission compared to the 2021 submission is shown in Table 5.18.

Table 5.18. Reported and updated values for liveweight of sheep in 2021 and 2022 submissions, kg

Submission year	Weight of sheep
2022 submission	67
2021 submission	46.57

[186] Hillar Kalda, board member of Estonian Sheep Breeding Association.

Weight of dairy cattle

Values for typical weight of dairy cattle were updated for 1990-2019 due to a new information gathered from milk production companies. According to new data, typical bodyweight values used in 2021 submission are correct for the base year 1990. The typical bodyweight values used in 2021 submission are also correct for other cattle groups than dairy cattle.

Typical weight of dairy cattle was underestimated in the previous submissions and was assumed to have stayed at one level for the whole timeseries like shown in Table 5.19. In fact, it has increased in correlation with the milk yield of dairy cows.

Table 5.19. Reported typical weight of dairy cattle in 1990-2019, kg

Breed	Estonian Red	Estonian Holstein	Estonian Native
Typical weight, kg	540[187]	550[187]	460[188]

The updated values of typical bodyweight of dairy cattle due to the updates in the 2022 submission are shown in Table 5.20.

Table 5.20. Updated typical weight of dairy cattle in 1990-2019, kg

	Breed		
	Estonian Red	Estonian Holstein	Estonian Native
	Typical weight		
1990	540	550	460
1995	553	564	466
2000	565	578	473
2005	578	593	480
2010	592	608	486
2011	595	611	488
2012	597	614	489
2013	600	618	491
2014	603	621	492
2015	606	624	493
2016	608	627	495
2017	611	630	496
2018	614	633	497
2019	614	637	499

Weight of breeding pigs

The liveweight of breeding pigs was updated for 1990-2019 due to an expert judgement.

Liveweight of breeding pigs was underestimated in the previous submissions and needed to be updated for 2022 submission.

[187] 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).
[188] Kalamees, K. Eesti Maakari. [www] https://www.etll.ee/?ARETUS/Piimaveised/EK (24.01.2022).

The updates and the comparison of the changed values for liveweight of pigs in the 2022 submission compared to the 2021 submission is shown in Table 5.21.

Table 5.21. Data on weight of main Swine categories used in the estimates, kg

Swine category	**Weight, 2021 submission**	**Weight, 2022 submission**
Piglets, live weight less than 20 kg	10	10
Young pigs, live weight 20–<50 kg	35	35
Fattening pigs		
live weight 50–<80 kg	65	65
live weight 80–<110 kg	95	95
live weight 110 kg or more	110	110
Breeding pigs, live weight 50 kg or more	75	110

Feed dry matter digestibility of cattle

Values for feed dry matter digestibility for cattle were updated for 1990-2019 due to new research by Kaasik, A., „Kariloomade söödaplaanide uuring 1990–2020“, page 18-19).

Previous submissions included feed digestibility data for cattle from the former report of dry feed digestibility by Kaasik et al., 2002. In the previous submissions, the digestibility of feed for dairy cattle was at the 67% level for all timeseries, for mature females at 62% and for mature males, bovine animals (aged 1-2 years) and calves (aged 0-6 months and 6-12 months), the digestibility of feed had remained at the 63% level for all timeseries. Feed digestibility coefficients needed to be corrected for the following reasons:

- The indicators did not match the definition given in the IPCC 2006 Vol.4 guidelines, Ch.10 page 10.14 “Feed digestibility (DE%)”.
- In Kaasik et al., 2002 article, in table 4, the digestibility of feed indicators are given only for organic matter. IPCC’s definition and methodology implies to the digestibility of feed for all feed ratios (dry matter), meaning both organic and inorganic matter. As in Estonia, the digestibility of organic matter is determined in laboratories by chemical standard analysis, the digestibility of dry matter needs to be calculated according to IPCC 2006, Vol.4 guidelines, Ch.10: Emissions from Livestock and Manure Management, p.10.14 as shown in the equation below:

Equation 5.20[189]

$$\mathbf{Digestibility\ of\ feed} = \frac{\mathbf{digestibility\ of\ OM \times OM\ content\ in\ natural\ feed}}{\mathbf{DM}} + \frac{\mathbf{digestibility\ of\ ash \times ash\ content\ in\ feed}}{\mathbf{DM}}$$

Where:

DM = dry matter, %;
OM = organic matter, %.
Average digestibility of ash is 40%.

[189] Kaasik, A., 2020. Project report „Kariloomade söödaplaanide uuring 1990–2020“, page 6, eq 1.

The updates and comparison of the changed values for digestibility of feed for cattle in the 2022 submission compared to the 2021 submission are shown in Table 5.22 and Table 5.23.

Table 5.22. Reported feed dry matter digestibility in 2021 submission for cattle in 1990–2019, %

Cattle group / Year	Dairy Cows	Mature Females	Mature Males	Bovine (aged 1-2)	Calves (6-12 months)	Calves 0-6 months)
1990-2019	67	62	63	63	63	63

Table 5.23. Updated feed dry matter digestibility in 2022 submission for cattle in 1990-2020, %

Cattle group / Year	Dairy Cows[190]	Mature Females[191]	Mature Males[192]	Bovine (aged 1-2)[193]	Calves (6-12 months)[194]	Calves 0-6 months)[195]
1990	65.2	59.3	59.3	59.95	59.95	61.5
1995	65.3	59.3	59.3	59.95	59.95	61.5
2000	65.6	61	61	60.79	60.79	62.3
2005	65.6	62	62	59.98	59.98	62.4
2010	65.7	62.2	62.2	61.73	61.73	63
2015	68.9	62.3	62.3	63.53	63.53	62.9
2020	70.2	63	63	65.08	65.08	63

Feed dry matter digestibility of swine

Values for digestibility of feed dry matter for piglets, live weight less than 20 kg and for young pigs, live weight 20–<50 kg were updated for 1990-2020 due to new research (Kaasik, A. Report of the project „Kariloomade söödaplaanide uuring 1990–2020", pages 18-19).

The comparison of the changed values for digestibility of feed dry matter for swine in the 2022 submission compared to the 2021 submission is shown in Table 5.24.

Table 5.24. Feed dry matter digestibility of swine in 1990-2020, %[196]

Submission year	Piglets, live weight less than 20 kg	Young pigs, live weight 20–<50 kg
2022 submission	83	83
2021 submission	85	85

CH_4 emissions from enteric fermentations in 1990-2019 were recalculated due to the calculating errors and/or changes in methodology for calculating the following: percentage of cows that gave birth in a year, methane emission factors of enteric fermentation of calves aged 0-6 months

[190] Kaasik, A., 2020. Project report „Kariloomade söödaplaanide uuring 1990–2020", page 18, tbl 13, column 2.
[191] Kaasik, A., 2020. Project report „Kariloomade söödaplaanide uuring 1990–2020", page 19, tbl 15, column 2.
[192] Kaasik, A., 2020. Project report „Kariloomade söödaplaanide uuring 1990–2020", page 19, tbl 15, column 5.
[193] Kaasik, A., 2020. Project report „Kariloomade söödaplaanide uuring 1990–2020", weighted average of page 18, table 13, column 5 and page 19, tbl 15, column 5.
[194] Kaasik, A., 2020. Project report „Kariloomade söödaplaanide uuring 1990–2020", weighted average of page 18, table 13, column 5 and page 19, tbl 15, column 5.
[195] Kaasik, A., 2020. Project report „Kariloomade söödaplaanide uuring 1990–2020", page 18, tbl 13, column 3.
[196] Kaasik, A., 2020. Report of the project „Kariloomade söödaplaanide uuring 1990–2020", page 20, table 17.

and calves aged 6-12 months, feed dry matter digestibility coefficients for cattle and swine, average weight of dairy cows, liveweight of sheep and some swine groups.

A comparison of the changed values of the amounts of CH_4 emissions due to the recalculations between 2022 and 2021 submissions are shown in Table 5.25.

Table 5.25. CH_4 emissions in 2021 and 2022 submissions from Enteric fermentation, kt

Enteric fermentation	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	49.11	26.53	20.16	20.68	20.45	20.80	20.48	20.76	20.79	21.07
2021 submission	49.21	25.89	19.65	20.17	20.17	21.62	21.27	21.55	21.59	21.85

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[197].

CH_4 emissions from Manure management formed 10.8% of the total agricultural emissions in Estonia in 2020.

The largest contributor to the CH_4 emissions in manure management in 2020 was the cattle subcategory. The total CH_4 emissions from livestock manure management were 6.52 kt in Estonia in 2020, the emissions declined by 1% in 2020 in comparison with the base year (Table 5.26, Figure 5.12). The main reason for this small decline is the recovering pork production in Estonia during the recent years after the outbreak of African swine fever in 2015.

Table 5.26. CH_4 emissions from Manure management in 1990–2020 in Estonia, kt

Year	Cattle	Swine	Sheep	Goats	Horses	Poultry	Fur animals	Rabbits	Total
1990	2.08	4.14	0.03	0.0003	0.013	0.15	0.16	0.007	6.58
1995	3.12	2.00	0.01	0.0003	0.007	0.06	0.09	0.006	3.33
2000	0.88	1.45	0.01	0.0005	0.007	0.04	0.03	0.005	2.43
2005	1.69	1.57	0.01	0.0004	0.007	0.05	0.09	0.007	3.43
2010	2.79	1.72	0.02	0.0006	0.011	0.06	0.07	0.003	4.67
2011	2.99	1.76	0.02	0.0006	0.01	0.06	0.08	0.003	4.92
2012	3.29	1.85	0.02	0.0007	0.01	0.06	0.08	0.003	5.31
2013	3.66	1.86	0.02	0.0007	0.01	0.06	0.08	0.004	5.68
2014	3.86	1.94	0.02	0.0006	0.01	0.07	0.08	0.003	5.97
2015	3.42	1.69	0.02	0.0007	0.01	0.07	0.08	0.002	5.28
2016	3.60	1.52	0.02	0.0007	0.009	0.07	0.03	0.002	5.25

[197] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.35.

Year	Cattle	Swine	Sheep	Goats	Horses	Poultry	Fur animals	Rabbits	Total
2017	3.89	1.67	0.02	0.0007	0.009	0.07	0.04	0.002	5.70
2018	4.13	1.72	0.02	0.0008	0.009	0.06	0.03	0.002	5.98
2019	5.45	1.69	0.02	0.0007	0.009	0.06	0.003	0.002	6.22
2020	4.51	1.93	0.01	0.0006	0.009	0.06	0.002	0.002	6.52

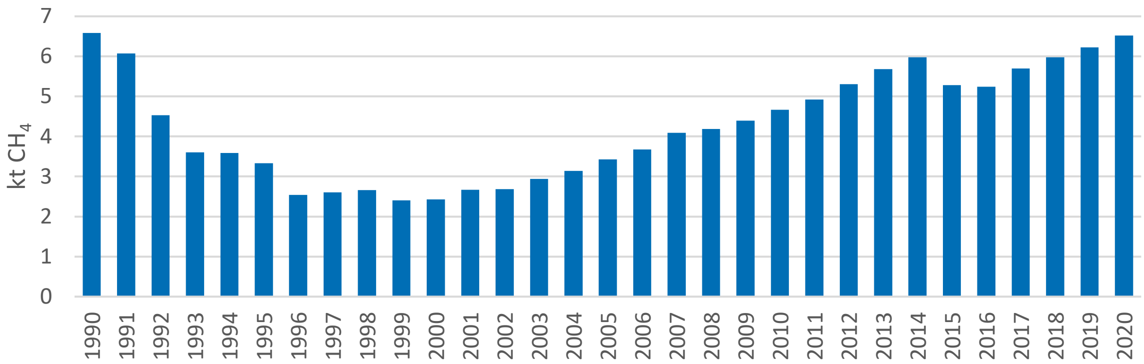

Figure 5.12. CH_4 emissions from Estonian livestock manure management in 1990–2020, kt

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 5.21–Equation 5.23).

Equation 5.21[198]

$$CH_4\_Emission_j = EF_j \times Population_j / (10^6 kg/Gg)$$

Where:

CH_4 Emissions$_j$ =	methane emissions from Manure management of *j* category of cattle, kt CH_4/year;
EF_j =	methane emission factor for *j* category of cattle, kg CH_4/head/year;
Population$_j$ =	the number of head in *j* category of cattle, heads.

[198] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.37, equation 10.22.

Equation 5.22[199]

$$EF_j = VS_j \times {}^{365\ days}/_{yr} \times B_{oj} \times 0.67\ {}^{kg}/_{m^3} \times \sum_{nK} MCF_{nK} \times MS\%_{jK}$$

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 5.27);
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 5.23[200]

$$VS = [GE \times (1 - (DE\%)/100) + (UE \times GE)][((1 - ASH)/18.45)]$$

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 5.27. Parameters used in the estimates

Cattle category	**Digestibility of feed, %[201]**	**Bo [202]**
		m^3 CH_4/kg VS
Mature cattle[203]		
Dairy	70.2	0.24
Non-dairy cattle:		
Mature females	63	0.17
Mature males	63	0.17
Bovine animals (aged between 1 and 2 years)	65.1	0.17
Calves (6–12 months old)	65.1	0.17
Calves (0–6 months old)	63	0.17

[199] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.41, equation 10.23.
[200]IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.42, equation 10.24.
[201] Kaasik, A. (2020) Report of the project "Kariloomade söödaplaanide uuring 1990–2020", pages 18-19.
[202] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.77–10.78, table 10A-4.
[203] 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).

The module on MMS (Annex A.3.2_IV) and CH_4 EFs employed in the estimations are presented in Table 5.28. 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 5.28. MMS usage, methane conversion factors (MCFs) and manure management emission factors for dairy cattle in 2020 in Estonia

	MMS, %			Emission factor, %
	Liquid/slurry	**Solid storage**	**Pasture/range**	**kg CH_4/head/yr**
Estonian average[204]	89.7	6.4	1.8	34.3
MCFs [205],%	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 frequent is solid manure which forms when litter is used. The share of loose housing which has become a dominant means of housing has been increased 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[206], the share of slurry stored in pit storage below the dairy cows is zero. In addition, the Estonian document on best available techniques (BAT)[207] for the intensive rearing of cows and its annex claim that 1) tie-stall housing where liquid manure is produced is not a BAT and 2) pit storage (fully slatted floor – a prerequisite for a pit storage) below the cows in loose-housing systems is not a BAT. In Estonia using BATs is obligatory for operators owning Air or Integrated Pollution Prevention and Control (IPPC) permit according to the Ambient air protection act[208].

Estonia uses MCF 10% for the liquid/slurry MMS in the inventory as crust is the main coverage for the dairy and non-cattle storages. Although no official national statistics are consistently gathered on about the covering of manure storage facilities, this statement is confirmed by a study of the Estonian University of Life Sciences[209].

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

[204] 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)
[205] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.45, table 10.17.
[206] KOTKAS, [www] https://kotkas.envir.ee/ (07.12.2021).
[207] 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).
[208] Riigi Teataja. Atmosfääriõhu kaitse seadus. [www] https://www.riigiteataja.ee/akt/A%C3%95KS (15.12.2021).
[209] Kaasik, A., Möls, M. Loomakasvatusest eralduvate saasteainete heitkoguste inventuurimetoodikate täiendamine ja heite vähendamistehnoloogiate kaardistamine. [www] https://envir.ee/media/5276/download (10.01.2022).

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.3.2_IV).

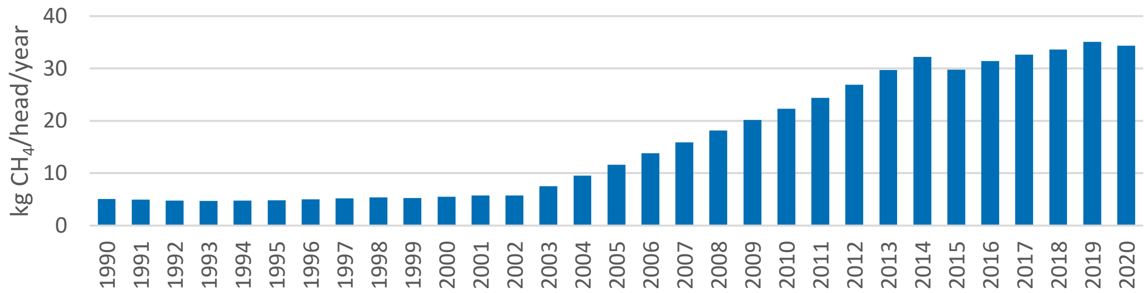

Figure 5.13. Implied CH_4 emission factor for dairy-cattle MMS in 1990–2020, kg CH_4/head/year

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[209]. Hence, in 2020 a share of mature non-dairy cattle manure was the following: 5% solid, 14% manure from pasture, 43% liquid and 38% deep litter MMS. In 2020 CH_4 EFs applied in the estimations of mature non-dairy cattle were the following: mature males – 19.24 kg CH_4/head/year and mature females – 12.71 kg CH_4 per head/year. MMSs used to store animal waste generated by growing cattle (bovine cattle and calves) and CH_4 EFs in Estonia are presented in Table 5.29. (See also Annex A.3.2_IV).

Table 5.29. MMS usage, methane conversion factors and manure management emission factors for growing cattle in 2020 in Estonia

	MMS, %[204]				**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	17.1	15.2	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). The change has been caused by shifts in the housing technology – from tie-stall housing to loose-housing system.

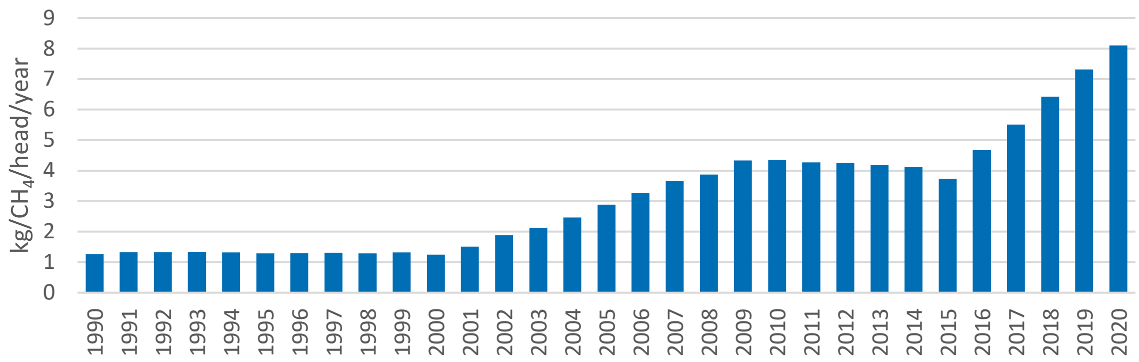

Figure 5.14. Implied CH_4 emission factor for growing cattle MMS in 1990–2020, kg CH_4/head/year

5.3.1.1.2. Quantitative overview – CH_4 emissions from cattle manure management in 2020

The total CH_4 emissions from cattle manure management were 4.51 kt in Estonia in 2020, the emissions increased by 116% by 2020 in comparison with the base year (Table 5.30). 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 5.30. CH_4 emissions from cattle manure management activities in 1990–2020 in Estonia, kt

Year	Dairy cattle	Other mature cattle	Growing cattle	Total emissions
1990	1.43	0.12	0.54	2.08
1995	0.89	0.05	0.21	3.12
2000	0.72	0.03	0.13	0.88
2005	1.31	0.04	0.34	1.69
2010	2.15	0.16	0.48	2.79
2011	2.35	0.18	0.47	2.99
2012	2.60	0.20	0.49	3.29
2013	2.91	0.23	0.52	3.66
2014	3.08	0.25	0.52	3.86
2015	2.70	0.26	0.46	3.42
2016	2.71	0.34	0.55	3.60
2017	2.82	0.41	0.66	3.89
2018	2.86	0.50	0.77	4.13
2019	2.98	0.58	0.88	5.45
2020	2.89	0.63	0.98	4.51

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 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 5.31.

The dataset used to develop the country-specific module on MMS in Estonia is described in Annex A.3.2_IV and the results are presented in Table 5.32. 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 in Energy sector.

Implied CH_4 emission factors for swine MMS have slightly changed in the period of 1990–2020 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 emission factors 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 the swine in the youngest swine 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.

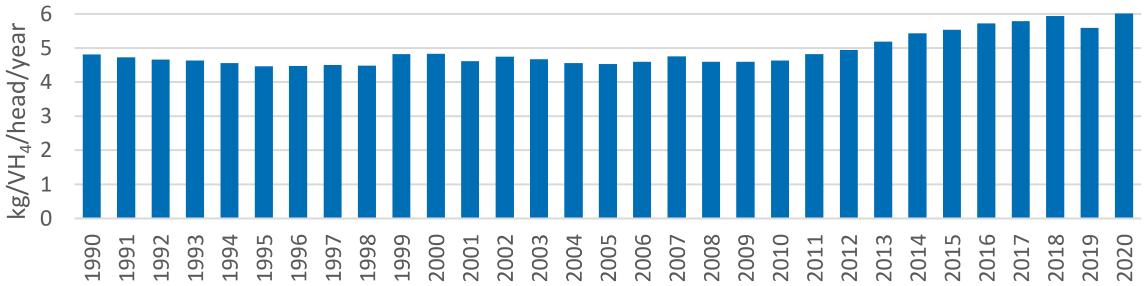

Figure 5.15. Implied CH_4 emission factor for swine MMS in 1990–2020, kg CH_4/head/year

Table 5.31. Parameters used in the estimates

Swine category	Feed digestibility, %[172]	VS, kg/h/d	Bo, m^3 CH_4/kg VS[210]	MCF, %[211]
Piglets, live weight less than 20 kg	83	0.12	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	0.38	0.45	0.6

Table 5.32. MMS usage, methane conversion factor and Manure management emission factors for swine in 2020 in Estonia

			Estonian average[204]	MCFs[212], %
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	-

[210] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.80-10.81, tables 10A-7 and 10A-8.
[211] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.35, table A-4.
[212] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.45, table 10.17.

5.3.1.2.2. Quantitative overview – CH_4 emissions from swine manure management in 2020

The total CH_4 emissions from swine manure management were 1.93 kt in Estonia in 2020 (Figure 5.16). The emissions decreased by 53% in 2020 compared with the base year due to the decrease in the number of the swine population.

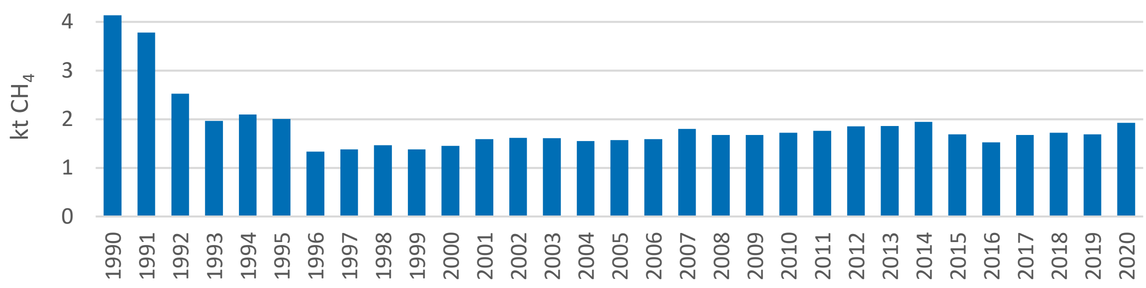

Figure 5.16. CH_4 emissions from swine MMSs in 1990–2020 in Estonia, kt

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 for other livestock were calculated in accordance with the Equation 5.21 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.3.2_IV). Animal wastes generated by livestock categories are stored in 'solid MMS' (Table 5.33).

Table 5.33. MMS usage and methane emission factors from Manure management of other livestock categories[213]

Livestock category	MMS, %		Emission factor[214], 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

[213] 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.
[214] 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).

5.3.1.3.2. Quantitative overview – CH_4 emissions from manure management of other livestock categories in 2020

The total CH_4 emission from the MMS of other livestock categories was 0.09 kt in Estonia in 2020 (Figure 5.17). The emission declined by 75% in 2020 compared with the base year due to the decrease in the number of other livestock population. The emissions in 2020 have decreased compared to the previous year mainly because of the fall of the number of fur animals and to a lesser extent due to the decrease of poultry, sheep and goat populations.

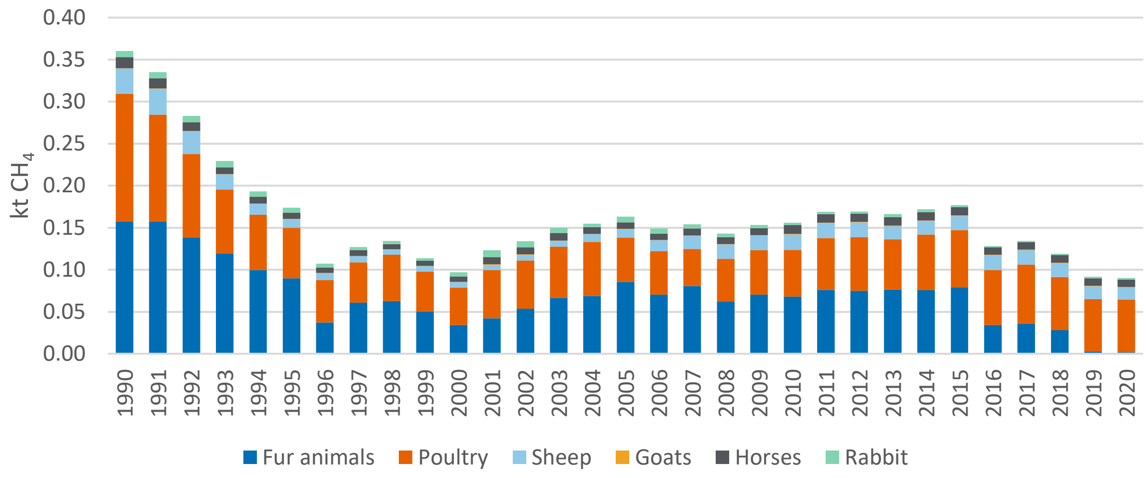

Figure 5.17. CH_4 emissions from other livestock MMSs in 1990–2020 in Estonia, kt

5.3.1.4. Category-specific recalculations

CH_4 emission factor for manure management for calves aged 0-6 months and calves aged 6-12 months

Methane emission factor for manure management for calves aged 0-6 months and calves aged 6-12 months was recalculated for 1990-2019 due to a calculation error.

Equation 5.16[178], as stated in the paragraph 5.2.3.1, is used to calculate the methane conversion factor for calves.

Equation 5.16 assumes that the emission factors are being developed for an animal category for an entire year (365 days). While a full year emission factor is typically used, in some circumstances the animal category may be defined for a shorter period (e.g., for the wet season of the year or for a 150-day feedlot feeding period). In this case, the emission factor would be estimated for the specific period (e.g., the wet season) and the 365 days would be replaced by the number of days in the period. Therefore, young calves (aged 0-6 and 6-12 months) are only in these categories for 6 months or 183 days, therefore the correct methodology is to multiply the daily intake of feed with 183 days instead of 365 days.

The comparison of the changed values of the CH_4 emission factor of calves aged 0-6 months and 6-12 months due to the recalculations in the 2022 submission compared to the 2021 submission is shown in Table 5.34.

Table 5.34. Reported CH_4 emission factors in the 2021 and 2022 submissions of Manure management of calves, kg CH_4/head/year

Age group	Manure management	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Calves, ages 0-6 months	2022 submission	0.3	0.3	0.3	0.5	0.8	1.1	1.2	1.4	1.5	1.7
Calves, ages 0-6 months	2021 submission	0.5	0.5	0.5	1	1.5	2.1	2.1	2.1	2.1	2.1
Calves, ages 6-12 months	2022 submission	0.8	0.8	0.8	1.7	2.4	3.1	3.5	3.9	4.4	4.8
Calves, ages 6-12 months	2021 submission	1.5	1.5	1.5	2.8	4.5	6.4	6.4	6.4	6.4	6.4

Cattle and swine manure management distribution

Values for distribution of cattle and swine manure management systems were updated for 2015-2019 due to new research (Kaasik, A. (2020). Eesti lauda- ja sõnnikukäitlustehnoloogiate ning sõnniku laotamise tehnoloogia uuring). Some values for cattle manure management system distributions were updated for 2001-2010 due to corrected calculation/interpolation errors. For the years 1990-2000, no changes were made.

The updated values and comparison of the changed values for distribution of cattle and swine manure management systems in the 2022 submission compared to the 2021 submission is shown in Table 5.35–Table 5.38.

Table 5.35. Reported country-specific MMS distributions of cows in 2001–2019, %

	Dairy cows				Bovine animals and bulls				Mature non-dairy females				Calves			
Year	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture / Range
2001	0	82.7	0	17.4	0	67.1	0	32.9	0	67.8	0	32.2	0	85.7	0	14.3
2002	0	82.6	0	17.4	0	67.1	0	32.9	0	67.8	0	32.2	0	85.7	0	14.3
2003	6.4	76.1	0	17.5	0.7	62.8	4	32.4	0.8	66	0	33.2	0.9	81.4	3.4	14.3
2004	12.9	69.5	0	17.6	1.5	58.5	8.1	31.9	1.6	64.2	0	34.2	1.9	77	6.8	14.4
2005	20.1	63	0	16.9	2.2	54.2	12.1	31.5	2.5	62.4	0	35.2	2.8	72.7	10.2	14.4
2006	26.3	59.9	0	13.8	2.9	52.8	14.9	29.4	7.8	59.2	0	33	3.6	70.6	12.4	13.4
2007	32.5	56.9	0	10.6	3.5	51.5	17.7	27.3	13.2	56	0	30.9	4.4	68.6	14.6	12.4
2008	38.7	53.8	0	7.5	4.2	50.2	20.4	25.2	18.6	52.7	0	28.7	5.2	66.5	16.9	11.4
2009	44.8	50.7	0	4.4	4.9	48.8	23.2	23.1	23.9	49.5	0	26.6	6	64.5	19.1	10.4
2010	51	45	0	3.9	5.5	47.5	26	21	29.3	46.3	0	24.4	6.8	62.4	21.4	9.4
2011	57.2	38.7	0	4.1	10.2	44.9	22.2	22.6	29.2	44	1.4	25.3	9.6	56.9	23.1	10.3
2012	63.3	32.4	0	4.3	14.9	42.4	18.4	24.3	29.1	41.7	2.9	26.3	12.4	51.5	24.9	11.2
2013	69.5	26.1	0	4.4	19.5	39.9	14.7	25.9	29	39.4	4.3	27.2	15.2	46	26.7	12.1
2014	75.6	19.8	0	4.6	24.2	37.4	10.9	27.5	29	37.2	5.7	28.2	18	40.5	28.4	13.1
2015	81.8	13.5	0	4.8	28.9	34.9	7.1	29.1	28.9	34.9	7.1	29.1	20.8	35.1	30.2	14
2016	81.8	13.5	0	4.8	28.9	34.9	7.1	29.1	28.9	34.9	7.1	29.1	20.8	35.1	30.2	14
2017	81.8	13.5	0	4.8	28.9	34.9	7.1	29.1	28.9	34.9	7.1	29.1	20.8	35.1	30.2	14
2018	81.8	13.5	0	4.8	28.9	34.9	7.1	29.1	28.9	34.9	7.1	29.1	20.8	35.1	30.2	14
2019	81.8	13.5	0	4.8	28.9	34.9	7.1	29.1	28.9	34.9	7.1	29.1	20.8	35.1	30.2	14

Table 5.36. Updated country-specific MMS distributions of cows in 2001–2019, %

Year	Dairy cows				Bovine animals and bulls				Mature non-dairy females				Calves			
	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range
2001	0	82.8	0	17.2	0.4	64.6	2.4	32.6	0.5	66.7	0	32.8	0.6	83.1	2	14.3
2002	0	82.9	0	17.1	0.9	62	4.8	32.3	1	65.7	0	33.4	1.1	80.5	4.1	14.3
2003	6.7	76.3	0	17	1.3	59.4	7.3	32	1.5	64.6	0	34	1.7	77.9	6.1	14.3
2004	13.41	69.6	0	16.9	1.8	56.8	9.7	31.8	2	63.5	0	34.6	2.2	75.3	8.1	14.4
2005	20.1	63	0	16.9	2.2	54.2	12.1	31.5	2.5	62.4	0	35.1	2.8	72.7	10.2	14.4
2006	26.3	59.4	0	14.3	2.9	52.8	14.9	29.4	7.8	59.2	0	33	3.6	70.6	12.4	13.4
2007	32.5	55.8	0	11.7	3.5	51.5	17.7	27.3	13.2	56	0	30.9	4.4	68.6	14.6	12.4
2008	38.7	52.2	0	9.1	4.2	50.2	20.4	25.2	18.6	52.7	0	28.7	5.2	66.5	16.9	11.4
2009	44.8	48.6	0	6.5	4.9	48.8	23.2	23.1	23.9	49.5	0	26.6	6	64.5	19.1	10.4
2010	51	45	0	3.9	5.5	47.5	26	21	29.3	46.3	0	24.4	6.8	62.4	21.4	9.4
2011	57.2	38.7	0	4.1	10.2	44.9	22.3	22.6	29.2	44	1.4	25.4	9.6	57	23.1	10.3
2012	63.3	32.4	0	4.3	14.9	42.3	18.7	24.2	29.1	41.7	2.9	26.3	12.4	51.5	24.9	11.2
2013	69.5	26.1	0	4.4	19.4	39.8	15.1	25.8	29	39.4	4.3	27.2	15.2	46	26.7	12.1
2014	75.6	19.8	0	4.6	24.1	37.2	11.4	27.3	29	37.2	5.7	28.2	18	40.5	28.4	13.1
2015	81.8	13.5	0	4.8	28.7	34.6	7.8	28.1	28.9	34.9	7.1	29.1	20.8	35.1	30.2	14
2016	83.4	12.1	0.4	4.2	25.8	27.7	19.4	27.1	31.8	28.8	13.3	26.1	19.7	28.1	38.1	14.2
2017	84.9	10.6	0.8	3.6	22.9	20.8	31	25.2	34.7	22.8	19.5	23	18.5	21	45.9	14.5
2018	86.3	9.2	1.2	3	20.1	13.9	42.6	23.4	37.6	16.8	25.7	20	17.4	14	53.8	14.8
2019	88.1	7.8	1.7	2.4	17.2	7	54.2	21.6	40.5	10.7	31.9	16.9	16.3	7	61.7	15.1

Table 5.37. Reported country-specific MMS distributions of swine in 2015–2019, %

Year	Fattening pigs				Sows and boars				Young pigs			
	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range
	%	%	%	%	%	%	%	%	%	%	%	%
2015	86.4	6.4	7.2	0	99.98	0	0.02	0	100.0	0	0	0
2016	86.4	6.4	7.2	0	99.98	0	0.02	0	100.0	0	0	0
2017	86.4	6.4	7.2	0	99.98	0	0.02	0	100.0	0	0	0
2018	86.4	6.4	7.2	0	99.98	0	0.02	0	100.0	0	0	0
2019	86.4	6.4	7.2	0	99.98	0	0.02	0	100.0	0	0	0

Table 5.38. Updated country-specific MMS distributions of swine in 2015-2019, %

Year	Fattening pigs				Sows and boars				Young pigs			
	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range	Liquid/ Slurry	Solid Storage	Deep litter	Pasture/ Range
	%	%	%	%	%	%	%	%	%	%	%	%
2015	86.4	6.4	7.2	0	99.98	0	0.02	0	100.0	0	0	0
2016	87.5	5.1	7.3	0	98.7	1.3	0.02	0	100.0	0	0	0
2017	88.6	3.8	7.5	0	97.5	2.5	0.01	0	100.0	0	0	0
2018	89.7	2.6	7.7	0	96.2	3.8	0.01	0	100.0	0	0	0
2019	90.8	1.3	7.9	0	95.0	5.0	0.004	0	100.0	0	0	0

Values for cattle and swine manure management system distributions for 1990-2020 are shown in the Annex A.3.2_IV.

See Chapter 5.2.7. for updated data about the percentage of cows that give births in a year, weight of dairy cattle, liveweight of sheep and liveweight of swine.

CH_4 emissions from Manure management in 1990-2019 were recalculated due to the corrected calculating errors and/or changes in methodology for calculating the following: percentage of cows that gave birth in a year, methane emission factors of manure management of calves aged 0-6 months and calves aged 6-12 months, average and typical weight of dairy cows, liveweight of sheep and some swine groups, values for distribution of manure management systems of cattle and swine.

A comparison of the changed values of the amounts of CH_4 emissions due to the recalculations between 2022 and 2021 submissions is shown in Table 5.39.

Table 5.39. Reported CH_4 emissions in the 2021 and 2022 submissions from Manure management, kt

Manure management	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	6.58	3.33	2.43	3.43	4.67	5.28	5.25	5.70	5.98	6.22
2021 submission	6.21	3.12	2.25	3.19	4.39	5.45	5.18	5.38	5.41	5.39

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[215].

[215] 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.

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 5.24–Equation 5.25).

Equation 5.24[216]

$$N_2O_{D(mm)} = \sum_{(S)} \{[\sum_{(T)} N_{(T)} \times Nex_{(T)} \times MS_{(T,S)}] \times EF_{3(S)}\} \times \frac{44}{28}$$

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;
$EF_{3(S)}$ = 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.3.2_I). Nitrogen excretion factors for all categories of cattle were calculated based on the nitrogen balance described in Equation 5.25[217]:

Equation 5.25

$$N_{excreta_j} = N_{feed_j} - (N_{milk} + N_{weight\_gain} + N_{embryo})_j$$

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.3.2_V.1). N_{milk}, N_{gain} and N_{embryo} were estimated as follows[218]:

[216] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.54, equation 10.25.
[217] 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.
[218] DIAS. Standard Values for Farm Manure. [www] https://dcapub.au.dk/djfpublikation/djfpdf/djfhd7.pdf (15.12.2021).

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.3.2_V. Values of the average milk protein content in Estonia in 1990–2019 were obtained from EARC.

The trend in (implied) nitrogen excretion rates reported in the CRF are presented in Table 5.40.

Table 5.40. Weight, milk yield per cow and protein content of milk in 1990–2020 (Annexes A.3.2_III.1, A.3.2_II.1–2, A3.2_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	74.27
1995	559.2	3 588	3.17	67.62
2000	574.1	4 660	3.28	78.09
2005	588.7	5 886	3.34	93.20
2010	604.0	7 021	3.36	117.41
2011	607.1	7 168	3.39	118.21
2012	610.3	7 526	3.39	120.16
2013	613.4	7 990	3.38	123.08
2014	616.5	8 233	3.37	125.04
2015	619.5	8 442	3.38	133.69
2016	622.5	8 878	3.36	137.55
2017	625.5	9 159	3.38	138.64
2018	629.3	9 287	3.39	139.24
2019	632.6	9 633	3.41	141.28
2020	635.9	9 943	3.39	140.05
IPCC default				
EE[219]	550	2 555[219]	-	96.4[220]
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 5.25. The N excretion rates are reported in Table 5.41.

Table 5.41. Nitrogen excretion rates of non-dairy cattle in 2020, kg N/head/year

Livestock category of non-dairy cattle	Nitrogen excretion rate, kg N/head/yr
Mature males (2 years and over)	75.1
Mature females (2 years and over)	57.6
Bovine animals (aged between 1 and 2 years)	56.3
Calves (6–12 months)[221]	16.0

[219] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.72, table 10A.1.
[220] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.59, table 10.19.
[221] 2-round production cycle was applied for calves (0–6 months and 6–12 months).

Livestock category of non-dairy cattle	Nitrogen excretion rate, kg N/head/yr
Calves (0–6 months)	2.9

5.3.2.2.2. Quantitative overview – Nitrogen excretion by cattle livestock in 2020

The total quantity of nitrogen generated by cattle was 18 045 tonnes in Estonia in 2020. The allocation of nitrogen excreted among different types of MMSs is presented in Table 5.42.

Table 5.42. 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	25 480 323	NO	7 107 059	32 587 381
1995	NO	13 335 142	NO	3 830 867	17 166 008
2000	NO	10 791 543	NO	2 776 777	13 568 319
2005	2 212 952	9 078 976	391 677	3 020 359	14 703 964
2010	6 321 397	7 095 201	696 980	1 285 412	15 398 990
2011	7 185 440	6 307 173	633 876	1 379 762	15 506 251
2012	8 213 796	5 662 375	613 973	1 525 946	16 016 089
2013	9 436 103	5 076 059	604 393	1 726 813	16 843 367
2014	10 281 445	4 225 558	562 352	1 854 635	16 923 990
2015	11 491 873	3 609 648	563 667	2 165 520	17 830 707
2016	11 435 273	3 025 745	1 120 925	1 953 731	17 535 674
2017	11 731 058	2 506 108	1 686 697	1 765 179	17 689 041
2018	11 849 547	1 975 432	2 291 996	1 594 869	17 711 844
2019	12 173 271	1 443 897	2 892 260	1 411 507	17 920 935
2020	12 223 856	877 400	3 676 631	1 267 510	18 045 396

5.3.2.3. Swine

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 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[222] (Table 5.43). Applied emission factors are indicated in Table 5.47.

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.

[222] 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).

Table 5.43. 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[223]	–	–
Market (average 50 kg)	–	10
Breeding (average 180 kg)	–	30

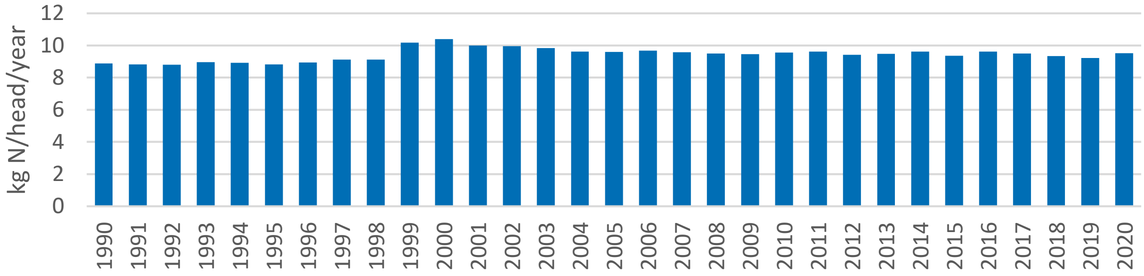

Figure 5.18. Implied swine nitrogen excretion rates reported in the CRF for 1990–2020, kg N/head/year

5.3.2.3.2. Quantitative overview – Nitrogen excretion by swine in 2020

The total quantity of nitrogen generated by pigs was 3 014 tonnes in Estonia in 2020. The allocation of nitrogen excreted among different types of MMSs is presented in Table 5.44. As the formation of a natural crust cover for uncovered pig slurry is highly unlikely, Estonia has applied a value of 0 kg N_2O–N (kg N ex)$^{-1}$ since the 2016 submission to estimate N_2O emissions from pig slurry management.

Table 5.44. 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	6 622 338	1 009 955	0	7 632 292
1995	3 158 209	804 949	0	3 963 158
2000	2 410 919	709 359	0	3 120 278
2005	2 610 264	718 483	0	3 328 747
2010	2 825 621	729 956	0	3 555 577
2011	2 904 672	593 742	17 732	3 516 146
2012	3 028 769	467 532	36 368	3 532 668
2013	3 018 079	327 740	54 276	3 400 095

[223] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.59, table 10.19.

Year	Liquid system	Solid storage	Deep litter	Total nitrogen
2014	3 159 062	207 241	73 700	3 440 002
2015	2 700 901	72 124	80 525	2 853 549
2016	2 424 801	59 405	73 315	2 557 520
2017	2 593 586	62 153	88 799	2 744 539
2018	2 56 3296	55 697	96 493	2 715 486
2019	2 645 808	47 087	87 258	2 780 153
2020	2 860 194	43 286	110 636	3 014 116

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 5.33 and nitrogen excretion rates (Table 5.45) were obtained from the IPCC 2006 Guidelines.

Table 5.45. Nitrogen excretion rates per head of animal, kg N/head/year

Livestock category[224]	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 2020

The total amount of nitrogen generated by other livestock was 2 865 tonnes in 2020. The breakdown of the quantity of nitrogen excreted by other livestock categories is reported in Table 5.46.

[224] 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 5.46. Nitrogen (in manure) excreted by other livestock categories, kg N/year

Year	Livestock category						Total nitrogen
	Sheep	Goats	Horses	Poultry	Fur animals	Rabbits	
1990	2 424 572	39 136	517 935	2 480 871	1 698 261	696 219	7 856 992
1995	846 843	36 962	277 035	970 375	1 305 061	607 533	4 043 809
2000	509 512	69 575	252 945	702 657	558 825	486 512	2 580 024
2005	848 212	58 493	289 080	843 713	869 846	676 295	3 585 640
2010	1 464 886	93 344	409 530	935 590	554 568	283 489	3 741 407
2011	1 437 415	89 993	391 463	1 051 295	617 478	272 121	3 859 764
2012	1 391 050	101 780	373 395	1 078 361	610 735	260 753	3 816 074
2013	1 264 732	94 436	379 418	1 002 034	622 716	400 861	3 764 196
2014	1 313 208	86 611	379 418	1 104 814	614 991	324 235	3 823 277
2015	1 348 454	95 881	379 418	1 127 481	644 567	247 609	3 843 410
2016	1 396 427	101 752	343 283	1 096 778	277 813	170 983	3 387 035
2017	1 372 803	105 849	343 283	1 159 269	294 877	170 983	3 447 064
2018	1 312 541	114 057	343 283	1 074 672	229 144	170 983	3 244 678
2019	1 237 847	100 381	343 283	1 066 594	21 212	170 983	2 940 298
2020	1 152 306	93 015	343 283	1 097 925	16 690	161 587	2 864 805

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 5.26–Equation 5.28) of the IPCC 2006 Guidelines[225] was applied to estimate indirect N_2O emissions from manure management due to volatilization:

Equation 5.26

$$N_2O_{G(mm)} = (N_{volatilization-MMS} \times EF_4) \times 44/28$$

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)$^{-1}$;

[225] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.54–10.56.

$$N_{volatilization-MMS} = \mathrm{NO_X - N + NH_3 - N};$$

Where:

$N_{volatilization\text{-}MMS}$ = amount of manure nitrogen that is lost due to volatilization of NH_3 and NO_x, kg N yr^{-1}. Estimates of NO_x and NH_3 are received from EstEA and are in line with the respective estimates reported in the Estonian Informative Inventory Report. The emission estimates have been calculated with the methodology provided by the EMEP/EEA guidebook 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[226] equations are used:

Equation 5.27

$$N_2O_{L(mm)} = \left(N_{leaching-MMS} \times EF_5\right) \times \frac{44}{28}$$

Where:

$N_2O_{\ L(mm)}$ = indirect N_2O emissions due to leaching and run-off from Manure management in the country, kg N_2O yr^{-1};

EF_5 = emission factor for N_2O emissions from nitrogen leaching and run-off, kg N_2O–N/kg N leached and run-off (default value 0.0075 kg N_2O–N (kg N leaching/run-off)$^{-1}$.

Equation 5.28

$$N_{leaching-MMS} = \sum_{S}\left[\sum_{T}\left[\left(N_T \times Nex_T \times MS_{T,S}\right) \times \left(\frac{Frac_{leachMS}}{100}\right)_{T,S}\right]\right]$$

Where:

$Frac_{leachMS}$ = percent of managed manure nitrogen losses for livestock category *T* due to run-off and leaching during solid and liquid storage of manure (typical range 1–20%).

Leaching and run-off of manure nutrients is prevented when the manure storage facility is compacted and sealed. According to an expert opinion[185] of the 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.

[226] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, pages 10.56–10.57.

The leak-tightness of manure storage facilities was studied in a 2010 survey[227] 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 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*[228] for Estonian farmers.

5.3.4. Quantitative overview – N_2O emissions from Manure management systems in Estonia in 2020

The total quantity of nitrogen generated by livestock and stored in solid, liquid and deep litter types of MMSs was 21 902 tonnes in 2020 (Table 5.48). 0.139 kt of direct and 0.064 kt of indirect N_2O emissions (Table 5.48 and Table 5.49) 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 5.47. 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 5.47. 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

[227] Keskkonnaministeerium. Algab sõnnikukäitluse inventuur. [www] https://envir.ee/uudised/algab-sonnikukaitluse-inventuur (16.02.2021).
[228] 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).

Table 5.48. Total nitrogen (in manure) excreted by livestock and direct N_2O emissions from MMSs in Estonia during 1990–2020

Year	Nitrogen excreted, kg[229]				N_2O emissions, kt			
	Liquid/ Slurry	Solid storage	Deep Litter	Total	Liquid/ Slurry	Solid storage	Deep Litter	Total [230]
1990	6 622 338	32 919 440	NO	39 541 778	NO	0.302	NO	0.302
1995	3 158 209	17 634 200	NO	20 792 409	NO	0.164	NO	0.164
2000	2 410 919	13 691 398	NO	16 102 317	NO	0.122	NO	0.122
2005	4 823 216	12 817 157	391 677	18 032 050	0.02	0.111	0.007	0.138
2010	9 147 018	10 629 822	696 980	20 473 820	0.048	0.088	0.015	0.150
2011	10 090 112	9 846 561	651 609	20 588 282	0.054	0.082	0.013	0.149
2012	11 242 565	9 056 340	650 340	20 949 245	0.062	0.076	0.013	0.151
2013	12 454 182	8 341 795	658 669	21 454 646	0.072	0.07	0.012	0.154
2014	13 440 507	7 409 829	636 052	21 486 388	0.079	0.063	0.011	0.153
2015	14 192 773	6 656 981	644 192	21 493 946	0.082	0.054	0.011	0.146
2016	13 860 073	5 592 282	1 194 239	20 646 594	0.08	0.05	0.01	0.140
2017	14 324 644	5 145 051	1 775 496	21 245 191	0.081	0.05	0.011	0.142
2018	14 412 843	4 431 206	2 388 489	21 232 538	0.08	0.049	0.011	0.140
2019	14 819 079	3 630 259	2 979 518	21 428 856	0.081	0.047	0.011	0.139
2020	15 084 049	3 030 285	3 787 267	21 901 601	0.081	0.047	0.011	0.139

Table 5.49. Indirect N_2O emissions from Manure management in 1990–2020

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	0.096	0.014	0.110
1995	0.049	0.007	0.056
2000	0.039	0.005	0.044
2005	0.048	0.004	0.052
2010	0.063	0.002	0.065
2011	0.064	0.002	0.066
2012	0.065	0.002	0.067
2013	0.065	0.002	0.067
2014	0.068	0.001	0.069
2015	0.067	0.001	0.069
2016	0.065	0.001	0.066
2017	0.066	0.001	0.066
2018	0.064	0.001	0.065
2019	0.064	0.001	0.065
2020	0.063	0.001	0.064

5.3.5. Uncertainties and time series consistency

CH_4 emissions from Manure management were calculated based on activity data and emission factors.

[229] 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.
[230] N_2O emissions from 'Pasture/range and paddock' were considered under Direct soil emissions.

Uncertainties in the estimates of CH_4 emissions from sheep, goats, horses, and poultry manure management are reported in (IPCC, 2006) (Table 5.50).

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 5.50.

Uncertainties associated with indirect N_2O emission factors are presented in Chapter 5.5.5. discussing indirect N_2O EF uncertainty of Agricultural soils. Default IPCC 2006 uncertainty ranges for total N losses ($Frac_{LossMS}$)[231] are implemented in the estimates.

Table 5.50. 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

[231] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.67, table 10.23 (Range of $Frac_{LossMS}$).

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 intake for cattle

Methodology for calculating and the values for nitrogen intake for cattle were updated for 1990-2019 due to new research.

For calculating the updated values of nitrogen intake of cattle, a following calculation was used:

Equation 5.29

$$N\ intake = Protein\ content/6{,}25\ \times DM\ intake$$

Where:

N intake =	Nitrogen intake per cattle, kg/year;
Protein content =	Protein content in food, from the report table 14 or 16[232], g/kg DM;
DM intake =	Dry matter intake per cattle, t/year.

The changed values for nitrogen intake of cattle in the 2022 submission compared to the 2021 submission are shown in Table 5.51.

[232] Kaasik, A. (2020). Report of the project ”Kariloomade söödaplaanide uuring (1990-2020)”, page 18 and 19, tbl 14 and 16.

Table 5.51. Reported and updated values for nitrogen intake of cattle in 1990-2019, kg/year

Year	Submission year	Dairy Cows, pregnant	Dairy Cows, not pregnant	Mature Females	Mature Males	Bovine (aged 1-2 years)	Calves (6-12 months)	Calves (0-6 months)
1990	2022	97.3	92.2	47	61.4	49.7	17.3	6.3
	2021	107.4	101.8	44.3	79.6	64.5	21.2	9
1995	2022	86.6	87.2	47.7	62.2	50.2	17.3	6.3
	2021	101.1	95.5	45	80.6	65.1	21.2	9
2000	2022	103.3	99.5	49.4	64.5	53	17.6	6.2
	2021	114.3	108.7	45	80	64.8	21.2	9
2005	2022	125.4	112.2	53.3	66.9	57.7	19.4	6.6
	2021	127	130.9	45	80.7	65.2	21.2	9
2010	2022	155.6	123.5	47.8	62.2	50.9	17.7	6.6
	2021	149.5	143.5	45.9	82	66	21.2	9
2011	2022	157.5	125	47	61.3	50.4	17.7	6.6
	2021	151.2	145.1	45.1	80.8	65.3	21.2	9
2012	2022	161.3	128.2	47.5	61.8	50.7	17.7	6.6
	2021	154.7	148.7	45.6	81.5	65.7	21.2	9
2013	2022	166.6	132.5	46.8	61	50.2	17.7	6.6
	2021	159.7	153.6	44.8	80.4	65	21.2	9
2014	2022	169.7	135.1	46.8	61	50.2	17.7	6.6
	2021	162.5	156.5	44.9	80.4	65	21.2	9
2015	2022	179.6	128.3	55.8	72.8	57.3	18	6.8
	2021	164.7	158.6	44.3	79.5	64.5	21.2	9
2016	2022	185.5	132.7	56.3	73.5	57.6	18	6.8
	2021	170	164	44.7	80.2	64.9	21.2	9
2017	2022	188.3	134.8	56.1	73.2	57.5	18	6.8
	2021	172.5	166.4	44.6	80	64.8	21.2	9
2018	2022	189.8	135.8	56.5	73.7	57.8	18	6.8
	2021	173.6	167.5	44.9	80.5	65.1	21.2	9
2019	2022	193.9	138.9	56	73.1	57.4	18	6.8
	2021	177.3	171.2	44.5	79.8	64.7	21.2	9

Indirect N_2O due to volatilization of N from Manure management

Indirect N_2O emissions from atmospheric deposition from Manure management were recalculated for 1990-2019 due to a calculation error.

Indirect N_2O emissions occur from microbial metabolism of so-called “reactive” nitrogen species, which include NO_x and NH_3 from volatilization, and leaching of NO_3^-. N_2 is emitted from manure management, but is not reactive, so just adds to the vast quantity of N_2 in the atmosphere and does not contribute to additional N_2O emissions.

Therefore, when calculating indirect N_2O emissions from atmospheric deposition, it is needed to just add up the quantity of N volatilized as NO_x and NH_3, and ignore N_2. It is stated in the IPCC 2006 guidelines in equation 10.27, as shown above, that the units of EF_4 are “kg N2O-N (kg NH3-N + NOx-N volatilized)$^{-1}$”.

Equation 5.26[225] of the IPCC 2006 Guidelines was applied to estimate indirect N_2O emissions from manure management due to volatilization.

In our previous submissions, we had included N_2, incorrectly, in the equation when calculating the amount of indirect N_2O emissions due to volatilization of N from Manure management.

The comparison of the changed values of the amounts of N_2O emissions due to the recalculations in the 2022 submission compared to the 2021 submission is shown in Table 5.52.

Table 5.52. Reported amount of NFR due to volatilization in the 2021 and 2022 submissions from Manure management, kt

Manure management	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	6.126	3.124	2.487	3.075	3.991	4.289	4.117	4.169	4.068	4.001
2021 submission	12.036	6.259	4.889	5.320	5.748	5.460	5.162	5.279	5.125	5.193

N_2O emissions from manure management in 1990-2019 were recalculated due to the calculating errors and/or changes in methodology for calculating the following: methane emission factors of manure management of calves aged 0-6 months and calves aged 6-12 months, average and typical weight of dairy cows, liveweight of sheep and some swine groups, values for distribution of manure management systems of cattle, values for nitrogen intake of cattle, updated and added values for retention in calves coefficient for dairy cows and mature female cattle, values of volatilized nitrogen from atmospheric deposition and updated values for NOx and NH_3 emissions from Manure management.

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[149].

A comparison of the changed values of the amounts of N_2O emissions between 2022 and 2021 submissions is shown in Table 5.53Table 5.53.

Table 5.53. Reported N_2O emissions in the 2021 and 2022 submissions from manure management, kt

Manure management	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	0.370	0.196	0.153	0.177	0.209	0.222	0.218	0.227	0.230	0.236
2021 submission	0.507	0.271	0.205	0.225	0.243	0.234	0.223	0.226	0.222	0.222

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[233].

[233] 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 27 years ago. Accordingly, direct N_2O emissions from managed soils decreased by 33% in 2020 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 2020 the main contributor to the direct N_2O emissions from agricultural soils was the use of synthetic fertilizers (33%), followed by emissions originating from the crop residues left on the fields (26%), cultivation of organic soils (24%), animal manure applied to soils (13%), animals grazing (3%), and the use of other organic fertilizers (1%). In 2020 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 1.9 kt in Estonia in 2020 (Figure 5.19).

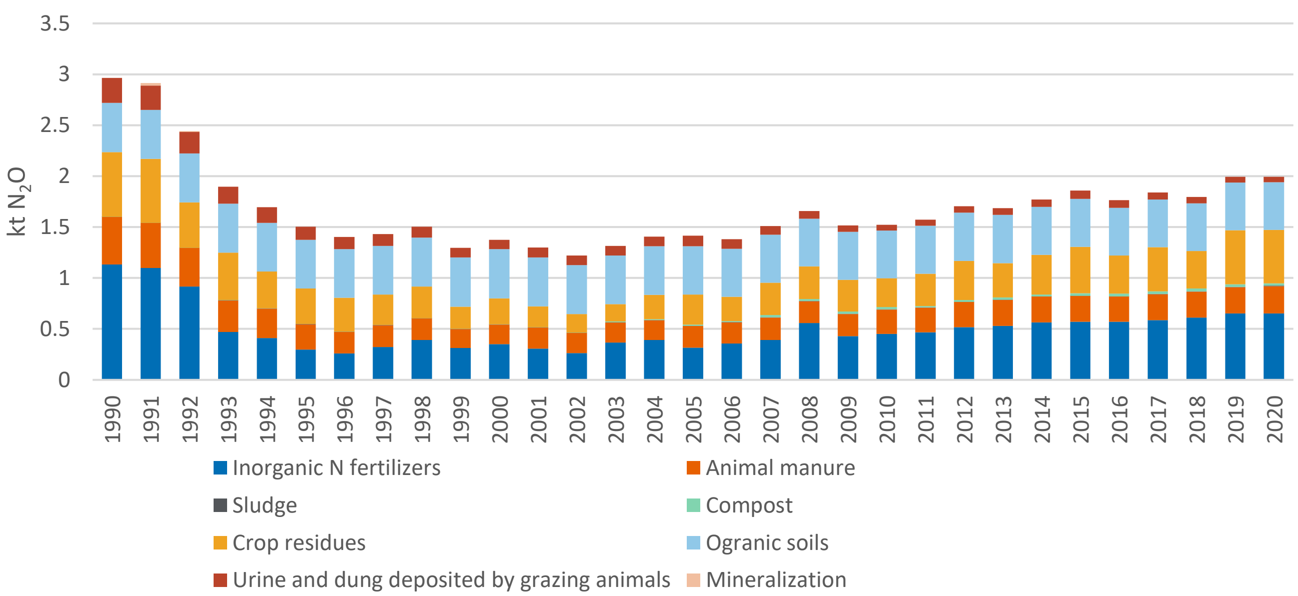

Figure 5.19. Direct N_2O emissions from Agricultural soils in Estonia in 1990–2020, kt

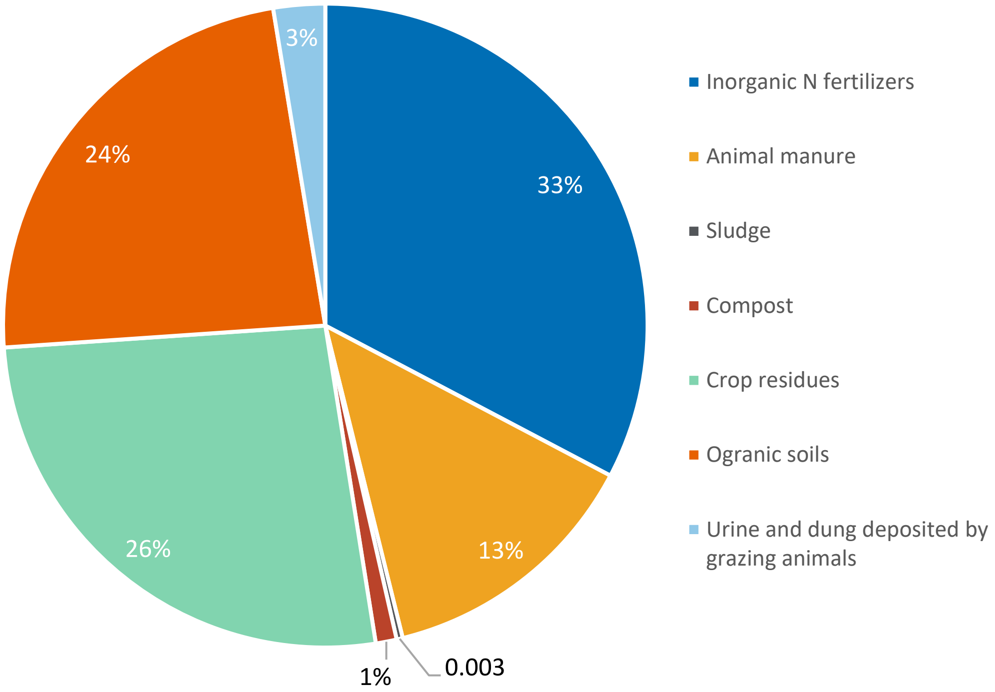

Figure 5.20. Direct N_2O emissions from Agricultural soils in Estonia in 2020, %

5.4.1.2. Activity data employed

Activity data on the amount 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 (Chapter 6 LULUCF).

Table 5.54. 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

Category	Emission factor			Source
Sheep and 'other animals'	EF_3PRP	0.01	kg N_2O–N (kg N)$^{-1}$	IPCC (2006), table 11.1
3.D.2 Indirect N_2O emissions				
N volatilization and re-deposition	EF_4	0.01	kg N_2O–N (kg NH_3–N + NO_x–N volatilized)$^{-1}$	IPCC (2006), Table 11.3
Leaching/run-off	EF_5	0.0075	kg N_2O–N (kg N leaching/run-off)	IPCC (2006), Table 11.3
Volatilization from synthetic fertilizers	$Frac_{GASF}$	0.1	(kg NH_3–N + NO_x–N) (kg N applied) $^{-1}$	IPCC (2006), Table 11.3
Volatilization from all organic N fertilizers applied, 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 5.54);

N_2O emissions into the atmosphere from the use of synthetic nitrogen were calculated based on the Equation 5.30:

Equation 5.30

$$N_2O_{direct} = F_{SN} \times EF \times \frac{44}{28}$$

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 2020

The total N_2O emissions from synthetic fertilizers applied onto agricultural soils were 0.65 kt in Estonia in 2020 (Figure 5.21). Since 2009 the emissions have been rising gradually as the area of agricultural crop production has increased. 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. The emissions declined by 42% in 2020 compared with the base year due to the decrease in the amounts of synthetic fertilizers applied to agricultural fields (Figure 5.21, Annex A.3.2_VI).

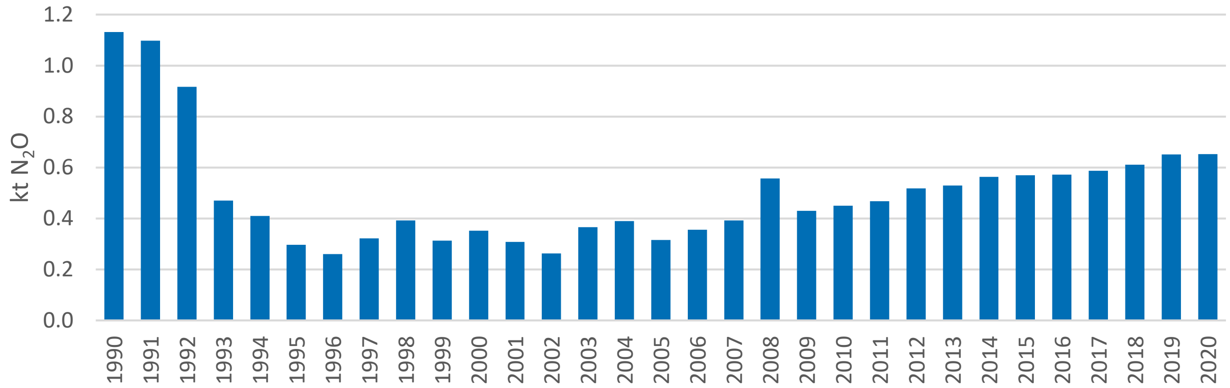

Figure 5.21. Emissions from synthetic fertilizers applied to agricultural soils in 1990–2020 in Estonia, kt N_2O

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 5.31–Equation 5.33):

Equation 5.31

$$N_2O_{direct} - N = F_{AM} \times EF_l$$

Equation 5.32[234]

$$F_{AM} = N_{MMS\ Avb} \times [1 - (Frac_{FEED} + Frac_{FUEL} + Frac_{CNST})]$$

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};

[234] 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.

$Frac_{FEED}$ = fraction of managed manure used for feed;
$Frac_{FUEL}$ = fraction of managed manure used for fuel;
$Frac_{CNST}$ = fraction of managed manure used for construction.

Equation 5.33[235]

$$N_{MMS\ Avb} = \sum_{S}\left\{\sum_{(T)}\left[\left[\langle N_{(T)} \times Nex_{(T)} \times MS_{(T,S)}\rangle \times \langle 1 - \frac{Frac_{LossMS}}{100}\rangle\right] + \left[N_{(T)} \times MS_{(T,S)} \times N_{beddingMS}\right]\right]\right\}$$

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 5.55).

Table 5.55. 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 2020

Direct N_2O emissions from animal manure applied on agricultural soils were 0.267 kt in Estonia in 2020 (Figure 5.19). The emission decreased by 43% in 2020 compared to the base year, due to the decline in the number of the livestock population.

[235] IPCC 2006 Guidelines, Volume 4, Chapter 10: Emissions from Livestock and Manure Management, page 10.65, equation 10.34.

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 5.56 illustrates 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 compiling the GHG inventory until 2012. During that period, limited waste related data was gathered by the predecessor of Estonian Environment Agency (EstEA) - Estonian Environment Information Centre - and therefore an assumption was made that 50% of the total amount of generated sewage sludge was used for improving the environmental situation (Table 5.56).

Data for the years 1999–2019 were obtained from datasets of EstEA and national online waste reporting system, JATS. 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.[371].

EstEA is doing data processing and validating the accuracy. What is more, Estonian Environmental Research Centre expert is validating data by asking companies and EstEA to clarify the amount of R10 sewage. 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 in CRF). 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 7.15. Please note that "sludge" in Table 7.15 includes sludge from composting activities (R3o), and does not include sludge reported under R10).

Since 2004, the amount of sewage sludge treated biologically has increased. However, the amounts of sewage sludge directly used for improving the environmental situation have decreased. 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 5.56. Amounts of municipal sludge application on agricultural land, tonnes[236]

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
2017	33 437
2018	33 733

[236] R10 of the European Waste Catalogue (2002) – Land treatment resulting in benefit to agriculture or improvement.

Year	R10
2019	54 971
2020	79 029

5.4.1.5.1. Methodology, data availability and sources, emission factors

The IPCC 2006 *Tier 1* (Equation 5.34) approach was employed in order to estimate N_2O emissions from sludge applied on agricultural land:

Equation 5.34

$$N_2O_{direct} = F_{SL} \times EF_1 \times \frac{44}{28}$$

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 5.54 and Table 5.57.

Table 5.57. Parameters and factors used in the estimates

Factor	Value	Unit
N content of sewage sludge[237]	4.9	% dry matter

5.4.1.5.2. Quantitative overview – N_2O emissions from sludge applied on agricultural land in 2020

The total N_2O emissions from sludge applied on agricultural land were 0.006 kt in Estonia in 2020 (Figure 5.22).

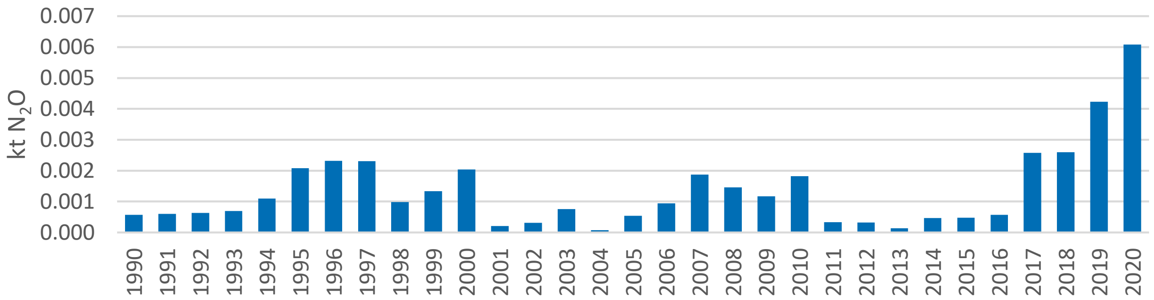

Figure 5.22. N_2O emissions from sewage sludge applied on agricultural land in Estonia in 1990–2020, kt

[237] 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 andpublished in EstEA's Tableau[371]. Tableau provides information about the entire waste stream, including quantities of composted (recovery code R3o). (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 5.35) approach was employed to estimate N_2O emissions from organic fertilizers applied to agricultural land:

Equation 5.35

$$N_2O_{direct} = F_{ON} \times EF_1 \times \frac{44}{28}$$

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 5.54 and Table 5.58.

Table 5.58. Parameters used in the estimates

Factor	Value	Unit
N content of compost[238]	1.83	% dry matter

5.4.1.6.2. Quantitative overview – N_2O emissions from compost applied on agricultural land in 2020

The total N_2O emissions from compost applied on agricultural land were 0.021 kt in Estonia in 2020 (Figure 5.23). Additional information on the fluctuations of composted waste can be found in Chapter 7.3 Biological treatment of solid waste.

[238] Linnasmägi, M.-L. (2012). Ülevaade Eestis toodetud jäätmekompostidest. Bachelor thesis, page 53.

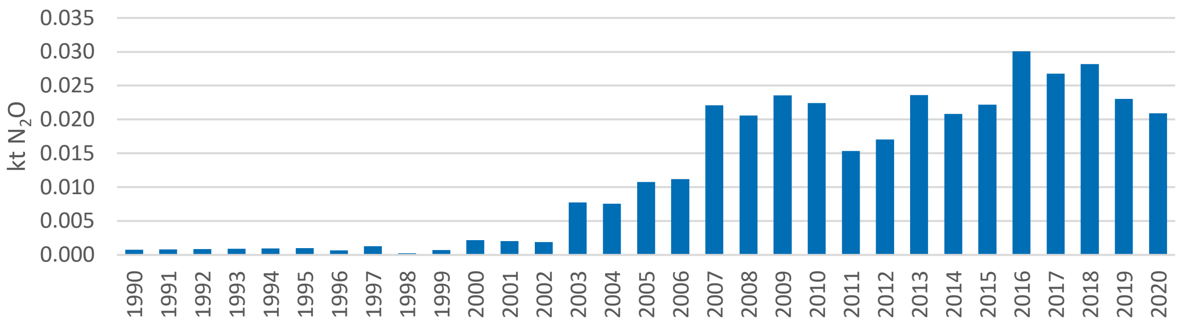

Figure 5.23. N_2O emissions from compost applied on agricultural land in Estonia in 1990–2020, kt

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 2020

The total N_2O emissions from pasture, range and paddock made up 0.052 kt in 2020. The emission decreased by 79% 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).

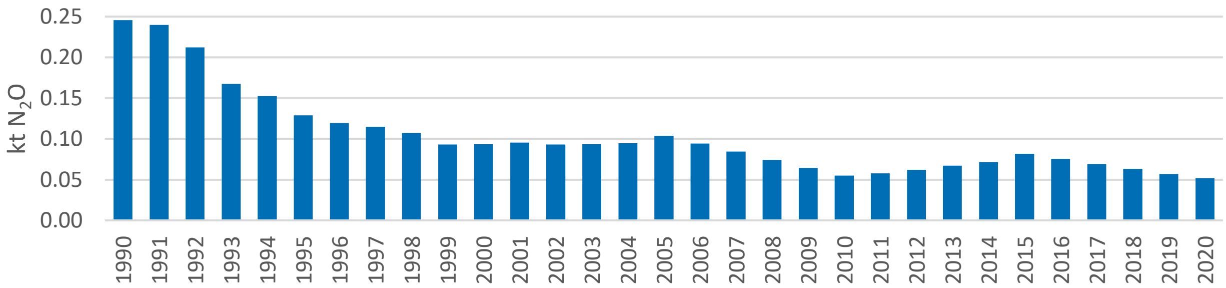

Figure 5.24. N_2O emissions from urine and dung deposited by grazing animals in 1990–2020, kt

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 5.36) method was used to estimate emissions from crop residues returned to the soil.

Equation 5.36[239]

$$F_{CR} = \sum_T \{Crop_T \times Frac_{Renew(T)} \times [(Area_{(T)} - Area\ burnt_{(T)} \times C_f) \times R_{AG(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)}) + Area_{(T)} \times R_{BG(T)} \times N_{BG(T)}]\}$$

Where:

Data for $Frac_{Remove}$ are not available in Estonia, therefore no removal was assumed. Also, as no agricultural burning practices have been carried out in Estonia, Area burnt $_{(T)}$ is zero. IPCC default values have been used for factors $R_{AG(T)}$, $N_{AG(T)}$, $R_{BG(T)}$ and $N_{BG(T)}$ available in Table 11.2 in the IPCC 2006 Guidelines[240].

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 5.37.

Equation 5.37[241]

$$N_2O_{direct} = F_{CR} \times EF_1 \times \frac{44}{28}$$

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[239] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.14, equation 11.6.
[240] 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.
[241] 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.

The selected crop residue statistics and factors used in the algorithm to estimate emissions from crop residues are presented in Table 5.59.

Table 5.59. Factors used in the algorithm to estimate N_2O emissions from crop residues, kg N/kg crop-N [242]

Factor	Value
$Frac_{REMOVE}$	0 [243]
$Frac_{RENEW\ annual}$	1
$Frac_{RENEW\ herbacous}$	8
$Frac_{RENEW\ legumes}$	4

5.4.1.8.2. Quantitative overview – N_2O emissions from Crop residues in 2020

2020 was a rather favourable year for crop production. According to Statistics Estonia[244], the total production of cereals was 1,632,800 tonnes. The total production of potatoes was 94,400 tonnes. Cereal production was record high in 2020, being the highest in 27 years. The total production of cereals included 840,000 tonnes of wheat, 561,000 tonnes of barley and 79,000 tonnes of rye. Cereal yield per hectare was 4.4 tonnes. The largest sown area of cereals in the past quarter of a century, i.e., 370,000 hectares, contributed to the record harvest. Winter crops accounted for almost a half of the sown area of cereals and more than a half of production. The total production of dry pulses and winter rape was also record high, respectively, 120,000 tonnes and 177,000 tonnes. The sown area of dry pulses was 49,500 hectares which is 15% higher than last year. However, the sown area of winter rape and winter turnip rape increased to 60,000 hectares, which is also a record high outcome. The yield per hectare of dry pulses was 2.4 tonnes which is 6% less than a year before, while the yield of winter rape grew up to 3.1 tonnes per hectare, which is 7% higher than a year before. The year was also favourable to produce potatoes and open-field vegetables. Even though the sown area of potatoes and open-field vegetables were 3,600 and 2,100 hectares, respectively, which is the record lowest, the average yield per hectare for potatoes hit a record of 26.0 tonnes. The previous record yield was in 2019, at 22.6 tonnes per hectare. The yield per hectare of open-field vegetables was of 23.3 tonnes which is 7% lower than a year before.[245]

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.3.2_VII. The inter-annual changes in crop production are explained by changes in the total sown area (Annex A.3.2_VII.2) and by weather conditions (Annex A.3.2_X).

[242] Expert opinion of the Estonian Agricultural Research Centre.
[243] $Frac_{REMOVE}$ at a value of 0 was applied because of a recommendation of the TERT (conducted in 2012).
[244] Statistics Estonia. Agricultural production in Estonia increased last year. [www] https://www.stat.ee/en/uudised/moodunud-aastal-eesti-pollumajandustoodang-taas-suurenes (27.12.2021).
[245] 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)

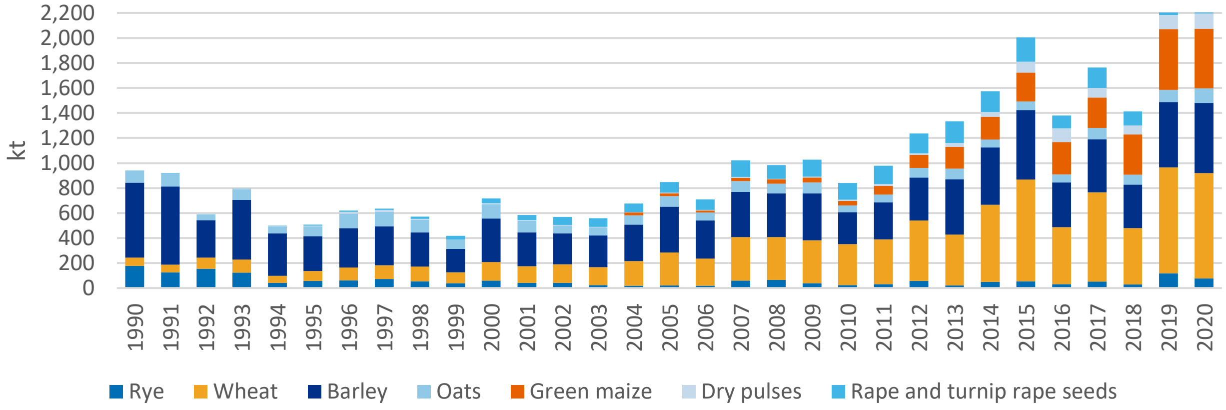

Figure 5.25. Cereals, maize, dry pulses and rape seed production in 1990–2020 in Estonia, kt

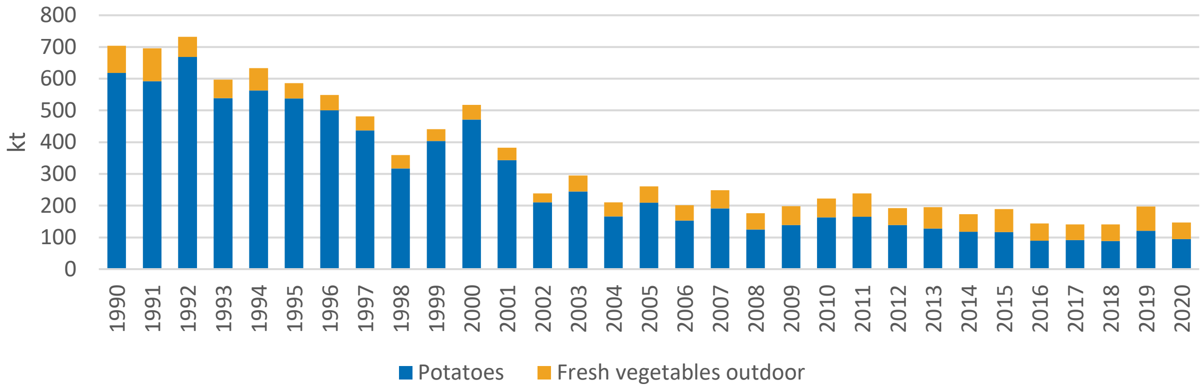

Figure 5.26. Potato and open-field vegetables production in 1990–2020, kt

The total N_2O emissions from crop residues left on agricultural land was 0.526 kt in 2020 (Figure 5.27). The respective emissions have declined by 17% 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.

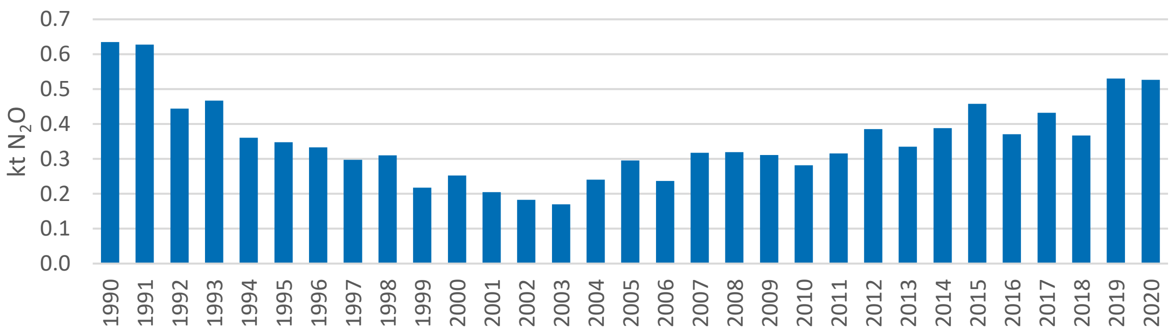

Figure 5.27. N_2O emissions from crop residues left on agricultural fields in 1990–2020 in Estonia, kt

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 5.38. 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 5.38[246]

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,\ LU} \times \frac{1}{R} \right) \times 1000 \right]$$

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 2020 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.

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[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, 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[247].

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 5.39). 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 from the 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 5.39[248]

$$N_2O_{direct} = F_{OS} \times EF_2 \times \frac{44}{28}$$

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 5.54).

5.4.1.10.2. Quantitative overview – N_2O emissions from organic soils cultivated in 2020

N_2O emissions from cultivation of organic soils were 0.468 kt in 2020 in Estonia (Figure 5.28). The estimation was carried out based on the data received in the framework of the National Forest Inventory (see Chapter 6 LULUCF).

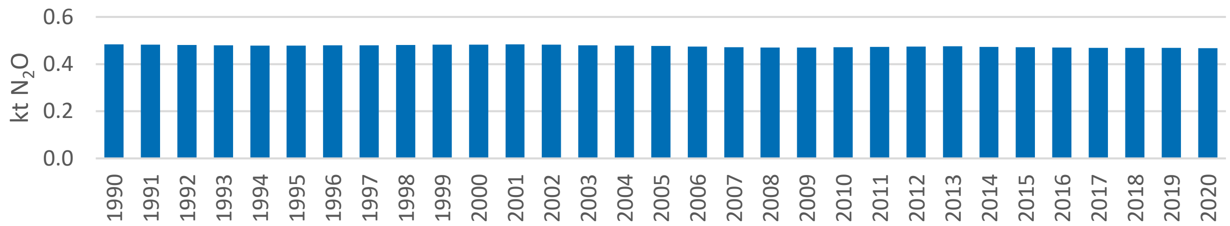

Figure 5.28. N_2O emissions from cultivation of organic soils in Estonia in 1990–2020, kt

[247] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.91.
[248] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.16.

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[249]. 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[250]. No similar research has been carried out in Estonia; therefore, the uncertainty of Finland was used in the estimates (Table 5.60).

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[251].

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 5.60).

Table 5.60. 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[252]
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

[249] Rypdal, K., Winiwarter, W. (2001). Uncertainties in greenhouses gas emission inventories – evaluation, comparability and implications. Environmental Science and Policy, no.4, p. 107–116.
[250] 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. .
[251] Revised 1996 IPCC Guidelines, Volume 3, Chapter 4: Agriculture, page 4.89.
[252] Kõlli, R., Ellermäe, O., Köster, T., Lemetti, I. Asi, E., Kauer, K. (2009). Stocks of organic carbon in Estonian soils. Estonian Journal of Earth Sciences, 58 (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) and Other Organic Fertilizers Applied to Soils (3.D.1.2.c) were recalculated for 1990-2019 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 Compost were recalculated for 2019 due to the corrected activity data use in compost calculations for 2019.
- The N_2O emissions from Urine and Dung Deposited by Grazing Animals (3.D.1.3) were recalculated for 1990-2019 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 1990-2019.

The results of the recalculations are presented in Table 5.61.

Table 5.61. Reported direct N_2O emissions in 2021 and 2022 submissions from Agricultural soils, kt

Direct N_2O emissions from agricultural soils	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	2.966	1.504	1.376	1.416	1.522	1.860	1.765	1.840	1.796	1.993
2021 submission	3.058	1.566	1.410	1.448	1.542	1.857	1.767	1.844	1.803	2.004

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[253].

5.4.2.1. Category description

The total indirect N_2O emissions from agricultural soils were 0.47 kt in 2020 (Figure 5.29). The emissions declined compared to the base year (1990) by 38% in 2020 due to the decrease in the number of the livestock population and synthetic and organic fertilizer application onto agricultural land.

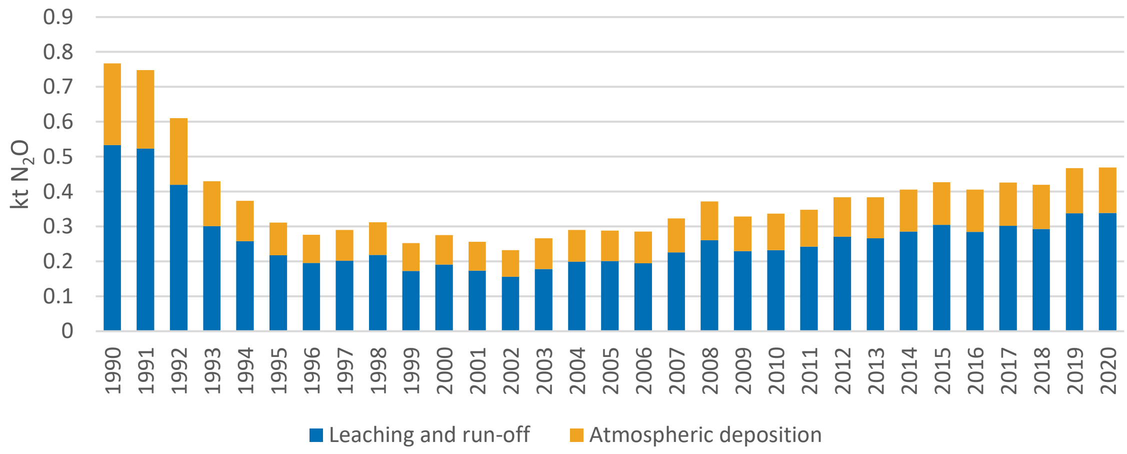

Figure 5.29. Indirect N_2O emissions from Agricultural soils in Estonia in 1990–2020, kt

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_4) fertilize soils and surface waters, which results in enhanced biogenic N_2O formation[254]. Total N_2O emissions from atmospheric deposition were 0.130 kt in 2020 in Estonia.

5.4.2.2.1. Methodology, data availability, data sources and emission factors

The *Tier 1* (Equation 5.40) method was used to estimate emissions from the Atmospheric deposition.

[253] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.53.

Equation 5.40[254]

$$N_2O_{(ATD)} - N = \left[(F_{SN} \times Frac_{GASF}) + \left((F_{ON} + F_{PRP}) \times Frac_{GASM}\right)\right] \times EF_4$$

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 5.54);

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 5.54);

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 5.54).

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[255]. The total N_2O emissions from leaching and run-off were 0.339 kt in 2020 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 5.41).

Equation 5.41[256]

$$N_2O_{(L)} - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH-(H)} \times EF_5$$

Where:

$N_2O_{(L)}$–N = annual amount of N_2O–N produced from leaching and run-off of N additions to managed soils in regions where leaching/run-off occurs, kg N_2O–N yr^{-1};

F_{SN} = annual amount of synthetic fertilizer N applied to soils in regions where leaching/run-off occurs, kg N yr^{-1};

[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 11.9.

[255] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.70.

[256] 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_{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 5.54);

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 5.54).

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 5.62).

Table 5.62. 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

Input	Uncertainties	References
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 and c, 3.D.1.3, 3.D.1.5 and 3.D.1.6) subcategory. The results of the recalculations are presented in Table 5.63.

Table 5.63. Reported indirect N_2O emissions in 2020 and 2021 submissions from Agricultural soils, kt

Indirect N_2O emissions from Agricultural soils	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2022 submission	0.767	0.311	0.275	0.289	0.337	0.427	0.406	0.426	0.419	0.467
2021 submission	0.790	0.325	0.280	0.294	0.337	0.420	0.399	0.418	0.412	0.460

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 2004, the burning of crop residues was prohibited by Estonian law[257]. 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

[257] 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).

by country and crop type. This is an area where locally developed, country-specific data are highly desirable'[258].

As no other official records of agricultural burning of crop residues exist in Estonia, then for the reporting period of 1990–2004 an inquiry to the Estonian Ministry of Rural Affairs (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. 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).

In the 2021 submission notation key NO has been applied for the whole time series. It is feasible that Estonia had been overestimating its emissions for 1990–2006 by applying the IPCC $Frac_{Burn}$ default value in the previous submissions.

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.[259]. Total CO_2 emissions from lime applied on agricultural land were 15.7 kt in Estonia in 2020, from which CO_2 emissions from dolomite were 1.7 kt and 14.0 kt from limestone (Figure 5.30)

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 have been growing steadily until 2018. Compared to the peak of emissions (25.8 kt) in 1999, CO_2 emissions have declined by 39.1% in 2020.

5.6.2. Methodology, emission factors and activity data employed

The *Tier 1* (Equation 5.42) 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

[258] IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 4: Agriculture, page 4.89.
[259] Loide, V. (2019). Põllumuldade kaltsiumisisaldusest ja lupjamisest. Presentation, 10th World Soil Day, Tartu, Estonia.

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 Estonian Research Institute of Agriculture[260]. 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 5.42[261]

$$\Delta C_{CC\ Lime} = M_{Limestone} \times EF_{Limestone} + M_{Dolomite} \times EF_{Dolomite}$$

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[262] for the time period of 1990–2001 and the sales records obtained from the Estonian Agricultural 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.3.2_VIII.

The emissions resulting from limestone application were calculated using the sales records of clinker dust, chalk and powdered limestone. The fraction of $CaCO_3$ in the cement clinker dust (40.48%) was received by a personal inquiry from the Estonian cement factory.

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260 Järvan, M. (2005). Põldude lupjamine. Saku: Maalehe Kirjastus, lk 6.

261 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.

262 Turbas, E. (2000). Muldade lupjamise mõtte ja lupjamistööde arengust Eestis. Agraarteadus, nr 11 (2), lk 117–131.

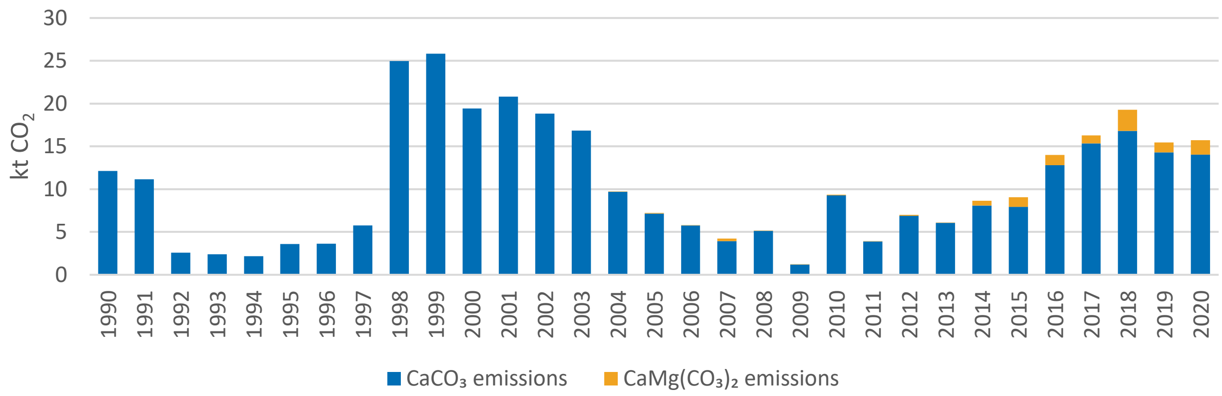

Figure 5.30. CO_2 emission from $CaMg(CO_3)_2$ and $CaCO_3$ in 1990–2020, kt

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 5.64).

Table 5.64. Amounts of lime fertilizers applied on the fields 1990–2020, kt/yr

Fertilizer	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Clinker dust	68	13.4	39.1	22.9	31.5	0	0	0	0	0	0
Other lime fertilizer	NO	NO	NO	NO	NO	6	8.9	11.6	10.1	10.4	4.4
Powder limestone	NO	2.7	28.3	7	8.3	12	20.3	23.3	28.1	22.1	27.5
Oil shale ash	68	8.7	NO	NO	NO	9.3	13.7	17.3	20.6	19.9	25.0
Ash	NO	NO	NO	NO	7.9	2.2	4.3	8.2	9.5	14.4	8.6
Powder dolomite	NO	NO	NO	0.1	0.2	2.3	2.5	2	5.2	2.4	3.6
Total	136	24.8	67.4	30	47.9	31.9	49.6	62.4	73.5	69.2	69.1

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 5.65.

Table 5.65. Uncertainties in the Liming category

IPCC category		Uncertainties %		EF references
		Activity data[263]	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.

[263] All activity data uncertainty estimates are obtained from the NFI.

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 from 0.01 to 1.55 kt CO_2 per year (Figure 5.31). In 2020, the emission from urea application was 0.13 kt.

5.7.2. Methodology, emission factors and activity data employed

Equation 5.43[264]

$$CO_2\ Emission = M \times EF \times \frac{44}{12}$$

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.

An approximate estimate of the amount of urea applied to soils on an annual basis is obtained using domestic production records and import/export data and Equation 5.43 (see also Annex A.3.2_IX.1). In compliance with the IPCC 2006 Guidelines, it can be assumed that all urea fertilizers produced annually minus annual exports is applied to soils[265]. The emission estimation was compiled based on the only urea fertilizer producer LLC Nitrofert in Estonia and import-export statistical data provided by SE. In 2011, 2012 and 2014–2020, 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 have been made using urea fertilizer marketing data provided by the Estonian Agricultural Board. Until the 2018

[264] 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.
[265] 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.

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 UNFCCC review team (in autumn 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 has been homogenized by correcting the values of the emissions from urea fertilizers since the year 2010, when only marketing data were available, except the year 2013, when data from the LLC Nitrofert were used. As the Estonian Agricultural Board does not collect data of the amounts of marketed urea fertilizers since 2019, then the emissions of 2018 are used as a 2019 and 2020 value. Now, a study is being carried out to find new possibilities to report data of urea fertilizers in the future.

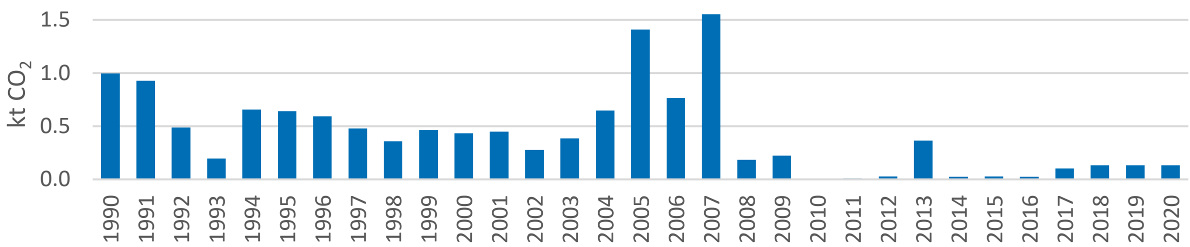

Figure 5.31. CO_2 emissions from urea fertilizer application 1990–2020, kt

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

There is planned to find a new data source to enable to report emissions from urea fertilizers in the future.

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 sector follows the IPCC 2006 Guidelines. Guidelines for LULUCF suggest the use of six top-level land categories (Forest land, Cropland, Grassland, Wetlands, Settlements, Other land), divided into Land remaining in the land-use category and Land converted to another land-use category. Harvested wood products (HWP) constitute a component of the carbon cycle for which carbon stock changes can be estimated based on national-level data. 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 2020, LULUCF sector acted as a net CO_2 source, resulting in net GHG emissions of 1 297.87 kt CO_2 equivalent, meaning that total emissions arising from the sector exceeded total removals. 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[266], therefore the net annual increment has been lower than in previous 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), the capacity of carbon sequestration in biomass has decreased in recent years. In addition, the annual increase in conversion from other land categories to Forest land (afforestation and reforestation) has been slowing – particularly in Cropland and Grassland conversion to Forest land, 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 2020, HWP was the only net sink category and unable to compensate emissions from other LULUCF sub-sectors.

In the 2022 annual submission Estonia reports emissions and removals about the following subcategories:

- Forest land (CRF 4.A): emissions/removals from/by Forest land 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 (CRF 4.B): emissions/removals from/by living biomass, dead organic matter (only to CL), mineral and organic soils. N_2O emissions related to land conversion to cropland are also reported under LULUCF, but 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 (CRF 4.C): emissions/removals from/by grassland living biomass, dead organic matter and mineral soil (only to GL), CO_2 emissions from drained organic soils and non-CO_2 emissions from wildfires;

[266] Yearbook Forest 2019, Table 1.3.5 (Distribution of stands by age classes and dominant tree species,10 years age classes). [www] https://keskkonnaagentuur.ee/media/882/download (10.01.2022).

- Wetlands (CRF 4.D): CO_2, N_2O and CH_4 emissions from peat extraction, 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 (CRF 4.E): 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 (CRF 4.F): CO_2 and N_2O emissions from Forest land, Cropland, Grassland and Wetlands conversion to other land; and
- Harvested wood products (CRF 4.G): emissions from 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 soils and litter for most of the land-use categories. As an interim approach, C stock change estimates of these pools are based on EF-s from the Sweden National Inventory Submission 2021[267] (considered as a *Tier 2* method). Estonia has launched several projects aimed at elaborating on country-specific data regarding omitted pools for future submissions (see Chapters 6.2.6, 6.3.6 & 6.4.6 Category-specific planned improvements). Also, studies by Kõlli *et al.* (2009[268], 2010[269]) were used to develop 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[270]) 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[271]	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[272]	NA/NA	NA/NA	NA/NA

[267] This approach is approved by ERT (FCCC/ARR/2012/EST para.94, 104; FCCC/ARR/2013/EST para. 63).
[268] 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.
[269] 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.
[270] 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.
[271] 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.
[272] Settlements remaining settlements reporting is not mandatory.

	Method applied / EF used		
GHG SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**
4.E.2 Land converted to settlements	T2/ CS, D,OTH	NA/NA	T1/D
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[273]/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	- collecting and providing data for the National Forest Inventory - collecting and providing data on land-use categories (Forest land, Cropland, Grassland, Wetlands, Settlements, Other land, HWP) - collecting and providing data on land-use changes (including AR and D areas) - collecting and providing data on Forest land, Grassland and Cropland woody biomass and deadwood stocks - areas of peat extraction - field inventories of wildfires (started in 2012) - area and number of storm-damaged forests
Estonian Rescue Service. State Forest Management Centre	www.rescue.ee www.rmk.ee/en	ERS. SFMC	- 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)

[273] The stock-difference method used for biomass estimates includes CO_2 loss from burning.

References	Link	Abbreviation	Activity
			- data on peat extraction - area of storm-damaged forests -- 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
Estonian Crop Research Institute	www.etki.ee/eng/	ECRI	- providing know-how for calculating Cropland mineral soil emissions (share of areas with different tillage practises)
Agricultural Research Centre	pmk.agri.ee/	ARC	- providing know-how for calculating Cropland mineral soil emissions (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		- 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[274]–2020 (NFI)[275], kha

	Forest land	**Cropland**	**Grassland**	**Unmanaged wetlands**	**Managed wetlands**	**Settlements**	**Other land**
1989	2 361.8	1 055.1	293.6	402.0	32.5	337.7	51.2
1990	2 363.5	1 054.5	293.0	401.9	32.6	337.3	51.0
1991	2 366.4	1 053.2	292.3	401.9	32.6	336.9	50.7
1992	2 370.3	1 051.1	291.5	401.7	32.6	336.5	50.2
1993	2 375.2	1 047.6	291.1	401.6	32.7	336.1	49.6
1994	2 380.2	1 043.2	292.0	401.2	32.7	335.7	48.9
1995	2 385.6	1 037.7	293.3	400.9	32.7	335.5	48.3
1996	2 391.4	1 031.6	295.0	400.6	32.6	335.0	47.7
1997	2 397.4	1 024.5	297.5	400.3	32.4	334.7	47.1
1998	2 403.1	1 018.0	300.0	400.1	32.1	334.2	46.4
1999	2 409.2	1 012.0	301.8	400.0	31.7	333.7	45.5
2000	2 414.7	1 006.5	303.6	399.9	31.4	333.2	44.6

[274] 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.
[275] 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
2001	2 419.1	1 002.0	305.5	399.6	31.0	333.0	43.7
2002	2 422.6	998.6	306.7	399.4	30.7	332.9	42.9
2003	2 426.4	995.2	307.1	399.1	30.6	333.5	42.1
2004	2 429.7	992.1	307.0	398.7	30.5	334.5	41.5
2005	2 432.7	989.5	305.9	398.2	30.6	335.7	41.2
2006	2 435.3	987.1	303.9	397.8	31.0	337.5	41.1
2007	2 437.5	985.2	301.7	397.4	31.4	339.5	41.1
2008	2 439.0	983.8	299.7	397.0	31.9	341.3	41.2
2009	2 440.0	983.0	297.3	396.5	32.6	343.1	41.4
2010	2 440.7	982.2	295.5	396.1	33.1	344.8	41.4
2011	2 441.9	981.6	293.8	395.7	33.4	346.3	41.2
2012	2 443.1	981.0	291.6	395.4	33.8	348.0	41.1
2013	2 444.2	981.0	289.0	395.1	34.1	349.6	41.0
2014	2 444.9	981.4	286.3	394.8	34.3	351.2	41.1
2015	2 445.2	982.3	283.3	394.6	34.4	352.9	41.1
2016	2 445.2	983.2	280.5	394.3	34.7	354.8	41.3
2017	2 444.7	984.4	278.3	393.9	34.9	356.1	41.6
2018	2 444.2	985.3	276.4	393.5	35.2	357.5	41.7
2019	2 443.8	985.6	275.3	393.2	35.3	358.8	41.9
2020	2 443.5	985.6	274.7	392.9	35.4	359.8	42.0

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. To obtain data for the period of 1990–1998, NFI data of 1999-2008 is extrapolated. The sampling design of the Estonian NFI and the method of estimation of land-use changes are described in Chapter 6.1.3. For the 2017 submission, large-scale methodological updates and improvements were conducted. These improvements mostly influenced standing volume calculations for Forest land and for Grassland. A more thorough explanation is given 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 whole 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 6.1.3.

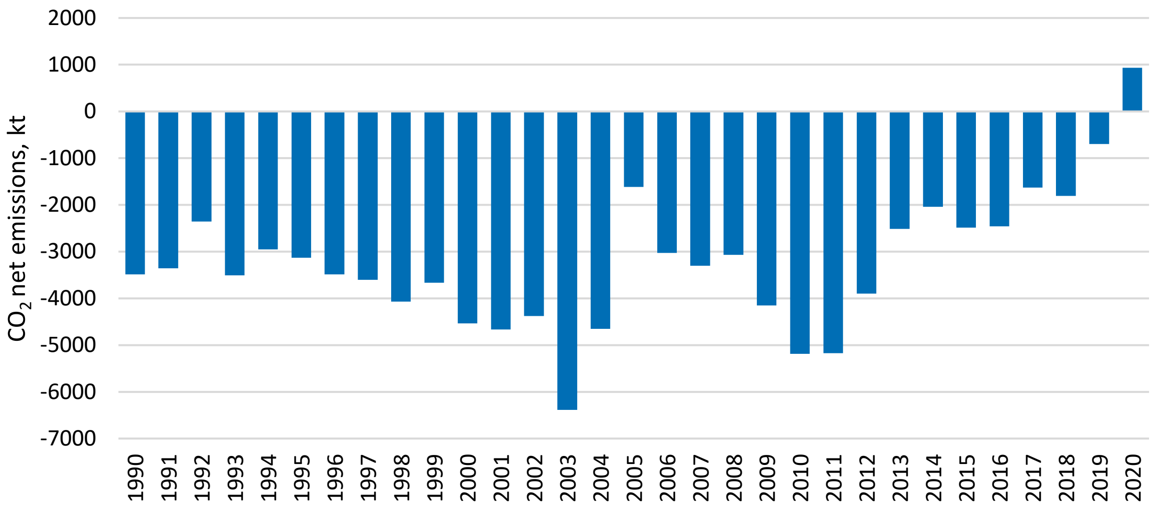

Figure 6.1. Annual change in emissions/removals of CO_2 from the Estonian LULUCF sector in 1990−2020, kt CO_2

Figure 6.2 and Figure 6.3 show total emitted quantities of CH_4 and N_2O during the period 1990–2020. 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.

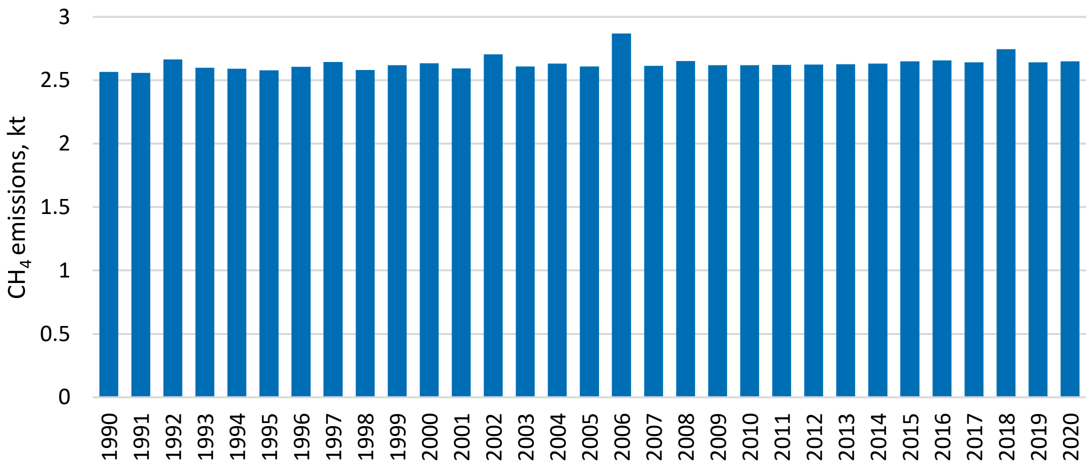

Figure 6.2. Emissions of CH_4 from the LULUCF sector in Estonia in 1990–2020, kt CH_4

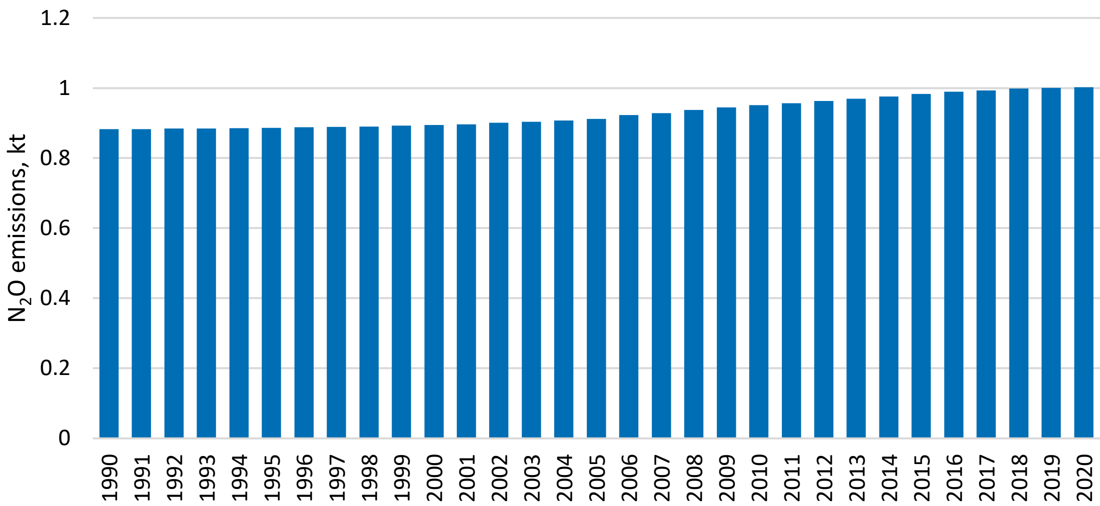

Figure 6.3. Emissions of N_2O from the LULUCF sector in Estonia in 1990–2020, kt N_2O

Key categories

The key categories in 2020 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3 and Annex 1.

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 31.12.2020. The largest decrease in area has occurred in the Cropland category (6.6%) as due to the lack of active management, many croplands have turned into grasslands. The area of the Grassland category has decreased by 6.4% during the last 31 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 the tree crown cover of grasslands exceeds 30% due to natural succession, then the land is counted as Forest land.

Table 6.4. The land-use change matrix for IPCC land-use categories from 31.12.1989 to 31.12.2020 (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	2 327.70	38.54	47.99	10.40	7.77	11.14	2 443.53
Cropland	1.70	960.46	23.24	0.21	0.00	0.00	985.60
Grassland	9.12	47.10	214.08	0.95	1.75	1.24	274.23
Wetlands	3.49	0.10	0.60	424.12	1.45	0.00	429.76
Settlements	16.73	8.28	6.96	0.15	325.82	0.89	358.82
Other land	3.05	0.57	0.26	0.12	0.00	37.96	41.96
Initial area	2 361.78	1 055.05	293.12	435.94	336.78	51.23	4 533.90
Change since 1990, kha	81.75	-69.45	-18.89	-6.18	22.05	-9.27	
Change since 1990, %	3.5	-6.6	-6.4	-1.4	6.5	-18.1	

6.1.2.1. Forest land definitions

Under the Kyoto Protocol, Parties are requested to make national parameter choices for the forest definition within the ranges allowed by Decision 16/CMP.1. Estonia established the 'definition of forest in the context of the Kyoto Protocol' in 2006 with the main parameters of the forest definition shown in Table 6.5. Estonia applies the same forest definition for both UNFCCC and KP reporting.

Table 6.5. Parameters for forest definition

Minimum tree crown cover	30%
Minimum land area	0.5 ha
Minimum tree height	2 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
- 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 and its Kyoto Protocol reporting, the NFI is compiling statistical analyses based on both the national and the Kyoto Protocol definition of a forest regarding the minimum area of a forest. The NFI has been recording information on forests, which remain in the area between 0.1 ha and 0.5 ha because the criterion of 0.5 ha has been the minimum forest area in one of the earlier redactions of the Forest Act, thus there is activity data that is applicable for LULUCF reporting. The same information is used for estimating forest area according to the FRA (UNFAO – Forest Resources Assessment) definition.

The criterion of 1.3 m is not 'the minimum tree height' in the context of the forest land definition. 1.3 m is the criteria for counting unstocked forest area as stocked forest. The minimum tree height *in situ* by the forest definition of the Forest Act is defined by tree species, the stand's age, and site index. Thus, there is no constant criteria for tree height in the national definition. As all forest tree species in Estonia reach the height of 2 m at maturity, the height criterion of the Kyoto Protocol Forest definition has been met in NFI statistics.

All temporarily unstocked forest areas and regeneration areas which have yet to reach a crown density of 30 per cent and a tree height of 2 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.

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.

The national definition corresponds to the IPCC classification.

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'). An overgrown wooded pasture with a canopy cover between 30 and 50% is classified as Grassland or forest, depending on the mainland-use purpose.

The national land cover category 'bushes' (area covered with natural or wildered cultivated bush and shrub species where the canopy cover is over 50%) is defined as IPCC 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.

The NFI Wetland areas are defined as IPCC Wetlands.

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. 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 forest 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 2015 and 2016, 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 45 339 km^2 (formerly known 45 227 km^2) and this figure is used in the NFI and GHG inventory starting from the 2018 submission.

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)[276] 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.

[276] In FCCC/ARR/2014/EST, paragraph 68, the ERT recommended increasing the sampling frequency.

Point estimates of parameters are calculated using data from the sample plots and form the basis for inferences to the entire population.

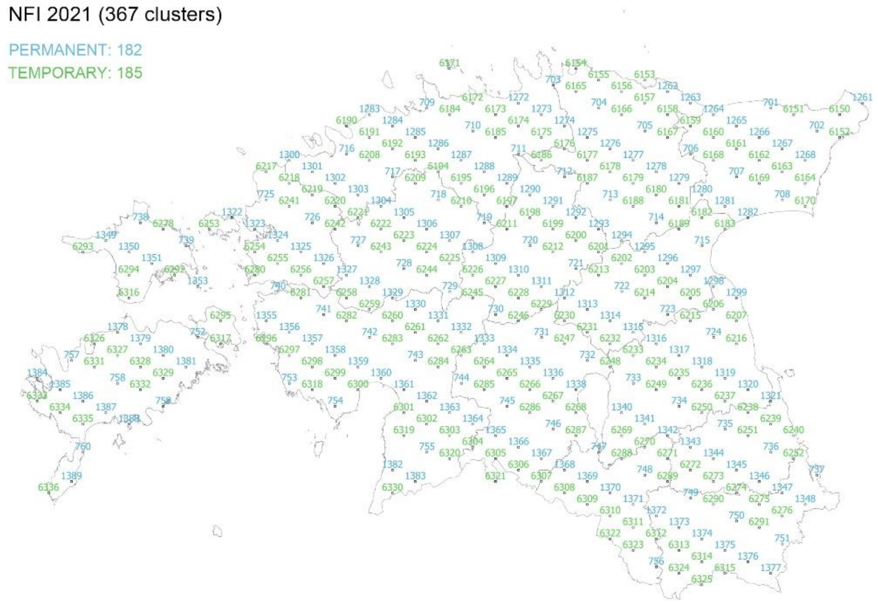

Figure 6.4. Cluster network of the Estonian National Forest Inventory

By 2001, the NFI assessments were used at the state level, as well as in compiling the strategic document "Estonian Forestry Development Program until 2010". Since that period the 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 at the national level. At present, the actual areas of the NFI monitoring system include global carbon cycles and the observation of features related to the protection of biological diversity.

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 reports under the United Nations Framework Convention on Climate Change.

Design of the Estonian NFI is a systematic sample without pre-stratification. No remote sensing is applied. 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.

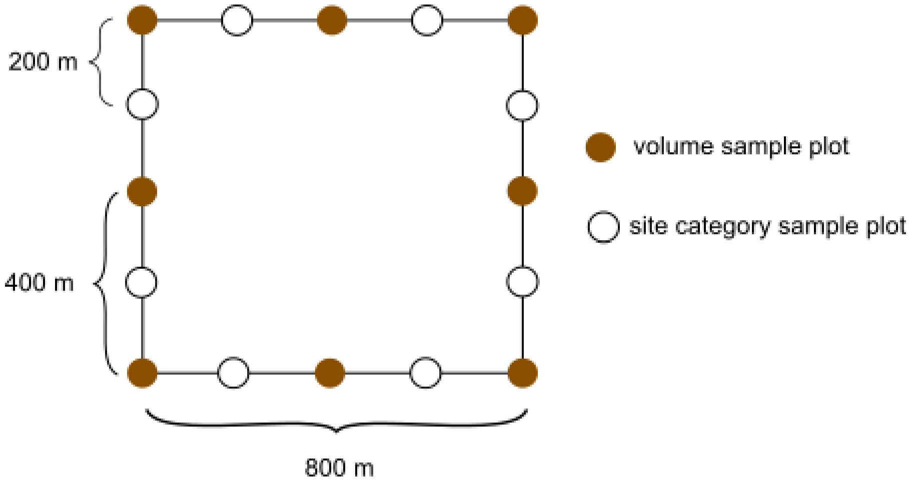

Figure 6.5. Estonian NFI cluster design

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.

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)[277].

From the 2017 submission, Estonia has implemented an improved average standing volume calculation that has led to significant recalculations of carbon stock changes in living biomass. Also increased frequency sampling cycle data are being used for NFI calculations that enable to increase the quality of the overall outcome.

Starting from NFI 2015, the average standing volume is calculated for every year based on the 15-year trend. For previous submissions it was calculated based on five-year measurements. Two consecutive years are independent samples and average standing volume estimates have confidence intervals; therefore, the new methodology is statistically more accurate.

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.

[277] 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.

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.

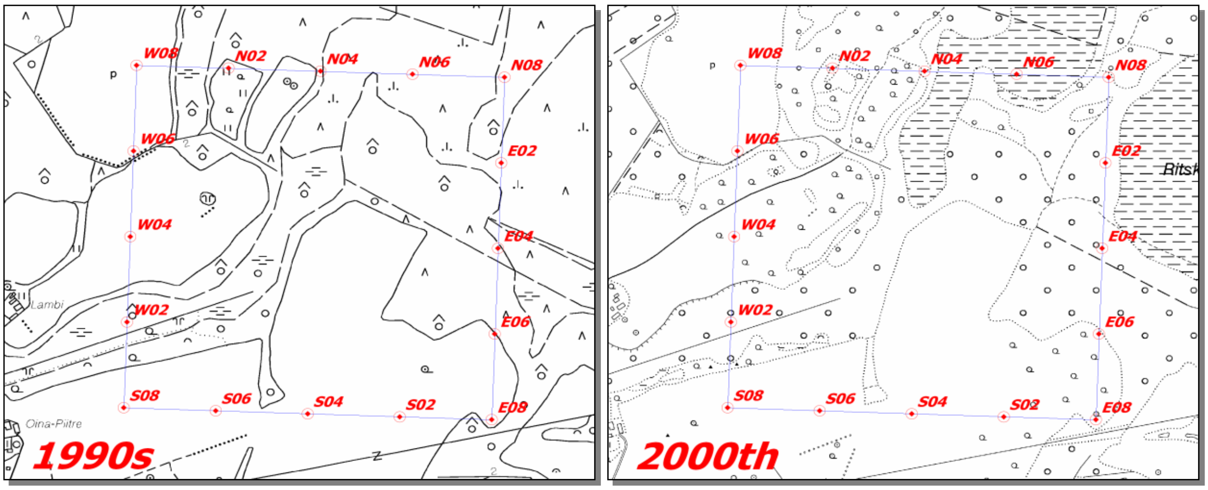

Figure 6.6. Base maps of the 1990s and the year 2000

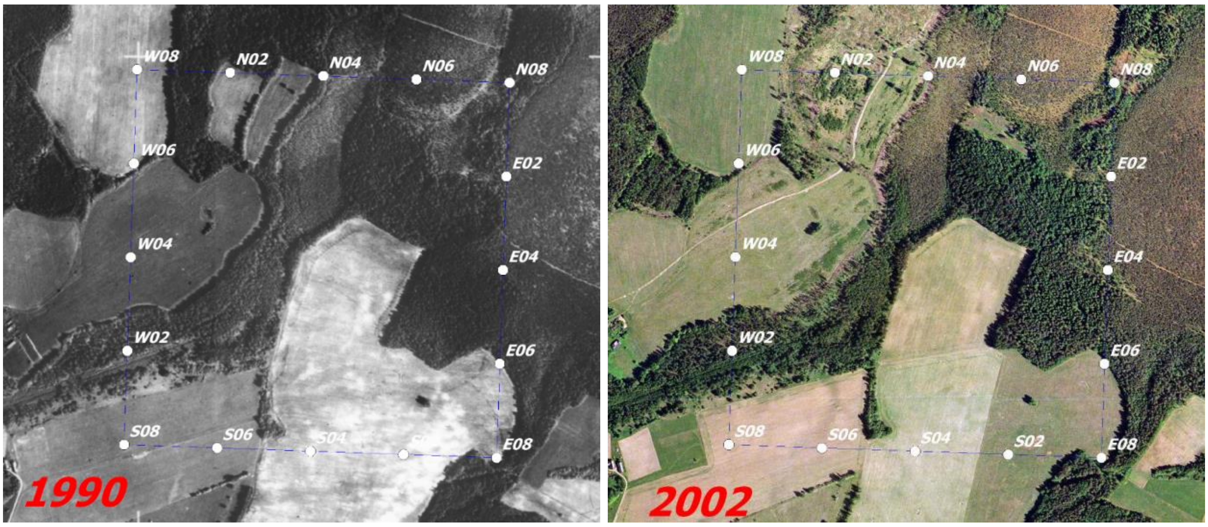

Figure 6.7. Orthophotos of 1990 and 2002

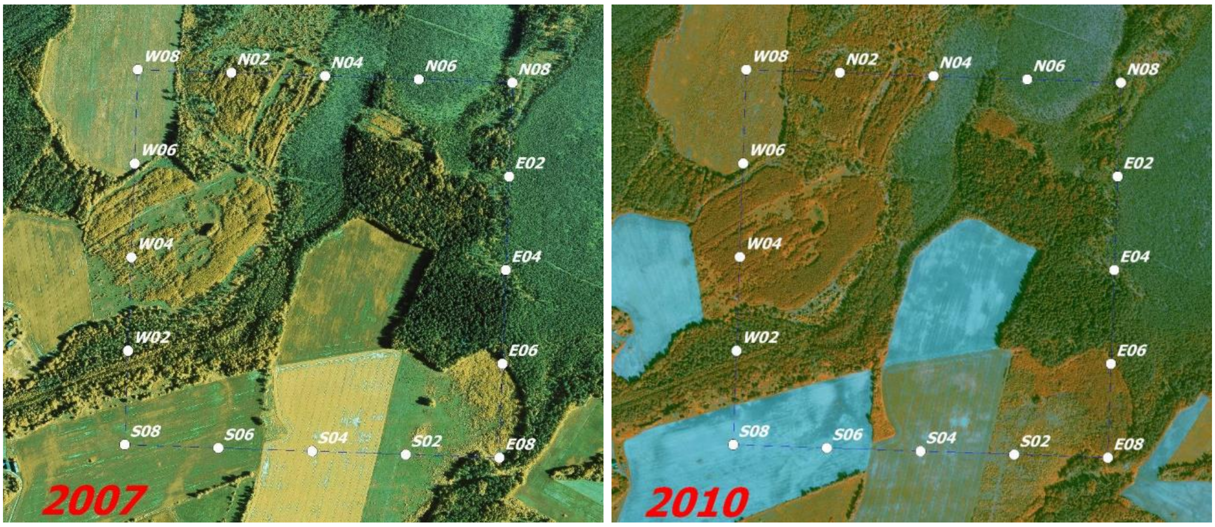

Figure 6.8. Orthophotos of 2007 and 2010

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 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 2020 (kha)

	Forest land	**Cropland**	**Grassland**	**Wetlands**	**Settlements**	**Other land**
Forest land (M)	2 120.21					
Unstocked forest land (MM)	204.75					
Arable land (excluding PK, PR) (PM)		654.21				
Permanent crops (PK)		1.88				
Long-term cultural grassland (PR)		329.51				
Bushes (P)	20.68		43.02			
Natural grassland (RM)	35.97		204.22			
Swamp, bog (S)	58.16		24.97	140.23		
Inland water bodies (SV)				262.57		
Peat quarry (KT)				25.55		
Opencast pit (excl. KT) (K)					8.68	
Settlements (excl. T, TR) (A)					205.65	
Roads and railways (T)					66.34	
Lines, power lines, etc. (TR)					79.10	
Unusable mineral land (KK)	3.76		2.50			35.39
Other land (Y)						6.57
Total	**2 443.53**	**985.60**	**274.70**	**428.35**	**359.76**	**41.96**

6.1.4. LULUCF cross-cutting issue: climate zones

According to GPG-LULUCF 2003 and IPCC 2006 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[278]) 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. Grassland biomass parameters are also chosen from the boreal zone. All other land-use categories follow the default allocation by IPCC 2006.

The issue related to using emission factors from different climate zones was also raised by the Joint Research Centre of the European Commission during assistance[279] in 2013. Since soil, biomass and other parameter values for the abovementioned climate zones are significantly

[278] 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.

[279] ADMINISTRATIVE ARRANGEMENT Nº071201/2011/611111/CLIMA.A2 (Analysis of and proposals for enhancing, monitoring, reporting and verification of land use, land use change and forestry in the EU – LULUCF MRV).

different, it may cause a large bias under land-use change estimates when the lands are in different climate zones. However, this is not the case in the current report, as most land-use change emission factors for soil are obtained from the Sweden NIR 2021 because Estonia does not currently have respective country-specific values. In some cases, e.g., Cropland mineral and organic soil, emission factors have the same value in both boreal and temperate zones[280].

Estonia assessed the impact of using temperate zone factors instead of the boreal zone for living biomass estimates[281]. The result was that the CO_2 sink increased almost twofold, which is an obvious overestimation based on expert opinions and does not follow the UNFCCC recommended conservative approach. For those reasons, Estonia has decided to continue using boreal climate zone parameters in the Forest land category.

6.2. Forest land (CRF 4.A)

6.2.1. Category description

The Forest land area has not increased in recent years. In total the total Forest land area has increased by 79.99 thousand hectares compared to 1990 (Figure 6.9).

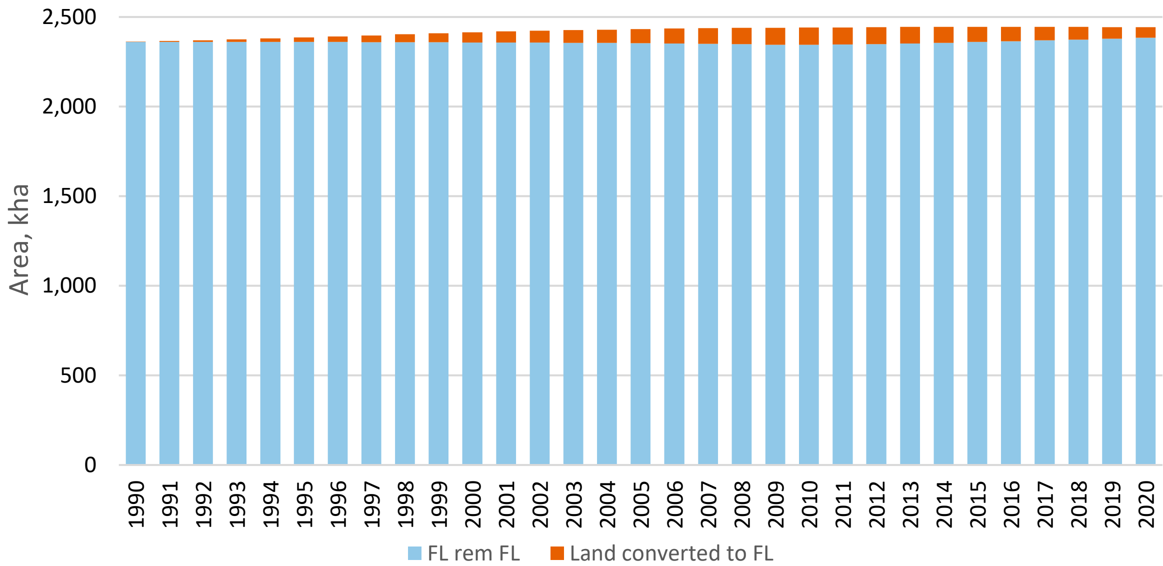

Figure 6.9. Forest land area in Estonia in 1990–2020, kha

The net emissions from Forest land were 139.17 kt CO_2 eq. (Figure 6.10) in 2020. 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.

[280] IPCC 2006 Guidelines, Volume 4, Chapter 5: Cropland, pages 5.17–5.19, Table 5.5 & Table 5.6.
[281] Kaie Kriiska, LULUCF leading expert, Estonian Environment Agency, 2014.

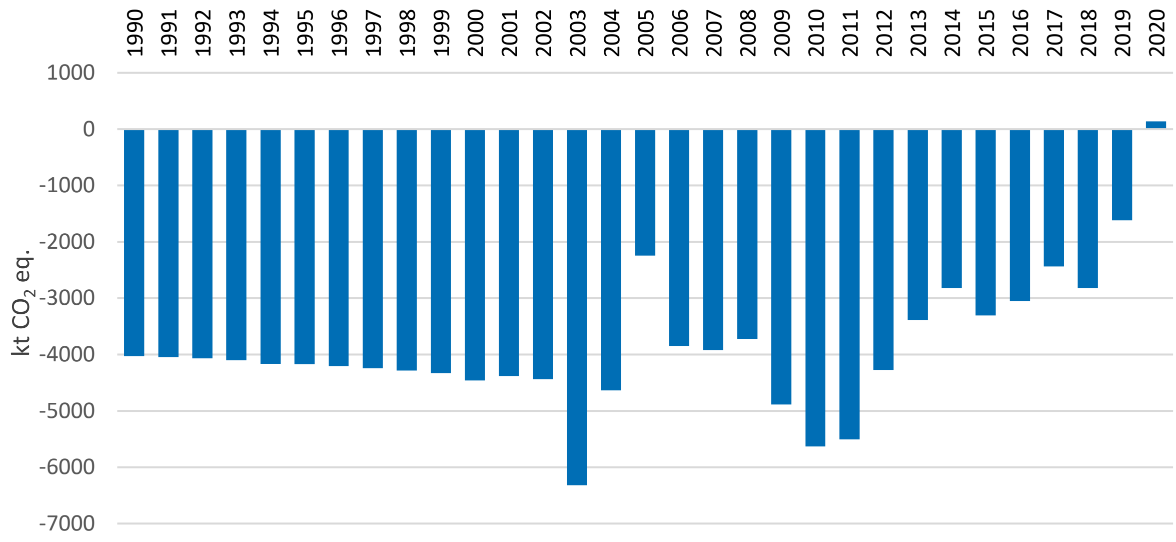

Figure 6.10. Annual net change in GHG emissions (+) and removals (-) from the Forest land category in 1990–2020, kt CO_2 eq.

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[282], therefore the net annual increment has been lower than in previous 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), the capacity of carbon sequestration in biomass has decreased in recent years. In addition, the annual increase in conversion from other land categories to Forest land (afforestation and reforestation) has been slowing – particularly in Cropland and Grassland conversion to Forest land, and the total 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 the period 1990–2002, the area of forest land remaining forest land decreased due to the 20-year transition period (the total forest land area increased). However, C sequestration increased due to the rapid increase in forest growing stock. In the period 2004–2008 C sequestration decreased as the felling volume increased strongly in the previous few years. Felling volumes in 2004–2011 were lower compared to the previous period.

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:

[282] Yearbook Forest 2019, Table 1.3.5 (Distribution of stands by age classes and dominant tree species,10 years age classes). [www] https://keskkonnaagentuur.ee/media/882/download (10.01.2022).

Equation 6.1[283]

$$\Delta C_{LU} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO}$$

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.

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 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 reporter nor in the NIR.

Equation 6.2[284]

$$\Delta C_B = \left[C_{t_o} - C_{t_{(0-1)}}\right] \times A$$

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};

[283] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.7, Equation 2.3.
[284] After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.12, Equation 2.8.

$BCEF_S$ = 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.)$^{-1}$.

To ensure that actual carbon stock changes are reported, and not artefacts resulting from changes in area over time, calculations of carbon stock changes were implemented in the following sequence: i) for each given area the carbon stock change is first calculated as a difference of carbon stocks between times t_1 and t_2, ii) these stock changes are summed for all areas.

According to the NFI, on Land converted to forest land areas, growing stock was assumed to increase at rate of 3.04 m^3 ha^{-1} yr^{-1}.

Table 6.7. Implemented values of $BCEF_S$[285]

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		0.645…0.647	
	SL to FL		0.640…0.648	
	OL to FL		0.681…0.692	

Estonian country specific $BCEF_S$ values were calculated based on NFI and sample trees data (Table 6.7). 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,” 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 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. Thus, the new country specific $BCEF_S$ values can be applied as instructed in the IPCC 2006 Guidelines.

Weighted average R values were calculated based on tree species distribution and above-ground biomass. Land converted to forest land subcategories were divided into human-induced (CL to

[285] Country-specific values

FL, WL to FL, SL to FL = AR) and natural regeneration (GL to FL, OL to FL) categories. The boreal climatic zone default IPCC parameter values are applied (see Chapter 6.1.4 for more information).

Table 6.8. Default values of root-to-shoot ratio R[286]

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		0.236		Human-induced 0.39 Natural 0.44

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[287]

Tree species	Forest land remaining forest land	Land converted to forest land	
		Human induced	**Natural regeneration**
Pinus sylvestris	0.299	0.40	0.16
Picea abies	0.254	0.56	0.09
Betula spp	0.232		
Populus tremula	0.070		
Alnus glutinosa	0.052		
Alnus incana	0.049		
Other	0.043	0.04 (mainly *Betula*)	0.75 (broadleaf)

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 1990−2020. The estimation for 1990−1998 is based on interpolated data since no exhaustive forest resources assessments were carried out during these years. The NFI that covers the whole country was started in 1999. Differences in annual carbon stock changes in Forest land living biomass are mainly due to NFI developments and uncertainty from sampling. The new NFI cycle with increased frequency took place during 2014–2018. Ongoing researches for example remote sensing project (Chapter 6.2.6) will help to improve the accuracy of emission estimates. Emissions and uptake from Forest land are predominantly determined by changes in forest growing stock and changes in forest land area. In recent years, both indicators have grown more slowly than before.

[286] IPCC 2006 Guidelines, Volume 4, Chapter 4: Forest Land, page 4.49, Table 4.4.
[287] Sims, A. (Forest statistics by NFI, 2021).

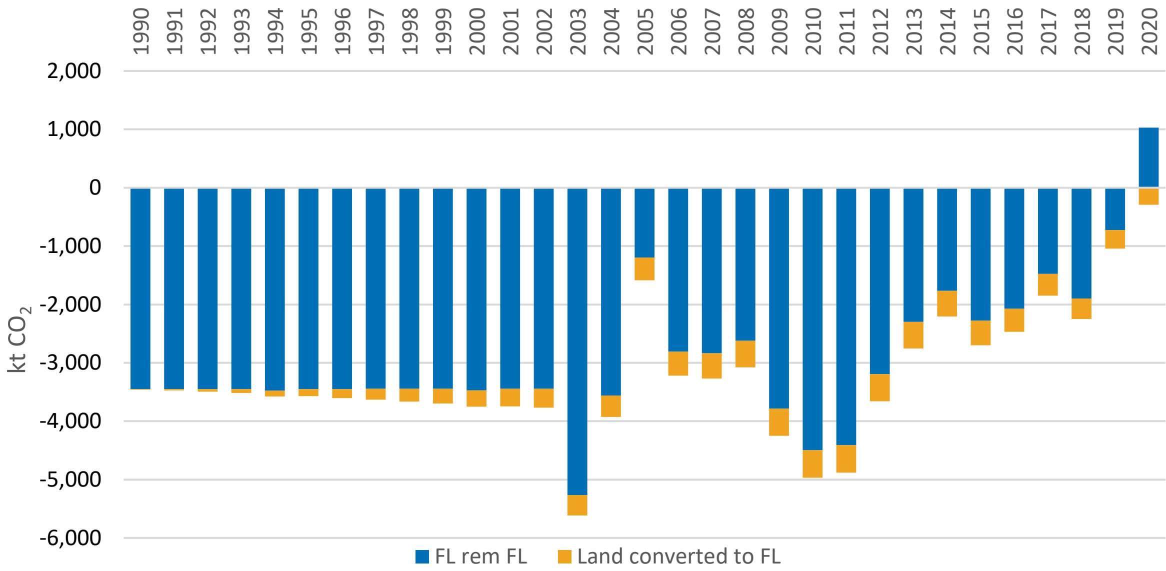

Figure 6.11. Annual carbon stock changes in Forest land living biomass in 1990–2020, kt CO_2

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. Also, inter-annual fluctuations in the carbon stock changes in the deadwood pool were reduced by using smoothed data from the NFI. Values of deadwood densities and C content were acquired from Köster *et al*. 2015[288].

Equation 6.3[289]

$$\Delta C_{DW} = \left[A \times \frac{(DW_{t_2} - DW_{t_1})}{T}\right] \times D \times CF$$

Where:

ΔC_{DW} = annual change in carbon stocks in deadwood (DW), tonnes C yr^{-1};
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};

[288] 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.
[289] After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.23, Equation 2.19.

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 dead organic matter stock changes on Land remaining forest land and Land converted to forest land. The stock of deadwood has increased constantly during the period 1990–2020 and the equilibrium has not reached jet. However, the rate of increase of the C stock has decreased. The increase in deadwood is caused by the age structure of forests[282] and the small share of thinning compared to clear fellings[290]. Stock changes per area vary only slightly from year to year; however, due to the multiplication by the forest area, the interannual differences become significantly larger.

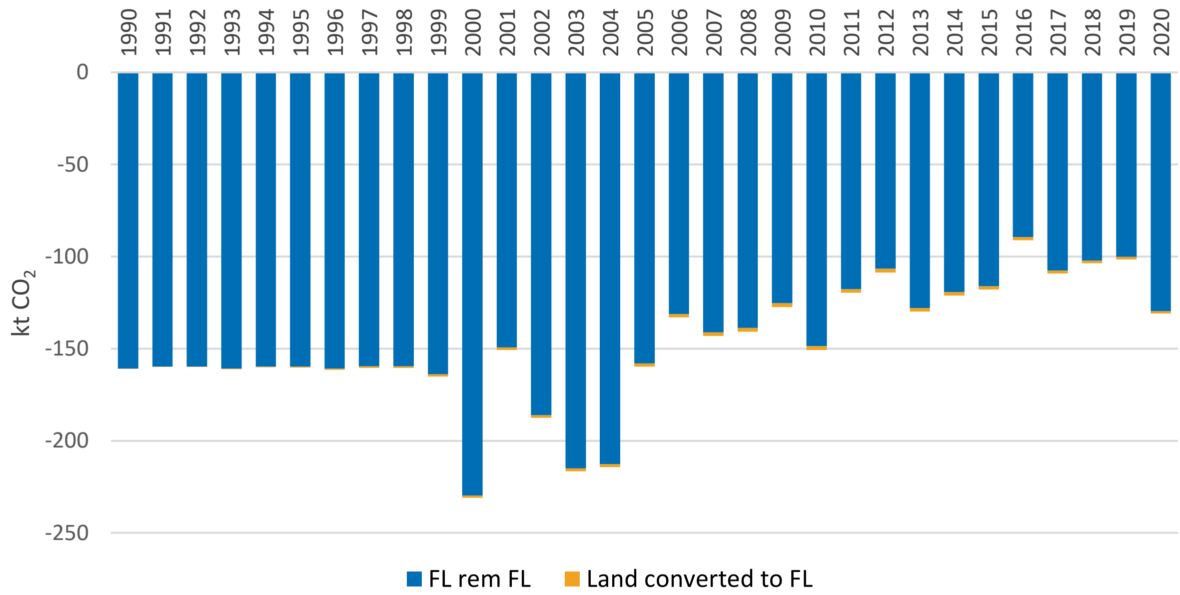

Figure 6.12. Net carbon stock change in forest deadwood pool in 1990–2020, kt CO_2

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, thus the changes in the litter pool are assumed to be zero. Under Land converted to forest land, the emission factor from Sweden NIR[291] (0.3 t C ha^{-1} yr^{-1}) is used for litter, maintaining consistency between the Convention and KP-LULUCF reporting. It was also possible to apply the Swedish EF of litter on Land remaining forest land, but it would have resulted in a carbon increase in the pool. Therefore, Estonia decided to implement a more conservative approach, i.e., *Tier 1*, assuming no change in the pool.

[290] Yearbook Forest 2019, Table 3.2.2 [www] https://keskkonnaagentuur.ee/media/882/download (10.01.2022).
[291] Sweden NIR 2021, Annexes, Table A3:2.12, page 141.

6.2.2.4. CO_2 emissions/removals from/by mineral forest soils

In Table 6.10 the cumulative area and proportion of Land-use changes to Forest land in 2020 are shown, as well as applied emission factors for mineral and organic soils. In the case of missing or insufficient country-specific data, emission factors from the Sweden 2021 annual submission were implemented with the agreement of ERT[292].

Table 6.10. Cumulative Land-use changes to Forest land in 2020 and implemented soil emission factors[293]

Land-use change	kha	%	EF mineral soil t C ha^{-1}	EF organic soil t C ha^{-1}
Cropland→ Forest land	14.05	23.8	0.17	-6.10
Grassland→ Forest land	29.70	50.3	-0.06	-0.34
Wetlands→ Forest land	7.55	12.8	-	-0.34
Settlements→ Forest land	3.07	5.2	0.17	-0.34
Other land→ Forest land	4.68	7.9	0.17	-0.34
Total	59.04	100.0		

Due to insufficient country-specific data regarding carbon stock changes in forest mineral soil, the emission factor from Sweden NIR[294] (0.162 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 national EFs were applied. Changes in mineral soil SOC stocks due to land-use conversions were obtained from the literature (Kõlli *et al.* 2010[269]) 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[268]). Implementation of emission factors from a neighbouring country is a temporary solution suggested by ERT (FCCC/ARR/2012/EST para.94). Currently Estonia is working on developing a *Tier 3* method for reporting on Forest land litter and soil carbon stock changes (Chapter 6.2.5).

In 2020, there was a net increase in the carbon stock of Forest mineral soils by -1 081.05 kt CO_2, of which -1 073.54 kt CO_2 was contributed by Land remaining forest land and -7.51 kt CO_2 in Land converted to Forest land. Overall, the annual carbon sequestration by forest mineral soils has remained at the same level compared to 1990 (Figure 6.13).

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[292] FCCC/ARR/2012, para 94.

[293] 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.

[294] The average implied emission factor of 1990–2019 in Sweden CRF tables 2021.

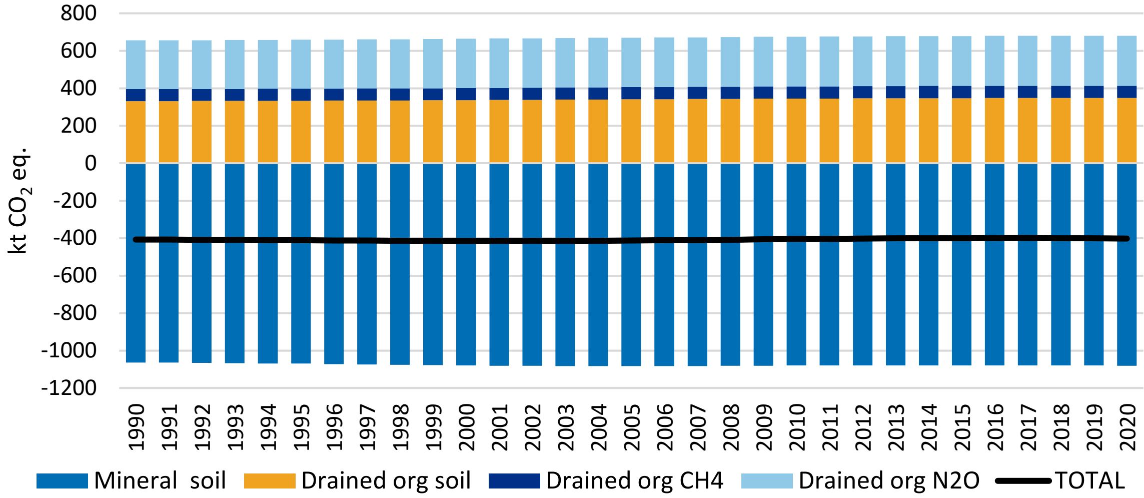

Figure 6.13. Annual stock change in Forest land mineral and drained organic soil pools including non-CO_2 emissions from drained soils in 1990–2020, kt CO_2 eq.

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 drainage ditch is up to 100 m. Equation 6.4 was applied for estimating carbon loss from drained organic forest soils.

Equation 6.4[295]

$$L_{Organic} = A \times EF$$

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.

ERT recommended Estonia to apply Swedish emission factors (Table 6.10 and Table 6.13) for drained organic forest soils, since default IPCC 2006 EFs would likely cause underestimation of emissions[296]. The emission factor from Sweden[294] (-0.329 t C ha^{-1} yr^{-1}) was implemented for Land remaining forest land.

Approximately 23.5% of all Estonian forest soils are organic soils, of which about 48.3% are drained according to the NFI. Emissions from drained organic forest soils have increased only by 0.03% since 1990 (Figure 6.13).

[295] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.35, Equation 2.26.
[296] FCCC/ARR/2012, para. 94.

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 2020 are presented in Table 6.11.

Equation 6.5 with factors from the IPCC 2013 Wetlands Supplement[297] (*Tier 1)* was applied for estimating CH_4 emissions from drained organic forest land and drainage ditches.

Equation 6.5[298]

$$CH_{4\_OS} = \sum_n A_n \times \left((1 - Frac_{ditch}) \times EF_{CH_4\_land_n} + Frac_{ditch} \times EF_{CH_4\_ditch}\right)$$

Where:

CH_{4_OS} = annual CH_4 loss from drained organic forest soils, kg CH_4 yr^{-1};

A_n = area of drained organic forest soils in nutrient status n, ha;

$EF_{CH_4\_land_n}$ = emission factors for direct CH_4 emissions from drained organic forest soils by nutrient status n, kg CH_4 ha^{-1} yr^{-1} (Table 6.11);

$EF_{CH_4\_ditch}$ = emission factor for CH_4 emissions from drainage ditches, kg CH_4 ha^{-1} yr^{-1} (Table 6.11);

$Frac_{ditch}$ = fraction of the total area of drained organic soils which is occupied by ditches (where “ditches” are considered to be any area of manmade channel cut into the peatland) (Table 6.11).

Equation 6.6 with default emission factors from the IPCC 2013 Wetlands supplement (*Tier 1)* was used for estimating N_2O emissions from drained organic forest land.

Equation 6.6[299]

$$N_2O_{OS} = \left[\left(A_{NR} \times EF_{N_2O-N,NR}\right) + \left(A_{NP} \times EF_{N_2O-N,NP}\right)\right] \times \frac{44}{28}$$

Where:

N_2O_{OS} = annual direct N_2O-N emissions from drained organic forest soils, kg N_2O yr^{-1};

A = area of drained organic forest soils, ha (the subscripts NR and NP refer to Nutrient-Rich and Nutrient-Poor, respectively);

EF_{N_2O-N} = emission factor for N_2O emissions from drained organic forest soils, kg N_2O-N ha^{-1} yr^{-1} (the subscripts NR and NP refer to Nutrient-Rich and Nutrient-Poor, respectively) (Table 6.11).

In 2020, non-CO_2 emissions from drained organic forest soils were equal to 331.91 kt CO_2 eq., which is 2.4% higher compared to the base year (Figure 6.13).

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[297] IPCC (2014b). 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (*IPCC 2013 Wetlands Supplement*).
[298] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.22, Equation 2.6.
[299] 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 2020, kha**	**Emission factors**			**$Frac_{ditch}$[300]**
			N_2O-N[301], kg N ha^{-1} yr^{-1}	**CH_4 land[302], kg CH_4 ha^{-1} yr^{-1}**	**CH_4 ditch[300], kg CH_4 ha^{-1} yr^{-1}**	
Nutrient-rich	166.43	169.77	3.2	2.0	217	0.025
Nutrient-poor	107.97	112.88	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 %[303]**	**Emission factor %**	**EF References**
4.A.1	Forest land remaining forest land – living biomass	2.0	47.0	IPCC 2003 & 2006[304]
4.A.1	Forest land remaining forest land – mineral soils	1.4	60.0	Sweden NIR 2021
4.A.1	Forest land remaining forest land – organic soils	3.0	40.0	Sweden NIR 2021
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	11.4	47.0	IPCC 2003 & 2006
4.A.2.1	Cropland converted to forest land – mineral soil	14.4	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	12.5	47.0	IPCC 2003 & 2006
4.A.2.2	Grassland converted to forest land – mineral soils	13.1	60.0	Kõlli *et al*. 2009 & 2010
4.A.2.2	Grassland converted to forest land – organic soils	48.0	40.0	Sweden NIR 2021
4.A.2.2	Grassland converted to forest land – deadwood	7.2	19.8	Köster *et al*. 2015
4.A.2.3	Wetlands converted to forest land – living biomass	31.4	47.0	IPCC 2003 & 2006
4.A.2.3	Wetlands converted to forest land – organic soils	33.7	40.0	Sweden NIR 2021
4.A.2.3	Wetlands converted to forest land – deadwood	18.1	19.8	Köster *et al*. 2015
4.A.2.4	Settlements converted to forest land – living biomass	114.4	47.0	IPCC 2006

[300] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.30, Table 2.4.
[301] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.33, Table 2.5.
[302] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.25, Table 2.3.
[303] All activity data uncertainty estimates are obtained from NFI.
[304] Parameters were applied from the IPCC 2006 Guidelines. However due to the lack of information in the IPCC 2006 Guidelines, the same EF uncertainty as in the GPG-LULUCF 2003 for calculating living biomass emissions was assumed.

IPCC category		Activity data %[303]	Emission factor %	EF References
4.A.2.4	Settlements converted to forest land – mineral soils	35.8	60.0	Sweden NIR 2021
4.A.2.4	Settlements converted to forest land – organic soils	90.5	40.0	Sweden NIR 2021
4.A.2.4	Settlements converted to forest land – deadwood	14.9	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	27.6	60.0	Sweden NIR 2021
4.A.2.5	Other land converted to forest land – deadwood	10.1	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)[305] 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[306]). 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)[307] found a small but statistically insignificant 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.

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305 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.
306 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.
307 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.

Changes in living biomass C pool compared to the previous submission have resulted from the recalculation of average growing stocks and changes in methodology for Land converted to forest land areas. After the transition to Forest land, average growing stock was assumed to increase at rate of 3.04 m^3 ha^{-1} yr^{-1}.

Soil emission factors were updated for Land remaining forest land and Land converted to forest land. Emissions from mineral and organic soils under Forest land remaining forest land have significantly decreased because of updated emission factors.

In Table 6.13 changes in applied parameters and in Table 6.14 a quantitative overview of recalculations is shown.

Table 6.13. Parameters used in Forest land category recalculations compared to the 15.04.2021 submission

Land-use category	**Parameter**	**2021 Submission**		**Source**	**2022 Submission**		**Source**
Forest land remaining forest land	EF organic soil [t C ha^{-1} yr^{-1}]	EF Sweden	-0.367	Sweden 2020, CRF (1990–2018 average)	EF Sweden	-0.329	Sweden 2021, CRF (1990–2019 average)
	EF mineral soil [t C ha^{-1} yr^{-1}]	EF Sweden	0.173	Sweden 2020, CRF (1990–2018 average)	EF Sweden	0.162	Sweden 2021, CRF (1990–2019 average)

Table 6.14. Quantitative overview of recalculations, kt C compared to the 15.04.2021 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 soil	Organic soil	Living biomass	Dead organic matter	Mineral soil	Organic soil	
1990	Previous submission	869.52	44.00	312.23	-103.26	2.26	0.58	0.12	-0.05	-4 126.50
	Current submission	940.78	43.88	218.99	-90.36	2.40	0.54	0.12	-0.05	-4 353.41
	Difference %	**8.2**	**-0.3**	**-7.1**	**-12.5**	**6.0**	**-7.2**	**0.0**	**0.0**	**5.5**
1995	Previous submission	869.12	43.67	312.08	-103.73	14.54	7.54	1.96	-0.70	-4 196.45
	Current submission	940.35	43.55	289.84	-90.26	33.57	7.62	1.96	-0.70	-4 495.12
	Difference %	**8.2**	**-0.3**	**-7.1**	**-13.0**	**130.9**	**1.1**	**0.0**	**0.0**	**7.1**
2000	Previous submission	867.30	62.84	311.63	-104.37	38.18	17.21	4.92	-1.59	-3 385.74
	Current submission	947.42	62.67	289.42	-90.18	76.27	17.37	4.92	-1.59	-4 789.78
	Difference %	**9.2**	**-0.3**	**-7.1**	**-13.6**	**99.8**	**1.0**	**0.0**	**0.0**	**9.2**
2005	Previous submission	327.00	43.24	310.96	-105.06	68.94	23.99	6.58	-2.68	-2 467.54
	Current submission	326.00	43.12	288.80	-90.25	106.36	24.18	6.58	-2.68	-2 574.77
	Difference %	**-0.3**	**-0.3**	**-7.1**	**-14.1**	**54.3**	**0.8**	**-0.03**	**0.0**	**4.4**

		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 soil	Organic soil	Living biomass	Dead organic matter	Mineral soil	Organic soil	
2010	Previous submission	1154.98	40.62	309.54	-105.54	91.08	29.48	7.07	-3.77	-5 586.03
	Current submission	1226.60	40.54	287.46	-90.22	128.61	29.23	6.94	-3.72	-5 959.92
	Difference %	**6.2**	**-0.2**	**-7.1**	**-14.5**	**41.2**	**-0.8**	**2.0**	**1.3**	**6.7**
2015	Previous submission	824.37	31.68	311.41	-106.09	28.28	27.16	5.65	-4.10	-4 100.64
	Current submission	621.32	31.67	289.19	-90.60	114.45	26.01	5.12	-4.02	-3 641.47
	Difference %	**-24.6**	**-0.04**	**-7.1**	**-14.6**	**304.7**	**-4.2**	**-9.3**	**-1.9**	**-11.2**
2019	Previous submission	299.49	27.89	313.70	-106.17	23.01	23.54	3.89	-3.79	-2 132.39
	Current submission	197.80	27.32	291.93	-91.05	87.28	19.73	2.64	-3.69	-1 950.51
	Difference %	**-34.1**	**-0.06**	**-7.2**	**-14.2**	**266.23**	**-10.0**	**-19.7**	**1.6**	**-8.5**

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 completer and 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 and controlled 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 of forest mineral soils with Yasso07, but it needs further research to provide data for the UNFCCC and Kyoto Protocol 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. The Estonian University of Life Sciences has an ongoing project “Development of new forest growth models”. The aim is to verify and specify forest biomass estimates. The model allows to specify the time series of changes in forest growing stock from 1990.

Project "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland" (LIFE OrgBalt, LIFE18 CCM/LV/001158)[308] 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 in the 2025 inventory submission.

6.3. Cropland (CRF 4.B)

6.3.1. Category description

Total net emissions from croplands were 417.00 kt CO_2 eq. in 2020 (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 cropland (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.

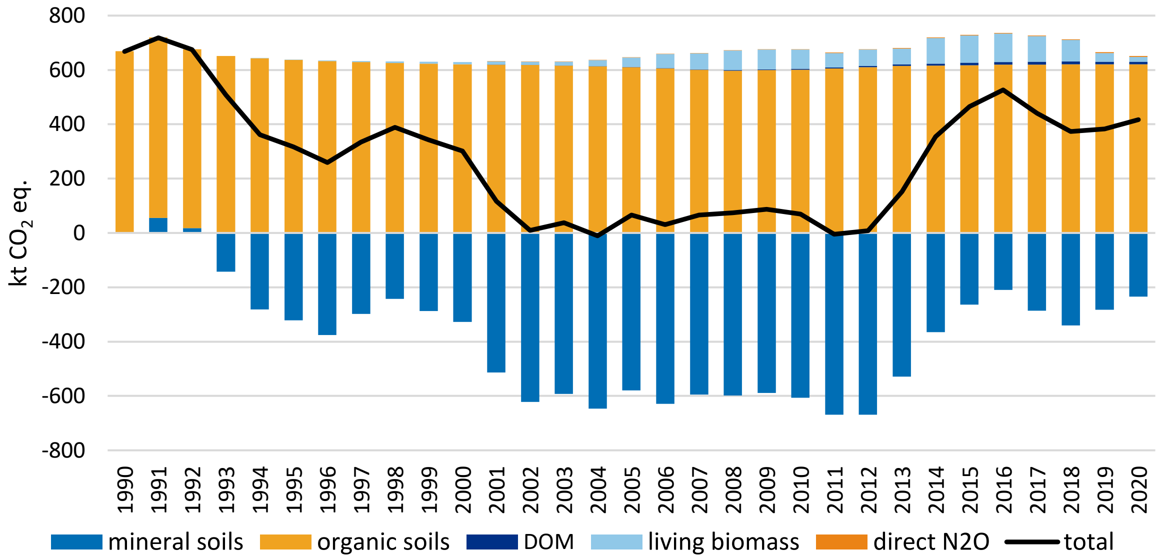

Figure 6.14. Emissions (+) and removals (-) in the Cropland category in 1990–2020, kt CO_2 eq

The area of croplands in Estonia has decreased by 6.5% 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

[308] LIFE OrgBalt project. [www] https://www.orgbalt.eu/ (10.01.2022).

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.

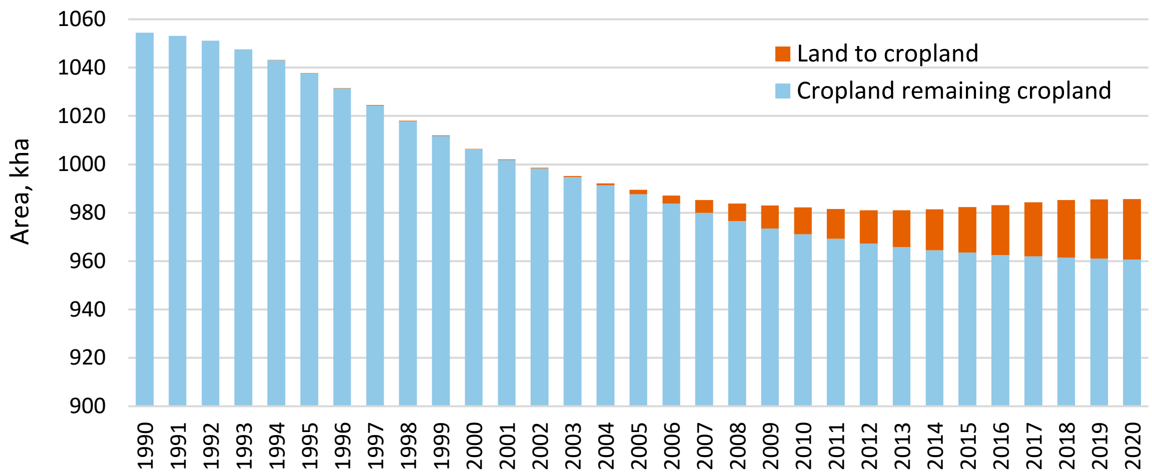

Figure 6.15. Cropland area in Estonia in 1990–2020, kha

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[309], 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[310]

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

309 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.
310 Metsaruum OÜ (2012). Põllumajandusmaadel kasvava puitse biomassi määramine. Report, unpublished.

The annual change in the biomass of perennial woody crops was calculated based on the inter-annual changes in the area of orchards (Equation 6.7, *Tier 2*).

Equation 6.7

$$\Delta C_B = \left[B_{total} \times \left(A_{t_2} - A_{t_2}\right) \times CF\right]$$

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 1 400 ha in 2020, thus the carbon stocks have decreased also, as seen in Figure 6.16.

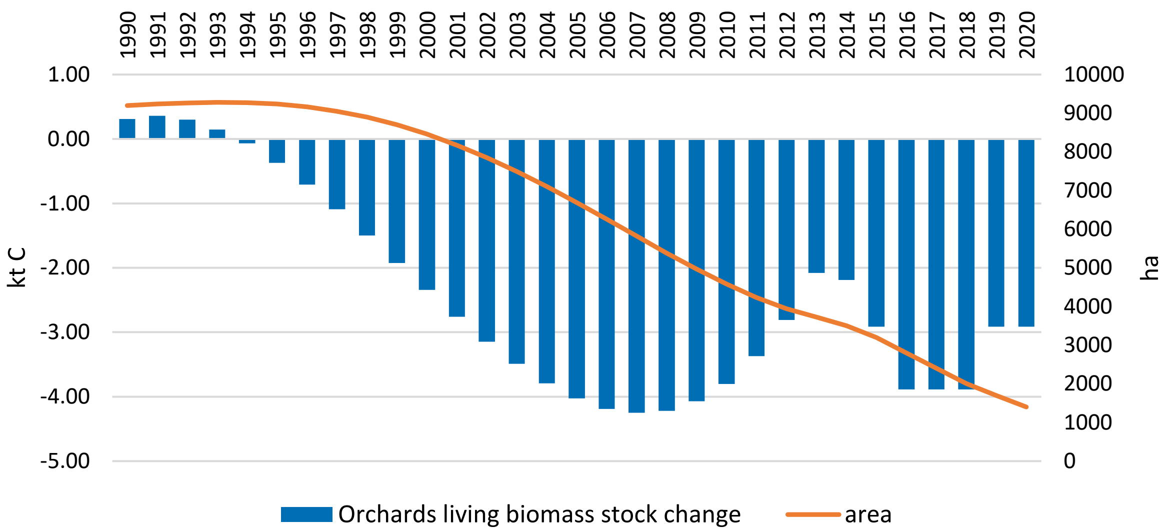

Figure 6.16. Area (ha) and annual change in the cropland perennial woody crops (orchards) living biomass stock (kt C)

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 6.8, respectively, and for Grassland in Table 6.23 and Table 6.24.

Equation 6.8[311]

$$\Delta C_{CONVERSION} = \sum_i [(B_{AFTER_i} - B_{BEFORE_i}) \times \Delta A_{TO\_OTHERS_i}] \times CF$$

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.

Table 6.16. Average living biomass and deadwood stocks in Forest land and Grassland

C pool	FL rem FL		GL rem GL	
	1990	2020	1990	2020
Living biomass (m^3 ha^{-1})	175.94	205.04	10.82	10.82
Deadwood (m^3 ha^{-1})	17.19	21.13	0.54	0.54

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

[311] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.20, Equation 2.16.

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[288] (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[312] (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 Agricultural Research Centre (documented in archive), 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 Estonian Crop Research Institute, traditional tillage was prevailing 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[313]

$$\Delta C_{Mineral} = \frac{\left(SOC_0 - SOC_{(0-T)}\right)}{D}$$

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;

[312] Sweden NIR 2021, Annexes, Table A3:2.12, page 141.
[313] After IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.30, Equation 2.25.

$A_{Mineral}$ =	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 2020

Land use	Area in 1990, kha	Area in 2020, kha
Long-term cultivated	897.35	643.31
High input	408.30	146.83
Medium input	421.75	487.01
Low input	67.30	9.46
Perennial	9.20	1.40
Set aside	118.08	289.80
Total CL rem CL, mineral soil	1 024.63	934.51

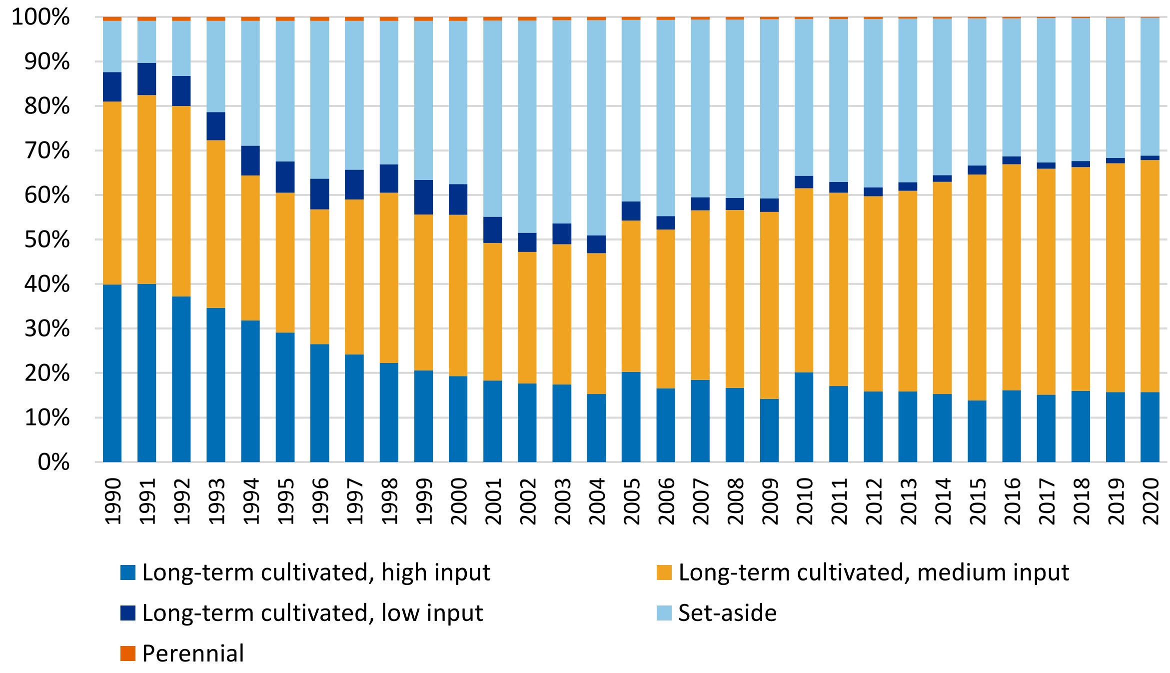

Figure 6.17. Relative shares of areas with different land use and input regimes within the Cropland remaining cropland category (mineral soils) in 1990–2020, %

Table 6.18. Proportions of different tillage practices in croplands[314] and related stock change factors[315]

Tillage practice	**Full tillage**	**Reduced tillage**	**No-till**
Proportion of cropland area 1990	1.00	0	0
Proportion of cropland area 2020	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[268]). 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[316]), 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).

Table 6.19. Stock change factors, SOC_{REF} and estimated SOC stocks for different management categories in Cropland

Land use	**Stock change factors[317]**			**SOC_{REF} t C ha^{-1}**	**IPCC 2006 default SOC_{REF}[318], t C ha^{-1}**	**Average SOC stocks, t C ha^{-1}**	
	F_{LU}	**F_{MG}**	**F_I**			**1990**	**2020**
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[269]) 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[268]). EFs for mineral and organic soil are presented in Table 6.20.

[314] Expert judgement by the Estonian Crop Research Institute (ECRI) (documented in archive).
[315] IPCC 2006 Guidelines, Volume 4, Chapter 5: Cropland, page 5.17, Table 5.5 (Temperate/Boreal moist).
[316] Kõlli, E., Ellermäe, O. (2003). Humus status of postlithogenic arable mineral soils. Agronomy Research, 1, 161–174.
[317] IPCC 2006, Vol 4, Table 5.5, p. 5.17 (Temperate/Boreal moist); ECRI (Table 6.19)
[318] IPCC 2006, Vol 4, Table 2.3, p. 2.31 (Cold temperate, moist).

Table 6.20. Cumulative land-use changes to Cropland in 2020 and soil emission factors

Land-use category	**Area, kha**	**%**	**EF mineral soil, t C ha^{-1} yr^{-1}**	**EF organic soil[312], t C ha^{-1} yr^{-1}**	**EF litter[312], t C ha^{-1} yr^{-1}**
Cropland remaining cropland	960.67	-	0.080[319]	-6.10	-
Forest land→ Cropland	1.70	6.8	-0.769	-	-1.50
Grassland→ Cropland	23.24	93.2	-0.422	-6.10	NA
Wetland→ Cropland	NO	-	-	-6.10	NA
Total Land to cropland	24.93	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 risen, but as its average SOC stock has also increased due to changes in management practices (Table 6.19), mineral soils on arable land continue to sequester C.

6.3.2.4. CO_2 emissions from organic soils

All croplands on organic soil are considered drained in Estonia. The *Tier 2* 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 emission factor from Sweden (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 (29.89 kha in 1990 to 27.75 kha in 2020).

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 2021, and national publications. For organic soil, the uncertainty for the IPCC default emission factor[320] was used since the actual uncertainty rate was not reported in Sweden NIR 2021. The uncertainties for mineral soil emission factors in the Land converted to cropland subcategories are based on expert judgements.

[319] Implied emission factor in 2020, varies between years.
[320] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.11, Table 2.1 (Cropland, drained).

Table 6.21. Uncertainties in the Cropland category

IPCC category		Uncertainties %		EF References
		Activity data[321]	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 soil	2.2	60.0	IPCC 2006, Kõlli *et al*. 2009
4.B.1	Cropland remaining cropland – organic soil	15.0	18.5	Sweden NIR 2021
4.B.2.1	Forest land converted to cropland – dead organic matter	68.0	50.0	Köster *et al*. 2015, Sweden NIR 2021
4.B.2.2	Grassland converted to cropland – living biomass	49.1	47.0	IPCC 2006
4.B.2.2	Grassland converted to cropland – deadwood	40.3	19.8	Köster *et al*. 2015
4.B.2	Land converted to cropland – mineral soil	18.1	60.0	Kõlli *et al*. 2009 & 2010
4.B.2	Land converted to cropland – organic soil	76.9	18.5	Sweden NIR 2021

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.

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[322]. 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 will be integrated into overall activity data. Also, average growing stocks in Forest land and Grassland are updated

[321] Activity data uncertainty estimates are obtained from NFI. For calculating activity data uncertainty for CL remaining CL mineral soil, also relative error estimates for within-category land use from Statistics Estonia were employed.

[322] 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.

annually, which has resulted in somewhat higher losses in living biomass after land use change to croplands.

Table 6.22. Quantitative overview of recalculations compared to the 15.04.2021 submission

		Cropland remaining cropland C stock change, kt			**Land converted to cropland** C stock change, kt				**Total net CO_2, kt**
		Living biomass	Mineral soil	Organic soil	Living biomass	DOM	Mineral soil	Organic soil	
1990	Previous submission	0.31	NO	-181.27	NO	NO	NO	NO	663.53
	Current submission	0.31	NO	-182.33	NO	NO	NO	NO	667.40
	Difference %	**0.0**	**-**	**0.6**	**-**	**-**	**-**	**-**	**0.6**
1995	Previous submission	-0.37	87.74	-172.21	NO	NO	NO	-0.50	312.90
	Current submission	-0.37	87.75	-173.26	NO	NO	NO	-0.50	316.75
	Difference %	**0.0**	**0.0**	**0.6**	**-**	**-**	**-**	**0.0**	**1.2**
2000	Previous submission	-2.34	89.34	-167.04	NO	NO	NO	-1.25	298.05
	Current submission	-2.34	89.36	-168.09	NO	NO	NO	-1.25	301.86
	Difference %	**0.0**	**0.0**	**0.6**	**-**	**-**	**-**	**0.0**	**1.3**
2005	Previous submission	-4.02	158.74	-164.21	-3.29	-0.07	-0.69	-1.25	54.25
	Current submission	-4.02	158.74	-165.26	-5.29	-0.07	-0.69	-1.25	65.44
	Difference %	**0.0**	**0.0**	**0.6**	**61.0**	**0.0**	**0.0**	**0.0**	**20.6**
2010	Previous submission	-3.80	170.00	-158.36	-12.50	-0.94	-4.49	-4.54	53.68
	Current submission	-3.80	169.99	-159.42	-15.37	-0.94	-4.49	-4.54	68.09
	Difference %	**0.0**	**0.0**	**0.7**	**23.0**	**0.0**	**0.0**	**0.0**	**26.9**
2015	Previous submission	-0.05	80.06	-157.50	-21.26	-2.35	-7.65	-9.92	435.14
	Current submission	-2.92	79.68	-158.81	-24.55	-2.35	-7.65	-9.67	462.95
	Difference %	**5900.0**	**-0.5**	**0.8**	**15.5**	**0.0**	**0.0**	**-2.5**	**6.4**
2019	Previous submission	NO	89.14	-158.50	-4.07	-2.67	-10.10	-9.73	351.73
	Current submission	-2.92	87.31	-159.56	-5.78	-2.68	-10.27	-9.73	379.94
	Difference %	**-**	**-2.1**	**0.7**	**42.0**	**0.4**	**1.7**	**0.0**	**8.0**

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)[308] 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, a simulation model will be applied to estimate changes in the C stock of agricultural soils.

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. The net emissions from Grassland were 64.14 kt CO_2 eq. in 2020. The Grassland category has been a source of CO_2 since 1990; highest emissions originate from drained organic soils and from living biomass in the years of higher deforestation rates (Figure 6.18). The mineral soil pool has been a sink for CO_2 due to land-use change to grasslands.

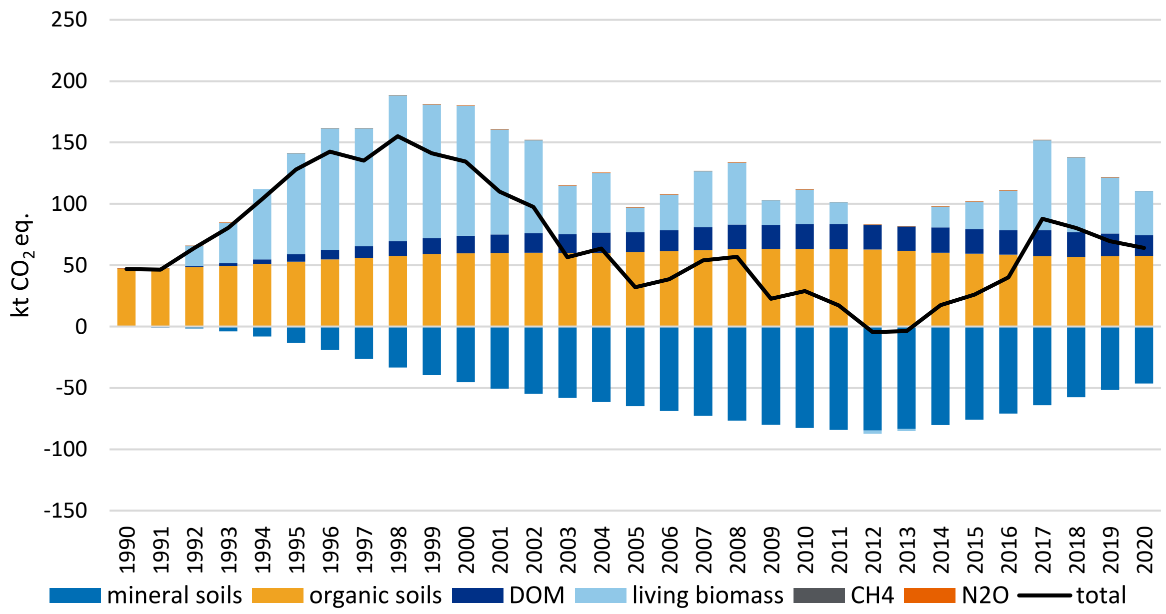

Figure 6.18. Annual GHG uptake (-)/emissions (+) from the Grassland category in 1990−2020, kt CO_2 eq.

The spatial share of the Grassland category was 6.1% of the overall Estonian area in 2020. The area of grasslands has decreased by 6.3% compared to the 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.

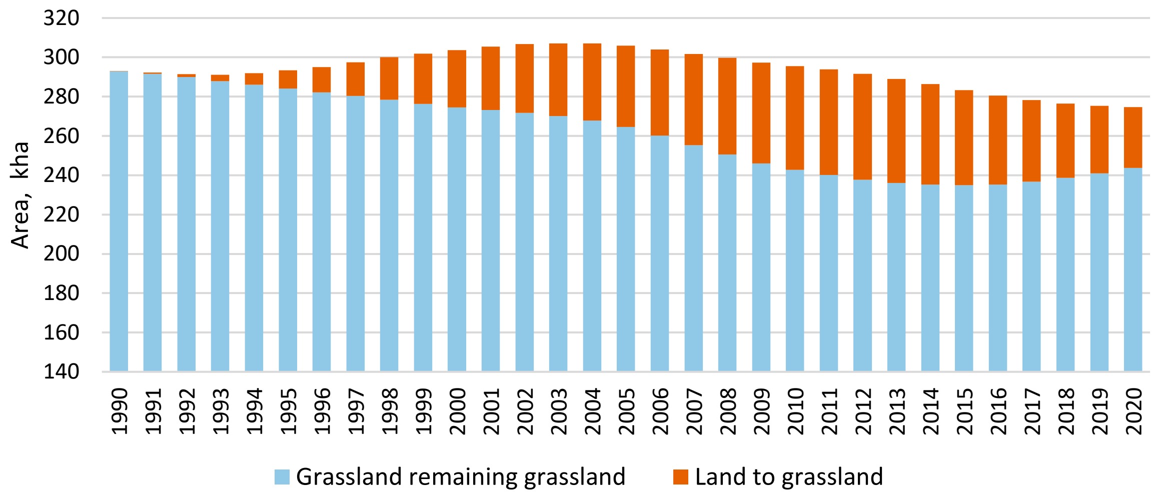

Figure 6.19. Grassland area in Estonia in 1990–2020, kha

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. Parameters from the IPCC 2006 Guidelines were applied to convert growing stock volumes to biomass C stock. 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 6.7 and 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 10.82 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 rate of 0.369 m^3 ha^{-1} yr^{-1}.

Table 6.23. Implemented values of BCEFs

Species	Growing stock level (m^3 ha^{-1})[323]			
	< 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 BCEFs	GL rem GL		0.682	
	FL to GL, biomass loss[324]		0.596	
	FL to GL, biomass increment		0.682	
	CL, WL, SL, OL to GL[325]		0.699	

Table 6.24. Average species distribution in the Grassland category and implemented values of root-to-shoot ratios R, deadwood densities and carbon fractions

Species	Distribution of tree species, living biomass (%)	R[326]	Distribution of tree species, deadwood (%)	Deadwood density (g cm^{-3})[327]	Deadwood CF
Pinus sylvestris	10.6	0.39	16.4	0.270	0.495
Picea abies	14.0	0.39	48.5	0.272	0.491
Betula spp.	28.2	0.46	4.4	0.262	0.482
Alnus incana	11.0	0.46	3.6	0.266	0.482
Alnus glutinosa	4.7	0.46	0.1	0.236	0.482
Other (hardwoods)	31.5	0.46	27.1	0.257	0.484
Weighted average		0.44		0.267	0.489
FL→GL, biomass, and deadwood loss		0.24		0.265	0.487

Figure 6.20 illustrates the annual change in the living biomass carbon pool in the Land converted to grassland subcategories. Emissions due to land-use change arise from deforestation (Forest land → 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.

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323 Country-specific values (see Chapter 6.2.2.1)
324 Same as FL rem FL (Table 6.7)
325 Growing stock level < 20 m^3 ha^{-1}
326 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).
327 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.

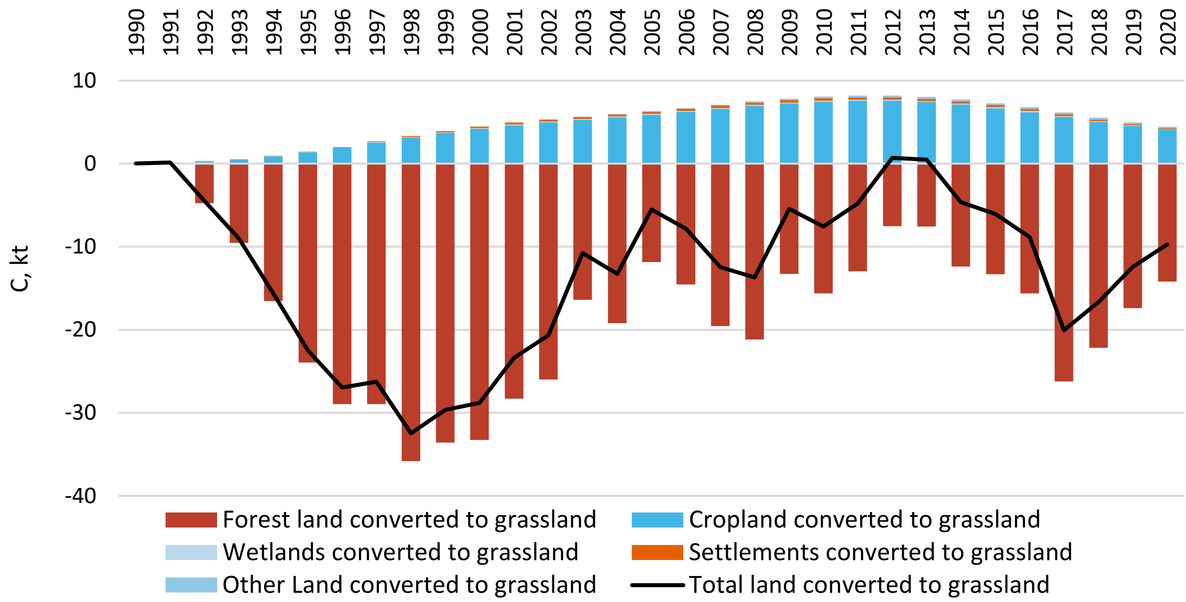

Figure 6.20. Carbon stock change in Grassland living biomass in 1990–2020, kt C

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[288] (Table 6.23). 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 0.536 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 change in deadwood in the year of conversion. After the transition, deadwood volume was assumed to increase at 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 and assure consistency between the Convention and Kyoto Protocol reporting.

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[269]). 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[268]). 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 2020, soil and litter emission factors

<table>
<tr><th>Land-use category</th><th>Area, kha</th><th>%</th><th>EF mineral soil, t C ha^{-1} yr^{-1}</th><th>EF organic soil, t C ha^{-1} yr^{-1}</th><th>EF litter, t C ha^{-1} yr^{-1}</th></tr>
<tr><td>Grassland remaining grassland</td><td>243.69</td><td>-</td><td>-</td><td>-1.495[328]</td><td>-</td></tr>
<tr><td>Forest land→ Grassland</td><td>5.49</td><td>17.7</td><td>0.080</td><td>-1.495</td><td>-0.750[312]</td></tr>
<tr><td>Cropland→ Grassland</td><td>23.20</td><td>74.8</td><td>0.563</td><td>-1.495</td><td>NA</td></tr>
<tr><td>Wetlands→ Grassland</td><td>0.40</td><td>1.3</td><td>-</td><td>-1.495</td><td>NA</td></tr>
<tr><td>Settlements→ Grassland</td><td>0.69</td><td>2.2</td><td rowspan="2">no emissions, soil C is not considered lost after LUC to Grassland</td><td>NA</td><td>NA</td></tr>
<tr><td>Other land→ Grassland</td><td>1.24</td><td>4.0</td><td>NA</td><td>NA</td></tr>
<tr><td>Total Land to grassland</td><td>31.02</td><td>100.0</td><td colspan="3"></td></tr>
</table>

6.4.2.4. CO_2 emissions from drained organic soils

The *Tier 2* method and Equation 6.4 were implemented to estimate the loss of carbon from drained grassland soils. The emission factor from Sweden (Table 6.25) was applied due to the lack of country-specific data.

The 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 from 14–17% in the Grassland remaining grassland subcategory during 1990–2020. All organic soils falling under Land converted to grassland are considered drained.

Emissions from grassland organic soils have increased by 72.8% compared to the base year (from 47.05 to 57.51 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 2021 and national publications, or based on expert judgement (Land converted to grassland mineral soil EF).

[328] Sweden 2021, CRF (1990–2019 average). Same EF was also applied for Land converted to grassland, organic soils (except for CL-GL areas)

Table 6.26. Uncertainties in the Grassland category

IPCC category		Uncertainties %		EF References
		Activity data[329]	**Emission factors**	
4.C.1	Grassland remaining grassland – organic soils	10.8	40.0	Sweden NIR 2021
4.C.2.1	Forest land converted to grassland – living biomass	54.2	47.0	IPCC 2006
4.C.2	Land converted to grassland – living biomass (excl. FL)	47.5	47.0	IPCC 2006
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 2021
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, Sweden NIR 2021
4.C.2	Land converted to grassland – organic soils	41.4	40.0	Sweden NIR 2021

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 and removals from/by living biomass have changed compared to the previous submission, both for Grassland remaining grassland and Land converted to grassland subcategories (Table 6.27) due to the recalculation of average growing stocks in Grassland and Forest land. Emissions from organic soils under Land converted to grasslands have significantly decreased because of updated emission factor for Cropland converted to grassland areas. To harmonise the reporting, in the current submission the same emission factor was used for all grassland organic soils.

[329] Activity data uncertainty estimates are obtained from NFI

Table 6.27. Quantitative overview of recalculations compared to the 15.04.2021 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 soil**	**Living biomass**	**DOM**	**Mineral soil**	**Organic soil**	
1990	Previous submission	2.30	NO	-14.16	NO	NO	0.05	-0.50	45.12
	Current submission	NO	NO	-12.71	0.04	0.0004	0.05	-0.12	46.74
	Difference %	–	–	**-10.2**	–	–	**-9.1**	**-75.5**	**3.6**
1995	Previous submission	2.23	NO	-13.32	-23.46	-1.60	3.66	-9.80	155.11
	Current submission	NO	NO	-11.83	-22.50	-1.59	3.63	-2.59	127.93
	Difference %	–	–	**-11.2**	**-4.1**	**-0.4**	**-0.7**	**-73.5**	**-17.5**
2000	Previous submission	2.16	NO	-13.02	-29.88	-3.96	12.49	-15.80	176.11
	Current submission	NO	NO	-11.52	-28.81	-3.96	12.37	-4.73	134.37
	Difference %	–	–	**-11.5**	**-3.6**	**-0.2**	**-0.9**	**-70.1**	**-23.7**
2005	Previous submission	2.08	NO	-12.54	-6.03	-4.41	17.94	-18.59	79.03
	Current submission	NO	NO	-11.02	-5.54	-4.40	17.74	-5.51	31.97
	Difference %	–	–	**-12.2**	**-8.2**	**-0.1**	**-1.1**	**-70.4**	**-59.5**
2010	Previous submission	1.91	NO	-12.14	-7.98	-5.58	22.88	-23.80	90.65
	Current submission	NO	NO	-10.60	-7.58	-5.58	22.53	-6.66	28.92
	Difference %	–	–	**-12.7**	**-5.1**	**-0.1**	**-1.54**	**-72.0**	**-68.1**
2015	Previous submission	1.82	NO	-12.84	-3.68	-5.67	22.41	-17.63	57.13
	Current submission	NO	NO	-11.32	-6.05	-5.47	20.68	-4.86	25.77
	Difference %	–	–	**-11.8**	**64.5**	**-3.5**	**-7.7**	**-72.4**	**-54.9**
2019	Previous submission	1.88	NO	-13.91	-5.78	-4.92	15.75	-11.42	67.49
	Current submission	NO	NO	-12.26	-12.43	-5.01	14.11	-3.38	69.59
	Difference %	–	–	**-11.8**	**114.8**	**1.9**	**-10.5**	**-70.4**	**3.1**

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)[308] 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 9.4% of the Estonia's territory in 2020. 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 1 130.77 kt CO_2 eq. in 2020. Emissions derive mainly from peat extraction, especially horticultural peat (Figure 6.22), and only a small part from land conversion to other wetlands (1.8% of total Wetland GHG emissions in 2020). Emissions related to peat extraction fluctuate between years due to variation in off-site emissions from the horticultural use of peat.

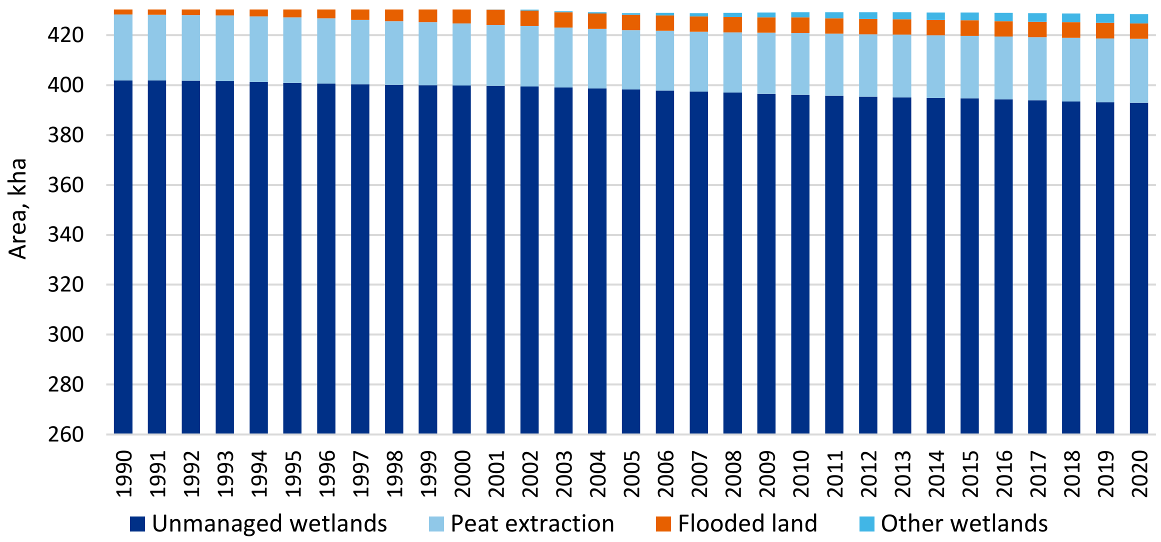

Figure 6.21. Area of Wetlands in Estonia in 1990–2020, kha

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[330]. 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 2020, the total area of peat extraction fields was 25.55 kha (Figure 6.21). In contrast to other land conversions that are assumed to last for 20 years, the transition period for the Land being converted for peat extraction category is five years, as recommended in IPCC 2006 Guidelines. Peat extraction usually proceeds in the same production area during several years. After extraction the area is restored.

[330] FCCC/ARR/2016/EST L.3

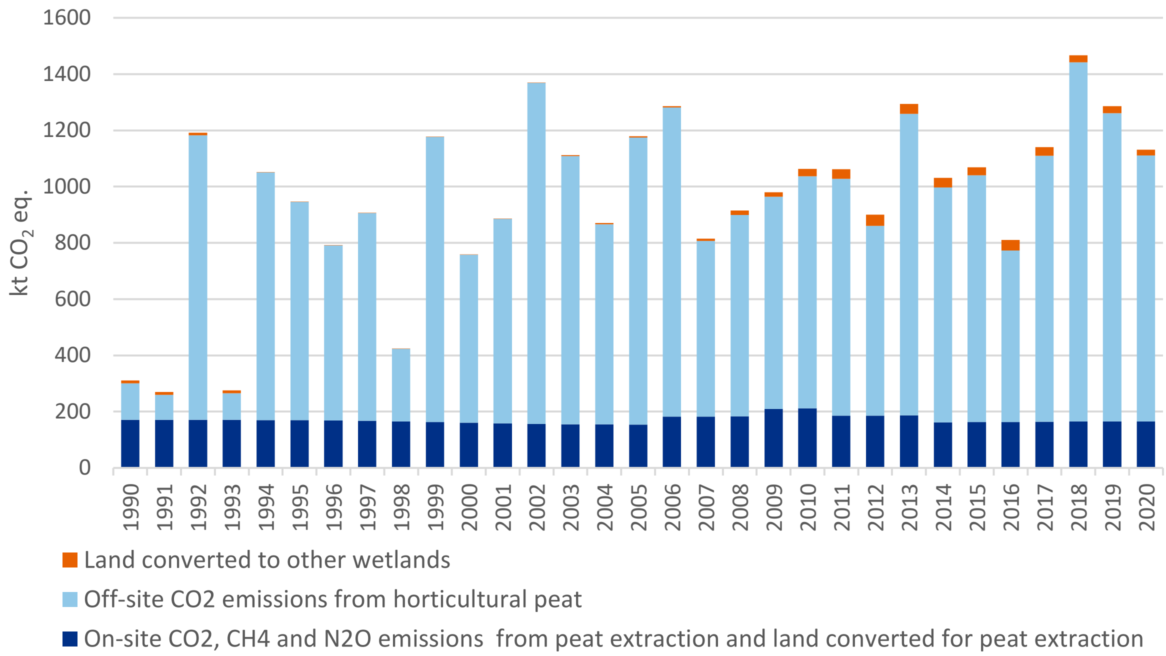

Figure 6.22. Annual GHG emissions from the Wetlands category in 1990−2020, kt CO_2 eq

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[331]. Therefore, no losses in litter pool are expected. When Forest land is converted to unmanaged wetlands, the average growing stock and deadwood volume across all forest types were used (Table 6.16). Since there is no country specific EFs for litter, Swedish factors were applied (Table 6.28).

[331] 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[332]

$$\Delta C_{CONVERSION} = \sum_i [(0 - B_{BEFORE_i}) \times \Delta A_{TO\_OTHERS_i}] \times CF$$

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.

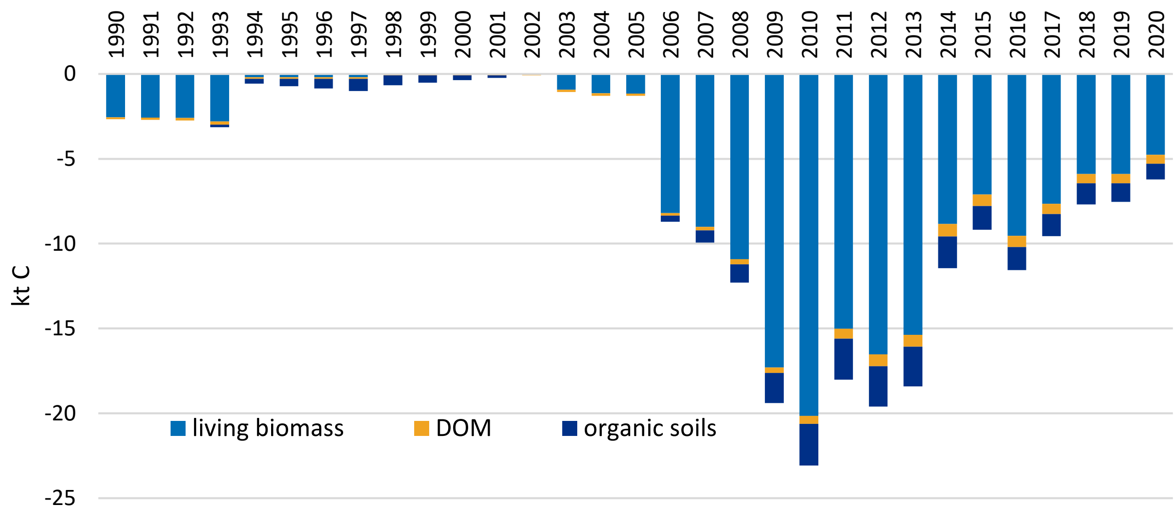

Figure 6.23. Carbon loss in living biomass, dead organic matter and soil after land conversion to peat extraction sites and other wetlands in 1990–2020, kt C

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[270] (Table 6.28). Equation 6.11 was implemented for estimating off-site CO_2-C emissions.

[332] 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[333]

$$CO_2\text{-}C_{WW_{peat_{off-site}}} = \frac{Wt_{dry\_peat} \times Cfraction_{wt\_peat}}{1000}$$

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[334]).

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 2020, 698.7 kt of peat was extracted, (data from the Estonian Land Board[335]), of which the production of energy peat was 54.6 kt[336]. Estimated production of horticultural peat was 644.1 kt in 2020, which is 13.8% less 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 2020, soil and litter emission factors

Land-use category	Area, kha	EF organic soil, t C ha^{-1} yr^{-1}	EF litter, t C ha^{-1} yr^{-1}
Peat extraction			
Peat extraction remaining peat extraction	25.02	-1.741[270] (on-site C emissions) -12.04[337](total C emissions)	NA
Forest land→Peat extraction Wetlands→ Peat extraction	NO 0.53	-1.741	NA[338] NA
Flooded land			
Flooded land remaining flooded land	6.18	NA	NA
Land to flooded land	NO	-	-
Other wetlands			

[333] IPCC 2006 Guidelines, Volume 4, Chapter 7: Wetlands, page 7.11, Equation 7.5.
[334] IPCC 2006 Guidelines, Volume 4, Chapter 7: Wetlands, page 7.13, Table 7.5 (Boreal and Temperate, Nutrient-Rich)
[335] Roosalu, R. (2021). Eesti Vabariigi 2020. aasta maavaravarude koondbilansid (seisuga 31.12.2020. a.). Tallinn: Maa-amet. [www] https://geoportaal.maaamet.ee/docs/geoloogia/maavaravarude_koondbilanss_2019_seletuskiri.pdf (10.01.2022).
[336] 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 (10.01.2022). Emissions related to the usage of peat for energy generation are reported under the Energy sector (Chapter 3).
[337] Implied EF in 2020, varies between years depending on off-site emissions.
[338] Litter stocks are considered negligible in the bog forest type.

Land-use category	**Area, kha**	**EF organic 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	1.38 0.10 0.41 1.45	no emissions, soil C is not considered lost after LUC to other wetlands	-0.495[339] 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[270] (*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[270] (*Tier 2*) was used for estimating N_2O emissions from peat extraction sites.

Equation 6.13[340]

$$N_2O_{WW_{peatExtraction}} = \left(A_{peatExtraction} \times EF_{N_2O\text{-}N}\right) \times \frac{44}{28} \times 10^{-6}$$

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 2020, non-CO_2 emissions from peat extraction areas were 4.09 t CH_4 and 7.63 t N_2O. Both emissions have decreased by 3.1% compared to the base year.

[339] Since there are no country-specific EFs nor Swedish EFs for land converted to Wetlands, the same litter emission factors as under land converted to Settlements were applied (Sweden NIR 2021, Annexes, Table A3:2.12, page 141).

[340] 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[341]	Emission factors	
4.D.1.1	Peat extraction remaining peat extraction – organic soils	23.8	50	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	47.0	IPCC 2006
4.D.2.3	Land converted to other wetlands – dead organic matter	72.0	39.7	Köster *et al.* 2015, Sweden NIR 2021
4(II) D.1	Emissions and removals from drainage and rewetting – CH_4	23.5	100.0	Salm *et al.* 2012
4(II) D.1	Emissions and removals from drainage and rewetting – N_2O	23.5	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[270]) 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[342]	1.2 … 8.25[343]	-0.03 … 0.64[344]

[341] Activity data uncertainty estimates are obtained from NFI
[342] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.14, Table 2.1.
[343] IPCC 2013 Wetlands Supplement, Chapter 2: Drained Inland Organic Soils, page 2.26, Table 2.3.
[344] 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. As recalculated peatland areas have increased compared to the previous submission, also GHG emissions from the Wetlands category are higher (Table 6.31).

Table 6.31. Quantitative overview of recalculations compared to the 15.04.2021 submission

Wetlands TOTAL emissions		CO_2, kt	CH_4, t	N_2O, t
1990	Previous submission	281.50	3.54	6.60
	Current submission	308.58	4.22	7.87
	Difference %	**9.6**	**19.1**	**19.1**
1995	Previous submission	917.25	3.51	6.56
	Current submission	944.56	4.19	7.82
	Difference %	**3.0**	**19.3**	**19.3**
2000	Previous submission	728.54	3.30	6.16
	Current submission	755.57	3.98	7.43
	Difference %	**3.7**	**20.5**	**20.5**
2005	Previous submission	1149.12	3.12	5.82
	Current submission	1176.49	3.80	7.09
	Difference %	**2.4**	**21.7**	**21.7**
2010	Previous submission	1033.29	3.29	6.13
	Current submission	1060.79	3.96	7.40
	Difference %	**2.7**	**20.6**	**20.6**
2015	Previous submission	1035.91	3.37	6.28
	Current submission	1066.22	4.01	7.49
	Difference %	**2.9**	**19.2**	**19.2**
2019	Previous submission	1242.87	3.44	6.41
	Current submission	1283.50	4.08	7.62
	Difference %	**3.3**	**18.9**	**18.9**

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 7.9% of Estonia's territory in 2020. 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 394.58 kt CO_2 eq. in 2020 (Figure 6.25).

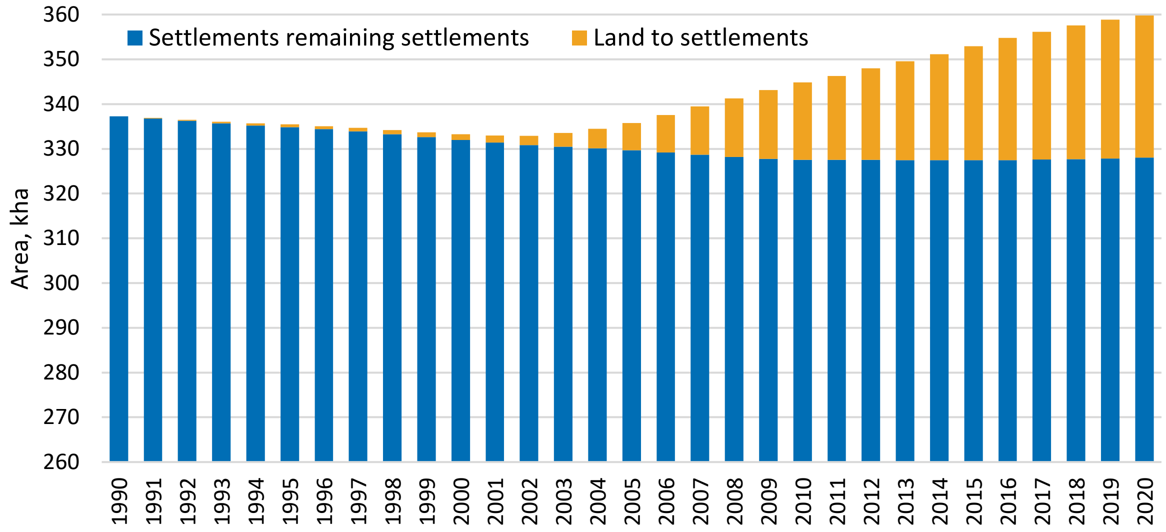

Figure 6.24. Area of Settlements in Estonia in 1990–2020, kha

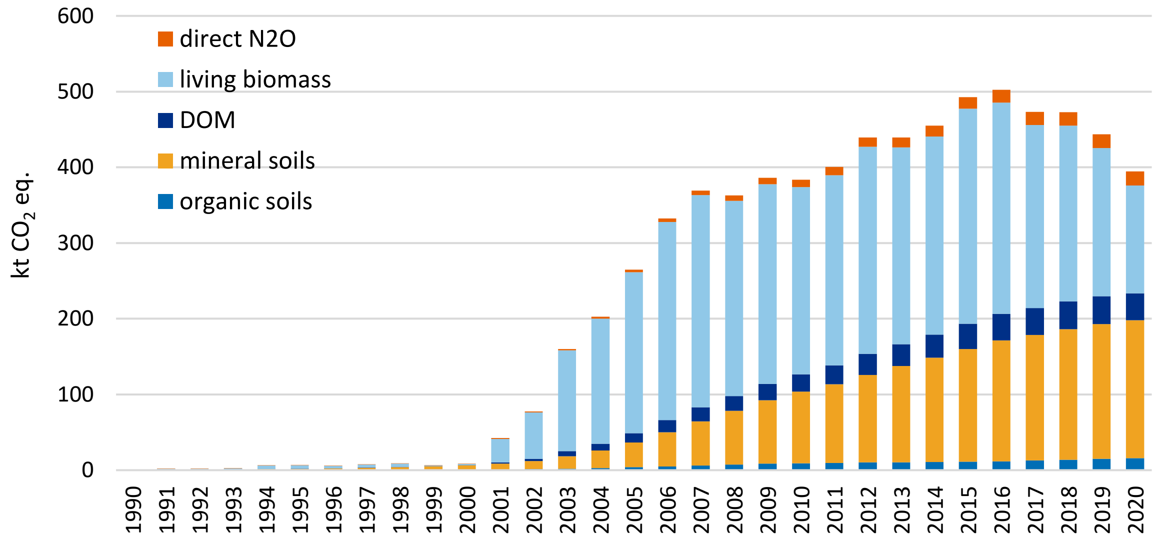

Figure 6.25. Emissions related to land conversion to settlements, 1990–2020, kt CO_2 eq.

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, EFs from Sweden were implemented (Table 6.32). Sweden and Estonia include similar land areas under the Settlements category according to the category descriptions in NIR; also, Swedish average mineral soil carbon stock is comparable to the Estonian value for the Grassland category (110[345] and 107 t C ha^{-1} [346], respectively) and somewhat higher for the Cropland category (100[345] and 66–94 t C ha^{-1} (Table 6.19), respectively). Therefore, if also proportions of land-use groups within Settlements (roads, power lines, proper settlement) are similar between countries, Swedish emission factors for conversion from CL or GL to SL should be appropriate for Estonian conditions. However, the average SOC stock in mineral forest soils is considerably lower in Sweden compared to Estonia (45[345] and 108 t C ha^{-1} [347], respectively), thus the Swedish EF for the FL-SL conversion was adjusted for Estonia. Based on a study by Karltun *et al.* 2017[348] conducted in Sweden, it was assumed that on average 30% of the SOC stock is lost over 20 years due to the FL-SL conversion, and the emission factor was calculated combining these assumptions with the average FL SOC stock in Estonia (Table 6.32). Other emission factors for Land converted to Settlements category, obtained from the NIR Sweden 2021, are also based on this study. Since there was no EF for organic soils in the Cropland converted to Settlement's category, the Cropland category EF was used. Similarly, emission factor for Forest land converted to settlements organic soils was also applied in case of Wetlands conversion to settlements.

Table 6.32. Cumulative land-use changes to settlements in 2020, soil and litter emission factors[349]

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	16.66	52.5	-1.62	-2.25	-0.495
Cropland→ Settlements	7.88	24.8	-2.67	-6.10	NA
Grassland→ Settlements	6.36	20.0	-0.55		NA
Wetlands→ Settlements	0.15	0.5		-2.25	NA
Other land→ Settlements	0.69	2.2	-1.13		NA
Total Land to settlements	31.73	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.

[345] Sweden NIR 2021, Annex 3:2: Land Use, Land-Use Change and Forestry (CRF sector 4), page 139.
[346] Kõlli, R., Köster, T., Kauer, K. (2007). Organic matter of Estonian grassland soils. Agronomy Research 5, 109–122.
[347] Kõlli, R., Asi, E., Köster, T. (2004). Organic carbon pools in Estonian forest soils. Baltic Forestry 10, 19–26.
[348] Karltun, E, Nilsson, T, Lundblad, M. (2017). Litter and soil carbon stock changes in connection to land-use changes – a method assessment for the Swedish LULUCF carbon inventory.
[349] Emission factors were obtained from Sweden NIR 2021, Annexes, Table A3:2.12, page 141, except for FL-SL mineral soil EF which was based on the Estonian average Forest land SOC stock and assumptions described in the text.

Table 6.33. Uncertainties in the Land converted to settlements category

IPCC category		Uncertainties %		EF References
		Activity data[350]	Emission factors	
4.E.2	Land converted to settlements – living biomass	20.9	47.0	IPCC 2006
4.E.2	Land converted to settlements – deadwood	21.0	19.8	Köster *et al.* 2015
4.E.2	Land converted to settlements – litter	21.1	50.0	Sweden NIR 2021
4.E.2	Land converted to settlements – soils	16.5	55.3	Sweden NIR 2021

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.

6.6.5. 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 Settlements. In Table 6.34 a quantitative overview of recalculations is shown, except for recalculations of direct N_2O emissions which are presented in Chapter 6.8.5.

The most significant changes compared to the previous submission have occurred in the living biomass pool, mainly due to the recalculation of average growing stock in grasslands and increase in land areas under Forest land and Grassland converted to settlements subcategories for the last five years.

Table 6.34. Quantitative overview of recalculations in the Settlements compared to the 15.04.2021 submission

Land converted to settlements		C stock change, kt				Total Settlements net CO_2, kt
		Living biomass	DOM	Mineral soil	Organic soil	
1990	Previous submission	NO	NO	NO	NO	NO
	Current submission	NO	NO	NO	NO	NO
	Difference %	-	-	-	-	-
1995	Previous submission	-1.11	-0.05	-0.49	NO	6.06
	Current submission	-1.27	-0.05	-0.49	NO	6.65
	Difference %	**14.5**	**0**	**0**	-	**9.7**
2000	Previous submission	-0.25	-0.04	-1.76	NO	7.54
	Current submission	-0.42	-0.04	-1.76	NO	8.13
	Difference %	**63.0**	**0**	**0**	-	**7.8**
2005	Previous submission	-56.51	-3.36	-8.90	-1.10	256.20
	Current submission	-57.94	-3.36	-8.90	-1.10	261.41

[350] Activity data uncertainty estimates are obtained from NFI

Land converted to settlements		C stock change, kt				Total Settlements net CO_2, kt
		Living biomass	DOM	Mineral soil	Organic soil	
	Difference %	**2.5**	**0.0**	**0.0**	**0.0**	**2.0**
2010	Previous submission	-65.70	-6.21	-25.80	-2.52	367.50
	Current submission	-67.41	-6.21	-25.80	-2.52	373.77
	Difference %	**2.6**	**0.0**	**0.0**	**0.0**	**1.7**
2015	Previous submission	-72.75	-8.99	-40.54	-3.08	459.65
	Current submission	-77.40	-9.13	-40.57	-3.08	477.32
	Difference %	**6.4**	**1.5**	**0.1**	**0.0**	**3.8**
2019	Previous submission	-33.08	-8.78	-46.59	-3.62	337.60
	Current submission	-53.33	-9.98	-48.63	-4.04	425.24
	Difference %	**61.2**	**13.6**	**4.4**	**11.8**	**26.0**

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 less than 1% of the total Estonian land territory. In the 2022 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 68.27 kt CO_2 eq. in 2020.

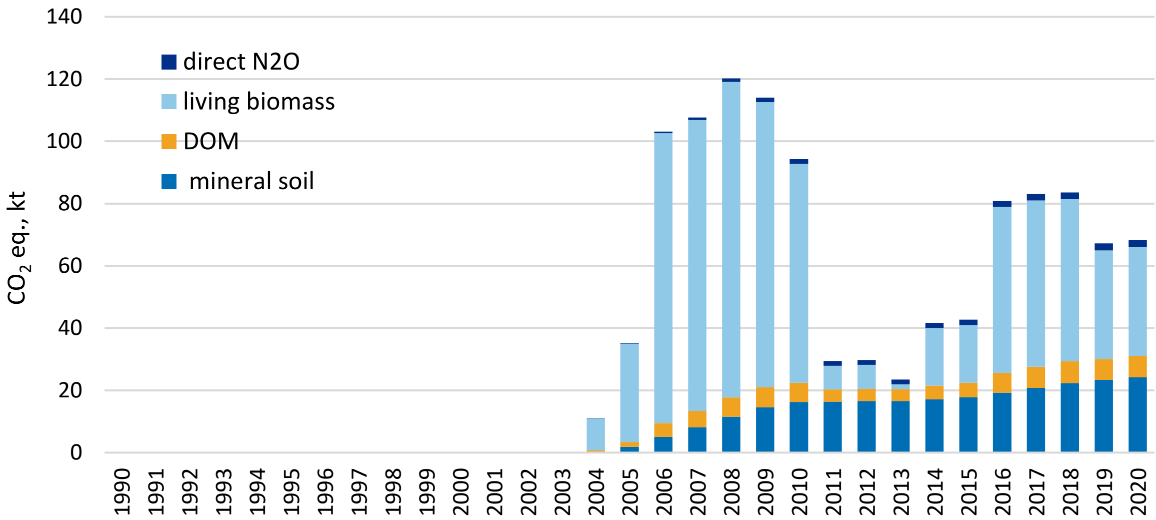

Figure 6.26. Emissions related to land-use changes to other land, 1990–2020, kt CO_2 eq.

6.7.2. Methodological issues

Carbon 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). Emissions from mineral soil and litter pools were calculated using emission factors from the NIR Sweden 2021, except for the FL-OL soil EF (Table 6.35). Since there are no Swedish EFs for Land converted to other land, the same emission factors as under Land converted to settlements were applied. The FL-SL soil emission factor was based on the Estonian average forest mineral soil SOC stock and assumptions described in Chapter 6.6.

Table 6.35. Cumulative land-use changes to Other land in 2020, soil and litter emission factors[351]

Land-use change	**kha**	**%**	**EF mineral soil, t C ha^{-1}**	**EF litter, t C ha^{-1}**
Forest land→ Other land	3.05	76.3	-1.62	-0.495
Cropland→ Other land	0.57	14.3	-2.67	NA
Grassland→ Other land	0.26	6.4	-0.55	NA
Wetlands→ Other land	0.12	3.0	NA	NA
Total Land to other land	4.00	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.

[351] Emission factors were obtained from Sweden NIR 2021, Annexes, Table A3:2.12, page 141, except for the FL-OL soil EF.

Table 6.36. Uncertainties used in the Land converted to other land category

IPCC category		Uncertainties %		EF References
		Activity data[352]	Emission factors	
4.F.2.1	Forest land converted to Other land – living biomass	52.6	47.0	IPCC 2006
4.F.2.1	Forest Land converted to other land – dead organic matter	52.6	40.4	Köster *et al.* 2015, Sweden NIR 2021
4.F.2	Land converted to other land – soil	50.6	60.0	Sweden NIR 2021

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.

Table 6.37. Quantitative overview of recalculations compared to the 15.04.2021 submission

		C stock change, kt			Total Other land net CO_2, kt
		Living biomass	DOM	Mineral soil	
1990/1995/ 2000	Previous submission	NO	NO	NO	NO
	Current submission	NO	NO	NO	NO
	Difference %	**-**	**-**	**-**	**-**
2005	Previous submission	-8.44	-0.40	-0.52	34.33
	Current submission	-8.63	-0.40	-0.52	35.02
	Difference %	**2.2**	**0.0**	**0.0**	**2.0**
2010	Previous submission	-18.91	-1.69	-4.42	91.76
	Current submission	-19.18	-1.69	-4.42	92.74
	Difference %	**1.4**	**0.0**	**0.0**	**1.1**
2015	Previous submission	-5.04	-1.27	-4.85	40.88
	Current submission	-5.07	-1.27	-4.85	41.00
	Difference %	**0.7**	**0.0**	**0.0**	**0.3**
2019	Previous submission	-8.85	-1.76	-6.33	62.13
	Current submission	-9.53	-1.81	-6.39	64.99
	Difference %	**7.7**	**2.4**	**0.9**	**4.6**

6.7.6. Category-specific planned improvements

There are no category-specific planned improvements.

[352] Activity data uncertainty estimates are obtained from the NFI.

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 2020, direct N_2O emissions from N mineralization were 24.76 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 2020, indirect N_2O emissions equalled 5.57 kt CO_2 eq.

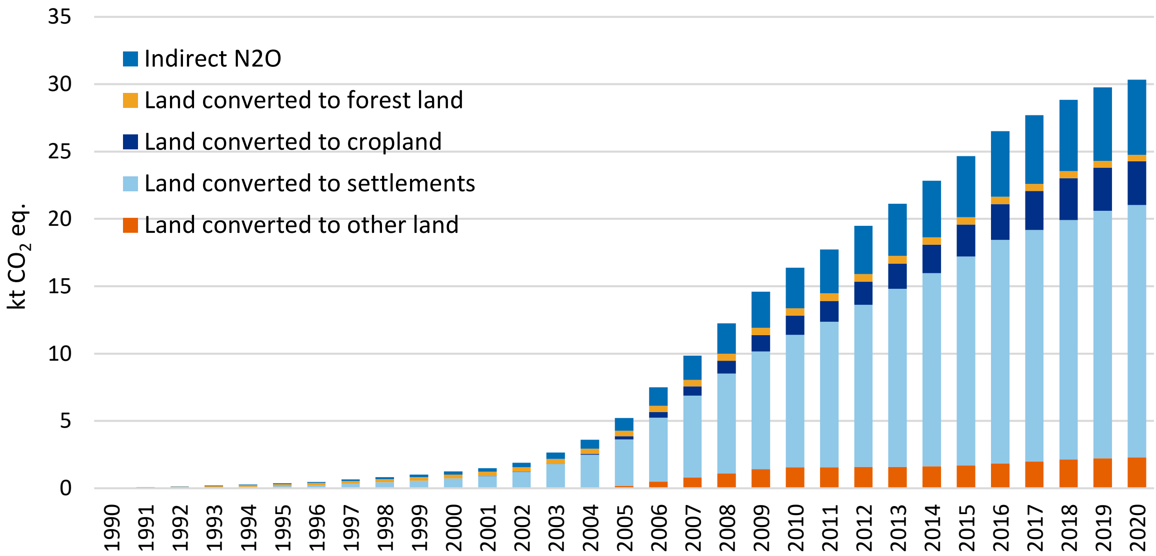

Figure 6.27. N_2O emissions from nitrogen mineralization and leaching, kt CO_2 eq.

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[353]

$$N_2O_{Min} = F_{SOM} \times EF_1 \times \frac{44}{28}$$

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[354])
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.

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[355]

$$N_2O_{(L)} = F_{SOM} \times Frac_{LEACH\text{-}(H)} \times EF_5 \times \frac{44}{28}$$

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[356] 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[356]).

[353] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.10, Equation 11.2, and page 11.16, Equation 11.8.
[354] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.11, Table 11.1.
[355] IPCC 2006 Guidelines, Volume 4, Chapter 11: N_2O emissions from managed soils, and CO_2 emissions from lime and urea application, page 11.21, Equation 11.10.
[356] 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.

6.8.3. 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	61.4	-80	230	IPCC 2006
4(III) B.2	Land converted to cropland – Direct N_2O emissions from N mineralization	62.7	-80	230	IPCC 2006
4(III) E.2	Land converted to settlements – Direct N_2O emissions from N mineralization	62.2	-80	215	IPCC 2006
4(III) F	Land converted to other land – Direct N_2O emissions from N mineralization	78.5	-80	220	IPCC 2006
4(IV)	Indirect N_2O emissions from managed soils – Nitrogen leaching and runoff	58.6	-90	350	IPCC 2006

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

Updated activity data from the NFI were used for estimating N_2O emissions due to land conversions. In Table 6.39 a quantitative overview of recalculations is shown.

Table 6.39. Quantitative overview of recalculations of N_2O emissions from N mineralization and leaching/runoff compared to the 15.04.2021 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	0.04	NO	NO	NO	0.01
	Difference %	**0.0**	**-**	**-**	**-**	**0.0**
1995	Previous submission	0.49	NO	0.51	NO	0.23
	Current submission	0.49	NO	0.51	NO	0.23
	Difference %	**0.0**	**-**	**0.0**	**-**	**0.0**
2000	Previous submission	1.00	NO	2.42	NO	0.77

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**	
	Current submission	1.00	NO	2.42	NO	0.77
	Difference %	**0.0**	**-**	**0.0**	**-**	**0.0**
2005	Previous submission	1.39	0.73	11.55	0.66	3.22
	Current submission	1.39	0.73	11.55	0.66	3.22
	Difference %	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**
2010	Previous submission	1.90	4.70	33.05	5.21	10.10
	Current submission	1.89	4.70	33.05	5.21	10.09
	Difference %	**-0.9**	**0.0**	**0.0**	**0.0**	**0.0**
2015	Previous submission	1.93	8.01	51.98	5.70	15.22
	Current submission	1.85	8.01	52.01	5.70	15.21
	Difference %	**-4.0**	**0.0**	**0.1**	**0.0**	**-0.1**
2019	Previous submission	1.70	10.58	59.31	7.43	17.78
	Current submission	1.65	10.76	61.64	7.49	18.35
	Difference %	**-3.3**	**1.7**	**3.9**	**0.8**	**3.2**

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 fires are 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 1990–2020 was 7.3 kt CO_2 eq. in 2006, that constituted 0.03% 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 affected biomass 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.

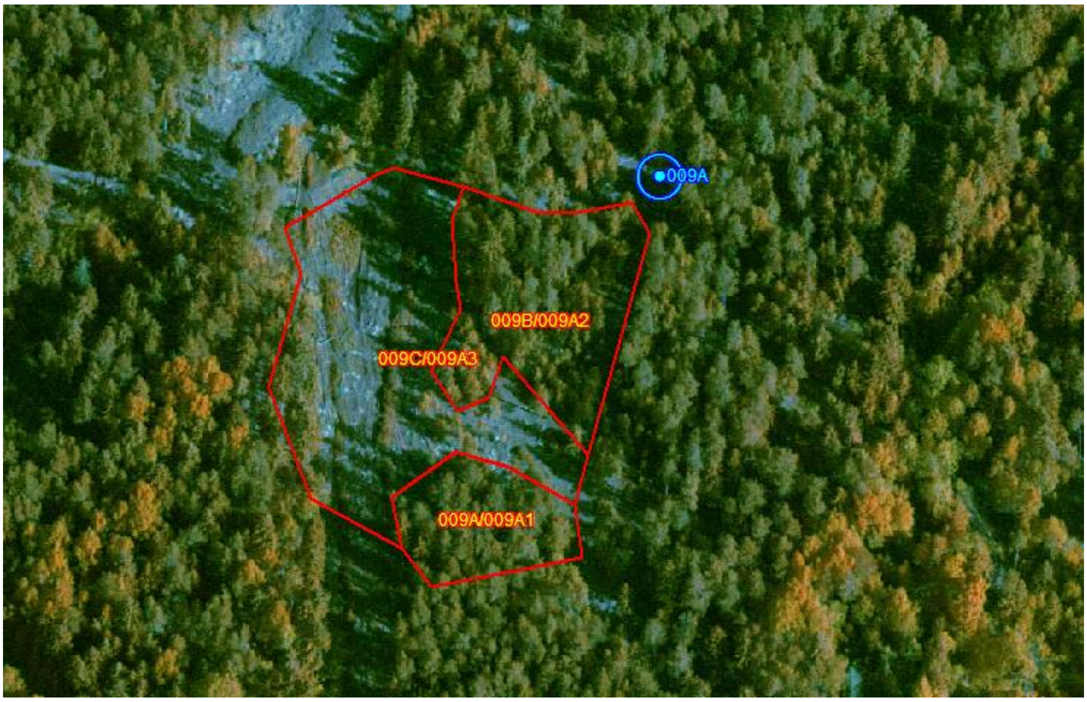

Figure 6.28. Reported fire location (blue circle), actual location (red border) and data analyses

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[357]

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

Where:

L_{fire} =	quantity of GHG released due to fire, tonnes of GHG;
A =	area burnt, ha;
M_B =	mass of ‘available’ fuel, kg dry matter ha^{-1};[358]

[357] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.42, Equation 2.27.

[358] For 1990–2011 year-specific average forest biomass growing stock was used as the basis for M_B.

C_f = combustion efficiency (or fraction of the biomass combusted), dimensionless; for 1990–2011 the value 0.15[359] 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 85.49 ha of forests and 108.47 ha of Grasslands in 2020 (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[360]

	CH_4	**N_2O**
Forest land	6.1	0.06
Grassland, Wetland	2.3	0.21

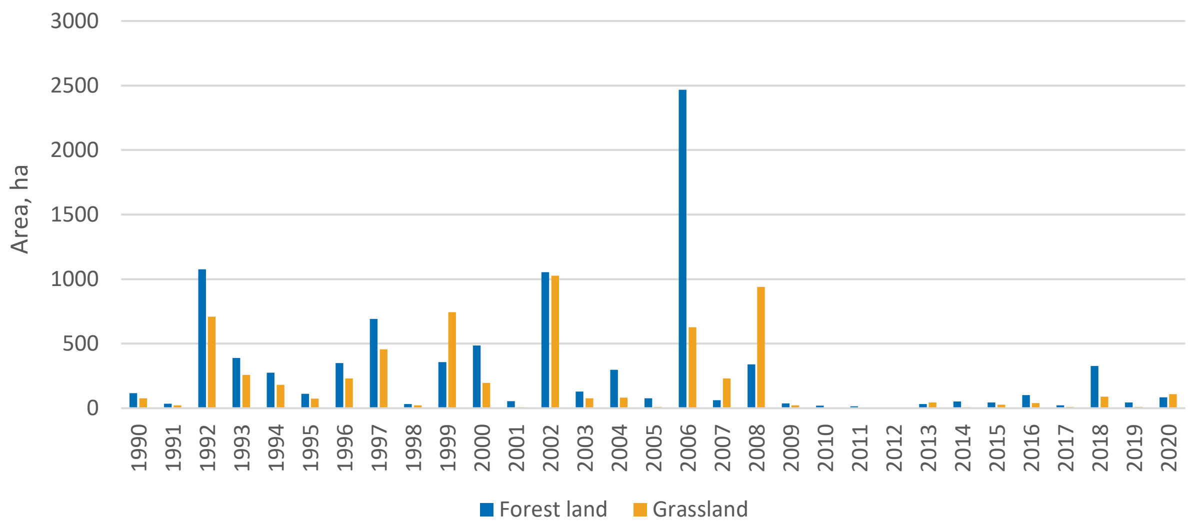

Figure 6.29. Annual area of Forest land and Grassland (incl. WL areas) affected by fires in 1990–2020, ha

The total amount of CH_4 and N_2O released after wildfires in 2020 was 11.46 t and 0.55 t, respectively. Non-CO_2 emissions from Grassland wildfires are rather insignificant compared to 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.

[359] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.48, Table 2.6 (Boreal forest, surface fire).

[360] 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).

Table 6.41. Uncertainties of non-CO_2 emission estimates from biomass burning

IPCC category	Uncertainties %		EF References
	Activity data[361]	Emission factors	
Biomass burning (CH_4)	34.5	70.0	LULUCF IPCC 2006, Table 2.5 p. 2.47
Biomass burning (N_2O)	34.5	70.0	LULUCF IPCC 2006, 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). Increase in emissions has been somewhat higher in the Grassland category due to the increase of average growing stocks in Grassland.

Table 6.42. Quantitative overview of recalculations of Non-CO_2 emissions from biomass burning compared to the 15.04.2021 submission

		Forest land		Grassland		Total, CO_2 eq.
		CH_4, t	N_2O, t	CH_4, t	N_2O, t	
1990	Previous submission	11.14	0.11	0.17	0.02	0.32
	Current submission	11.22	0.11	0.23	0.02	0.33
	Difference %	**0.7**	**0.7**	**39.3**	**39.3**	**1.8**
1995	Previous submission	10.91	0.11	0.16	0.01	0.31
	Current submission	11.11	0.11	0.22	0.02	0.32
	Difference %	**1.8**	**1.8**	**39.1**	**39.1**	**2.8**
2000	Previous submission	48.61	0.48	0.42	0.04	1.38
	Current submission	49.85	0.49	0.59	0.05	1.42
	Difference %	**2.6**	**2.6**	**39.0**	**39.0**	**3.1**
2005	Previous submission	7.72	0.08	0.02	0.00	0.22
	Current submission	8.03	0.08	0.03	0.00	0.23
	Difference %	**3.9**	**3.9**	**38.9**	**38.9**	**4.1**
2010	Previous submission	2.15	0.02	0.01	0.00	0.06
	Current submission	2.24	0.02	0.01	0.00	0.06
	Difference %	**4.2**	**4.2**	**39.0**	**39.0**	**4.4**
2015	Previous submission	12.06	0.12	2.47	0.23	0.47
	Current submission	12.06	0.12	2.47	0.23	0.47

[361] All activity data uncertainty estimates are obtained from the NFI.

	Difference %	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
2019	Previous submission	3.88	0.04	0.08	0.01	0.11
	Current submission	3.88	0.04	0.08	0.01	0.11
	Difference %	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

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) are a key source of CO_2 removals and 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.[362] 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 taken into account 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 ERT in 2018[363] was made to get estimates for these years (Chapter 6.10.2).

The net emissions in the HWP category in 2020 were -922.24 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 the harvest rate. 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-lives 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.

[362]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)
[363] FCCC/ARR/2018/EST KL.12

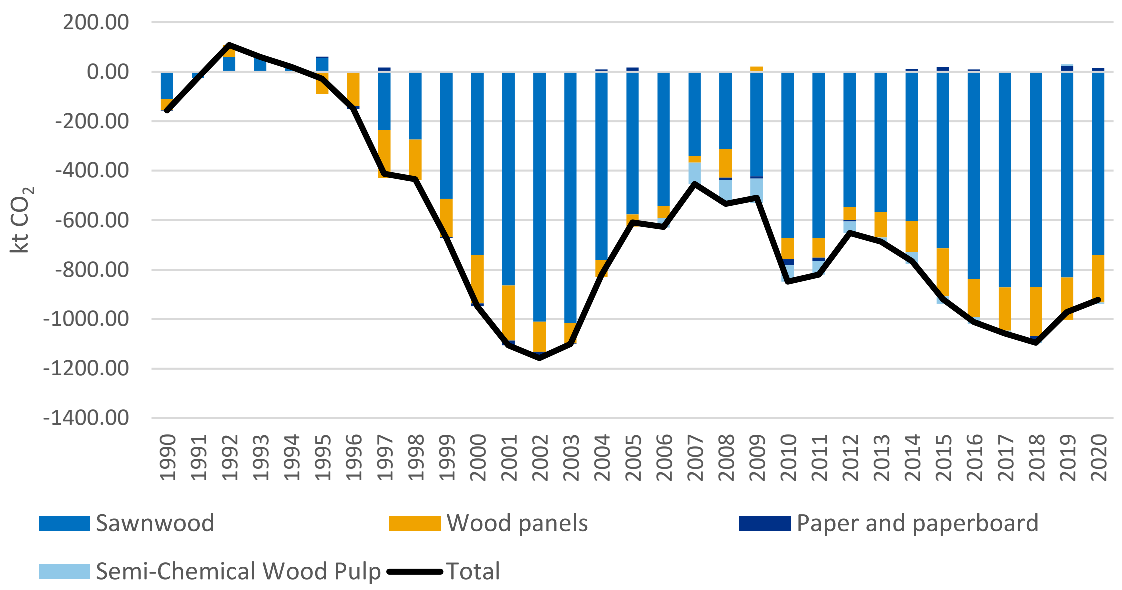

Figure 6.30. Net emissions from HWP categories of Solid wood, Paper and paperboard and Semi-chemical wood pulp in Estonia in 1990–2020, kt CO_2

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 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[364]. 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[365], production data from Statistics Estonia was applied. In accordance with the equation 2.8.6 the inherited emissions are included starting from 1990. Default conversation factors (Table 6.43) and half-lives from Table 2.8.2[366] 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 kt C/m^3) for 2006–2020. The following inputs were used to include it 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 fraction is 0.5% Inherited emissions are included in the HWP estimations.

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 originates from SE. Production data for these commodities for 1991 is an average of the years 1990 and 1992. Foreign trade data for IRW

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364 IPCC 2013 KP Supplement, pp. 2.115 & 2.116
365 IPCC 2013 KP Supplement, pp. 2.118, 2.120 & 2.121
366 IPCC 2013 KP Supplement, Chapter 2.8.3.2, p. 2.123, Table 2.8.2.

and production data of veneer sheets, wood pulp, paper and paperboard of 1992 was repeated for 1990 and 1991.

Table 6.43. Default conversion factors for default HWP categories and their subcategories[367]

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 6.44.

Table 6.44. Uncertainties in the HWP category

IPCC category	Uncertainties %		EF References
	Activity data[368]	Emission factors	
Wood panels and sawnwood	39	57	LULUCF IPCC 2006, p. 12.22 Table 12.6 Lamlom and Savidge, 2003
Paper and paperboard	30	57	LULUCF IPCC 2006, p. 12.22 Table 12.6 Lamlom and Savidge, 2003
Semi-chemical wood pulp	30	57	LULUCF IPCC 2006, p. 12.22 Table 12.6 Lamlom and Savidge, 2003

[367] IPPCC 2013 KP Supplement, Chapter 2.8.3.1, page 2.122, Table 2.8.1 (except for semi-chemical wood pulp).
[368] 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 6.45, a quantitative overview of recalculations has been shown.

Table 6.45. Quantitative overview of recalculations, kt C (15.04.2021 submission)

		Harvested wood product			**TOTAL** HWP net CO_2
		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 %	**0.0**	**0.0**	**-**	**0.0**
1995	Previous submission	9.67	-1.83	NE	-28.75
	Current submission	9.67	-1.83	NE	-28.75
	Difference %	**0.0**	**0.0**	**-**	**0.0**
2000	Previous submission	255.19	3.2	NE	-947.59
	Current submission	255.19	3.2	NE	-947.59
	Difference %	**0.0**	**0.0**	**-**	**0.0**
2005	Previous submission	170.54	-4.61	NE	-608.41
	Current submission	170.54	-4.61	NE	-608.41
	Difference %	**0.0**	**0.0**	**-**	**0.0**
2010	Previous submission	206.45	6.88	18.14	-848.75
	Current submission	206.45	6.88	18.14	-848.75
	Difference %	**0.0**	**0.0**	**0.0**	**0.0**
2015	Previous submission	247.47	-5.03	8.18	-918.97
	Current submission	247.47	-5.03	8.18	-918.97
	Difference %	**0.0**	**0.0**	**0.0**	**0.0**
2019	Previous submission	285.14	-6.63	-1.78	-1 014.68
	Current submission	273.29	-6.59	-1.74	-971.53
	Difference %	**-4.2**	**-0.6**	**-2.3**	**-4.3**

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 (extended until the end of 2022)[369]. 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 290.51 kt in 2020 and covered 2.5% of total GHG emissions in 2020 (Figure 7.1).

[369] Waste Management Plan 2014–2020. Ministry of the Environment. [www] https://envir.ee/ringmajandus/jaatmed/riigi-jaatmekava (15.11.2021).

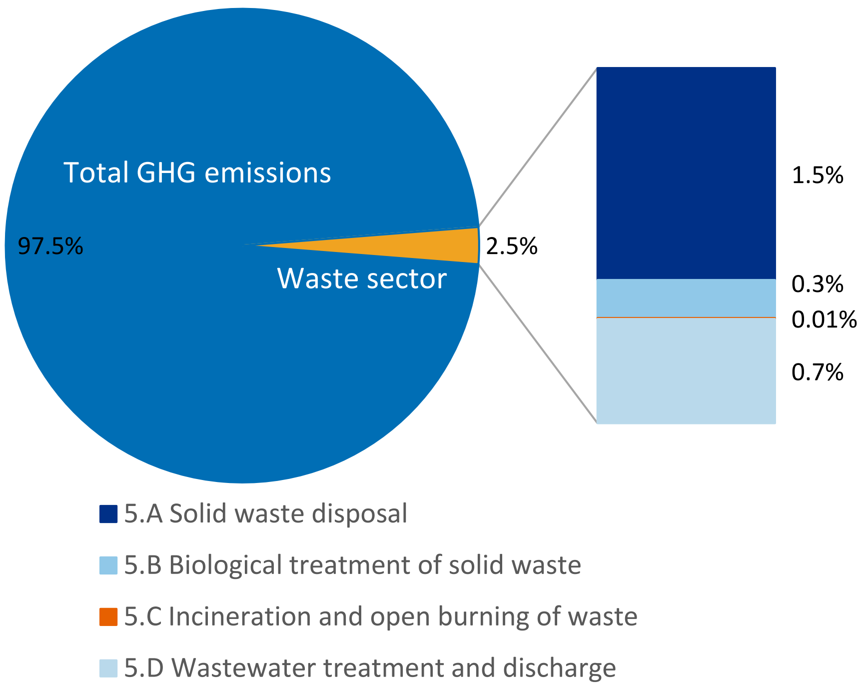

Figure 7.1. CO_2 eq. emissions from the Waste sector compared to total GHG emissions in Estonia in 2020, %

Total CO_2 eq. emissions from the Waste sector (Table 7.2) in 2020 decreased by 3.9% compared to 2019. In recent years, total emissions have followed a declining trend. Compared to the base year of 1990, the amount of CO_2 eq. emissions in 2020 were 21.5% smaller. Compared to the base year, CO_2 eq. emissions from Solid waste disposal (SWD) have decreased by 18.6%, CO_2 eq. emissions from Waste incineration and Open burning of waste by 78.9%, and from Wastewater treatment and discharge by 44.1%. On the other hand, CO_2 eq. emissions from Biological treatment of solid waste have, compared to the base year of 1990, increased by 2586.3%.

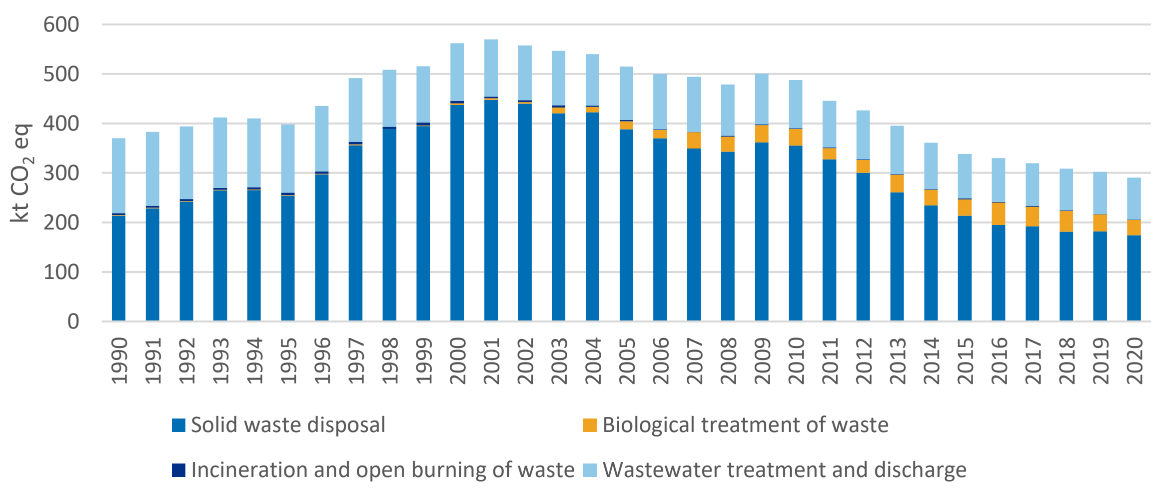

Figure 7.2. Trends of GHG emissions in the Waste sector by source categories in 1990–2020, kt CO_2 eq.

As seen in Figure 7.2 and Table 7.2, the lowest GHG emissions from waste management occurred in 2020; these were mainly caused by the decrease in landfilling and using recovered landfill gas. The highest CO_2 eq. emissions in 2001 were related to a significant increase in emissions from SWD. Emissions from Waste incineration and Open burning were marginal during the whole period compared to other activities involved. Compared to 2019, the emissions from Biological treatment on solid waste decreased because the amount of biodegradable waste composted decreased. Main driver for the decrease was sludge which is treated under other waste handling activities. In 2020 two more biogas facilities are built in Estonia and the use of biowaste for biogas production has increased. Fluctuations in the emission quantities are caused by fluctuations in waste material that is biologically treated.

Table 7.2. GHG emissions from the Waste sector in Estonia in 1990–2020, kt

Year	**SWD**	**Waste incineration and Open burning of waste**			**Biological treatment of solid waste**		**Wastewater treatment and discharge**			**Total CO_2 eq. emissions**
		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	369.9
1995	10.15	2.99	0.07	0.0010	0.04	0.002	0.11	4.15	NO	398.0
2000	17.50	2.82	0.08	0.0012	0.08	0.005	0.10	3.42	0.06	562.5
2005	15.54	1.46	0.03	0.0005	0.37	0.022	0.10	2.84	0.29	515.2
2010	14.21	0.84	0.02	0.0003	0.78	0.047	0.11	2.06	0.61	488.90
2011	13.09	0.80	0.01	0.0002	0.53	0.032	0.11	2.05	0.47	445.77
2012	12.02	0.86	0.02	0.0003	0.59	0.036	0.10	2.04	0.69	426.58
2013	10.44	1.04	0.02	0.0003	0.82	0.049	0.11	2.04	0.55	395.30
2014	9.38	0.97	0.02	0.0003	0.73	0.044	0.11	2.03	0.46	361.10
2015	8.54	0.51	0.01	0.0002	0.77	0.046	0.11	1.94	0.38	337.69
2016	7.81	0.60	0.01	0.0002	1.05	0.063	0.11	1.94	0.31	329.55
2017	7.68	0.53	0.01	0.0002	0.93	0.056	0.11	1.94	0.24	318.82
2018	7.26	0.58	0.01	0.0002	0.98	0.059	0.11	1.94	0.12	308.74
2019	7.27	0.57	0.01	0.0002	0.80	0.048	0.11	1.95	0.20	302.38
2020	6.96	0.49	0.01	0.0002	0.73	0.044	0.11	1.95	0.17	290.51

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.

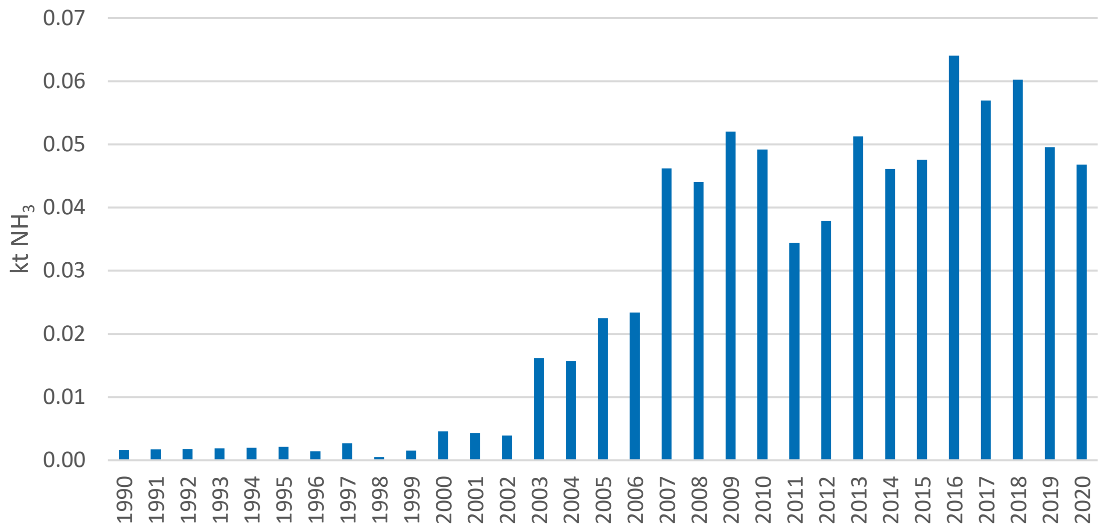

Figure 7.3. NH_3 emissions from SWD, Biological treatment of solid waste, Industrial waste incineration, and Industrial and domestic wastewater treatment, kt

Key categories

The key categories in 2020 by level and trend (Tier 1 and Tier 2) are presented in Table 1.3 and Annex 1.

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[370]

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

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%

370 IPCC 2006 vol 1, Chapter 3. Equation 3.1, p 3.28.

Source category	Gas	Combined uncertainty %
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 2020, 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.

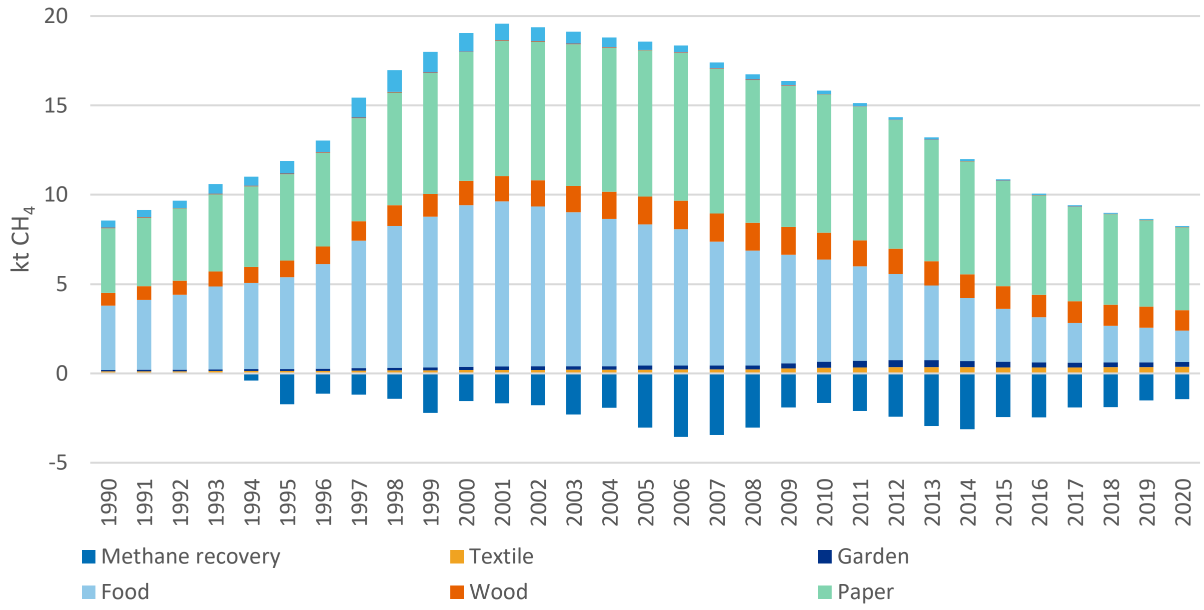

Figure 7.4. CH_4 emissions and recovery from landfills in Estonia in 1990–2020, kt CH_4

Estonia's total CH_4 emissions from SWD into landfills in 2020 amounted to 6.96 kt CH_4 (Table 7.4). The decreasing trend in total CH_4 emissions is driven by the amount of landfill gas recovered, waste incinerated in Iru waste incineration plant, and the amount of waste recycled. Emissions from Iru waste incineration plant have been reported under the Energy sector.

Table 7.4. Quantities of CH_4 emissions and recovery from biodegradable solid waste deposited in landfills in 1990–2020, 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
1991	3.9	0.1	3.8	0.8	0.1	0.4	0.03	0.0	9.14
1992	4.2	0.1	4.0	0.8	0.1	0.4	0.03	0.0	9.68
1993	4.6	0.1	4.3	0.8	0.1	0.5	0.03	0.0	10.59
1994	4.8	0.1	4.5	0.9	0.1	0.5	0.04	–0.4	10.60
1995	5.1	0.1	4.8	0.9	0.1	0.7	0.04	–1.7	10.15
1996	5.8	0.1	5.3	1.0	0.1	0.6	0.04	–1.1	11.88
1997	7.1	0.1	5.8	1.1	0.2	1.1	0.04	–1.2	14.25
1998	7.9	0.2	6.3	1.2	0.2	1.2	0.04	–1.4	15.54
1999	8.4	0.2	6.8	1.3	0.2	1.1	0.04	–2.2	15.80
2000	9.0	0.2	7.2	1.4	0.2	1.0	0.03	–1.5	17.50
2001	9.2	0.2	7.6	1.4	0.2	0.9	0.03	–1.7	17.90
2002	9.0	0.2	7.8	1.5	0.2	0.8	0.03	–1.8	17.60
2003	8.6	0.2	7.9	1.5	0.2	0.7	0.03	–2.3	16.82
2004	8.2	0.2	8.1	1.5	0.2	0.6	0.03	–1.9	16.89
2005	7.9	0.2	8.2	1.6	0.2	0.5	0.03	–3.0	15.54
2006	7.6	0.2	8.3	1.6	0.2	0.4	0.03	–3.5	14.81
2007	6.9	0.2	8.1	1.6	0.2	0.3	0.03	–3.4	13.97
2008	6.4	0.2	8.0	1.6	0.2	0.3	0.03	–3.0	13.71
2009	6.1	0.3	7.9	1.5	0.3	0.2	0.03	-1.9	14.46
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

Figure 7.5 shows CH_4 emissions from SWD with and without energy recovery.

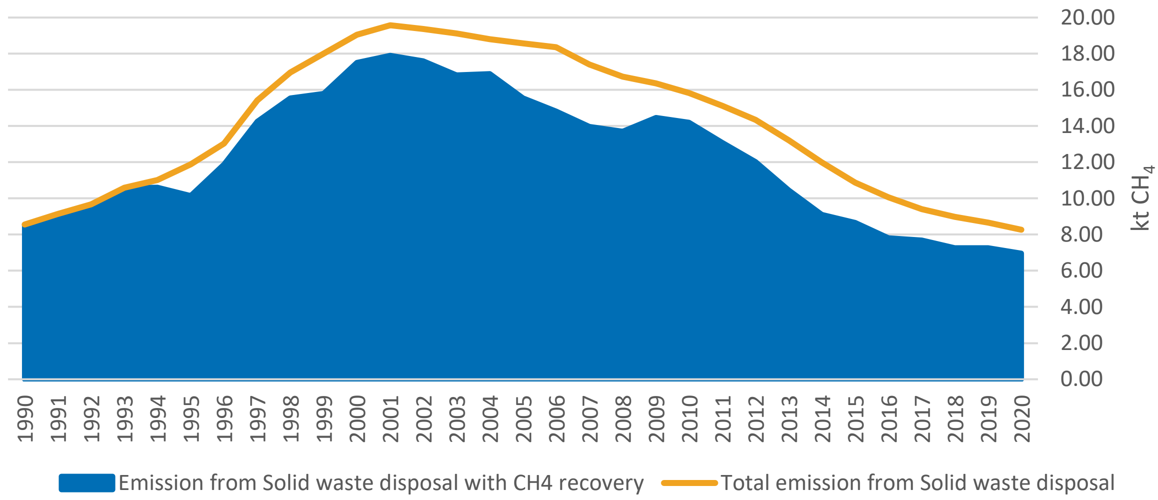

Figure 7.5. CH_4 emissions from SWD with and without energy recovery, kt CH_4

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 EstEA's Tableau[371]. 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.

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[371] Estonian Environment Agency's Waste data visualizing system (Tableau). [www] https://public.tableau.com/app/profile/keskkonnaagentuur (15.12.2021).

- The company has discovered that the data submitted the previous year was given in wrong units. In this case, they correct the error at the beginning of the subsequent year.
- The company is making an inventory at the beginning of the year and if there have been any inconsistencies in the quantities reported at the end of the previous year, then the company corrects the data at the beginning of the subsequent year. If such changes are made, they are tracked and there will be a comment about them in the online waste reporting system.

Differences between the activity data at the end of one year and at the beginning of the following year are characteristic of the national system; nevertheless, all waste data has been considered in doing emission calculations. The matter of activity data at the end of one year and at the beginning of the following year has been discussed with the National Audit Office of Estonia, who is aware of the current situation but has not proposed a method for enhancing the reporting system.

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 2020 was about 16.7 million tonnes, which is 17.4% lower than in 2019. The proportion of degradable and inert waste generated in 2020 was 4.77% and 93.13%, respectively. The proportion of separately collected waste was 2.06% of the total waste generated. The annual trend of inert and degradable waste generated in Estonia in 1990–2020 is presented in Figure 7.6.

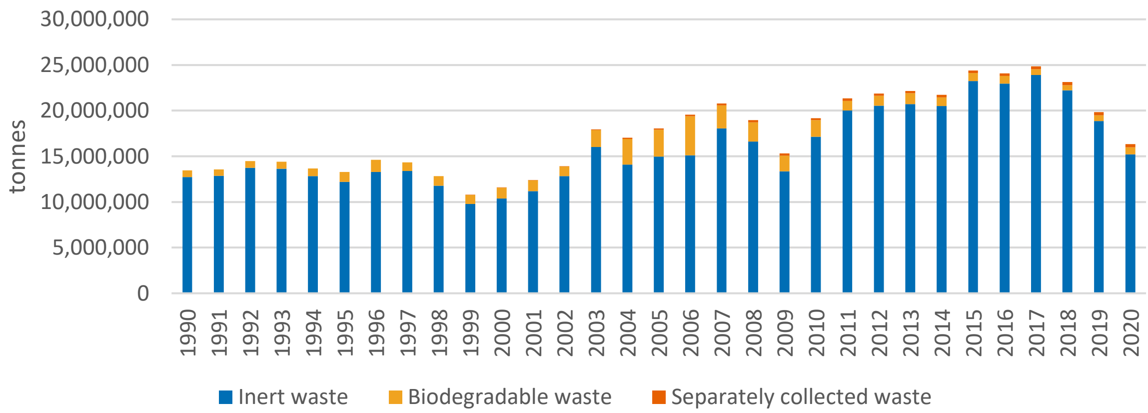

Figure 7.6. Quantities of waste generated in Estonia in 1990–2020, tonnes

In 2020, waste generated by the oil shale industry constituted 67% 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[372]. In comparison, the waste of the oil shale industry in 2019 covered 72.9% of the total waste generated. Oil shale mining decreased in 2020 compared to 2019. 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 2020 was about 322 271 tonnes in addition to a separately collected fraction, which amounted to 342 765 tonnes. The total amount of MSW generated was about 1.93% of the total waste generated. The total amount of waste deposited in landfills was 6 million tonnes, from which MSW comprised 52.8 thousand tonnes and industrial waste 5.9 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 7.9). Separately collected MSW is separately reported in Tableau. The amount of deposited MSW has decreased compared to last year due to the decreased amount of generated MSW and increased possibilities to sort waste separately.

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
1991	147.3	3.5	88.5	11.5	3.1	5.4	95.8	NE	349.8	NO
1992	182.1	4.3	109.4	14.3	3.9	2.5	118.5	NE	432.6	NO
1993	156.5	3.7	94.1	12.3	3.3	0.5	101.9	NE	371.8	NO
1994	149.3	3.5	89.7	11.7	3.2	1.3	97.2	NE	354.7	NO
1995	192.5	4.6	115.7	15.1	4.1	0.9	125.3	NE	457.3	NO
1996	237.7	5.6	142.9	18.6	5.1	1.9	154.7	NE	564.7	NO
1997	249.8	5.9	150.1	19.6	5.3	3.1	162.6	NE	593.3	NO
1998	234.6	5.6	141.0	18.4	5.0	2.8	152.7	NE	557.2	NO
1999	239.4	5.7	143.9	18.8	5.1	18.6	155.8	NE	568.6	4.5
2000	231.0	5.5	138.8	18.1	4.9	8.2	150.3	NE	548.7	1.7
2001	168.0	4.0	101.0	13.2	3.6	4.2	109.3	NE	399.1	0.3
2002	175.5	4.2	105.5	13.8	3.8	1.4	114.2	NE	416.8	0.2
2003	155.0	3.7	93.2	12.2	3.3	NO	100.9	NE	368.2	1.9
2004	154.7	3.7	93.0	12.1	3.3	NO	100.7	NE	367.5	11.2
2005	152.2	3.6	91.5	11.9	3.3	0.2	99.1	NE	361.6	6.7
2006	82.0	1.9	49.2	6.4	1.8	0.0	53.3	NE	194.7	6.7
2007	98.1	2.3	59.0	7.7	2.1	NO	63.9	NE	233.1	5.8
2008	104.8	16.9	60.8	3.4	13.5	NO	138.5	NE	337.9	5.7
2009	87.7	14.1	50.9	2.8	11.3	NO	116.0	NE	282.9	3.6
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

[372] 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
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

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
1991	36.7	0.7	11.4	2.5	0.6	NO	48.3	10 248.8
1992	45.3	1.9	17.9	1.5	1.9	NO	118.0	10 645.2
1993	37.4	0.6	10.8	1.0	0.7	NO	47.8	10 886.4
1994	11.6	0.0	10.0	0.6	0.6	NO	126.1	8 769.1
1995	48.7	0.1	8.0	1.2	0.2	NO	32.2	10 071.9
1996	127.9	0.7	23.3	1.8	0.5	NO	303.9	10 579.9
1997	74.4	0.7	19.0	4.2	0.3	NO	152.8	11 176.0
1998	61.5	0.6	26.9	5.4	0.3	NO	71.9	10 005.1
1999	90.5	0.3	22.7	0.5	0.1	NO	23.4	8 505.4
2000	47.3	0.9	5.3	0.2	0.2	NO	25.5	9 261.2
2001	24.8	0.0	16.1	0.5	0.1	NO	2.1	9 063.4
2002	2.8	0.4	4.7	0.1	0.06	NO	2.3	9 447.2
2003	3.3	0.9	15.6	0.4	NO	NO	3.6	11 556.4
2004	3.8	1.7	13.3	NO	0.01	NO	2.5	11 131.2
2005	4.6	1.2	5.9	NO	NO	NO	1.0	11 058.9
2006	5.2	1.0	2.2	NO	NO	NO	4.0	10 587.7
2007	1.8	0.9	3.2	NO	NO	NO	4.4	11 756.6
2008	1.8	1.0	3.1	NO	NO	NO	0.7	11 335.0
2009	1.5	0.7	1.9	NO	NO	NO	0.7	8 234.7
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

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 2020 (Figure 7.7) increased by approximately 5.0% compared to the base year of 1990. In comparison with the year 2019, the amount of DOC has decreased by about 3.4%, due to decreased waste generation. The ratio of DOC landfilled to DOC generated has decreased slightly from 4.32% to 4.29%.

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.

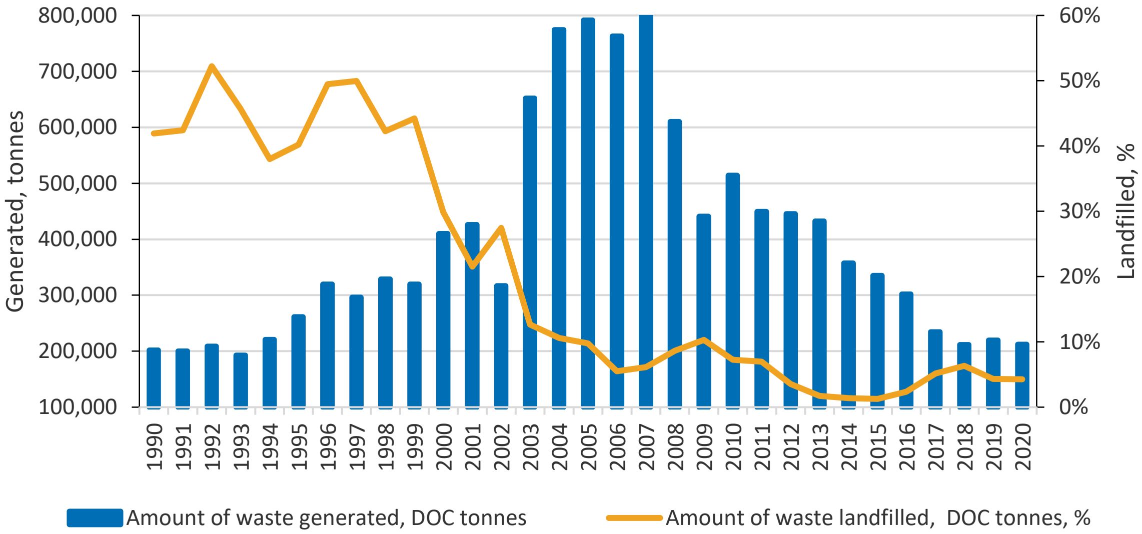

Figure 7.7. Quantity of DOC generated (tonnes) and ratio of DOC landfilled to DOC generated (%) in 1990–2020

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%[373].

The data on the amount of recovered methane in 1994–2006 is based on REN-Estonia – an annual questionnaire on renewables and waste[374]. 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 2020 was 1.4 kt (Figure 7.8).

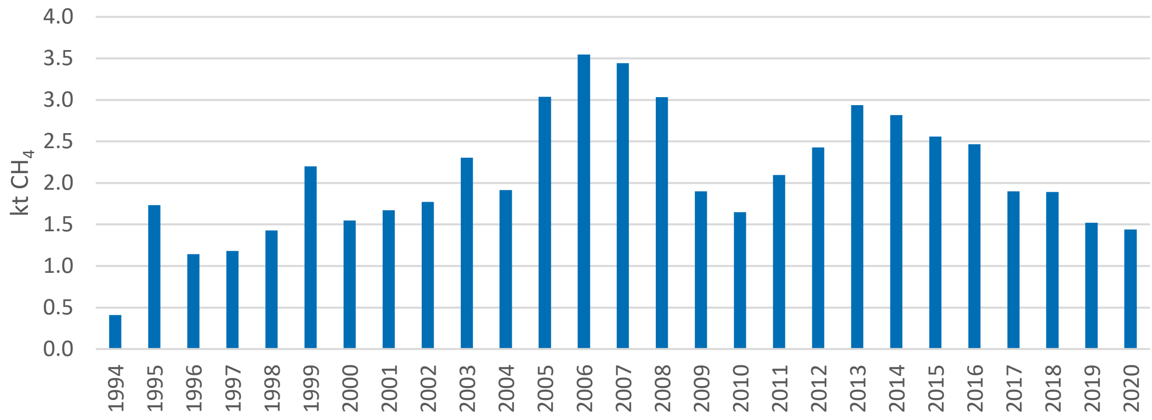

Figure 7.8. CH_4 recovered from landfills in 1994–2020, kt

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.

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.

[373] Parameters were determined during consulting with EstEA

[374] REN. 2013. IEA – Eurostat-UNECE. Energy Questionnaire – Renewables and Waste.

Emission factors

Emission factors used in the calculations of emissions from SWD sites are default emission factors from IPCC 2006 Guidelines (Table 7.7). No accurate analysis of DOC in different waste types has been carried out in Estonia, therefore IPCC 2006 Guideline's default DOC contents for the FOD model are used in emission calculations (Table 7.8).

Table 7.7. Emission factors and parameters used in calculations

Factor/Parameter	Value
MCF – anaerobic[375]	1
MCF – uncategorised SWD sites[375]	0.6
DOCf[376]	0.5
F[377]	0.5
OX[378]	0.09
Methane generation rate constant[379]	
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 7.8. Default DOC content of different waste types (wet basis)[380]

Waste group	DOC content (fraction)
Municipal solid waste	
Food/Grease	0.15
Municipal	see Table 7.11
Garden	0.2
Paper	0.4
Textile	0.24
Wood	0.43
Municipal sludge	0.05
Industrial waste	
Organic	0.15
Textile	0.24
Wood	0.43
Paper	0.4
Leather	0.39
Rubber	0.39
Industrial sludge	0.045

375 IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.14, table 3.1.
376 IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.13.
377 IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.15.
378 IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.15, table 3.2.
379 IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.17, table 3.3.
380 IPCC 2006 Guidelines, Volume 5, Chapter 2: Waste generation, composition and management data, pages 2.14, 2.16, table 2.4 and 2.5.

Calculations in the FOD model are based on the country-specific data about the waste composition of MSW (Table 7.9). Four studies have been carried out in Estonia about waste composition in MSW: in 2000, 2008, 2013 and 2020. The period of 1950–1999 is retroactively covered with composition data derived from studies carried out in Estonia in 2000; the period of 2000–2007 is covered with data from a study carried out in 2000. The period of 2008–2011 is covered with data from a study carried out in 2008, the period of 2012-2018 is covered with data from a study carried out in 2012. Starting from 2019, the MSW composition from the study of 2020 was used.

Calculations made under SWD comprise managed and uncategorised disposal sites. CH_4 emissions in 1990–1993 are derived from uncategorised disposal sites; emissions since 2009 are derived only from managed disposal sites, while CH_4 emissions in 1994–2008 were generated in both managed and uncategorised waste disposal sites. In 1994–2008, a managed disposal site was considered Pääsküla landfill in Tallinn, where landfill gas was recovered. A type of uncategorised waste management was chosen, as there is no accurate data available, or research conducted in Estonia about the distribution of waste by waste management type (unmanaged shallow or unmanaged deep). CH_4 emissions from both landfill types are reported together in the NIR, as the waste model used for calculations does not allow reporting emissions separately.

Table 7.9. Composition of MSW, %

	1950–1999[381]	**2000–2007**[381]	**2008–2011**[382]	**2012–2018**[383]	**2019-onward**[384]
Organic household waste and non-defined non-separated waste	43.1	43.1	36	31.8	31.7
Paper and cardboard	25.3	25.3	18	13.5	17.0
Wood	3.3	3.3	1	2	1.3
Textiles	0.9	0.9	4	5.1	5.8
Inert	27.4	27.4	41	47.6	39.2
Nappies	-	-	-	-	5

The composition of furniture waste (Table 7.10) is based on an expert judgement and a study carried out by the Stockholm Environment Institute Tallinn Centre[385].

[381] Vaania, (2000). Study on the composition of municipal solid waste including different regions in Estonia (in Estonian).
[382] 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 (01.11.2021).
[383] 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 (01.11.2021).
[384] 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 (01.11.2021).
[385] 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 (01.11.2021).

Table 7.10. Composition of furniture waste, % in 1990–2019

Composition of furniture waste	%
Wood	49.3%
Textile	24.3%
Metal	12.2%
Plastic	14.2%

Table 7.11. DOC content of mixed MSW in Estonia in 1950–2020

	1950–1999	2000–2007	2008–2011	2012–2018	2019-onward
DOC content in MSW	0.20	0.20	0.16	0.14	0.15

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[386]	
Total MSW	±10%
Total uncertainty of waste composition	±10%
MSW sent to SWD sites	±10%
Emission factors	
Uncertainty for default half-life($t_{1/2}$)[387]	
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[386]	±20%
Fraction of DOC decomposed (DOC_f)[386]	±20%
Methane correction factor 1.0[386]	–10%
Methane recovery[386]	±30%
Fraction of CH_4 in generated landfill gas[386]	±5%

[386] IPCC 2006 Guidelines, Volume 5, Chapter 3. Solid Waste Disposal, page 3.27, table 3.5.
[387] 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[388]. 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

Recalculation was done due to fixing calculation error for 2014-2015 methane recovery data (Table 7.13) and updated CH_4 emissions are shown in Table 7.14.

Table 7.13. Methane for energy recovery, kt 2014-2015

	Methane for energy recovery, kt	
	2021 submission	2022 submission
2014	2.35268460735	2.05222066665
2015	2.35694279865	2.48314899525

Statistics Estonia switched to a new Eurostat methodology for calculating GDP. New methodology was implemented to ensure a common methodology for comparing countries data. Corrected GDP values and methane emissions are shown in Table 7.14.

Table 7.14. Estonian GDP (eur) and corrected CH_4 emissions

	GDP. eur		**CH_4 emissions**	
	2021 submission	**2022 submission**	**2021 submission**	**2022 submission**
1995	2 858.37	2 861.60	10.151924	10.151892
1996	3 675.50	3 680.00	11.884647	11.884621
1997	4 567.05	4 573.00	14.248204	14.248182
1998	5 093.09	5 100.40	15.543773	15.543754
1999	5 411.72	5 406.90	15.799328	15.799312
2000	6 179.77	6 171.60	17.504154	17.504140
2001	6 992.22	6 987.10	17.903644	17.903631
2002	7 827.34	7 822.60	17.604935	17.604924
2003	8 747.63	8 744.40	16.819737	16.819728
2004	9 776.24	9 777.50	16.892264	16.892256
2005	11 336.46	11 343.30	15.539207	15.539199
2006	13 560.52	13 568.90	14.813176	14.813169
2007	16 398.74	16 401.30	13.965768	13.965762
2008	16 638.29	16 618.10	13.705931	13.705925
2009	14 211.81	14 131.90	14.464257	14.464252
2010	14 860.70	14 741.10	14.207104	14.207100
2011	16 826.80	16 677.30	13.087932	13.087928

[388] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance / Quality Control and Verification.

	GDP. eur		CH_4 emissions	
	2021 submission	**2022 submission**	**2021 submission**	**2022 submission**
2012	18 050.74	17 916.70	12.021329	12.021325
2013	19 033.39	18 910.80	10.443536	10.443532
2014	20 179.99	20 048.20	9.106862	9.384787
2015	20 782.22	20 631.40	8.658708	8.543857
2016	21 931.50	21 747.90	7.806535	7.806532
2017	23 857.70	23 833.60	7.682349	7.682346
2018	25 937.60	2 5817.70	7.260865	7.260863
2019	28 112.40	27 732.30	7.270838	7.270835

7.2.6. Category-specific planned improvements

Historical data on waste generation per capita and distribution of waste-by-waste management type will be investigated and updated as data becomes available.

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 2020 comprised 0.73 kt CH_4 and 0.04 kt N_2O emissions (Figure 7.9). 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 2019, the emissions from Biological treatment on solid waste decreased because the amount of biodegradable waste composted decreased. Main driver for the decrease was sludge which is treated under other waste handling activities. In 2020 two more biogas facilities are built in Estonia and 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.

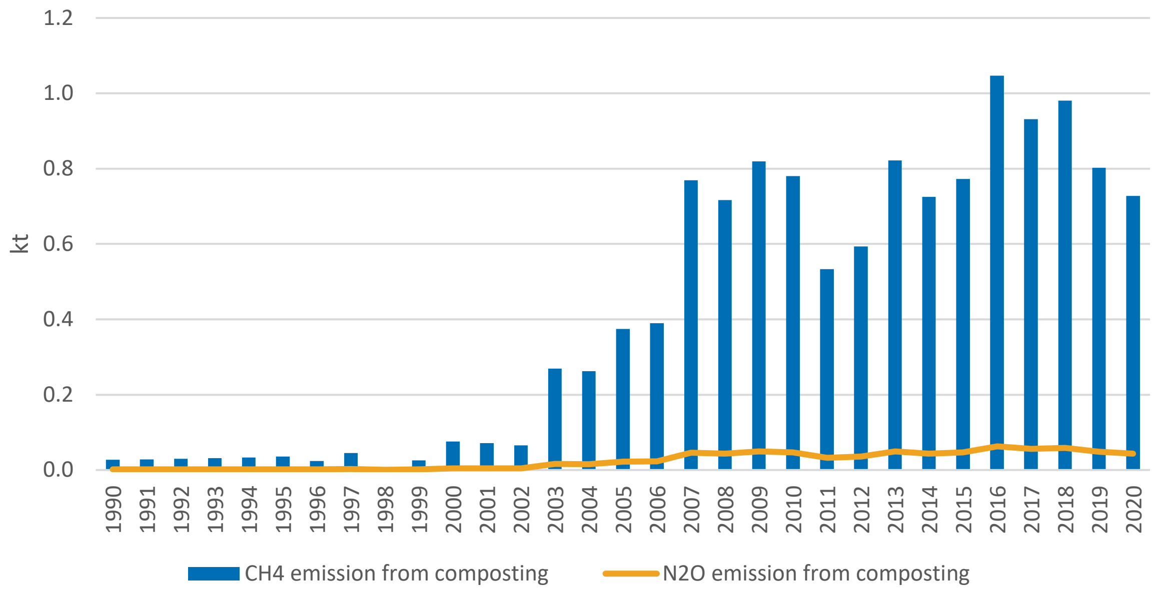

Figure 7.9. CH_4 and N_2O emissions from Biological treatment of solid waste in 1990–2020, kt

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)[389] 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 2020, the leakages comprised 0.05 kt which is 0.0004% 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 2020 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 2020, 72 797 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 7.15 organic, sludge and wood waste contribute the most to composting in Estonia. Abbreviation NO indicates that the waste type was not composted.

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[389] 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).

Table 7.15. Quantities of waste composted in 1990–2020, tonnes dry weight [390]

Year	MSW	Organic waste	Paper	Sludge	Textiles	Wood	Total
1990	NO	1 500	NO	51	58	1 101	2 710
1991	NO	1 579	NO	51	58	1 159	2 847
1992	NO	1 662	NO	51	58	1 220	2 991
1993	NO	1 750	NO	51	58	1 284	3 143
1994	NO	1 842	NO	51	58	1 352	3 302
1995	0.4	1 939	0.3	51	146	1 423	3 560
1996	NO	2 325	NO	NO	24	53	2 402
1997	NO	3 620	NO	41	29	797	4 487
1998	NO	150	NO	31	32	598	811
1999	NO	1 054	NO	NO	128	1 392	2 574
2000	NO	6 078	NO	48	168	1 311	7 604
2001	NO	2 062	0.02	4 113	NO	999	7 175
2002	NO	3 375	23	1 546	22	1 578	6 544
2003	5	9 259	4	14 350	33	3 284	26 936
2004	NO	98	NO	21 619	NO	4 523	26 240
2005	NO	1 543	NO	27 056	NO	8 832	37 431
2006	NO	1 589	243	32 548	NO	4 553	38 933
2007	NO	3 030	251	60 254	NO	13 366	76 902
2008	NO	4 920	323	51 110	NO	15 328	71 682
2009	NO	6 379	20	58 002	NO	17 549	81 950
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

NO – not occurring

[390] 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.

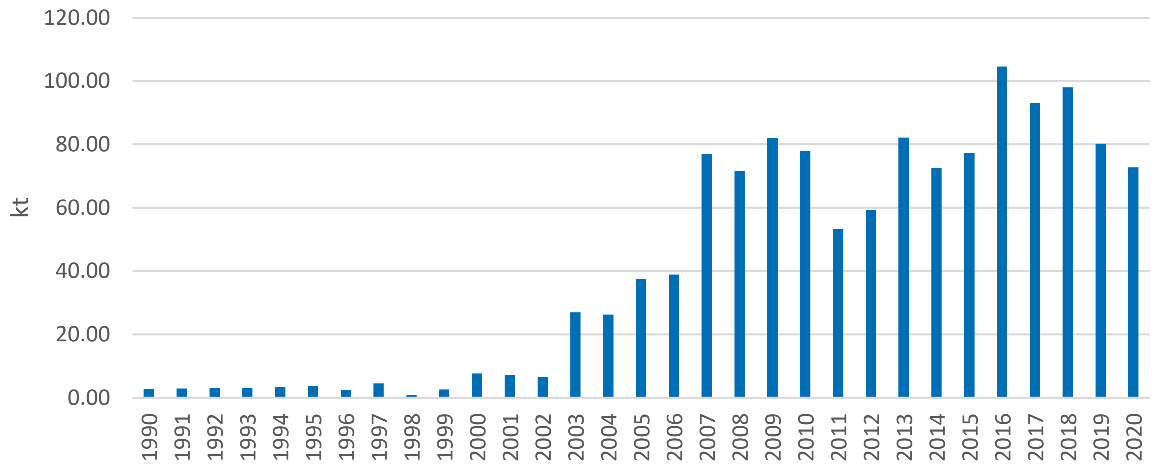

Figure 7.10. Composted organic waste in 1990–2020 (kt, dry weight)

As seen in Figure 7.10 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. 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 is mostly caused by the opening of two more 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[391] noting it is assumed that the moisture content in wet waste is 60%.

Equation 7.2[392]

$$CH_4\ Emissions = \sum_i (M_i \times EF_i) \times 10^{-3} - R$$

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.

[391] IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.6,table 4.1, remark
[392] IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.5, equation 4.1.

Equation 7.3[393]

$$N_2O\ Emissions = \sum_i (M_i \times EF_i) \times 10^{-3}$$

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.

Emission factors

IPCC 2006 Guidelines default dry weight emission factors are used in the calculations (Table 7.16).

Table 7.16. Default emission factors for calculating CH_4 and N_2O emissions from Biological treatment of solid waste[394]

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 7.17) 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 7.17. Default uncertainty ranges for Biological treatment of solid waste

Input	Value
Activity data[395]	
Waste composition	±10%
Total MSW	±10%
Emission factor[396]	
CH_4 (Composting)	(4) 0.03…8
N_2O (Composting)	(0.3) 0.06…0.6

393 IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.5, equation 4.2.
394 IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological treatment of Solid Waste, page 4.6, table 4.1.
395 IPCC 2006 Guidelines, Volume 5, Chapter 3: Solid Waste Disposal, page 3.27, table 3.5.
396 IPCC 2006 Guidelines, Volume 5, Chapter 4: Biological Treatment of Solid Waste, page 4.6, table 4.1.

7.3.4. Category-specific QA/QC and verification

Complete QA and QC were carried out pursuant to the procedures described in IPCC 2006 Guidelines[397]. 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.

7.3.5. Category-specific recalculations

In 2019 CH_4 and N_2O emissions are recalculated, due to the activity data error (Table 7.18). The quantity of sludge from one company were counted twice.

Table 7.18. Modified amounts of compost and recalculation of CH_4 and N_2O emissions

	Composted, sum kt (dry weight)		CH_4 emission, kt		N_2O emission, kt	
	2021 submission	2022 submission	2021 submission	2022 submission	2021 submission	2022 submission
2019	89.12	80.20	0.89	0.80	0.053	0.048

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 (Figure 7.11) from non-biogenic sources in 2020 amounted to 0.000074 kt and from biogenic sources to 0.001 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

[397] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance/Quality Control and Verification.

energy recovery, for example in 2020 only 0.65 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 7.19.

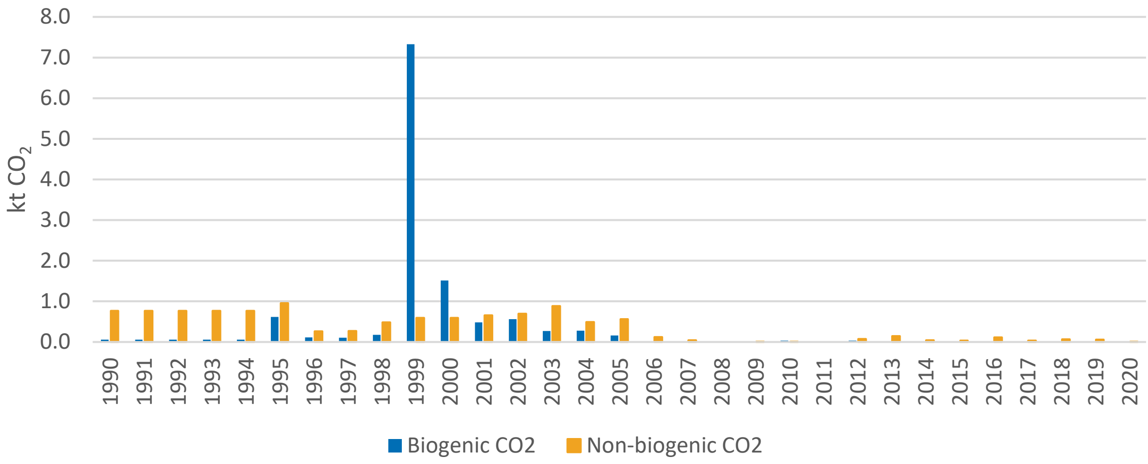

Figure 7.11. CO_2 emissions from Waste incineration without energy recovery in Estonia in 1990–2020, kt

Total CH_4 emissions (Figure 7.12) from Waste incineration without energy recovery in 2020 amounted to 0.0000031 kt, of which 0.000003 kt was of biogenic origin and 0.0000002 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 7.19.

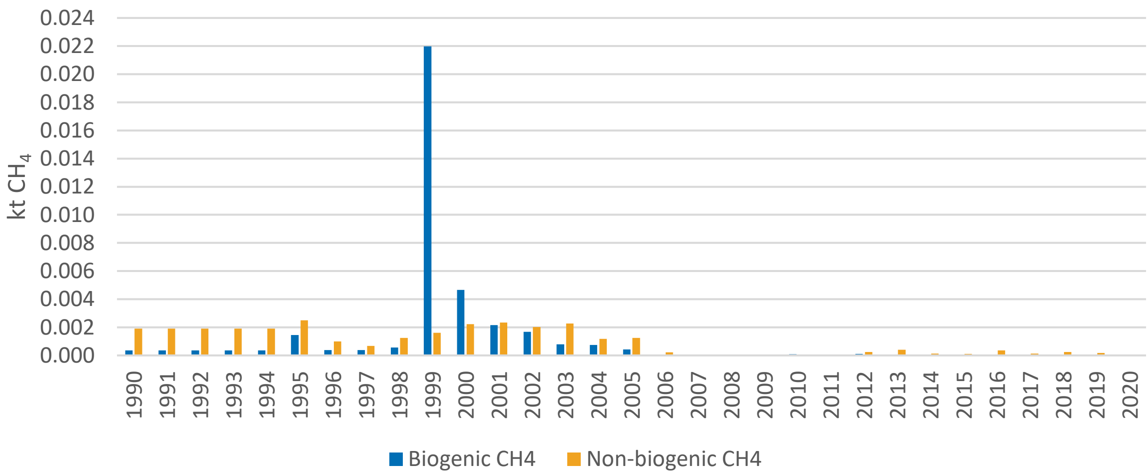

Figure 7.12. CH_4 emissions from Waste incineration without energy recovery in Estonia in 1990–2020, kt

N_2O emissions (Figure 7.13) from Waste incineration in 2020 was 0.01 kg, of which 0.005 kg was non-biogenic and 0.007 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 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 7.19.

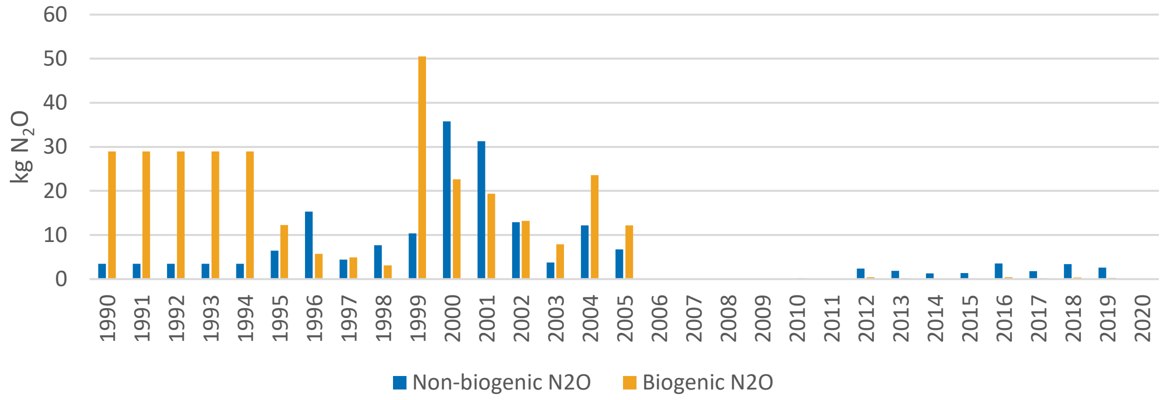

Figure 7.13. N_2O emissions from Waste incineration without energy recovery in Estonia in 1990–2020, kg

In Estonia, Open burning of waste is not a common practice for eliminating waste, as open burning of MSW 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 7.14, Figure 7.15, Figure 7.16) 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 2020, Open burning of waste resulted in 0.5 kt biogenic CO_2 and 0.5 kt non-biogenic CO_2.

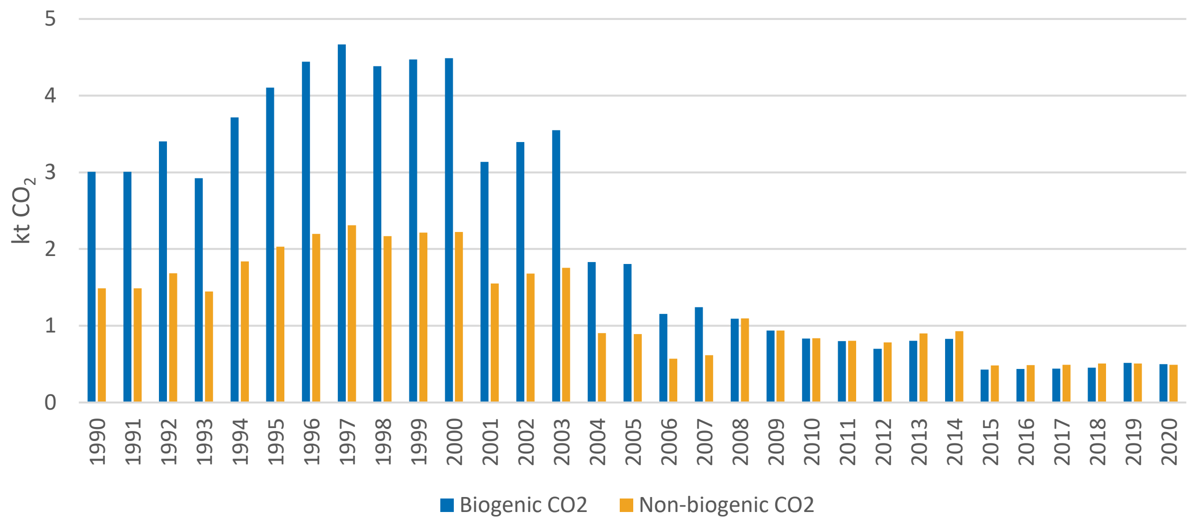

Figure 7.14. CO_2 emissions from Open burning of waste in Estonia in 1990–2020, kt

Total CH_4 emissions of 0.01 kt are divided into 0.006 kt biogenic CH_4 and 0.004 kt non-biogenic CH_4.

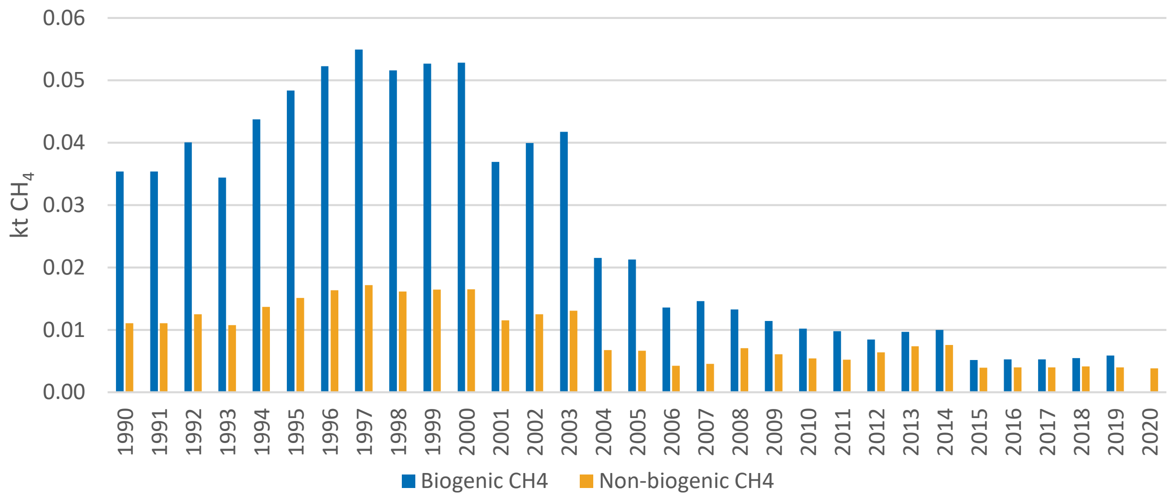

Figure 7.15. CH_4 emissions from Open burning of waste in Estonia in 1990–2020, kt

Total N_2O emissions of 0.0002 are divided into 0.00008 kt biogenic N_2O and 0.00008 kt non-biogenic N_2O.

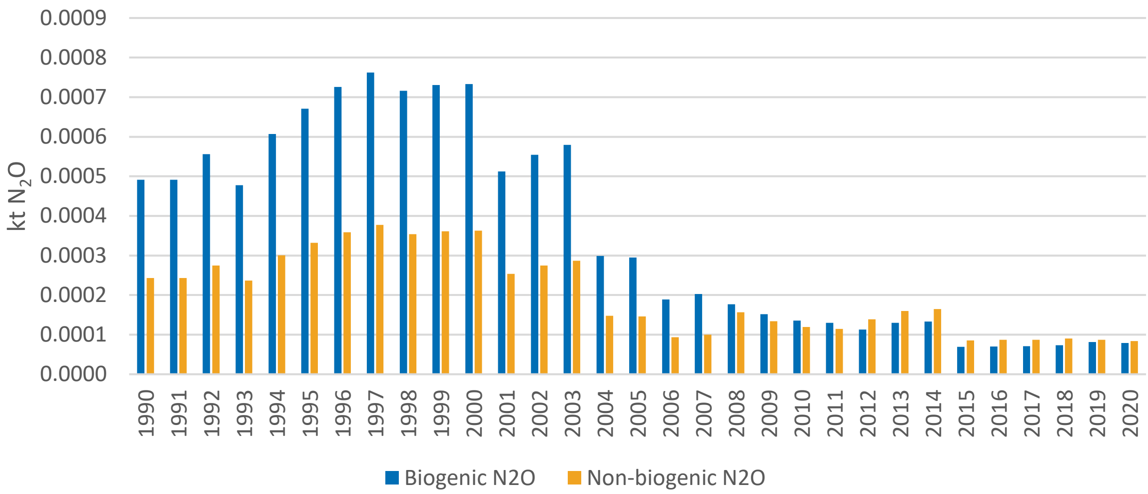

Figure 7.16. N_2O emissions from Open burning of waste in Estonia in 1990–2020, kt

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 2020, the quantity of waste incinerated without energy recovery was 0.65 tonnes (Table 7.19) 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 7.19. Quantities of waste incinerated without energy recovery in Estonia in 1990–2020, tonnes[398]

	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
1991	23	1	4	94	148	1	17	NO	20	6	60	3	NO	5	381
1992	23	1	4	94	148	1	17	NO	20	6	60	3	NO	5	381
1993	23	1	4	94	148	1	17	NO	20	6	60	3	NO	5	381
1994	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
1996	148	3	14	1	7	0.8	24	NO	35	4	NO	25	NO	6	266
1997	21	4	2	39	30	0.7	55	NO	40	12	NO	2	NO	14	220
1998	42	5	8	0.2	125	0.2	14	NO	7	19	NO	0	90	8	317
1999	88	24	NO	NO	145	NO	0	NO	16	10	NO	9	4 643	5	4 940
2000	362	78	3	NO	3	NO	41	NO	2	5	NO	20	815	12	1 341
2001	336	NO	NO	NO	2	50	12	470	19	0.05	13	47	3	10	961
2002	123	NO	NO	NO	124	50	15	NO	10	NO	NO	85	272	17	696
2003	27	NO	NO	NO	203	84	3	NO	3	NO	0.5	55	122	19	516
2004	85	NO	NO	NO	52	70	1	NO	2	NO	NO	251	NO	22	482
2005	50	NO	NO	NO	106	60	0.3	NO	2	NO	NO	128	10	10	366
2006	NO	NO	NO	NO	NO	40	0.1	NO	NO	NO	NO	NO	NO	0.8	41
2007	NO	NO	NO	NO	NO	14	NO	NO	NO	NO	NO	NO	7	NO	21
2008	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2009	NO	NO	NO	NO	NO	NO	NO	NO	2	NO	NO	NO	NO	NO	2
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	0.05	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.6	NO	0.65

NO – not occurring

Time series of open burning of MSW is shown in Figure 7.17. 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

[398] D10 operation of waste disposal activities – Incineration on land.

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 is most used for open burning or eliminate any waste fractions. The fluctuation of burned MSW seen in Figure 7.17 is connected to the fluctuation of MSW generation.

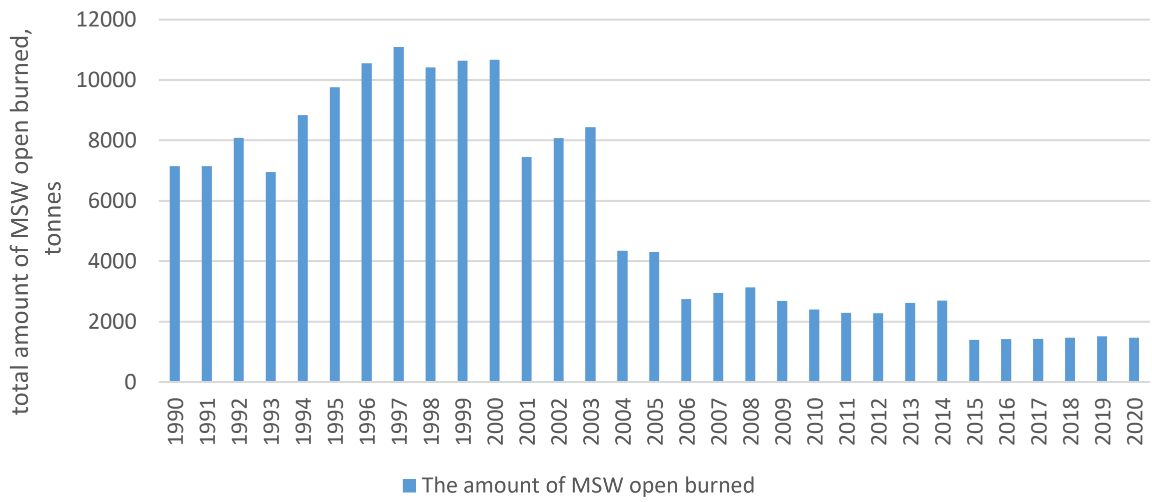

Figure 7.17. Quantities of waste open burned in Estonia in 1990–2020, tonnes

The specific composition of open burned MSW is based on the MSW sorting studies (Table 7.20). 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 7.20. 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
1991	3 215	1937	254	NO	72	886	782	7146
1992	3 639	2193	287	NO	81	1003	886	8089
1993	3 128	1884	247	NO	70	862	761	6952
1994	3 976	2 396	314	NO	89	1 096	968	8 838
1995	4 392	2 646	346	NO	98	1 211	1 069	9 763
1996	4 751	2 862	375	NO	106	1 309	1 156	10 560
1997	4 991	3 007	394	NO	112	1 376	1 214	11 094

Year	Food waste	Paper/ Cardboard	Wood	Garden	Textiles	Plastic	Other	Total
1998	4 687	2 824	370	NO	105	1 292	1 141	10 419
1999	4 784	2 882	377	NO	107	1 319	1 164	10 634
2000	4 800	2 892	379	NO	107	1 323	1 168	10 670
2001	3 354	2 021	265	NO	75	925	816	7 456
2002	3 632	2 188	286	NO	81	1 001	884	8 072
2003	3 795	2 287	299	NO	85	1 046	923	8 436
2004	1 957	1 179	154	NO	44	539	476	4 349
2005	1 932	1 164	152	NO	43	532	470	4 294
2006	1 235	744	97	NO	28	340	300	2 745
2007	1 329	800	105	NO	30	366	323	2 953
2008	1 114	614	15	185	155	652	400	3 135
2009	955	527	13	158	133	560	343	2 689
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

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[399]

$$CO_2Emissions = \sum_i (SW_i \times dm_i \times CF_i \times FCF_i \times OF_i) \times 44/12$$

Equation 7.5[400]

$$CO_2Emissions = MSW \times \sum_j \left(WF_j \times dm_j \times CF_j \times FCF_j \times OF_j\right) \times 44/12$$

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 7.9 under SWD on land were used.

Emission factors

IPCC 2006 Guidelines' default oxidation factor (Table 7.21) and emission factors (Table 7.22) have been used for calculating CO_2 emissions from both sub-categories of Waste incineration and Open burning of waste.

Table 7.21. Default oxidation factors used in Waste incineration and Open burning of waste calculations[401]

	Incineration of waste	Open burning of MSW
Oxidation factor in % of carbon input	100%	58%

[399] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.7, equation 5.1.
[400] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.7, equation 5.2.
[401] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and open burning of waste, page 5.18, table 5.2.

Table 7.22. 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[402]			
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[403]			
Textile	80	40	16
Pulp and paper	90	41	1
Clinical waste	65	40	25
Industrial waste[404]	90[403]	50	90
Sewage sludge	10[405]	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[406]

$$N_2O\ Emissions = \sum_i (IW_i \times EF_i) \times 10^{-6}$$

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;
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 7.23).

402 IPCC 2006 Guidelines, Volume 5, Chapter 2: Waste generation, composition and management data, page 2.14, table 2.4.
403 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.
404 IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and open burning of waste, page 5.18, table 5.2.
405 IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and open burning of waste, page 5.15.
406 IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and open burning of waste, page 5.14, eq 5.5.

Table 7.23. N_2O emission factors used in calculations of Waste incineration and Open burning of waste[407]

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[408]

$$Emissions_{GHG\ fuel} = Fuel\ Consumtpion_{fuel} \times Emission\ factor_{GHG\ fuel}$$

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[409]

$$CH_4Emissions = \sum_i (IW_i \times EF_i) \times 10^{-6}$$

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;
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 7.24 and emission factors from Table 7.25 were implemented in calculations.

407 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.
408 IPCC 2006 Guidelines, Volume 2, Chapter 2: Stationary Combustion, page 2.11, equation 2.1.
409 IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.12, eq 5.4.

Table 7.24. 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	9.89	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 [410]

Table 7.25. Emission factors for calculating CH_4 emissions from incineration without energy recovery and open burning of waste

Waste category	Emission factor
Waste incineration[411]	
Wood; industrial waste; MSW (non-biomass fraction); MSW (biomass fraction); other primary solid biomass; waste oil	300 kg CH_4 /TJ
Open burning[412]	
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 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 7.26.

The combined uncertainty rates related to the sub-category of Waste incineration are given in Table 7.3.

Table 7.26. Default uncertainty ranges for Waste incineration

Input	Uncertainties
Activity data[413]	

[410] IPCC 2006 Guidelines, Volume 2, Chapter 1: Introduction, page 1.18, table 1.2.
[411]. IPCC 2006 Guidelines, Volume 2, Chapter 2: Stationary Combustion, page 2.21, table 2.4.
[412] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.20.
[413] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.24.

Input	Uncertainties
Quantities of waste incinerated without energy recovery	±5%
Quantity of waste open burned	
Dry matter content	±30%
Waste composition[386]	±10%
Quantity of waste open burned	±5%
Emission factors[414]	
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[415]. 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

In the previous submission (2021), CO_2, CH_4, N_2O emission recalculation in subcategory 5.C.2 open burning of waste were made based on the updated amount of waste open burned (2015-2019). However, the updated waste amounts were not reflected in NIR and CRF. This correction is included in the 2022 submission, with no further updates on emissions calculations (Table 7.20).

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 2020 consists of 1.95 kt from domestic wastewater handling (Figure 7.18) and 0.17 kt from industrial wastewater handling (Figure 7.19).

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

[414] IPCC 2006 Guidelines, Volume 5, Chapter 5: Incineration and Open Burning of Waste, page 5.23.
[415] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance / Quality Control and Verification.

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.

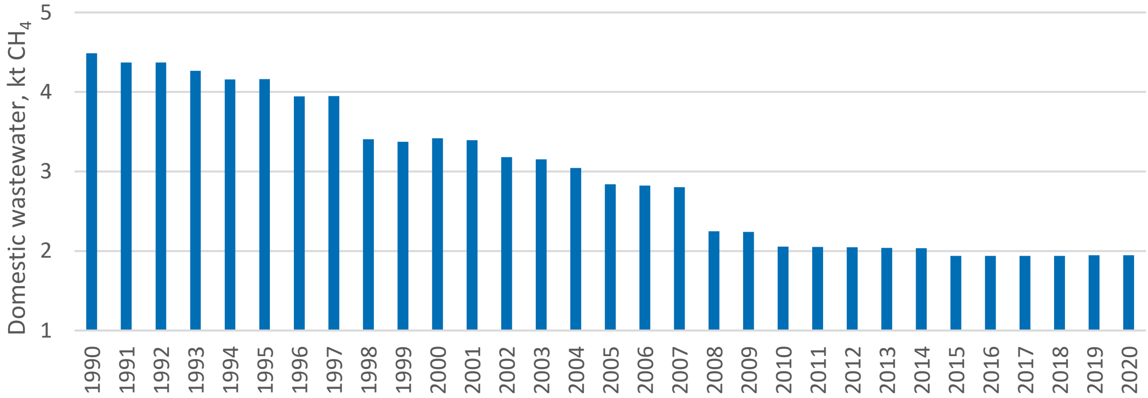

Figure 7.18. CH_4 emissions from domestic wastewater handling in 1990–2020, kt CH_4

Industrial wastewater CH_4 (Figure 7.19) 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.

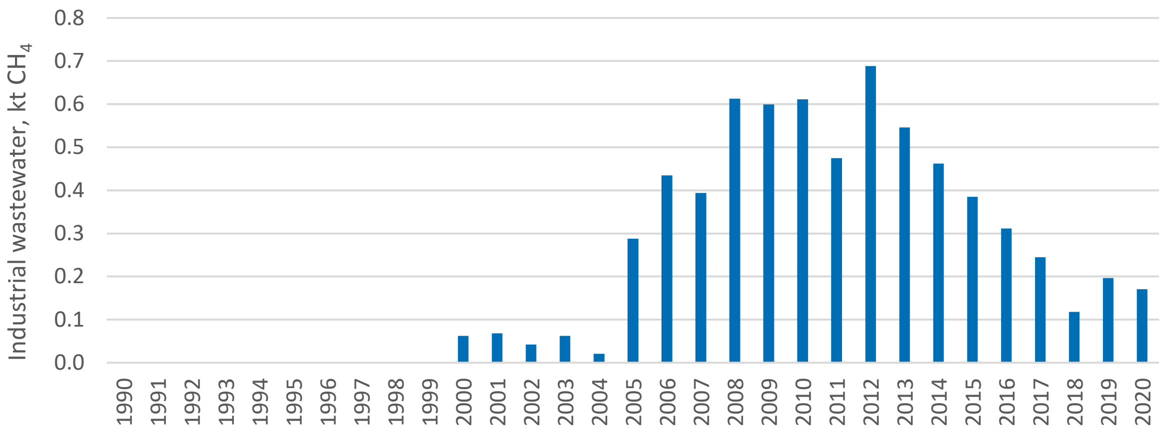

Figure 7.19. CH_4 emissions from industrial wastewater handling in 1990–2020, kt CH_4

N_2O emissions from domestic sources are presented in Figure 7.20. The total amount of N_2O emissions from wastewater in 2020 was 0.11 kt. The minor fluctuation in the time series is related to changes in protein consumption values per capita.

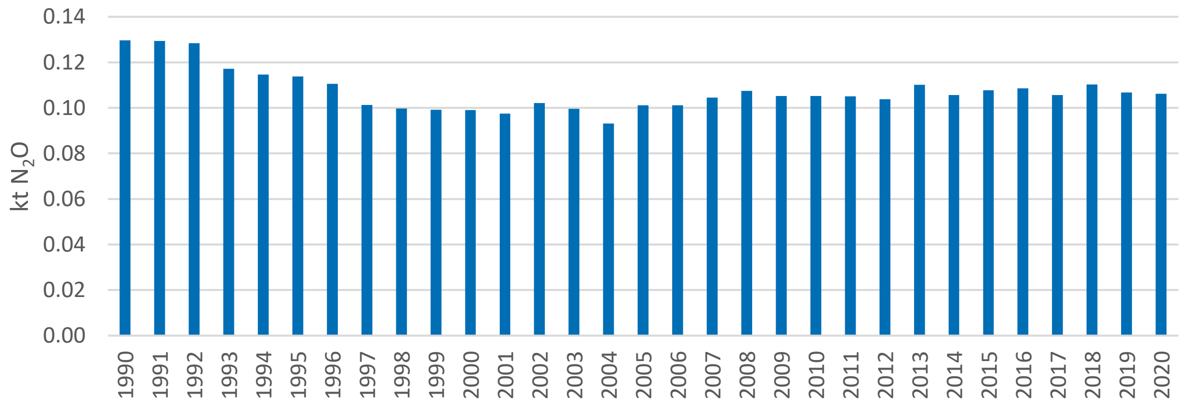

Figure 7.20. N_2O emissions from domestic wastewater handling in 1990–2020, kt N_2O

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[416]. As suggested by the ESD review team in 2017, the balance scheme of wastewater pathways was added (Figure 7.21) which are also shown in Table 7.27 and Table 7.28.

[416] Table is based on a study by Infragate, (2014). Hajaasustuse reovee kohtkäitlussüsteemide inventuuri aruanne.

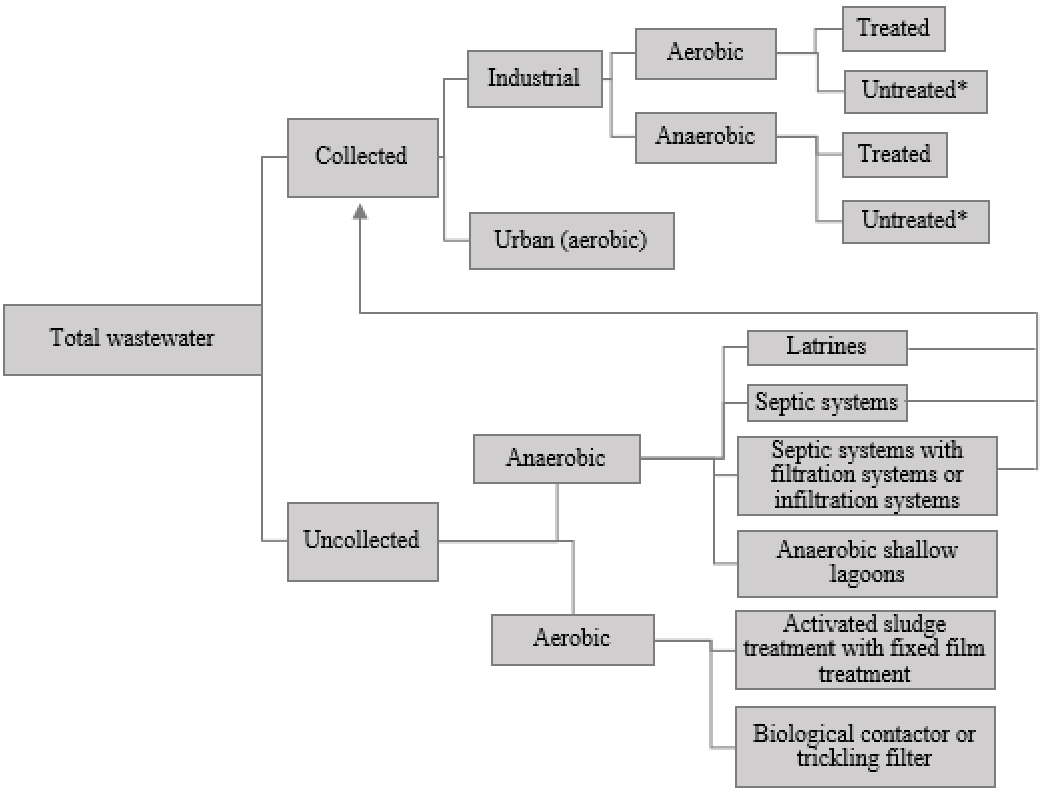

Figure 7.21. Typical balance of wastewater pathways for domestic wastewater in Estonia

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 7.27):

- 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 7.27. Wastewater treatment systems in low population settlements %[416]

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
1991	NO	0.7	2.3	0.4	23.1	2.3	59.5	0.1	11.6	100
1992	NO	0.7	2.3	0.4	22.9	2.2	59.4	0.1	12.0	100
1993	NO	0.7	2.3	0.5	22.6	2.2	59.3	0.1	12.3	100
1994	NO	0.7	2.3	0.5	22.4	2.2	59.2	0.1	12.7	100
1995	NO	0.8	2.2	0.5	22.2	2.2	59.1	0.1	13.0	100
1996	NO	0.8	2.2	0.5	22.0	2.1	59.0	0.1	13.3	100
1997	NO	0.8	2.2	0.5	21.8	2.1	58.9	0.1	13.5	100
1998	NO	0.8	2.2	0.6	21.6	2.1	58.8	0.1	13.8	100
1999	NO	0.8	2.1	0.6	21.5	2.1	58.8	0.1	14.1	100
2000	0.01	0.8	2.1	0.6	21.0	2.1	58.2	0.2	15.0	100
2001	0.02	0.8	2.0	0.6	20.6	2.1	57.8	0.2	15.8	100
2002	0.03	0.8	2.0	0.6	20.2	2.2	57.3	0.3	16.6	100
2003	0.04	0.8	1.9	0.6	19.8	2.2	56.9	0.4	17.3	100
2004	0.05	0.8	1.9	0.7	19.5	2.2	56.5	0.4	18.0	100
2005	0.06	0.8	1.9	0.7	19.2	2.2	56.1	0.5	18.7	100
2006	0.07	0.8	1.8	0.7	18.8	2.2	55.7	0.5	19.3	100
2007	0.07	0.8	1.8	0.7	18.5	2.2	55.4	0.6	19.9	100
2008	0.08	0.8	1.7	0.7	18.3	2.3	55.1	0.6	20.5	100
2009	0.09	0.8	1.7	0.7	18.0	2.3	54.8	0.6	21.0	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

NO – not occurring

Anaerobic wastewater treatment systems in high population settlements (Table 7.28) (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 1998–2020 has been obtained from EstEA.

Table 7.28. 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
1991	11.5	25.0	63.5	100
1992	11.6	24.2	64.2	100
1993	11.7	23.5	64.8	100
1994	11.7	22.8	65.5	100
1995	11.7	22.2	66.1	100
1996	11.5	21.0	67.5	100
1997	11.5	20.4	68.1	100
1998	7.6	23.4	69	100
1999	7.6	23.4	69	100
2000	7.4	23.6	69	100
2001	7.3	23.7	69	100
2002	6.7	22.3	71	100
2003	6.5	22.5	71	100
2004	6.3	21.7	72	100
2005	5.7	20.3	74	100
2006	5.7	20.3	74	100
2007	5.6	20.4	74	100
2008	4.2	15.8	80	100
2009	4.2	15.8	80	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

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 $F_{IND-COM}$ 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[417]

$$CH_4 Emissions = \sum \left(TOW_j \times EF_j\right) - S - R$$

Equation 7.10[418]

$$CH_4\ Emissions = \sum_i [(TOW_i - S_i) \times EF_i - R_i]$$

Equation 7.11[419]

$$EF_{j/i} = B_o \times MCF_{j/i}$$

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.

417 Equation proposed by TERT.
418 IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.20, equation 6.4.
419 IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.12, equation 6.2

CH_4 emissions are calculated from uncollected wastewater treatment systems with no additional industrial wastewater.

Equation 7.12[420]

$$TOW = P_j \times BOD_j \times 0.001 \times 365$$

Where:

TOW = total organic matter in wastewater in inventory year kg BOD/yr;
P_j = country population in inventory year (person);
BOD_j = country-specific BOD per capita in inventory year g/person/day
j = each treatment/discharge pathway or system;
0.001 = conversion from g BOD to kg BOD.

Equation 7.13[421]

$$TOW_i = P_i \times W_i \times COD_i$$

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[422]

$$N_2O\ Emissions = N_{EFFLUENT} \times EF_{EFFLUENT} \times 44/28$$

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.

[420] Equation proposed by TERT.
[421] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.22, equation 6.6.
[422] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.25, equation 6.7.

Equation 7.15[423]

$$N_{EFFLUENT} = (P \times PROTEIN \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM}) - F_{SLUDGE}$$

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.

Emission factors

The IPCC 2006 Guidelines default emission factors used in calculations are presented in Table 7.29

Table 7.29. 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)[424]	0.6
Degradable organic component (g BOD/person/day)[425]	60
MCF anaerobic lagoon[426]	0.2
MCF septic system[426]	0.5
MCF latrines[426]	0.7
MCF centralised wastewater treatment[426]	0
CH_4 from industrial wastewater	
Bo (kg CH_4/kg COD)[427]	0.25
MCF[428]	0.8
N_2O from wastewater[429]	
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

[423] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.25, equation 6.8.
[424] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.12, table 6.2.
[425] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.14, table 6.4.
[426] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.13, table 6.3.
[427] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.21.
[428] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.21, table 6.8.
[429] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.27, table 6.11.

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 7.30. The data on protein consumption per capita was received from FAO databases; the uncertainty of this parameter is not recorded.

Table 7.30. Default uncertainty ranges for Wastewater treatment and discharge

Input	Uncertainties
CH_4 from domestic Wastewater[430]	
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[431]	
Activity data	
Industrial production	±5%[1]
Wastewater/unit production	±50%
COD/unit wastewater	
Emission factor	
Maximum methane producing capacity (Bo)	±30%
Methane correction factor[427]	±20%
N_2O from wastewater[432]	
Activity data	
Human population	±10%
Protein	±10%
FNRP (kg N/year)	(0.16) 0.15–0.17
$F_{NON-CON}$	(1.4) 1.0–1.5
$F_{IND-COM}$	(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.

[430] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.17, table 6.7.
[431] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.23, table 6.10.
[432] IPCC 2006 Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, page 6.27, table 6.11.

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[433]. 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.

7.5.5. Category-specific recalculations

In the previous submission (2021) a recalculation was made for N_2O emissions due to the changed protein supply information from FAOSTAT. In CRF $N_{EFFLUENT}$ values 2014-2019 were not changed then. By now $N_{EFFLUENT}$ values 2014-2019 has been corrected.

Due to the transition to the new database degree of utilization have been specified and values will be presented as a whole number. CH_4emission from domestic wastewater have been recalculated for 2010-2019 (Table 7.31).

Table 7.31. Specified utilization degrees and CH_4 emissions from domestic wastewater

2021 submission			2022 submission		
Year	**Degree of utilization, %**	**CH_4 emission**	**Year**	**Degree of utilization, %**	**CH_4 emission**
2010	81.6	2.09262	2010	82	2.05642
2011	81.7	2.07832	2011	82	2.05127
2012	81.7	2.07225	2012	82	2.04531
2013	82.2	2.02076	2013	82	2.03863
2014	82.4	1.99812	2014	82	2.03375
2015	82.6	1.97384	2015	83	1.93834
2016	82.8	1.95746	2016	83	1.9397
2017	82.9	1.94636	2017	83	1.93749
2018	83.46	1.89834	2018	83	1.93919
2019	83.46	1.90429	2019	83	1.94528

FAOSTAT has published protein supply information for 2019. In the previous submission (2021) 2018 value have used. Due to the updated protein supply information, N_2O emission are recalculated (Table 7.32).

[433] IPCC 2006 Guidelines, Volume 1, Chapter 6: Quality Assurance / Quality Control and Verification.

Table 7.32. Protein consumption per capita and recalculated N_2O emission

	2021 submission		2022 submission	
Year	**Protein consumption, kg/person/year**	**N_2O emission**	**Protein consumption, kg/person/year**	**N_2O emission**
2019	38.4637	0.1099900522798	37.35775	0.106766645986

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 2022 inventory submission by the CRF category and their implications

SECTOR	IPCC CATEGORY	RECALCULATION
Energy	1.A.1. Energy industries	Emissions were recalculated due to using updated Joint Questionnaire dataset made by Statistics Estonia, which is sent to Eurostat and IEA databases and using country specific CH_4 and N_2O emission factors for 1-50MW combustion plants in 1.A.1.a.
	1.A.2 Manufacturing and construction	Emissions were recalculated due to using updated Joint Questionnaire dataset made by Statistics Estonia, which is sent to Eurostat and IEA databases, using country specific CH_4 and N_2O emission factors for 1-50MW combustion plants in all sub-sectors, and using CH_4 and N_2O country specific emission factors for other mobile sources in 1.A.2.g.
	1.A.3.Transport	Emissions were recalculated due to using updated Joint Questionnaire dataset made by Statistics Estonia, which is sent to Eurostat and IEA databases, updated data from COPERT model, and using country specific CH_4 and N_2O emission factors for CNG and biomethane for buses and passenger cars in 1.A.3.b.
	1.A.4 Other sectors	Emissions were recalculated due to using updated Joint Questionnaire dataset made by Statistics Estonia, which is sent to Eurostat and IEA databases, using country specific CH_4 and N_2O emission factors for 1-50MW combustion plants in 1.A.4.a and 1.A.4.c, and using country specific CH_4 and N_2O emission factors for other mobile sources in 1.A.4.b and 1.A.4.c.
	1.A.5 Other	Emissions from military vehicles in 1.A.5 Other are incliuded in category 1.A.4.a Commercial/insitutional, because of Joint Questionnaire dataset
	1.B Fugitive emissions	Emissions were recalculated due to using Joint Questionnaire dataset made by Statistics Estonia, which is sent to Eurostat and IEA databases, instead of national energy balance and venting category was added.
IPPU	2.C.5 Lead production	Emissions were recalculated because more CO_2 emitting processes were considered: 1) use of ammonium bicarbonate for precipitation of rare earth metal carbonates from acidic solution; 2) rare earth metal carbonate calcination into oxides

SECTOR	IPCC CATEGORY	RECALCULATION
	2.F.3 Fire protection	Emissions were recalculated because service companies reported additional stock.
	2.F.1 Refrigeration and air conditioning	The recalculations were done because 1) stock of reefer containers (2.F.1.d), 2) stock and decommissioned domestic refrigerators were changed because more accurate source data was obtained, 3) the amounts of R-134a filled into new industrial refrigeration equipment were changed because of new data was obtained.
	2.F.2 Foam blowing agents	Emissions were recalculated because new data on HFC-containing spray foams sold in Estonia were obtained from a survey.
	2.G.1 Electrical equipment	Emissions were recalculated because the stock of SF_6 in medium-voltage switchgear was recalculated as one operator changed the methodise of determining their SF6 stock.
Agriculture	3.A Enteric fermentation	Corrected methodology for calculating the percentage of cows which gave birth in a year, updated CH_4 emission factors for enteric fermentation for calves aged 0-6 months and 6-12 months, liveweight of sheep, dairy cattle, and breeding pigs, updated feed dry matter digestibility of cattle and swine.
	3.B.1 Manure management, CH_4 emissions	Corrected the methodology and activity data for calculating nitrogen intake for cattle and corrected methodology for calculating indirect N_2O emissions from atmospheric deposition.
	3.B.2 Manure management, N_20 and NMVOC emissions	Updated CH_4 emission factors for manure management for calves aged 0-6 months and 6-12 months, cattle and swine manure management distributions, corrected rounding errors for calculating the average fur population in 2017 and 2018. Corrected activity data for calculating indirect N_2O emissions due to the updates made in the Estonian Informative Inventory Report 1990–2019.
	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 1990-2019 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 Compost were recalculated for 2019 due to the corrected activity data use in compost calculations for 2019. The N_2O emissions from Urine and Dung Deposited by Grazing Animals (3.D.1.3) were recalculated for 1990-2019 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 1990-2019.

SECTOR	IPCC CATEGORY	RECALCULATION
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. Soil emission factors were updated for Forest land remaining forest land. Also, methodology for living biomass C pool in Land converted to forest land areas has changed (see Chapter 6.2.2.1). In Table 6.13 changes in applied soil parameters and in Table 6.14 quantitative overview of recalculations is shown.
	4.B Cropland	Updated activity data from the NFI were used in calculations. 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 and emission factors for organic soil were updated. To harmonise the reporting, in the current submission the same emission factor was used for all grassland organic soils. Please see Chapter 6.4.5 and Table 6.27.
	4.D Wetlands	Updated activity data from the NFI (please see Chapter 6.3.5 and Table 6.31).
	4.E Settlements	Updated activity data from the NFI (please see Chapter 6.6.5, Table 6.34 and Table 6.39).
	4.F Other land	Updated activity data from the NFI (please see Chapter 6.7.5, Table 6.37 and Table 6.39).
	4.G Harvested wood products	Updated activity data. In Table 6.45, a quantitative overview of recalculations has been shown.
Waste	5.A Solid waste disposal	Recalculation was done due to fixing calculation error for 2014-2015 methane recovery data. Statistics Estonia switched to a new Eurostat methodology for calculating GDP, years 1995-2019 have been recalculated. New methodology was implemented to ensure a common methodology for comparing countries data.
	5.B Biological treatment of solid waste	In 2019 CH_4 and N_2O emissions are recalculated, due to the activity data error. The quantity of sludge from one company were counted twice.
	5.D Wastewater treatment and discharge	Due to the transition to the new database degree of utilization have been specified and values will be presented as a whole number. Years 2010-2019 have been recalculated. FAOSTAT has published protein supply information for 2019. In the previous submission (2021) 2018 value have used. Due to the updated protein supply information, N_2O emission are recalculated.

10.1.2. KP-LULUCF inventory

Areas subject to Afforestation/reforestation, Deforestation and Forest management are annually updated by the NFI, new data is integrated into overall activity data.

10.2. Implications for emission levels

10.2.1. 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 2022 submission for years 1990–2019. Differences in % between 2022 GHG emissions compared to the and April 2021 submission for Estonia

	National Total GHG emissions without LULUCF			
	Submission 2021 kt CO_2 eq.	**Submission 2022, kt CO_2 eq.**	**Recalculation difference, kt CO_2 eq.**	**Recalculation difference, %**
1990	41045.5	40175.2	-870.33	-2.1%
1991	37100	37295.3	195.32	0.5%
1992	27159.8	27136.7	-23.14	-0.1%
1993	21714.3	21688.6	-25.73	-0.1%
1994	22223.3	22181.2	-42.12	-0.2%
1995	20273.8	20080.5	-193.27	-1.0%
1996	21180.7	21033.5	-147.17	-0.7%
1997	20759.1	20750.1	-9.00	0.0%
1998	19021.4	19000.0	-21.40	-0.1%
1999	17850.1	17851.3	1.25	0.0%
2000	17495.9	17479.5	-16.38	-0.1%
2001	17933.9	17909.6	-24.31	-0.1%
2002	17342.1	17313.1	-28.99	-0.2%
2003	19284.1	19262.3	-21.81	-0.1%
2004	19482.3	19390.5	-91.76	-0.5%
2005	19257.1	19157.5	-99.62	-0.5%
2006	18598.9	18502.0	-96.93	-0.5%
2007	22206.9	22105.8	-101.13	-0.5%
2008	20083.7	20050.3	-33.44	-0.2%
2009	16661.6	16570.9	-90.69	-0.5%
2010	21218.2	21180.8	-37.39	-0.2%
2011	21286.2	21134.1	-152.06	-0.7%
2012	20114.9	20023.4	-91.45	-0.5%
2013	22019.8	21931.2	-88.62	-0.4%

	National Total GHG emissions without LULUCF			
	Submission 2021 kt CO_2 eq.	Submission 2022, kt CO_2 eq.	Recalculation difference, kt CO_2 eq.	Recalculation difference, %
2014	21176.4	21104.5	-71.95	-0.3%
2015	18139.3	18036.7	-102.61	-0.6%
2016	19808.9	19721.6	-87.31	-0.4%
2017	21066.4	20965.5	-100.93	-0.5%
2018	20206.4	20125.7	-80.66	-0.4%
2019	14699.1	14636.1	-62.98	-0.4%

Table 10.3 Recalculation difference of Estonia's 2022 GHG emissions compared to the 2021 April submission by sector, kt CO_2 eq.

	Submission 2021		Submission 2022		Recalculation difference	
	1990	2019	1990	2019	1990	2019
Energy	37015.87	12277.72	36213.2	12210.9	-2.2%	-0.5%
IPPU	963.29	618.42	963.74	621.35	0.0%	0.5%
Agriculture	2696.4	1496.87	2628.34	1501.48	-2.5%	0.3%
LULUCF	-2959.74	-715.61	-3159.9	-334.56	6.8%	-53.2%
Waste	369.93	306.11	369.93	302.38	0.0%	-1.2%

10.2.2. KP-LULUCF inventory

Quantitative changes due to recalculations under ARD and FM are shown in Table 10.4, Table 10.5 and Table 10.6.

Table 10.4. AR: Changes in emission estimates due to recalculations of C stock changes, kt C

	2013	2014	2015	2016	2017	2018	2019
2021 submission							
Above-ground biomass	41.85	41.60	40.40	42.97	44.83	41.91	43.95
Below-ground biomass	16.44	16.34	15.87	16.88	17.61	16.46	17.26
Litter	16.19	16.38	16.48	16.61	16.68	16.72	16.74
Deadwood	0.25	0.27	0.29	0.29	0.30	0.31	0.32
Mineral soils	7.33	7.40	7.45	7.50	7.52	7.53	7.53
Organic soils	-3.46	-3.52	-3.54	-3.59	-3.62	-3.65	-3.68
Total kt CO_2 in 2021	-288.25	-287.71	-282.13	-295.73	-305.51	-290.71	-301.11
2022 submission							
Above-ground biomass	43.48	41.31	38.54	35.49	32.05	28.75	25.61
Below-ground biomass	17.08	16.23	15.14	13.94	12.59	11.29	10.06
Litter	16.25	16.46	16.58	16.73	16.83	16.90	16.95
Deadwood	0.28	0.26	0.25	0.23	0.20	0.18	0.16
Mineral soils	7.33	7.40	7.45	7.50	7.52	7.53	7.53
Organic soils	-3.50	-3.57	-3.61	-3.67	-3.73	-3.80	-3.86
Total kt CO_2 in 2022	-296.70	-286.31	-272.64	-257.45	-240.02	-223.16	-206.99
TOTAL change % 2022/2021	**2.93**	**-0.49**	**-3.36**	**-12.94**	**-21.44**	**-23.24**	**-31.26**

Table 10.5 D: Changes in emission estimates due to recalculations of C stock changes, kt C

	2013	2014	2015	2016	2017	2018	2019
2021 submission							
Above-ground biomass	-87.77	-90.71	-90.07	-93.58	-83.29	-68.45	-46.94
Below-ground biomass	-20.70	-21.39	-21.24	-22.07	-19.64	-16.14	-11.07
Litter	-13.20	-14.10	-15.16	-16.26	-17.26	-18.08	-18.56
Deadwood	-4.13	-4.27	-4.24	-4.40	-3.93	-3.24	-2.22
Mineral soils	-18.86	-20.67	-22.54	-24.46	-25.93	-27.17	-28.03
Organic soils	-5.81	-5.94	-6.11	-6.24	-6.49	-6.69	-6.86
Total kt CO_2 in 2021	551.01	575.94	584.28	612.37	573.95	512.46	416.82
2022 submission							
Above-ground biomass	-87.35	-91.93	-95.43	-105.78	-103.15	-93.94	-70.96
Below-ground biomass	-20.60	-21.68	-22.50	-24.94	-24.32	-22.15	-16.73
Litter	-13.00	-14.08	-15.20	-16.41	-17.62	-18.68	-19.41
Deadwood	-4.08	-4.31	-4.48	-4.97	-4.87	-4.44	-3.36
Mineral soils	-18.80	-20.63	-22.57	-24.69	-26.45	-28.15	-29.42
Organic soils	-5.82	-5.96	-6.13	-6.31	-6.60	-6.84	-7.05
Total kt CO_2 in 2022	548.70	581.47	609.80	671.34	671.01	638.77	538.76
TOTAL change % 2022/2021	**-0.42**	**0.96**	**4.37**	**9.63**	**16.91**	**24.65**	**29.25**

Table 10.6 FM: Changes in emission estimates due to recalculations of C stock changes, kt C

	2013	2014	2015	2016	2017	2018	2019
2021 submission							
Above-ground biomass	897.23	482.20	676.97	674.18	506.86	244.32	244.28
Below-ground biomass	211.58	113.71	159.64	158.98	119.53	57.61	57.60
Litter	NA	NA	NA	NA	NA	NA	NA
Deadwood	35.55	33.08	32.15	24.73	29.67	28.11	27.49
Mineral soils	344.92	344.91	344.89	344.82	344.73	344.65	344.59
Organic soils	-98.91	-98.98	-99.07	-99.11	-99.12	-99.11	-99.09
Total kt CO_2 in 2021	-5 098.04	-3 208.04	-4 086.83	-4 046.52	-3 306.09	-2 110.45	-2 107.86
2022 submission							
Above-ground biomass	515.81	395.23	509.10	462.11	328.05	421.65	160.59
Below-ground biomass	121.63	93.20	120.05	108.97	77.36	99.43	37.87
Litter	NA	NA	NA	NA	NA	NA	NA
Deadwood	35.46	32.99	32.07	24.66	29.58	28.03	27.41
Mineral soils	281.10	281.08	281.05	280.96	280.86	280.76	289.69
Organic soils	-94.85	-94.80	-94.77	-94.76	-94.74	-94.72	-94.70
Total kt CO_2 in 2022	-3 150.21	-2 594.92	-3 107.48	-2 867.11	-2 277.43	-2 695.59	-1 510.16
TOTAL change % 2022/2021	**-38.21**	**-19.11**	**-23.96**	**-29.15**	**-31.11**	**27.73**	**-28.26**

10.3. Implications for emission trends, including time series consistency

10.3.1. 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.

The implications of the recalculations are further shown in Annex 6.1. Recalculations.

10.3.2. KP-LULUCF inventory

See Chapter 10.1.2. KP–LULUCF inventory.

10.4. Planned improvements, including in response to the review response

10.4.1. GHG inventory

Table 10.7 summarises the sectoral improvement needs for the forthcoming inventories recognised by the Estonian experts responsible for the calculations. More detailed information about planned improvements can be found under the sectoral chapters.

Table 10.8 summarises Estonia's responses to the 2015/2016 and 2018 inventory review report (FCCC/ARR/2020/EST).

Table 10.7. Sector-specific improvement needs of Estonia's national greenhouse gas inventory

SECTOR	IPCC CATEGORY	IMPROVEMENTS
Energy	1.A.4.b residential	With an ongoing project (2020-2023) Estonia is developing country-specific emission factors for combustion plants in households in sub-sector 1.A.4.b. Results are used in future submissions.
IPPU		There are no improvements planned for the next submission.
Agriculture	3.A Enteric fermentation	No category-specific improvements are planned.
	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.
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 improve the method for calculating C stock changes in living biomass.
	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.
	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.

SECTOR	IPCC CATEGORY	IMPROVEMENTS
	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 has an ongoing research project that aims to determine country-specific C content in peat removed for horticultural use.
	4.G Harvested wood products	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.
Waste	5.A Solid waste disposal	Historical data on waste generation per capita and distribution of waste-by-waste management type will be kept under investigation and updated when data available.
	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 10.8. Response to the review of the 2015/2016/2018 and 2020 inventory submissions

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
1.A. Fuel combustion – sectoral approach – other fuels – CO_2	Addressing. A list of non-biogenic waste types is included in the NIR (table 3.9, p.84). Estonia also provided a cross reference to the categories where the non-biogenic waste was included in the sectoral approach (waste oils are allocated to category 1.A.2.f and municipal solid waste to 1.A.1.a). During the review the Party clarified that there is only one waste incineration plant in Estonia, which reports its annual waste consumption and calorific value to the Estonian Environmental Board on an annual basis through an integrated environmental information system. These reports are used to quantify non-biogenic waste consumption under the reference approach. Estonia also clarified that in the reference approach non-biogenic waste is allocated under waste (non-biomass fraction) in CRF table 1.A(b). However, this information was not provided in the NIR chapter 3.2.1, which is dedicated to the comparison of the sectoral and reference approaches.	ARR2020/E.4 (E.7, 2018) (E.11, 2016) (E.10, 2015)	The clarity of AD and EFs has been improved in 2021 submission.	Chapter 3.2.4.2
1.A.3.b Road transportation – liquid fuels – CO_2, CH_4 and N_2O	Addressing. The Party reported in NIR a reconciled set of data on the number of vehicles (table 3.25, p.104) and road traffic mileage (table 3.26, p.104) using the same vehicle categories as the COPERT model and ensuring consistency across the time-series. However, the ERT considers that the issue has not yet been fully resolved because the NIR does not transparently explain how national data were reorganized to fit the COPERT model.	ARR 2020/E.7 (E.15, 2018) (E.18, 2016) (E.17, 2015)	NIR 2022 includes additional information including the number of vehicles (Table 3.25) and mileage (Table 3.26) that are updated according to the same division used in the COPERT model.	Chapter 3.2.5.3
1.B.2.a Oil – CH_4	Addressing. The Party reported the unit “kt” under the column “unit” and “NE” under the column “value” for “distribution of oil products” but continued to report “NO” instead of “NA” in CRF table 1.B.2 for oil (category 1.B.2.a)	ARR 2020/E.16 (E.19, 2018) (E.21, 2016) (E.20, 2015)	The relevant columns in CRF have been corrected according to the recommendation.	CRF 1.B.2 - Oil and Natural Gas and Other Emissions from Energy Production
General (KP-LULUCF) – CO_2	Addressing. In the NIR (p.411), Estonia indicated that it has taken note of the recommendation and plans to use a technical correction to exclude the effect of past disturbances in the FMRL. During the review, the Party confirmed this and noted that it will implement technical corrections at the end of the commitment period as it is not mandatory to make technical corrections annually.	ARR2020/KL3 (2016, KL.5) (2018,KL4) (2015, KL.5)	Estonia has performed a technical correction of the FMRL according to the Decision 2/CMP.7 and the guidance in section 2.7.6 of the IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol and included the information in NIR 2022. Estonia will not apply the ND provision during the CP.	Chapter 11.5.2.3
Forest management– CO_2	Addressing. The NIR (p.411) notes that Estonia is working to obtain necessary data and apply a tier 2 method for estimating	ARR2020/KL.4 (2016/ KL.7) (KL.6, 2018) (KL.7, 2015)	Estonia is working to obtain necessary data to apply Tier 2 method for estimating carbon stock changes under the litter pool.	Chapter 6.2.5
Forest management – CO2	Addressing. The NIR (p.41) indicates that Estonia has taken note of the encouragement and will include the information in the NIR once the technical correction has been conducted. During the review, the Party confirmed this and noted that it will implement technical corrections at the end of the commitment period as it is not mandatory to make technical corrections annually.	ARR2020/KL.5 (2016/ KL.10) (KL.8, 2018) (KL.10, 2015)	Estonia has performed a technical correction of the FMRL and included the information in NIR 2022	Chapter 11.5.2.3
CH_4 and N_2O emissions from drained and rewetted organic soils	Addressing. The Party reported CH4 and N2O emissions from drained organic soils in CRF table 4(KP-II)2 for FM. The ERT considered that estimates for AR and deforestation are also needed in order to fully address this recommendation, or alternatively an explanation as to why the AD cannot be disaggregated to enable the reporting of “IE”. During the review, the Party indicated that estimates for AR will be included in the next submission, and that it is exploring the possibility of providing estimates for deforestation. The ERT notes that the 2006 IPCC Guidelines do not contain emission estimation methods for rewetting of previously drained wetlands, and so the Party can only identify the prevalence of rewetting activities in the country and consider estimating the emissions using country-specific methods where they are potentially significant. The continued reporting of “NA” for rewetting is otherwise appropriate.	ARR2020/KL.7(2016 / KL.11) (KL.11, 2015) (KL.10, 2018)	Estonia has reported CH4 and N2O emissions (NIR 2021) associated with drainage of organic forest soils according to the recommendation.	Chapter 6.2.2.6, Chapter 11.3.1.1.6

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
International navigation – liquid fuels – CO2, CH4 and N2O	Not resolved. In NIR (Ch. 3.2.2, p.68), the Party reported recalculations due to corrections made by Statistics Estonia for 2017 only. For 2011–2012, Estonia continued to report in its NIR (chap. 3.2.2, p.67) that an AD-related methodology change by Statistics Estonia caused estimated fuel consumption to roughly double from 7,838 TJ for 2011 to 16,665 TJ for 2012. During the review, the Party stated that Statistics Estonia, which provides information for this category, has been notified of this issue and is looking into the matter with the intention of resolving the data consistency issue. The ERT considers that the issue has not been resolved because a sharp difference remains between the emission estimates reported for 2011–2012.	ARR2020/E.1 (2018/E.20)	Statistics Estonia, who provides information for this category, has been notified of this issue and they are looking into the matter to fix the data consistency issue. The explanation on solving the issue has been added into NIR 2022	Chapter 3.2.2.
1.A.3.b Road transportation – biofuels – CO2, CH4 and N2O	Addressing. Regarding (1) the types of biofuels, the Party reported in its NIR (Ch. 3.2.5.3, p.103) information provided by the Estonian Environment Agency about the fossil and biogenic origin of the biofuels. Regarding (2) the biogenic nature of the biofuels, Estonia confirmed during the review that information on the nature and type of bioethanol and biodiesel consumed is currently collected by the Estonian Environmental Board and stored in a database that is under development, which is why information on the biogenic nature of the biofuels was not reported in the NIR. Regarding (3) how biofuels are consumed, the NIR states that bioethanol is consumed only as a blend with petrol, while biodiesel is consumed both as a mix with diesel and in pure form. However, the NIR did not include information on the amount of pure biodiesel consumed and biodiesel consumed as part of a blend or in the composition of the blends, as this information is currently collected by the Estonian Environmental Board and stored in a database that is under development.	ARR2020/E.10 (ARR2018/E.25)	Consumed biofuel data reported in the GHG inventory is received from the Estonian Environment Agency. Bioethanol is only allowed mixed with petrol, biodiesel both mixed and in pure form. The Estonian Environment Agency is making its calculations based on assumption that biodiesel is marked as B7 and bioethanol as E5. Information regarding the types of bioethanol and biodiesel is currently not collected. Explanation is provided in NIR 2022.	Ch. 3.2.5.3, table 3.24, p. 107;
1.A.3.b.iv Motorcycles – gasoline – CO2, CH4, and N2O	Addressing. Estonia stated in the NIR (Ch. 10.4.1, p.419) that the COPERT model has been using more precise data since 2019, as the number of demolished motorcycles is deducted from the totals. The Party further stated that the number of motorcycles reported in the NIR (table 3.25, p.104) is consistent with the number used in the COPERT model. However, the ERT considers that the issue has not yet been fully addressed because the NIR does not report the differences between the number of motorcycles reported by the national registry and the number of motorcycles used to estimate emissions in the COPERT model or explain the reasons for the differences.	ARR2020/E.11 (2018/E.26)	Until now the number of motorcycles has been given to us by Statistics Estonia. This number includes motorcycles that have been demolished, but haven´t taken out from the national registry by the owners. For the 2022 submission we are using data that is being used in the Copert model, as in the model demolished motorcycles have been deducted and the data is more precise. Also, the timeline for the number of motorcycles has been updated according to Copert. Also, the data for the whole time-series has been checked for consistency.	Ch. 3.2.5.3, table 3.25, p. 108
1.A.3.d Domestic navigation – liquid fuels – CO2, CH4, and N2O	Addressing. Liquid fuel consumption increased by 149.4 per cent between 2013 and 2014 (from 174.00 to 433.94 TJ) and by 51.0 per cent between 2015 and 2016 (from 543.00 to 820.00 TJ), followed by a sharp decrease between 2016 and 2017 of 60.9 per cent (from 608.00 to 238.00 TJ). Estonia reported in its NIR (Ch. 3.2.5.5, p.110) that CO2, CH4 and N2O emissions for category 1.A.3.d increased between 2014 and 2016 owing to an increase in the number of passengers and declined between 2017 and 2018 because of an energy balance update by Statistics Estonia. During the review, the Party clarified that Statistics Estonia, which provides information for this category, has been notified of this issue. However, Estonia stated that prior to the energy balance update, Statistics Estonia accounted for liquefied natural gas as a fuel under the domestic navigation category. However, since 2017 liquefied natural gas has been used only in international bunkering and not in domestic navigation. The Party also clarified that it is continuing to work with Statistics Estonia to check and correct the inconsistency in the reported domestic navigation diesel oil consumption for the entire time series.	ARR2020/E.12 (2018/E.27)	Statistics Estonia, who provides information for this category, has been notified of this issue and they are looking into the matter to fix the data consistency issue. The explanation on solving the issue has been added into NIR 2022 Ch. 3.2.2.	Ch 3.2.5.3, table 3.20, p. 100
2.A.1 Cement production – CO2	Addressing. The Party reported in its NIR (chapter 4.2.1.3) how the overall uncertainty for the clinker EF value was calculated. However, the impact of possible errors in the chemical analysis on the final uncertainty value was not explained in the NIR. During the review, the Party clarified that, to establish the emission uncertainty, the uncertainties of the EF and AD are combined by multiplication. The uncertainty of the EF is established by summing the uncertainty of the EFs for clinker and cement kiln dust, and the uncertainties of the EFs for both materials are caused by uncertainties (possible errors) in the chemical analysis of calcium oxide and magnesium oxide. The uncertainty of the AD relates to the uncertainty of weighing clinker and cement kiln dust and does not	ARR2020/I.1 (2018/I.8)	The plant is using World Business Council for Sustainable Development methodology for calculations and provided methodology approval documentation signed by the environmental minister of Estonia. This information has been included in NIR 2022.	Chapter 4.2.1.3.

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
	reflect the chemical analysis. The ERT considers that the recommendation has not been completely resolved because the Party did not include this information in its NIR and did not explain in its response to the ERT			
2.F.1 Refrigeration and air conditioning – HFC	Addressing. The Party reported in the NIR (p.409) that it is addressing the recommendation and reiterated that the overhauled reporting system or database for commercial and industrial refrigeration AD on use and consumption of HFCs in the country is expected to be in place by the 2022 annual submission at the earliest, and most probably later, as the project scope is sizeable and involves a multistep process. During the review, the Party confirmed the information above and stated that the reporting system or database should be fully developed by 2021. The ERT concluded that per capita emissions in Estonia were not significantly lower than those of neighboring countries with similar climatic, economic and urban planning conditions and 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. The ERT believes that future ERTs should consider this issue further to ensure that there is not an underestimation of emissions for this subcategory. The ERT considers that the project should be completed soon enough to enable it to be included in the reporting in the annual submission for the final year of the second commitment period of the Kyoto Protocol.	ARR2020/I.7 (2018/I.7) (I.10, 2016) (I.9, 2015)	2020 years activity data was collected partly from the database for equipment containing F-gases and ozone depleting substances (FOKA) and partly by questionnaires sent to service companies by e-mail. The uncertainty of activity data was at the same level as in the previous submission. 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.	Chapters 4.6.1.1.3 and 4.6.1.3.3.
2.F.1 Refrigeration and air conditioning – PFC, HFC, SF6	Addressing. The Party stated in its NIR (p.179) that in accordance with the EU directive on emissions from air-conditioning systems in motor vehicles (directive 2006/40/EC), since 1 January 2017 the air-conditioning systems of new types of ‘M1’ and ‘N1’ category vehicles, as defined in Council directive 70/156/EEC, placed on the EU market shall be filled with a refrigerant that has a global warming potential of 150 or less (HFC-134a does not comply with this requirement). The most common refrigerant meeting this criterion is HFO1234yf. During the review, the Party clarified that for 2006 onward (i.e. for reported years) it has used country-specific data on the share of vehicles charged with HFC-134a for new makes and models of cars in addition to incomplete data on HFO-1234yf use for mobile air conditioning in passenger cars in 2014 for the validation of German data (HFO-1234yf is proposed as an alternative for HFC134a and has a lower global warming potential). Estonia indicated that it found information on the share of vehicles charged with HFC-134a to be consistent for new makes and models of Estonian and German cars, which all used HFC-134a for mobile air conditioning until 2014. However, significant differences were identified in the share of HFC-134a used in 2016 (e.g. for 2016 the Estonian HFC-134a share of 54 per cent of cars was used instead of the share of 43.7 per cent in Germany). 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 for confidentiality reasons. The Party also indicated that collecting country-specific data for 2016–2017 from Estonia’s car sellers enabled it to use more accurate data compared with using German data without validation. This also enabled the Party 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 establishing a framework for the approval of motor vehicles (directive 2007/46/EC), which stipulates that, for a limited period of time only, EU member States may register and permit the sale or entry into service of vehicles conforming to a type of vehicle whose European Community type approval is no longer valid. The ERT considers that this recommendation has not yet been addressed since the Party did not include in the NIR the explanations related to this issue provided during the review.	ARR2020/I.6 (2018/I.13)	Estonia explained in the NIR why country-specific data on passenger cars´ air conditioners has been used for 2016-2018.	Chapter 4.6.1.5.1
3.B.4 Other livestock – CH4 and N2O (A.7, 2018) Comparability	Addressing. The Party reported poultry manure as dry lot (on yards) in its NIR (table 5.24, p.244) and CRF table 3.B(a)s2; and used the dry lot EF from the 2006 IPCC Guidelines (vol. 4, chap. 10, p.10.40) for its estimations. In CRF table 3.B(b), dry lot poultry manure was reported under “Other” instead of under “Solid storage and dry lot”. The ERT considers that the recommendation has not yet been fully addressed because the Party did not report N2O emissions in CRF table 3.B(b) under “Solid storage and dry lot”.	ARR2020/A.5 (A.7, 2018)	The relevant columns have been corrected according to the recommendation.	Chapter 5.3.1.3 and Chapter 5.3.2.4

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
4. General (LULUCF) – N2O	Addressing. The NIR (p.404) identifies planned improvements, including Estonia's plan to acquire land-use change data for 1970–1990 for LULUCF. During the review, the ERT identified statements in the NIR regarding the pre1990 history of cropland activity. Despite concerns regarding the consistency of these statements (see ID# L.17 in table 5), the ERT considers that this demonstrates that the Party has made progress in addressing this issue and should be capable of recalculating emissions for the next submission, but notes that it should describe its progress in addressing this recommendation in future NIRs to assist future ERTs.	ARR2020/L.2 (2018/L.3)	Estonia will acquire the land-use change data for the 1970–1990 period and recalculate related GHG emissions in the 2023 submission.	
4.A Forest land – CO2	Addressing. The Party included a relevant citation in the NIR (p.301) to address this issue. Table 1.3.5 of the cited publication, Yearbook Forest 2018, shows the age-class distribution of forests in Estonia. Contrary to the description in the NIR, which indicates that Estonia has a significant number of old-age forests, Yearbook Forest 2018 shows that over 90 per cent of forests in Estonia have a stand age of less than 100 years. The ERT considers that, based on the information cited, the age-class distribution of Estonia's forests would be better described as dominated by medium-age forests, which would be consistent with the DOM accumulation rates shown in the Estonian inventory and supported by the cited literature. During the review, the Party confirmed that a state of equilibrium has not been reached in most of Estonia's forests, which is consistent with forests of these growth-dominated age classes. To fully address this recommendation, the ERT considers that the Party should update its description of Estonian forests to more transparently reflect the country's national circumstances, including by reporting the relevant data on the decadal age classes of Estonian forests.	ARR2020/L.4 (2018/L.5)	The description of Estonian forests has been added to the NIR 2022.	Chapter 6.2.1
4.B.1 Cropland remaining cropland – CO2, CH4, N2O	Addressing. The ERT did not find any information on the Party's progress in addressing this issue in the NIR. However, during the review, the Party explained that it has investigated the matter and found no available data sources that would provide sufficiently detailed information to enable it to either report biomass burning in cropland or confirm that no fires occur. Estonia plans to report these emissions as "NE" as a disproportionate amount of effort would be required to collect the AD and estimate the emissions, which would be insignificant in terms of the overall level of and trend in national emissions. In 1990–2018, emissions from forest wildfires peaked at 7 kt CO2 eq in 2006, which constitutes less than 0.05 per cent of the national total GHG emissions (without LULUCF). GHG emissions from biomass burning in cropland would be very unlikely to exceed those emissions, as the biomass density of cropland is considerably lower than that of forest land. The ERT accepts this conclusion and anticipates that this recommendation will be resolved once the relevant notation keys reported have been updated to "NE" and an accompanying explanation has been added to the NIR.	ARR2020/L.5 (2018/L.7)	Estonia has investigated the matter and found no available data sources that would provide sufficiently detailed information on possible biomass burning in cropland. GHG emissions from biomass burning in cropland are therefore reported as "NE" as a disproportionate amount of effort would be required to collect the AD and estimate the emissions. The accompanying explanation has been added since NIR 2021.	Chapter 6.9.1
4.E.2 Land converted to settlements – CO2	Addressing. The NIR (table 6.32, p.334) contains revised CSC factors for organic soils that are higher than those in the previous submission and includes appropriate explanations for the choice of EFs. However, after the review, the ERT identified that CRF table 4.E contains the same EF of –1.62 t C/ha for mineral and organic soils in forest land converted to settlements. The ERT does not consider the issue to have been fully resolved because CRF table 4.E does not demonstrate full implementation of the revised CSC factors for organic soils in forest land converted to settlements.	ARR2020/L.10 (2018/L.12)	The issue has been resolved in the 2021 NIR submission.	Chapter 6.6.2
Inventory planning	Estonia reported on the inventory planning, preparation, and management processes in the NIR (chap. 1.2.2, pp.26–27), which cover April of the previous year to May of the submission year. These processes mainly deal with the compilation and approval of the national GHG inventory, the implementation of the QA/QC plan and the official submission of the inventory under the EU and UNFCCC processes. The ERT noted that the time frames reported in NIR table 1.1 do not include the GHG inventory preparation and, particularly, information on appropriately selecting methods and EFs, estimating GHG emissions and removals, implementing the uncertainty assessment and verifying the inventory data at the national level. During the review, Estonia clarified that the inventory preparation plan developed by the Estonian Environmental Research Centre includes an AD collection process and inventory calculations differentiated by time of AD availability. AD collection starts in April of the year preceding the inventory submission. The Party indicated that it intends to update the time frame	ARR2020/G.2	EERC has developed an inventory production plan that sets out the schedule for inventory preparation, which is annually reviewed. Updated production plan is included in NIR 2022.	Chapter 1.2.2.

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
	for inventory development in the next NIR and describe the AD collection process more transparently in future annual submissions. The ERT encourages Estonia to update the description of its inventory planning, preparation, and management processes in its NIR and include a description of the time frames for appropriately selecting methods and EFs, estimating GHG emissions and removals, implementing the uncertainty assessment and verifying the inventory data.			
National system	Estonia reported in the NIR (p.460) that there have been no major changes in its national system. The ERT noted that this reporting is not in accordance with paragraph 21 of the annex to decision 15/CMP.1, which requires any changes in the national system to be reported. During the review, Estonia clarified that no changes have been made to the national system since the 2019 annual submission. The ERT recommends that the Party enhance the transparency of its reporting by including in its next NIR a clear statement on any changes made to the national system since the previous annual submission.	ARR2020/G.3	We can confirm that the National System described in Chapter 1.2.1 is complete and there are no changes to the national system.	Chapter 1.2.1 / Chapter 13
Uncertainty analysis	Estonia reported on its quantitative uncertainty assessment in line with approach 1 from the 2006 IPCC Guidelines in the NIR (tables A.2.1–A.2.2, annex 2, pp.23–57). However, the Party did not provide information on the methods used and the underlying assumptions or explain how the uncertainty estimates help to prioritize efforts to improve the accuracy of the national inventory in the future and to guide decisions on methodological choice. This is not in accordance with paragraph 42 of the UNFCCC Annex I inventory reporting guidelines, which states that the NIR should contain information on the uncertainties estimated, as well as methods used and underlying assumptions, for the purpose of helping to prioritize efforts to improve the accuracy of national inventories in the future and to guide decisions on methodological choice. During the review, the Party clarified that the estimated uncertainties help it to enhance its inventory methods, solve problems and identify necessary improvements. However, Estonia did not provide information on the methods used and underlying assumptions that help to prioritize efforts to improve the accuracy of the national inventory and to guide decisions on methodological choice. The ERT recommends that Estonia report in its next NIR on methods and underlying assumptions used for the uncertainty assessment for the purpose of helping to prioritize efforts to improve the accuracy of the national inventory in the future and to guide decisions on methodological choice in accordance with paragraph 42 of the UNFCCC Annex I inventory reporting guidelines	ARR2020/G.4	As brought out in the NIR chapter 1.2.1 under subsection ´Procedural Arrangements' annual meetings are held between the core institutions compiling the inventory to discuss and agree on methodological issues, problems that have arisen and improvements that need to be implemented. 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.	Chapter 1.6.1
Uncertainty analysis	Estonia reported on its quantitative uncertainty assessment including and excluding LULUCF for the latest inventory year and the trend between the base year and the latest inventory year in the NIR (tables A.2.1–A.2.2, annex 2, pp.23– 57). However, the uncertainty assessment for the base year was not reported. The ERT noted that this is not in accordance with paragraph 15 of the UNFCCC Annex I inventory reporting guidelines. During the review, the Party clarified that it performed the uncertainty assessment for the entire time series including the base year and the latest inventory year but did not report the estimates for the base year because of a lack of AD as the information available does not allow for the calculation of separate uncertainty values for different years. The ERT recommends that Estonia perform the quantitative uncertainty assessment for the base year including and excluding LULUCF, following approach 1 from the 2006 IPCC Guidelines (vol. 1, chap. 3), and report the results in its NIR (e.g., using the structure provided in the 2006 IPCC Guidelines (vol. 1, table 3.3)).	ARR2020/G.5	Estonia acknowledges the observation and UNFCCC Annex I inventory reporting guidelines requirement, however because of lack of activity data there is no separate information available for calculating separate uncertainty percentages for the base year. 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. In some categories Estonia is also using country specific / emission source specific uncertainty information that is unfortunately not representative for 1990. We are looking into possibilities of getting sufficient activity data for the base year estimations.	Chapter 1.6.1

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
Uncertainty analysis	Estonia used approach 1 from the 2006 IPCC Guidelines to calculate the uncertainties of the estimates. During the review, Estonia indicated that it strives to continuously enhance the quality of its inventory as permitted by the available resources. The Party clarified that it does not plan to calculate uncertainties by undertaking an uncertainty analysis using approach 2 from the 2006 IPCC Guidelines soon. The ERT encourages Estonia to assess uncertainties using approach 2 from the 2006 IPCC Guidelines (vol. 1, Ch. 3) with the aim of progressing the general assessment of the inventory and enhancing the improvement plan.	ARR2020/G.6	Estonia is consistently working on enhancing the quality of the inventory and is striving to further enhance our uncertainty analysis methodology for the subsequent submissions as resources become available. As of now, Estonia has no concrete plans for the near future to implement approach 2 uncertainty analysis.	–
1.A Fuel combustion – sectoral approach – biomass – CO2, CH4 and N2O	The Party reported total gas biomass consumption under fuel combustion (category 1.A) of 448.0 TJ for 2016 in CRF table 1.A(b) (300 TJ under category 1.A.1 energy industries and 148 TJ under category 1.A.2 manufacturing and construction). However, IEA reported an apparent consumption of gas biomass under category 1.A of 722.0 TJ for the same year (458 TJ under category 1.A.1 energy industries; 151 TJ under category 1.A.2 manufacturing and construction; 45 TJ under subcategory 1.A.4.a commercial/institutional; and 68 TJ for the combined subcategories 1.A.4.b and 1.A.4.c agriculture/fishing/residential), resulting in a total difference of 274.0 TJ between the two data sources. During the review, the Party explained that, according to Statistics Estonia, 448.0 TJ is an outdated figure and 722.0 TJ is the correct value for gas biomass consumption for 2016. The ERT estimated the emissions using the correct biogas consumption for 2016 (722.0 TJ) under fuel consumption (category 1.A) by subcategory and noted a difference of 0.015 kt CO2 eq (excluding biogenic CO2) between the emission estimate for 2016 in the 2020 submission and the revised estimate (0.025 and 0.040 kt CO2 eq, respectively, excluding biogenic CO2). This difference is equivalent to 0.00008 per cent of the total national emissions for 2018 (19,974.14 kt CO2 eq excluding LULUCF). Therefore, this finding for 2016 does not trigger an adjustment procedure in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with decision 4/CMP.11. The ERT recommends that Estonia corrects its CO2, CH4, and N2O emission estimates using the corrected biogas consumption data for 2016 and report the corrected estimates in its NIR and CRF tables 1.A(a) and 1.A(b).	ARR2020/E.17	The gas biomass consumption has been corrected	CRF 1.A(a), CRF 1.A(b)
1.A.2.d Pulp, paper, and print – gaseous fuels – CO2, CH4 and N2O	In CRF table 1.A(a)s2, under category 1.A.2.d (Pulp, paper, and print), fuel consumption for gaseous fuels increased from 216 to 739 TJ between 2017 and 2018, leading to a 226.05 per cent increase in GHG emissions. In the NIR (Ch. 3.2.4.1, p.74), Estonia reported that this increase was due to changes in companies' reporting to Statistics Estonia. During the review, Estonia explained that the change relates to a company that until 2018 had reported natural gas consumption to Statistics Estonia under district heating, which was incorrect according to the 2006 IPCC Guidelines (vol. 1, Ch. 8.5, p.8.9). In 2018, the company reported natural gas separately to Statistics Estonia. The Party acknowledged the consistency issue for previous years and stated that Statistics Estonia was not able to correct the time-series consistency issue in time for corresponding corrections to be made in the inventory for the 2020 submission. The ERT recommends that Estonia correct the CO2, CH4 and N2O emission estimates under category 1.A.2.d (pulp, paper and print) for 1990–2017 using the updated gaseous fuel consumption values reported by Statistics Estonia and report the corrected estimates in its NIR and CRF table 1.A(a)s2 and, to avoid double counting, correct the CO2, CH4 and N2O emission estimates under category 1.A.1.a (public electricity and heat production) for 1990–2017 and report the corrected estimates in its NIR and CRF table 1.A(a)s1.	ARR2020/E.18	The gaseous fuels consumption and CO2, CH4, and N2O emissions in 1.A.2.d category have been corrected	1.A(a)s2; Ch 3.2.4.1, Table 3.6

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
1.A.3.b Road transportation – biomass – CO_2, CH_4 and N_2O	The Party reported liquid biomass consumption of 84.73 TJ for 2016 in CRF table 1.A(b). This liquid biomass relates to bioethanol consumed under category 1.A.3.b (road transportation) (NIR Ch. 3.2.5.3, table 3.24, p.103). However, IEA reported the apparent consumption of liquid biomass as 191.80 TJ for 2016, resulting in a difference of 107.07 TJ between the two data sources. During the review, the Party explained that the information regarding the value for liquid biomass consumption used for estimating emissions (84.73 TJ) was received from the Estonian Tax and Customs Board, while the information from the IEA database was reported by Statistics Estonia. The Party informed the ERT that Statistics Estonia has been notified of this issue in the reporting and is investigating. The ERT estimated the emissions using 191.80 TJ as the possible correct value for 2016 liquid biomass consumption under category 1.A and noted that the difference between the estimate for 2016 in the 2020 submission and the ERT estimate for the same year (0.0215 and 0.0485 kt CO_2 eq, respectively, excluding biogenic CO_2) amounts to 0.0270 kt CO_2 eq taking into account only CH_4 and N_2O emissions, which is equivalent to only 0.00014 per cent of the total national emissions for 2018 (19,974.14 kt CO_2 eq excluding LULUCF). Therefore, this finding for 2016 does not trigger an adjustment procedure in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with decision 4/CMP.11. The ERT recommends that the Party select and use the correct value for liquid biomass consumption to estimate emissions for 2016 and explain in its NIR the reasons for selecting the AD used and, if necessary, correct the 2016 emission estimates and report the corrected estimates in its NIR and CRF tables.	ARR2020/E.19	Liquid biomass consumption is taken from COPERT model provided by Estonian Environmental Agency and is received from the Estonian Tax and Customs Board.	Ch. 3.2.5.3, Table 3.24
1.A.3.b Road transportation – biogas – CO_2, CH_4 and N_2O	Biogas consumption (54 TJ) was reported in the 2018 national energy balance under land transport (NIR annex 4, p.149) but was not reported in NIR table 3.20 (p.96) or NIR table 3.24 (p.103) under road transport (category 1.A.3.b) for the years in which the consumption occurred, and the corresponding emissions were not estimated. During the review, the Party explained that biogas is consumed in Estonia under road transport by buses and passenger vehicles. Estonia provided unofficial revised estimates (0.08 kt CO_2 eq excluding biogenic CO_2) based on biogas consumption for category 1.A.3.b. The ERT noted that the estimates represent less than 0.0004 per cent of the national total emissions in 2018 (19,974.14 kt CO_2 eq excluding LULUCF). Therefore, this finding for 2018 does not trigger an adjustment procedure in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with decision 4/CMP.11. The ERT recommends that Estonia estimate emissions from biogas consumption under road transport (category 1.A.3.b) for the years in which the consumption occurred and report the AD and estimates in its NIR and CRF table 1.A(a)s3.	ARR2020/E.20	The consumption of biogas has been corrected according to the AD provided by Statistics Estonia and included in NIR 2022. Annex 4 with energy balance data is not published the NIR since 2021. Estonia is using the Joint Questionnaire (JQ) dataset compiled by Statistics Estonia since 2021. JQ files are available upon request.	Ch. 3.2.5.3, Table 3.24; 1.A(a)s3
1.A.3.b Road transportation – gaseous fuels – CO_2, CH_4 and N_2O	Since 2012, Statistics Estonia has reported natural gas (CNG) consumption under land transport in the national energy balance. However, natural gas consumption was not reported under road transportation in the NIR (table 3.20, p.96) and the corresponding emissions were not estimated. During the review, the Party acknowledged the error and stated that CNG consumption under road transportation (category 1.A.3.b) will be included in the 2021 submission. The ERT calculated the emissions based on the CNG consumption reported in the national energy balance for 2018 (168 TJ) under road transportation, the country-specific carbon content (15.07 t C/TJ) reported by Estonia in its NIR (table 3.9, p.84) and the CH_4 and N_2O default EFs provided in the 2006 IPCC Guidelines (vol. 2, Ch.3, p.3.16). Estonia agreed with the new estimates. The estimate of the ERT for 2018 (9.82 kt CO_2 eq) is equivalent to 0.0492 per cent of the national total emissions for 2018 (19,974.14 kt CO_2 eq excluding LULUCF), which is below the threshold for commencing an adjustment procedure in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with decision 4/CMP.11. The emission estimate calculated by the ERT for 2017 (12.74 kt CO_2 eq) using the CNG consumption value reported in the national energy balance for 2017 under road transportation (218 TJ) exceeds the significance threshold of 0.05 per cent (0.0638 per cent) of the national total emissions for the latest year of the time series (2018). However, as no recalculations were reported in the 2020 submission for this category for natural gas, this finding for 2017 does not trigger an adjustment procedure in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with	ARR2020/E.21	The consumption of CNG has been corrected according to the AD provided by Statistics Estonia and included in NIR 2022.	Ch. 3.2.5.3, Table 3.20;

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
	decision 4/CMP.11. The ERT recommends that Estonia estimate emissions from natural gas consumption under road transport (category 1.A.3.b) for the years in which the consumption occurred and report the AD and estimates in its NIR and CRF tables. The ERT believes that future ERTs should consider this issue further to ensure that there is not an underestimation of emissions for this category.			
1.A.3.b Road transportation – LPG – CO2, CH4 and N2O	Estonia reported in its NIR (Ch. 3.2.5.3, p.104) that emissions from LPG consumption in road transportation (category 1.A.3.b) were not estimated using the COPERT model but were calculated separately using AD from national energy statistics. However, the NIR does not explain whether vehicles using LPG are extracted from the total number of vehicles under road transportation used as input to the COPERT model for estimating emissions from diesel and gasoline consumption, making it difficult for the ERT to assess whether this leads to an under- or overestimation of CO2, CH4 and N2O emissions for this category. During the review, the Party explained that vehicles that use LPG as fuel do not run exclusively on LPG; they usually have a biofuel system that uses gasoline or diesel as a second additional fuel. Estonia stated that, as the vehicles do not run purely on LPG, they are not accounted separately from the COPERT model inputs to ensure the accounting of the emissions from the second fuel. The ERT considers that the method used and the accounting of vehicles that use LPG in the COPERT model is correct. The ERT recommends that Estonia explain in the NIR (Ch. 3.2.5.3) that vehicles using LPG are not extracted from the total number of vehicles used in the COPERT model because diesel or gasoline is used as a second fuel.	ARR2020/E.22	The explanation that LPG vehicles run on biofuel 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 model to ensure the accounting of the emissions from the second fuel has been added in the NIR 2022.	Ch. 3.2.5.1, p. 108
1.A.3.b.iv Motorcycles – gasoline – CO2, CH4 and N2O	The NIR (table 3.25, p.104) indicates that there was a significant increase (60 per cent) in the number of motorcycles between 2012 and 2013 (14,000 compared with 23,000). During the review, Estonia clarified that this increase was due to the introduction of new legislation in Estonia in mid-2012 that made it compulsory to register mopeds. As mopeds are categorized under the 'L' vehicle class along with motorcycles, this caused the number of registered motorcycles to rise from 2013 onward. The Party acknowledged the consistency issue. The ERT recommends that the Party work with the national vehicle registry to report the correct number of motorcycles reported for 1990–2012 by including mopeds under the motorcycles category (e.g. by using a data gap filling technique in accordance with the 2006 IPCC Guidelines (vol. 1, Ch. 5, p.5.14)); and revise the estimated emissions under motorcycles (subcategory 1.A.3.b.iv) using the updated AD for 1990–2012, ensuring time-series consistency and documenting the estimates in the NIR.	ARR2020/E.23	Until 2019 the number of motorcycles has been provided by Statistics Estonia. This number includes motorcycles that have been demolished, but haven´t taken out from the national registry by the owners. For the 2020 we are using data that is being used in the Copert model, as in the model demolished motorcycles have been deducted and the data is more precise. Also, the timeline for the number of motorcycles has been updated according to Copert. The correction has been included in NIR 2022.	Ch. 3.2.5.3, Table 3.25, p. 108
1.A.3.d Domestic navigation – diesel oil – CO2, CH4 and N2O	In the NIR (table 3.20, p.96), the Party reported LPG consumption under domestic navigation (category 1.A.3.d) for 2017 and 2018 as 212 and 238 TJ, respectively, in accordance with the energy balance reported in NIR annex 4. These figures differ from the LPG consumption values reported for domestic navigation by IEA for 2017 and 2018 (279 and 274 TJ, respectively). During the review, the Party acknowledged the error and stated that Statistics Estonia has implemented the corrections to its energy consumption data for diesel oil consumption in domestic navigation for 2017 (277 TJ) and 2018 (272 TJ), which are like the values reported by IEA. The Party indicated that the corrected AD for diesel consumption for 2017–2018 from Statistics Estonia will be used for the next submission. The ERT calculated the emissions using the correct diesel consumption value for domestic navigation for 2018 (272 TJ) and the CO2, CH4 and N2O EFs reported by Estonia in its NIR (table 3.31, p.111). There was a difference of 4.6 kt CO2 eq between the emissions estimated for the 2020 submission (15.50 kt CO2 eq) and the revised emission estimate calculated by the ERT and the Party (20.10 kt CO2 eq), equivalent to 0.022 per cent of the national total emissions for 2018 (19,974.14 kt CO2 eq excluding LULUCF). Therefore, this finding for 2017–2018 does not trigger an adjustment procedure in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with decision 4/CMP.11. The ERT recommends that Estonia correct the CO2, CH4 and N2O emission estimates	ARR2020/E.24	The fuel consumption has been corrected according to the recommendation. Annex 4 with energy balance data is not published the NIR since 2021. Estonia is using the Joint Questionnaire (JQ) dataset compiled by Statistics Estonia since 2021. JQ files are available upon request.	Ch. 3.2.5.1, table 3.20; 1.A(a)s3

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
	based on the corrected diesel oil consumption data under domestic navigation for 2017–2018 and report the updated estimates in its NIR and CRF table 1.A(a)s3.			
1.A.4 Other sectors – liquid fuels – CO_2, CH_4 and N_2O	The Party reported in its NIR (chap. 3.2.6.2, pp.115–116) that liquid fuel consumption data for the subcategories commercial/institutional (1.A.4.a), residential (1.A.4.b) and agriculture/forestry/fishing (1.A.4.c) were collected by Statistics Estonia from energy and fuel producers and consumers using a survey sampling for energy consumers and a random selection procedure for smaller companies. The ERT considers that using this data-collection method may have led to inconsistencies for the category other sectors (1.A.4) as the survey process targets only a part of the small energy installations, which may lead to an underestimation or overestimation of the AD and emissions if only the smallest or largest fuel users are covered in each survey. During the review, the Party acknowledged that the data-collection method used by Statistics Estonia for small companies is likely to cause inconsistencies in the AD. The ERT recommends that the Party work with Statistics Estonia to collect AD on total liquid fuel consumption for the subcategories commercial/institutional (1.A.4.a), residential (1.A.4.b) and agriculture/forestry/fishing (1.A.4.c), ensure the accuracy of the AD and recalculate emissions for all years (1990–2018).	ARR2020/E.25	Statistics Estonia, who provides information for this category, has been notified of this issue and they are looking into the matter to fix the data consistency issue.	Ch. 3.2.6.2
2.F.1 Refrigeration and air conditioning – HFC-143a	The Party reported several significant inter-annual changes in the AD (HFC-143a filled into new manufactured products) for industrial refrigeration, including for 2010–2011 (261.3 per cent increase) and 2015–2016 (172.0 per cent increase) in CRF table 2(II)B-Hs2. During the review, the Party clarified that there had been an error related to the interpretation of the data for 2016 and that the AD will be recalculated for the 2021 annual submission. The ERT checked the emission estimates for the category for the entire time series and concluded that the erroneously interpreted AD do not affect the consistency of the estimates. The ERT recommends that the Party ensure that CRF table 2(II)B-Hs2 includes the correct AD for HFC-143a filled into new manufactured products for 2016 and include an explanation of significant inter-annual changes in AD in its next annual submission.	ARR2020/I.8	Estonia explained in 15th April 2021 submission´s NIR that there was an error in interpreting data and corrected 2016 year´s amounts of R-404A.	15th April 2021 submission´s NIR; chapter 4.6.1.3.5
2.F.1 Refrigeration and air conditioning – HFC-143a	The Party reported several significant inter-annual changes in the AD (HFC-143a remaining in products at decommissioning) for industrial refrigeration, including for 2014–2015 (13.9 per cent increase) and 2017–2018 (12.2 per cent decrease) in CRF table 2(II)B-Hs2. During the review, the Party clarified that higher amounts of HFC-143a at decommissioning in 2015–2017 were caused by the decommissioning of all equipment in stock containing R-507, which is a blend of HFC-143a and HFC125. The ERT recommends that the Party clarify in the NIR the significant changes in the HFC-143a remaining in products at decommissioning for industrial refrigeration between 2015 and 2017.	ARR2020/I.9	The reason for significant inter-annual changes in HFC-143a in decommissioned equipment between 2014/2015 are because most of R-507 in stock was decommissioned in 2015. The reason for significant inter-annual change between 2017/2018 is caused by an error. In 2016 and 2017 errors were found caused by double counting of some equipment decommissioned already in 2015. These errors were corrected in 15th April 2021 submission recalculations.	15th April 2021 submission´s NIR; chapter 4.6.1.3.5
3.A.1 Cattle – CH_4	The Party reported in its NIR (p.235, table 5.15) that the uncertainty of the EFs for enteric fermentation is based on the 2006 IPCC Guidelines (vol. 4, chap. 10, p.10.33). Uncertainties were reported as 20 per cent for cattle and swine and 40 per cent for other animals. The ERT noted that this is not in accordance with the 2006 IPCC Guidelines (vol. 4, chap. 10, p.10.33), which state that the use of the tier 2 method should involve an uncertainty analysis reflecting the inventory compiler's situation, and, in the absence of this analysis, the uncertainty under the tier 2 method should be assumed to be similar to the uncertainty under the tier 1 method, and that the accuracy of EFs estimated using the tier 1 method is unlikely to exceed 30 per cent and the uncertainty may be up to 50 per cent. During the review, the Party acknowledged the issue. The ERT recommends that the Party use 40 per cent as the uncertainty of the EFs for enteric fermentation as an average of the uncertainties provided in the 2006 IPCC Guidelines (vol. 4, chap. 10, p.10.33).	ARR2020/A.10	The relevant columns have been corrected according to the recommendation in NIR 2022.	Chapter 5.2.5

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
3.D.a.2.b Sewage sludge applied to soils – N2O	In addition to providing information on AD and methodology in the NIR (p.262), the Party explained during the review that information on the amount of sewage sludge applied to soils was obtained through two sources: the Estonian Environment Information Centre for 1990–2003 and the national waste reporting system for 2004–2018. The amount of sewage sludge applied to soils varies significantly across the time series and the NIR (p. 262) only explains the trend for the last two years of the time series. The trend in CO2 emissions across the time series suggests that different values were provided in the two sources of information (see NIR figure 5.23). During the review, Estonia did not provide further information on ensuring time-series consistency for sewage sludge applied to soils. The ERT considers that the Party did not ensure time-series consistency for this subcategory. Moreover, Estonia did not provide complete information to explain the large fluctuations in the data, but provided information for 2017 only. The ERT recommends that the Party provide strong evidence that the information on the amount of sewage sludge applied to soils provided by the two sources and used for the estimates is consistent, or ensure time-series consistency by using any of the methods provided in the 2006 IPCC Guidelines (vol. 1, chap. 5). In addition, the ERT recommends that Estonia include information in the NIR explaining the fluctuations in the time series of sewage sludge applied to soils.	ARR2020/A.11	Estonia included explanation of the fluctuations of time-series in NIR 2022.	Chapter 5.4.1.5
3.G Liming – CO2	The Party reported in its NIR (p. 278) that the AD on areas of agricultural land on which lime was applied were obtained from the Estonian Ministry of Rural Affairs for 1990–2004 and from Statistics Estonia for 2005 onward. During the review, the Party clarified that data for 2004 were not obtained from the Estonian Ministry of Rural Affairs but were interpolated from the data provided by the Ministry for 2003 and those provided by Statistics Estonia for 2005. The ERT recommends that the Party clearly state in its next NIR the source of the liming application data used for 2004.	ARR2020/A.12	NIR 2022 includes explanation that data for 2004 has been interpolated based on the data given by the Ministry of Rural Affairs in 2003 and from the data of Statistics Estonia in 2005.	Chapter 5.6.1
4. General (LULUCF) – EFs	The Party frequently used Swedish EFs for LULUCF as a substitute where country-specific information is lacking and where their use was supported by local expert judgment confirming similarities between the national circumstances of Estonia and Sweden. The suitability of these EFs has been questioned by previous ERTs, and the Party has made sufficient improvements to the NIR to explain and justify the use of these EFs (see ID# L.9 in table 3). However, given the extent of the use of Swedish EFs, the ERT considers that the inventory would benefit from QA by Sweden on the choice of EFs. This would ensure that the EFs selected consider Swedish knowledge on their limitations and suitability. The ERT encourages the Party to engage with the Swedish inventory compilers or their experts to provide QA of the use of Swedish EFs.	ARR2020/L.11	Implementation of emission factors from a neighboring country is a temporary solution suggested by ERT (FCCC/ARR/2012/EST para.94). Estonia used data from Sweden, as it has similar circumstances and forest conditions. Currently Estonia is working on developing a Tier 3 method for reporting on Forest land litter and soil carbon stock changes. Estonia will consider engaging with the Swedish inventory compilers to provide QA of the use of Swedish EFs.	Chapter 6.2.6
Land representation – areas	The Party indicated in the NIR (p.286) that the areas of unmanaged wetlands reported in NIR table 6.3 include the category land converted to unmanaged wetlands, which are considered managed wetlands in CRF table 4.1. However, as land cannot be simultaneously managed and unmanaged, this creates a consistency issue. During the review, the Party clarified that the 2016 ERT recommended that Estonia exclude unmanaged wetlands from other wetlands reported in CRF table 4.D and instead reflect them as unmanaged wetlands in the land matrix reported in CRF table 4.1 (FCCC/ARR/2016/EST, table 5, ID# L.3). The Party attempted to follow the recommendation, but CRF table 4.D includes land converted to unmanaged wetlands as emissions were reported for that subcategory. Therefore, the Party redefined these lands as managed wetlands in CRF table 4.1. The ERT considers that the treatment in the CRF tables is correct but that the NIR contains confusing nomenclature, given that identifying these lands as “unmanaged” rather than “managed” wetlands in the NIR implies that the lands do not emit anthropogenic emissions. The ERT notes that the 2006 IPCC Guidelines (vol. 4, chap. 3.2) describe managed land as land where human interventions and practices have been applied to perform production, ecological or social functions, and that emissions and removals do not need to be reported for unmanaged land. During the review, the Party agreed that further clarification in the NIR would be useful. Where emissions from	ARR2020/L.12	Land areas converted to other wetlands have been defined since NIR 2021 as managed lands.	Chapter 6.1, Chapter 6.5

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
	land converted to “unmanaged wetlands” are reported in the NIR and where these areas are identified as “managed wetlands” in CRF tables 4.1 and 4.D, the ERT recommends that the Party does not use the term “unmanaged” to describe these lands in the NIR and that it provides more transparent descriptions in the NIR (chap. 6.1) to identify these lands as managed lands.			
Land representation – areas	CRF table 4.1 (land-transition matrix) contains the final areas of wetlands (managed) and other land, which are inconsistent with the initial areas of the same land types reported for 2006–2011. For example, for other land, the final area in 2009 was 37.71 kha, whereas the initial area in 2010 was 37.68 kha. This suggests that the area of wetlands (managed) converted to other land was not correctly accounted for in the calculation of wetlands remaining wetlands and other land remaining other land. During the review, the Party confirmed that there was an error in the land-transition matrix and there has been no conversion of wetlands to other land in Estonia. The Party indicated that this will be corrected in the next NIR. The ERT considers that this will also have implications for the reporting in CRF tables 4.D (wetlands remaining wetlands) and 4.F (wetlands converted to other land). The ERT recommends that Estonia improve QC procedures and ensure that the final areas reported for each year under wetlands and other land are equal to the initial areas reported for the following year in CRF table 4.1, that CRF table 4.D reports the correct area of wetlands remaining wetlands, and that CRF table 4.F reports the area of wetlands converted to other land as “NO”.	ARR2020/L.13	The error in the CRF table 4.1 has been corrected in NIR 2021.	-
Land representation – areas	When considering issue ID# KL.1 in table 3 (KL.11, 2018), the ERT noted that, although the NIR includes an explanation of the Party’s use of aerial photography to identify land use and land-use change in 1990–1999, it was not clear from NIR chapter 6.1 that this information can be found in NIR chapter 11.2. The ERT encourages the Party to refer to the aerial photography analysis in NIR chapter 6.1.3 in addition to NIR chapter 11.2 with a view to ensuring that future ERTs are able to readily understand the methods used by Estonia.	ARR2020/L.14	Reference to the aerial photography analysis has been added to the NIR 2022.	Chapter 6.1.3
4.A Forest land – CO2	Emissions from FM for 2013 were reported as –5,260 kt CO2, compared with –3,415 kt CO2 in the 2019 submission, a recalculation of –1,845 kt CO2. In analysing the reasons for this recalculation, the ERT identified the same order of recalculation for the Convention reporting category forest land, where the trend in the emission time series has moved four years into the future compared with the reporting in the previous submission. For example, a peak in emissions in 2001 reported in the previous NIR is now identified as being in 2005. During the review, the Party explained that differences following the recalculations to forest land emissions were mainly due to NFI developments and uncertainty from sampling. Estonia noted that the results of the latest NFI with increased sampling frequency, which took place in 2014–2018, were included in the 2020 submission, and that ongoing research from a remote sensing project is expected to improve the accuracy of emission estimates. These comments also appear in the NIR (p.308). In response to requests for further clarification, the Party explained that, although the NFI started in 1999, the first cycle ended in 2003, and that since the average growing stock of one year’s stands is calculated on the basis of five-year data it is more correct to take 2003 as a base year and extrapolate from the growing stocks in previous years. The ERT is concerned that the explanation in the NIR regarding updates to the NFI series associated with new data collected in 2014–2018 is not sufficient to explain the recalculations to estimates for 1999–2013 given that, according to previous submissions, inter-annual changes in forest land emissions became more volatile from 1999 onward, reflecting the launch of the Estonian NFI program in that year, while, according to the 2020 submission, these more volatile trends commenced in 2003 and follow the time series of trends reported in previous submissions with a four-year delay. The change in methodologies for historical time-series management is key to understanding these recalculations, but this is not explained in the NIR. The ERT recommends that Estonia provide additional information in the NIR on how it carries out time-series management with NFI data to allocate AD to individual years with a view to ensuring that its estimates remain accurate and reliable as recalculations occur (see also ID# KL.10 below).	ARR2020/L.15	The information about time-series management has been added to the NIR 2022.	Chapter 6.1.3 Chapter 6.2

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
4.B Cropland – areas	The NIR (p.309) describes the national circumstances of Estonian cropland and refers to arable land abandoned between 1991 and 2005. The ERT was confused by this description, thinking it might relate to cropland converted to grassland. However, during the review, the Party clarified that abandoned cropland is categorized as cropland remaining cropland if it retains arable land features. While this is an acceptable approach to land representation, the ERT considers that the NIR could be clearer on how Estonia categorizes abandoned arable land. The ERT encourages the Party to explain in its NIR that abandoned cropland continues to be categorized as cropland and is not categorized as cropland converted to grassland.	ARR2020/L.16	The explanation about abandoned croplands has been added since NIR 2021.	Chapter 6.1.2.2, Chapter 6.3.1
4.B Cropland – AD	The NIR contains contradictory statements regarding pre-1990 cropland activity in the country (see ID# L.2 in table 3). The NIR (p.309) states that cropland area increased until the 1990s in Estonia, but it (p.315) also notes that the management of agricultural land remained relatively stable during that period. During the review, the Party clarified that the preliminary results of its efforts to collect pre-1990 land-use data point to a relatively small increase in arable land area in 1970–1990. The ERT recommends that the Party ensure that historical pre-1990 cropland activity in Estonia is described consistently throughout the NIR.	ARR2020/L.17	The issue has been resolved in the 2021 submission.	Chapter 6.3
4.B.1 Cropland remaining cropland – CO2	The NIR (p.310) states that CSCs in DOM in orchards on cropland are assumed to be at equilibrium in accordance with the tier 1 approach. However, this method does not consider DOM gained or lost during the establishment and removal of orchards, as is reported for living biomass, meaning that the reporting may be incomplete. During the review, the Party confirmed that transitions to and from cropland are evaluated independently from increases or decreases to orchard area. In the view of the ERT, this implies that orchards are assumed to only exist on cropland remaining cropland for reporting and accounting purposes. The Party also confirmed that DOM losses are not considered owing to lack of country-specific data on DOM in orchards and that the 2006 IPCC Guidelines (vol. 4, chap. 5) do not provide default values for this pool, also noting that there is generally little deadwood in orchards as it is removed. The ERT considers that, if accompanied by an assessment showing that emissions from DOM would likely be less than 500 kt CO2 or below 0.05 per cent of the national total emissions (excluding LULUCF), this explanation would be considered an appropriate justification for reporting “NE” in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines; however, the Party reported this carbon pool as “NO” in CRF table 4.B. The ERT recommends that the Party either identify an EF and estimate CSCs from DOM resulting from changes in orchard area, or report “NE” in CRF table 4.B and justify its use on the basis of negligible emissions in the NIR and in CRF table 9.	ARR2020/L.18	Carbon stock changes in DOM pool were not estimated and reported as "NE", as they would be insignificant in terms of the overall level and trend in national emissions. The explanation has been added since NIR 2021.	Chapter 6.3.2.2
4.G HWP – CO2	The Party reported in the NIR (p.345) that it calculated emissions from HWP using the methods for HWP reporting under the Kyoto Protocol using the Kyoto Protocol Supplement. The NIR notes that CO2 emissions due to roundwood production on deforested land were estimated using the instantaneous oxidation method as per decision 2/CMP.7, annex, paragraph 31. However, this reporting is incorrect because reporting under the Convention does not contain a provision for treating wood products arising from different sources using different methodological tiers. According to the Kyoto Protocol Supplement (section 2.8), the methods available are similar to those specified under the production approach in the 2006 IPCC Guidelines (vol. 4, chap. 12, p.12.29) but decision 2/CMP.7 imposes a number of additional constraints and limits the extent of HWP that can be included in the Kyoto Protocol estimates and accounting. The Kyoto Protocol Supplement (figure 2.8.1) provides clear guidance on the circumstances that require Parties to use the tier 1 approach of instantaneous oxidation where the 2006 IPCC Guidelines (vol. 4, figure 12.1) would advise otherwise. Therefore, as some guidance from the Kyoto Protocol Supplement is inconsistent with the 2006 IPCC Guidelines owing to decision 2/CMP.7, the document should be used with caution for reporting under the Convention. This may be particularly relevant to Estonia, where significant changes to its national economy in the post-Soviet period may have resulted in a meaningful amount of timber sourced from areas of deforestation, and where the Party applies a tier 2 estimation	ARR2020/L.19	The issue has been resolved in the 2021 submission. Under the Convention reporting, CO2 emissions due to roundwood production in deforested land were not accounted using the instantaneous oxidation method but similarily to HWP originating from other areas.	Chapter 6.10

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
	methodology for HWP. During the review, the ERT asked the Party how the reporting of emissions from HWP under the Convention would differ if products harvested from cleared (deforested) land were accounted for using Estonia's tier 2 methods rather than on the basis of instantaneous oxidation. The Party stated that it will consider the matter further and add corresponding information in the next submission. The ERT recommends that the Party include in its tier 2 methods and reporting for HWP under the Convention the accumulation and decay of wood products in use arising from activities that would be defined as deforestation under the Kyoto Protocol.			
4.G HWP – CO2	The NIR (p. 346) identifies the use of a tier 3 approach under HWP for estimating semi-chemical wood pulp. However, the NIR did not specify how this tier 3 model differs from a tier 2 model, since the NIR seems to imply that the only difference in methodology applied was the use of a country-specific carbon conversion factor. During the review, the Party clarified that semi-chemical wood pulp is a feedstock for paper manufacturing that is exported by Estonia and must be included under tier 3 to ensure completeness of accounting. The ERT agrees that semi-chemical wood pulp should be included in the NIR, but disagrees that the approach should be referred to as tier 3, which usually applies when country-specific models are used because the core methodology provided in the 2006 IPCC Guidelines (vol. 4, chap. 12.2.1) is not appropriate or adequate, with Parties required to provide a highly detailed description of the models, including verification information in line with the 2006 IPCC Guidelines. On the basis of the descriptions provided by Estonia, which include information on the use of methods from the Kyoto Protocol Supplement (chap. 2.8), the ERT considers that semi-chemical wood pulp may be suitably identified as a disaggregation of the paper and paperboard category, for which country-specific parameters are used as part of a tier 2 model. The ERT recommends that the Party correct the reference to the tier used in the description of the methodology for estimating emissions from semi-chemical wood pulp.	ARR2020/L.20	Reference to the Tier has been corrected in the CRF table 4G and definition of semi-chemical wood pulp has been added since NIR 2021.	Chapter 6.10
5. General (waste) – CH4	The Party reported in the NIR (table 1.3, p.44) CH4 emissions from composting (category 5.B.1) twice as two separate key categories: biological treatment of waste and composting. During the review, the Party clarified that in NIR table 1.3 the biological treatment of waste and composting are treated as the same category as composting (category 5.B.1) and that AD and emissions should be reported together. The ERT recommends that the Party correct the information in the NIR and make sure that each category appears only once in the key category analysis.	ARR2020/W.6	Estonia has made the correction	Will be in 15.03.2022 NIR Annex 1
5. General (waste) – CO2	The Party reported in the NIR (annex 5, p.159) CO2 emissions as "NE" for aerobic managed waste disposal sites (subcategory 5.A.1.a), biogenic waste incineration (subcategory 5.C.1.1) and biogenic open burning of waste (subcategory 5.C.2.1). This does not correspond to the data presented in CRF tables 5.A and 5.C, where emissions for these subcategories were reported as "NA", "NO" and 0.906 kt CO2, respectively. During the review, the Party explained that a technical error occurred in relation to its reporting of "NE" and stated that these issues will be resolved in the next submission. The ERT recommends that the Party improve QC procedures and report consistent information in the NIR and the CRF tables.	ARR2020/W.7	Estonia has made the correction in CRF and NIR 2022	NIR Annex 4, p 108 and CRF
5.D Wastewater treatment and discharge – N2O	The Party reported in the NIR (p.390) that data on protein consumption (kg/person/year) were obtained from FAOSTAT. In CRF table 5.D the Party reported that protein consumption in 2018 was 37.92 kg/person/year. The protein consumption remained unchanged in 2013–2018. However, the data presented in CRF table 5.D are not consistent with the data from FAOSTAT, which are higher (e.g., 39.24 kg/person/year for 2018). During the review, the Party explained that, at the time of inventory compilation, the inventory team was not aware that the "new food balances" data set was available and stated that the new data from the Food and Agriculture Organization of the United Nations will be included in the next submission. The ERT performed a preliminary	ARR2020/W.8	Estonia has made the correction in CRF and in current NIR. Protein consumption data from FAOSTAT (2014-2018) is used in calculations.	15th April 2021 submission´s NIR; chapter 7.5.1; 7.5.2 and 7.5.5

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
	estimate of N2O emissions from domestic wastewater treatment and discharge using the protein consumption data obtained from FAOSTAT. The results indicated that estimated emissions for 2018 would increase by 1.14 kt CO2 eq, or 0.006 per cent of the national total emissions (excluding LULUCF), which is 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. The ERT recommends that Estonia correct its protein consumption data (kg/person/year) on the basis of the new data from the Food and Agriculture Organization of the United Nations and revise its N2O estimates for 2018 for its next submission.			
FM – CO2	In respect of the natural disturbances provision, the NIR must include information on how the Party avoids the expectation of net credits or net debits during the commitment period (decision 2/CMP.7, annex, para. 33). The ERT was unable to identify this information in the NIR. Furthermore, in the NIR (p.454) the series for estimating the background level shows an upward trend in emissions, which could indicate an expectation of net credits in the commitment period. During the review, the Party noted that it will look into this matter and consider using 1990–2012 for estimating the background level and margin. The ERT welcomes this intention. The ERT recommends that the Party ensure that its methodology relating to the natural disturbances provision avoids the expectation of net debits or net credits during the commitment period, and transparently describe in the NIR how this requirement is satisfied in accordance with decision 2/CMP.7, annex, paragraph 33.	ARR2020/KL.9	Background level and margin were recalculated using data from 1990-2012 and included the information in NIR 2022. Estonia will not apply the ND provision during the CP.	Chapter 11.5.2.4
FM – CO2	Emissions from FM for 2013 were reported as –5,260 kt CO2, compared with –3,415 kt CO2 in the 2019 submission, a recalculation of –1,845 kt CO2. In analysing the reasons for this recalculation, the ERT identified the same order of recalculation for the Convention reporting category forest land, where the trend in the emission time series has moved four years into the future compared with that reported in the previous submission. For example, a peak in emissions in 2001 reported in the previous NIR is now identified as being in 2005. The ERT recognizes that Estonia has elected to carry out commitment period accounting but was nonetheless concerned that the 2013 estimate under the second commitment period may represent a potential underestimation of emissions (overestimation of sequestrations) by 1,845 kt CO2. During the review, the Party explained that differences following the recalculations to forest land emissions were mainly due to NFI developments and uncertainty from sampling. Estonia noted that the results of the latest NFI with increased sampling frequency, which took place in 2014–2018, were included in the 2020 submission, and that ongoing research from a remote sensing project is expected to improve the accuracy of emission estimates. These comments also appear in the NIR (p.308). In response to requests for further clarification, the Party explained that, although the NFI started in 1999, the first cycle ended in 2003, and that 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 from the growing stocks in previous years. The ERT is concerned that the explanation in the NIR regarding updates to the NFI series associated with new data collected in 2014–2018 is not sufficient to explain the recalculations to estimates for 1999–2013 given that, according to previous submissions, inter-annual changes in forest land emissions became more volatile from 1999 onward, reflecting the launch of the Estonian NFI programme in that year, while, according to the 2020 submission, these more volatile trends in forest land emissions commenced in 2003 and follow the time series of trends reported in previous submissions with a four-year delay. The change in methodologies for historical time-series management is key to understanding these recalculations, but this is not explained in the NIR. The ERT recommends that Estonia 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.	ARR2020/KL.10	The explanations about historical time-series management and technical correction to the FMRL in accordance with the recalculations has been added to the NIR 2022.	Chapter 6.1.3 Chapter 6.2 Chapter 11.5.2.3

10.4.2. KP-LULUCF inventory

The Estonian University of Life Sciences has a project “Carbon and nitrogen cycling in drained forests” in cooperation with the State Forest Management Centre. This study can potentially provide useful information for estimating emissions for the non-mandatory land-use categories and carbon pools: non-CO_2 emissions from drainage of forest soils. The Estonian University of Life Sciences also had a project about forest litter: “Forest litter, research and modelling”. The project started in 2015 and 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 and controlled 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 of forest mineral soils with Yasso07, but it needs further research to provide data for the UNFCCC and Kyoto Protocol reporting. An additional project has been launched to provide missing data and enhance the accuracy for implementing the Yasso model.

In addition, a remote sensing project for forest resources was started in 2018 with the purpose of annually calculating country-wide tree cover maps (tree species, growing stock, etc.). These maps help monitor annual tree cover gain and identify areas converted to other wooded land (grassland) or to forest land. 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 for cropland.

PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

11. KP-LULUCF

11.1 General information

Under Article 3, paragraph 3 of the Kyoto Protocol (KP), Estonia reports emissions and removals from Afforestation (A), Reforestation (R) and Deforestation (D), and under Article 3, paragraph 4, emissions and removals from Forest management (FM). Estonia will apply the natural disturbance provision under FM if needed, but not under AR. Estonia will not use the provision of carbon equivalent forest (the emissions/removals from the harvest and conversion of forest plantations to non-forest land described in decision 2/CMP.7, annex, paragraphs 37–39) in the accounting of FM. The estimates of emissions and removals are prepared and reported consistently with the IPCC 2006 Guidelines and 2013 Revised Supplementary Methods and Good Practical Guidance Arising from the Kyoto Protocol (KP Supplement), Decisions 15/CMP.1 and 16/CMP.1 of the KP.

An overview of CO_2 emissions and removals of Article 3.3 activities are presented in Table ES.3. In 2020, net emissions from Article 3.3 activities were 290.90 kt CO_2 eq. The uptake from Afforestation and Reforestation activities including emissions from biomass burning was estimated at -187.29 kt CO_2 eq., whereas Deforestation resulted in a net emission of 478.20 kt CO_2 eq. Areas subject to AR and D were 56.70 and 34.11 kha, respectively, by the end of 2020. Annual rates of afforestation have declined continuously from 0.89 kha to 0.19 kha during the period 2013–2020. Deforestation annual areas have also declined compared to 2013, when D area was 1.55 kha per year. In 2020, it was 0.96 kha per year (Table 11.4).

Under Article 3.4 activities, an overview of CO_2 emissions and removals from Forest management are presented in Table ES.3. In 2020 FM contributed to the total GHG balance with an uptake of -365.38 CO_2 eq. (with HWP). The total area of FM was 2 386.83 kha.

11.1.1 Definition of forest, national forest and any other criteria

Under the Kyoto Protocol, Parties are requested to make national parameter choices for the forest definition within the ranges allowed by Decision 16/CMP.1. Estonia established the definition of forest in the context of the Kyoto Protocol in 2006 with the main parameters of the forest definition shown in Table 11.1. Estonia applies the same forest definition for both UNFCCC and KP reporting.

Table 11.1. Parameters for forest definition

Minimum tree crown cover	30%
Minimum land area	0.5 ha
Minimum tree height	2 m

Estonian Forest Act stipulated forest land as land which meets at least one of the following requirements:

- is entered in the cadastral register as a forest land parcel; or
- has an area of at least 0.1 hectares of land, growing woody plants with a minimum height of 1.3 meters and a tree crown cover of at least 30 percent.

Based on aerial photos, data in the cadastral register are occasionally updated. To process this for the whole country, it takes time; thus, data are not always up to date. An area, which is not in the cadastral register, but found to meet the second criterion in fieldwork, is considered as forest.

To meet the requirements of UNFCCC and its Kyoto Protocol reporting, the NFI is compiling statistical analyses based on both the national and the Kyoto Protocol definition of the forest, regarding the minimum area of a forest. The NFI has been recording information on forests which remain in the area between 0.1 ha and 0.5 ha since the criterion of 0.5 ha has been the minimum forest area in one of the earlier wordings of the Forest Act. Thus, there is activity data that is applicable for KP-LULUCF reporting. The same information is used to estimate the forest area according to the FAO's Forest Resource Assessments (FRA) definition.

The criterion of 1.3 m is not 'the minimum tree height' in the context of the forest land definition. 1.3 m is the criteria for counting unstocked forest area as stocked forest. The minimum tree height *in situ* by the forest definition of the Forest Act is defined by tree species, the stand's age, and site index. Thus, there is no constant criteria for tree height in the national definition. As all forest tree species in Estonia reach the height of 2 m at maturity, the height criterion of the Kyoto Protocol Forest definition has been met in NFI statistics.

All temporarily unstocked forest areas and regeneration areas which have yet to reach a crown density of 30 per cent and a tree height of 1.3 m are also included as forest, as they 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 forest.

All forest land is considered managed in Estonia – the whole forest land in Estonia is or has been covered with forest management plans. In addition, protected forests are covered with a protection scheme.

By definition, a natural forest is a forest or other wooded land of naturally regenerated native species; there are no clearly visible indications of human activities, and the ecological processes are not significantly disturbed (FRA 2005). According to Estonia's NFI, a natural forest must also meet the following requirements:

- forest has natural tree species composition and the age classes for dominant tree species differ from each other by at least 2 age groups; or in the same age stand, the average age for conifers must be higher than 100 and for deciduous trees at least 80 years;
- younger trees can grow in a failure patch in a stand;
- the portion of fallen timber and standing dead trees must be at least 5% of the growing stand; highly decayed deadwood must make 50% out of all the fallen timber; and
- it is not possible to distinguish harvest in any extent that could affect the natural tree species composition (the main stand must be at least 100 years (deciduous) or 120 years (conifers) old).

All natural forests in Estonia are protected, thus Estonia does not have emissions arising from the conversion of natural forests to planted forests. For planted forests Estonia uses the FAO definition: forest / wooded land where trees have been established through planting or seeding.

11.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

Estonia has decided not to elect any of the activities under Article 3.4 of the Kyoto Protocol. For the second commitment period of 2013–2020, Estonia accounts Forest management as it became a mandatory activity under Article 3.4 of the Kyoto Protocol.

Forest management areas are determined according to the methodology of the NFI.

11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

Estonia started making efforts to monitor, estimate and report carbon flows related to Afforestation, Reforestation and Deforestation activities for the first time in 2009, when the NFI started reporting land-use changes. Considering Forest management (FM), Estonia started estimating and reporting carbon flows in 2015.

Until 2013 submission, Afforestation and Reforestation areas were obtained from Statistics Estonia. Today, NFI field data about land-use changes are used, if cropland, wetland, and settlement conversion to forest land reported under the Convention is directly human-induced land conversion. These areas are summed to get the AR area (Table 11.3). Conversion of the grassland and other land into Forest land is considered as not directly human-induced. Grassland conversion to Forest land occurs mainly due to natural succession after land abandonment, therefore these areas are not considered for Afforestation reporting. With the new approach, all AR areas are identified and georeferenced – detailed information about growing stock, mineral and organic soil distribution is obtained from the NFI and consistency between UNFCCC and KP-LULUCF reporting is assured.

Data about Deforestation is also acquired from the NFI. All land use changes from Forest land to other land-use categories reported under the Convention are considered Deforestation (Table 11.3).

11.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified

Article 3.4 activity Forest management area equals to the total Forest land area from which the Article 3.3 activity AR area is subtracted. Thus, the 2020 FM area also equals to the sum of the 2020 Convention Forest land remaining forest land, Grassland to forest land and Other land to forest land minus the sum of the 2000 Cropland to forest land, Wetland to forest land and Settlements to forest land (2020 (FM) = 2020 (FF+GF+OF) – 2000 (CF+WF+SF)). The main difference between the emissions in Table 11.2[434] is driven by the biomass calculations and the different emission factors used for different categories. Carbon stock change net emissions/removals includes estimates from living biomass, deadwood, mineral and organic soils.

[434] ARR2016, Table 5, KL.8

Table 11.2. Forest management emissions and area comparison

	Area (kha)	Carbon stock change net emissions/removals (kt CO_2)
Forest Management (2020)	2 386.83	219.03
2020 (FF+GF+OF) – 2000 (CF+WF+SF)	2 386.83	150.04
UNFCCC (FF 2020)	2 384.49	160.66

11.2 Land-related information

Estonia implements the *Reporting Method 1* for lands subject to Article 3.3 activities. The area of Estonia is not divided into regions because it is relatively small and homogeneous in terms of ecological conditions. The *Approach 2* is used to determine the land areas and land-use changes related to Afforestation/Reforestation and Deforestation. Data for land-use changes is obtained from the National Forest Inventory.

The NFI is a sampling-based inventory system that covers the whole country and all land-use categories (Figure 6.4). During fieldwork, land categories are determined (Table 6.6), whereby the "LULUCF former land category" is registered if there are signs of any land category change after the base point (31.12.1989). The year of change is first estimated directly in the field, mainly based on the age of trees and characteristics of the surrounding landscape. 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 is presented in Chapter 6.1.3.

All permanent sample plots that may also include detected land-use changes are inventoried every 5 years (more information in Chapter 6.1.3).

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3 and Article 3.4

The spatial assessment unit to determine the area of units of land under Article 3.3 and Article 3.4 is 0.5 ha, which is the same as the minimum area of forest.

11.2.2 Methodology used for developing the land transition matrix

The *Approach 2* is employed to estimate areas of land-use change in the LULUCF sector. To collect data about land-use transitions, NFI started additional field studies in 2009. Collected data provides information on different land-use classes (there is about 20 years' worth of data), the year of changes and the soil type. During field inventory, "LULUCF former land category" is registered on every sample plot 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. Since 1999 there is information available on permanent sample plots. The land-use matrix is compiled based on obtained NFI data.

The FM area coincides with the total Forest land area from which the Afforestation/Reforestation area has been subtracted.

The areas of land-use changes under the Convention and Kyoto LULUCF reporting do not have a full match (Table 11.3). Once the time period for UNFCCC reporting of converted lands has elapsed (i.e. 20 years) the land is reported in the land remaining category, whereas under Kyoto reporting, this displacement is not applied.

Table 11.3. Comparison of the Convention and KP-LULUCF cumulative areas in 2020

	the Convention		**KP-LULUCF**	
Land-use change	**kha**	**%**	**kha**	**%**
			Afforestation/Reforestation	
Cropland → Forest land	14.05	23.8	38.54	68.0
Grassland → Forest land	29.70	50.3		
Wetlands → Forest land	7.55	12.8	10.40	18.3
Settlements → Forest land	3.07	5.2	7.77	13.7
Other land → Forest land	4.68	7.9		
Total	59.04	100%	56.70	100%
			Deforestation	
Forest land → Cropland	1.70	6.0	1.70	5.0
Forest land → Grassland	5.49	19.4	9.12	26.7
Forest land → Wetlands	1.38	4.9	3.52	10.3
Forest land → Settlements	16.66	58.9	16.73	49.0
Forest land → Other land	3.05	10.8	3.05	8.9
Total	28.28	100%	34.11	100%
			Forest management	
Forest land remaining forest land	2 384.49	100%	2 386.83	100%

11.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

The area of Estonia is not divided into geographical regions. The spatial assessment unit defined in Estonia's national territory, the geographical location of the boundaries of the areas that encompass units of land subject to ARD and FM is that of the entire country.

11.3 Activity-specific information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

The same methodology, emission factors and data sources are used for reporting LULUCF under the KP as for reporting under UNFCCC.

The activity data subject to Afforestation/Reforestation, Deforestation and Forest management areas are presented in Table 11.4.

Table 11.4. Annual areas subject to Afforestation/Reforestation (AR), Deforestation (D) and Forest management (FM) activities in 2020, kha (NFI)

Year	Afforestation/Reforestation	Deforestation	Forest management
1990	0.82	0.04	2 362.71
1991	1.37	0.04	2 364.17
1992	2.00	0.12	2 366.06
1993	2.69	0.21	2 368.36
1994	2.99	0.30	2 370.35
1995	3.39	0.42	2 372.34
1996	3.81	0.50	2 374.31
1997	4.07	0.50	2 376.25
1998	3.81	0.61	2 378.15
1999	3.64	0.56	2 380.59
2000	3.45	0.55	2 382.70
2001	2.85	0.60	2 384.17
2002	2.19	0.68	2 385.54
2003	2.40	0.82	2 386.93
2004	2.37	1.03	2 387.82
2005	2.04	1.18	2 388.82
2006	1.92	1.89	2 389.51
2007	1.83	2.05	2 389.90
2008	1.42	2.08	2 389.96
2009	1.14	2.13	2 389.78
2010	1.12	2.09	2 389.42
2011	0.94	1.61	2 389.63
2012	1.02	1.66	2 389.83
2013	0.89	1.55	2 389.99
2014	0.69	1.63	2 390.02
2015	0.42	1.69	2 389.96
2016	0.51	1.87	2 389.42
2017	0.33	1.83	2 388.63
2018	0.22	1.66	2 387.90
2019	0.19	1.25	2 387.32
2020	0.19	0.96	2 386.83

11.3.1.1 Description of the methodologies and the underlying assumptions used

11.3.1.1.1 Carbon stock changes in living biomass

Estimations on carbon stock changes in living biomass in AR and FM areas are made following the same methodology and parameters as under the UNFCCC reporting of Land converted to forest land and Forest land remaining forest land (see Chapter 6.2.2.1). Above-ground and below-ground biomass are reported separately under KP reporting. Activity data and growing stocks are obtained from the NFI.

Equation 6.8 and the same parameters as under Forest land converted to other land uses are applied to estimate carbon stock changes in above- and below-ground biomass pools for D areas. Although small biomass growth occurs on Forest land converted to Grassland areas, only carbon losses due to Deforestation have been taken into account.

11.3.1.1.2 Carbon stock changes in mineral and organic soils

Emissions from mineral and organic forest soils are calculated as under the Convention applying areas from Table 11.3. Emission factors for AR lands are given in Table 6.10, and for D in Table 6.20, Table 6.25, Table 6.28, Table 6.32, and Table 6.35.

Due to insufficient country-specific data regarding stock change in forest mineral and organic soils, the emission factors from Sweden NIR 2021[435] (0.155 t C ha^{-1} yr^{-1}) for mineral and (-0.342 t C ha^{-1} yr^{-1}) organic soils were implemented for FM.

11.3.1.1.3 Carbon stock changes in litter and deadwood

Changes in the litter pool were estimated using the same approach as under Land converted to forest land for AR and Forest land converted to other land uses for D. The applied litter emission factor from Sweden NIR[436] (0.3 t C ha^{-1} yr^{-1}) is used for AR, emission factors for D are presented in Table 6.20, Table 6.25, Table 6.28, Table 6.32, and Table 6.35.

For FM Estonia does not have sufficient data regarding litter stocks, thus the *Tier 1* method was implemented, assuming that carbon stocks are in equilibrium. Therefore, changes in the litter pool are assumed to be zero. In ARR 2016[437] ERT recommended to obtain necessary data for the litter pool to avoid underestimation of emissions from deforestation and assure consistency between the Convention and Kyoto Protocol reporting.

Estonia has some initial results from a project to obtain litter stock data, but further tests and verification is still needed. A more thorough explanation is added in Chapter 6.2.6.

The amount of deadwood present in AR lands were measured and carbon stocks changes were estimated following the methodology described in Chapter 6.2.2.2. The FM deadwood pool was calculated in the same way as the deadwood pool for land remaining the same type and the conversion to forest land described also in Chapter 6.2.2.2.

Emissions related to deadwood loss in D areas were calculated using Equation 6.3. It was assumed that all deadwoods will be lost after deforestation, except for the Forest land converted to Grassland areas, where the deadwood stock after land use change is given in Table 6.16. Increment in deadwood stock on Land converted to grassland areas was not considered in C stock change estimations.

An overview of Afforestation/Reforestation and Deforestation activities emissions and removals by carbon pools during the first and second Kyoto commitment period is presented in Figure 11.1 and Figure 11.2.

[435] The average implied emission factor for the period of 1990–2019 in Sweden CRF tables 2021.
[436] Sweden NIR 2021, Annexes, Table A3:2.12
[437] ARR 2016, KL.7, p.31.

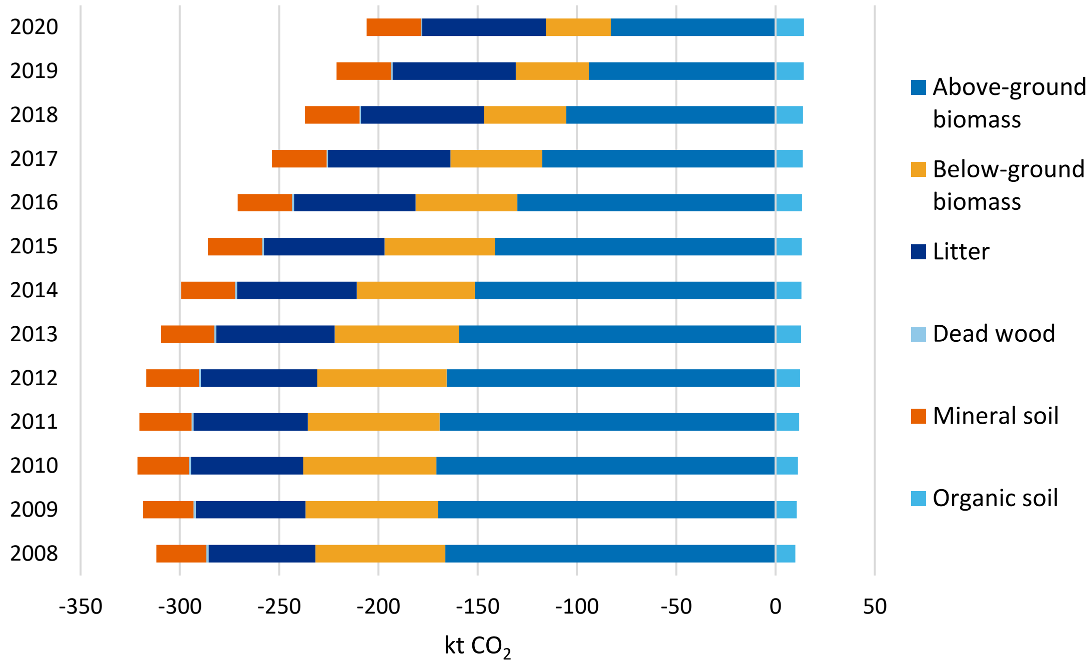

Figure 11.1. Afforestation/Reforestation emissions (+) and removals (-) in 2008–2020, kt CO_2

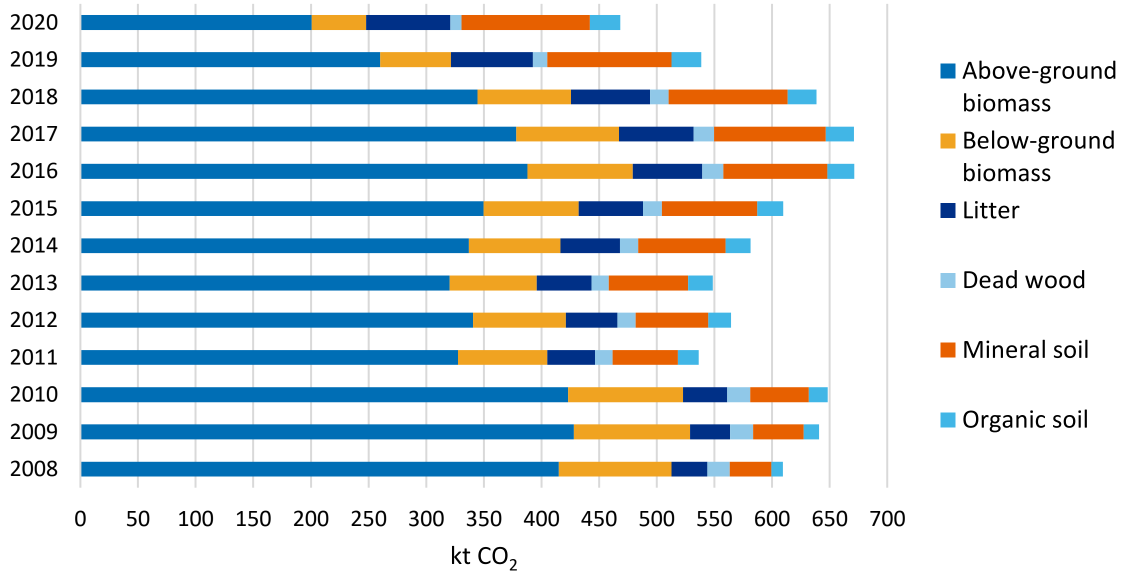

Figure 11.2. Deforestation emissions in 2008–2020, kt CO_2

11.3.1.1.4 Harvested wood products

The HWP pool was estimated according to the methodology given in the IPCC 2013 KP Supplement (IPCC 2014a) Chapter 2.8. Mainly the *Tier 2* (first-order decay) function is used, with default half-lives for sawn wood (35 yr.), wood panels (25 yr.) and paper (2 yr.) (IPCC 2014a), correspondingly to the method used in Chapter 6.10. CO_2 emissions due to roundwood production in deforested land are accounted using the instantaneous oxidation method.

The carbon dioxide emissions from harvested wood products in solid waste disposal sites are not accounted, and the carbon dioxide emissions from wood harvested for energy purposes have been accounted based on instantaneous oxidation under carbon losses from living biomass.

11.3.1.1.5 Biomass burning

Non-CO_2 emissions from biomass burning were provided for AR and FM areas. The methodology described under the Convention reported in Chapter 6.9 and Equation 6.16 were implemented, and parameters indicated in Table 11.5 were used. Data regarding forest growing stock (biomass burnt) was obtained from the NFI. Combustion efficiency (or fraction of the biomass combusted) is estimated during field inventory. Calculation and factors were the same as for the Convention reporting.

Table 11.5. Parameters used for biomass burning estimation in AR areas

	CH_4 emission factor[438]	N_2O emission factor[438]
FM, AR	6.1	0.06

In 2020 emissions from AR areas were not estimated, as they did not occur. Instant oxidation is assumed for all biomass under Deforestation, therefore it is reported that burning does not occur under D areas.

11.3.1.1.6 Non-CO_2 emissions from drained organic forest soils

CH_4 and N_2O emissions from drained organic soils were calculated for FM and AR as under the Convention (Chapter 6.2.2.6), applying FM and AR drained organic soil areas from NFI. The same principle was used to divide the area into nutrient-rich and nutrient-poor areas as for Forest land. In 2020, non-CO_2 emissions from FM drained organic forest soils were 327.54 kt CO_2 eq. and AR areas 4.33 kt CO_2 eq.

11.3.1.1.7 Fertilization

Emissions from forest fertilization are not estimated, as they do not occur.

11.3.1.1.8 N_2O emissions from N mineralization

N_2O emissions from N mineralization occurred in D areas due to C losses in mineral soil after land use change. Emissions were estimated as under the Convention (Chapter 6.8).

11.3.1.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

No pools have been omitted in the 2022 submission. Missing country-specific data is replaced with emission factors obtained from Sweden 2021 NIR. This approach has been approved by the ERT as an interim measure.

11.3.1.3 Information on whether indirect and natural GHG emissions and removals have been factored out

Estonia has not factored out emissions and removals from elevated carbon dioxide concentrations, indirect nitrogen deposition or the dynamic effects of the age structure. The IPCC does not give methods for factoring them out.

[438] IPCC 2006 Guidelines, Volume 4, Chapter 2: Genetic Methodologies Applicable to Multiple Land-Use Categories, page 2.47, Table 2.5 (Biofuel burning).

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

Areas subject to Afforestation/Reforestation, Deforestation and Forest management are updated annually by NFI, new data is integrated into the overall activity data. New method was applied for estimating carbon stock changes in living biomass under the AR category; previously it was calculated on the basis of differences in the aggregate average growing stocks for the total AR area, but in the current submission after the transition to Forest land average growing stock was assumed to increase at rate of 3.04 m^3 ha^{-1} yr^{-1} in the subcategories (CLtoFL, WLtoFL, SLtoFL). Soil emission factors were updated for AR and FM areas. Emissions from mineral and organic soils under FM have significantly decreased because of updated emission factors.

In Table 10.4, Table 10.5 and Table 10.6 an overview of the quantitative impact of ARD and FM recalculations has been provided.

Methodological consistency between the reference level and reporting for forest management during the 2nd commitment period, including the area accounted for the treatment of harvested wood products is secured by implementation of the same methodological approaches for the whole accounting period and recalculation of the whole time series according to a new methodology.

11.3.1.5 Uncertainty estimates

Tier 1 was implemented to estimate uncertainty rates related to activity data and emission factors employed in the estimates under Article 3.3 activities and Article 3.4 Forest management activity.

Table 11.6. Uncertainties of ARD and FM activities.

IPCC category		Uncertainties %		EF References
		Activity data[439]	Emission factors	
KP.A.1.1	Afforestation and reforestation – living biomass	11.95	46.95	IPCC 2003 & 2006
KP.A.1.1	Afforestation and reforestation – deadwood	11.76	19.84	Köster et al. 2015
KP.A.1.1	Afforestation and reforestation – litter	11.71	50.00	Sweden NIR 2021
KP.A.1.1	Afforestation and reforestation – mineral soil	13.01	60.00	Kõlli *et al.* 2009 & 2010; Sweden NIR 2020
KP.A.1.1	Afforestation and reforestation – organic soil	27.92	40.00	Sweden NIR 2021
KP.A.1.1	Afforestation and reforestation – biomass burning (CH_4)	22.09	70.00	LULUCF, 2003, p. 3.50
KP.A.1.1	Afforestation and reforestation – biomass burning (N_2O)	22.09	70.00	LULUCF, 2003, p. 3.50
KP.A.2	Deforestation – living biomass	18.00	46.95	IPCC 2003 & 2006
KP.A.2	Deforestation – litter	17.87	50.00	Sweden NIR 2021
KP.A.2	Deforestation – deadwood	17.87	19.84	Köster et al. 2015

[439] All activity data uncertainty estimates are obtained from NFI.

IPCC category		Uncertainties %		EF References
		Activity data[439]	**Emission factors**	
KP.A.2	Deforestation – mineral soil	19.41	60.00	Kõlli *et al.* 2009 & 2010; Sweden NIR 2021
KP.A.2	Deforestation – organic soil	46.66	40.00	Sweden NIR 2021
KP.B.1	Forest management – living biomass	2.40	46.95	IPCC 2003 & 2006
KP.B.1	Forest management – deadwood	1.10	19.84	Köster et al. 2015
KP.B.1	Forest management – mineral soil	1.81	60.00	Sweden NIR 2021
KP.B.1	Forest management – organic soil	3.64	40.00	Sweden NIR 2021
KP.2	Emissions and removals from drainage and rewetting – CH_4	2.90	55.0	IPCC 2014b
KP.2	Emissions and removals from drainage and rewetting – N_2O	2.90	39.0	IPCC 2014b
KP.4	Biomass burning (CH_4)	34.50	70.00	LULUCF IPCC 2006, p. 4.7, Table 4.13; p. 2.48, Table 2.6
KP.4	Biomass burning (N_2O)	34.50	70.00	LULUCF IPCC 2006, p. 4.7, Table 4.13; p. 2.48, Table 2.6
KP.4.1 C	Wood panels	28.00	57.00	LULUCF IPCC 2006, p. 12.22, Table 12.6 Lamlom and Savidge, 2003
KP.4.1 C	Sawnwood	28.00	57.00	LULUCF IPCC 2006, p. 12.22, Table 12.6 Lamlom and Savidge, 2003
KP.4.1 C	Paper and paperboard	30.00	57.00	LULUCF IPCC 2006, p. 12.22, Table 12.6 Lamlom and Savidge, 2003
KP.4.1 C	Semi-Chemical wood pulp	30.00	57.00	LULUCF IPCC 2006, p. 12.22, Table 12.6 Lamlom and Savidge, 2003

11.3.1.6 Category-specific QA/QC and verification

A complete Quality Assurance (QA) and Quality Control (QC) were carried out for the LULUCF sector according to the IPCC *Tier 1* method. The activities are carried out every year during inventory. The QC checklist is used during the inventory.

In accordance with paragraph 65 of ARR2013, a summary table consisting of a comparison matrix of the Convention and KP-LULUCF reporting areas has been added (Table 11.3) for QA/QC purposes in the current NIR.

ERT has recommended several times to verify the area of Deforestation in Estonia[440], since detection of small and scattered events such as A/R or Deforestation (D) may be underestimated due to the density of the NFI sampling grid (5 km × 5 km).

In 2020, the harvesting permits show higher deforestation area and higher amount of deforested biomass compared to the NFI. The main reason is that harvesting permits do not represent undertaken activities, but only planned harvest and deforestation. It is also important to note that the definition of deforestation is not identical according to the forest notifications (i.e., harvesting permits) and the IPCC guidelines. In addition to forest land-use changes, clear-cuttings on grasslands, under power lines and road ditches are sometimes regarded as deforestation according to the harvesting permits, which is an indication that the system of forest notifications, including harvesting permits is not unequivocal and transparent. Therefore, when reporting and accounting land-use changes from Forest land to other land-use categories and Deforestation, NFI data is implemented. On the other hand, the NFI does not provide the exact biomass loss in Deforested areas, but the average growing stock of forest stands is the basis for calculating the biomass loss due to Deforestation, which may lead to overestimation of emissions. One-third of Deforested areas are the result of clearing grassland from trees where the biomass amount is lower than the average forest biomass.

11.3.1.7 Information on other methodological issues

A more accurate assessment of AR and D sites is under development in the framework of the NFI. NFI data is applied, because it is the only continuous inventory and monitoring system in Estonia that covers all land uses and gives reliable estimates for land-use areas and tree growth.

11.3.1.8 The year of the onset of an activity, if after 2008

Accounting of anthropogenic greenhouse gas emissions by sources and removals by sinks resulting from land use, land-use change and forestry activities under Article 3.3 and 3.4, shall begin with the onset of the activity or the beginning of the commitment period, whichever comes later (*Marrakesh Accords*).

All Article 3.3 activities occurred before 2013, therefore the accounting of these activities began in 2013. Estonia accounts Article 3.4 Forest management activity for the second commitment period of 2013–2020.

11.4 Article 3.3

Estonia reports all emissions by sources and removals by sinks from AR activities under Category A.1.1 Afforestation/Reforestation: units of land not harvested. Forests afforested or reforested since 1990 have not reached the regeneration age by the first commitment period. According to the guidelines for good silviculture, the rotation time varies from 30 to 120 years depending on the tree species and site index of a forest.

The areas of Article 3.3 activities are estimated and described in Chapter 11.2 – the cumulative sum of areas Afforested/Reforested and Deforested since 1990.

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[440] ARR2013, paragraph 62 & paragraph 79

11.4.1 Information that demonstrates that activities under KP.A.1.2 Units of land harvested since the beginning of the commitment period do not occur

In ARR2013, paragraph 78, the ERT identified that Estonia did not report units of land harvested in A/R activities since the beginning of the commitment period. Justifications are as follows:

- Rules of Forest management (under the Forest Act) enact harvest, reforestation/afforestation, and forest protection activities. According to the Rules of Forest management, clear-cutting is not allowed in stands with the dominant tree species (*Pinus sylvestris*, *Picea abies*, *Betula*, *Populus tremula*, *Alnus glutinosa* and hardwoods), if the stand age is less than 30 … 130 years, depending on the site index class.
- Considering reasonable resources for tracking A/R units (NFI) and available data, there is no evidence of harvesting in A/R areas.
- Trees in A/R areas could be (a maximum of) 23 years old, hence it is not profitable (little stem volume) to harvest a forest of this age.

11.4.2 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are directly human-induced

The reported AR activities are directly human induced because these were undertaken when it was decided not to continue with the previous activities but start with the Forest management activities instead. The planting of new forest is the main human-induced reforestation activity directed towards the increase in forest area in Estonia. Afforestation activities have been implemented mainly in agricultural lands and exhausted quarries.

Changes in Deforested areas are detected on NFI sample plots. The land-use category at the end of 1989 was assessed during field measurements; supporting maps and aerial photos were used where necessary.

11.4.3 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from Deforestation

According to Estonian legislation, the land category change by humans is allowed only with orders from local authorities and/or the Minister of the Environment. This must be preceded by the reassignment of the land (e.g., commercial, residential or transport land), which is reflected both in the Land Cadastre and Land Registry. When an NFI sample plot is located in a clear-cut area, the surveyor assesses whether the cutting has been done for regeneration purposes or for a land-use change. Clear signs of a land-use change can be seen in the surroundings and location of the area; also, relevant data from Land Cadastre and Land Registry is checked.

According to the Forest Act, the forest owner is obliged to implement reforestation techniques to such an extent that within five years after logging or forest death a renewed forest is ensured. Re-establishment of a forest usually starts within 2 years after harvesting.

11.4.4 Information on the size and geographical location of forest areas that have lost forest cover but are not yet classified as deforested

Clear-cut forest areas, which have not been classified as Deforestation, were classified as temporarily unstocked forest (including development classes treeless area and area under regeneration). The last five-year average of unstocked forest area in Estonia is 190.6 thousand hectares. All areas that have lost forest cover (if there is a reason to expect a permanent change of the land-use class) are considered as deforested and reported as non-forest land. The total area of clear-fellings in 2000–2020 can be found in Table 11.7. Their geographic locations are determined by analysis of remote sensing data and administrative data about planned clear-fellings[441].

Table 11.7 Clear-cut Forest areas (kha) in Estonia in 2000–2020

Year	Area
2000	23.2
2001	28.9
2002	26.5
2003	23.8
2004	18.3
2005	15.0
2006	12.2
2007	12.7
2008	12.8
2009	17.3
2010	22.8
2011	25.0
2012	27.4
2013	28.6
2014	29.7
2015	31.5
2016	32.4
2017	35.6
2018	34.3
2019	29.9
2020	30.2

Source: National Forest Inventory

11.4.5 Information related to the natural disturbances provision under Article 3.3

Estonia does not exclude emissions from natural disturbances under Article 3.3.

11.4.6 Information on Harvested Wood Products under Article 3.3

Emissions from HWP under Article 3.3 AR activities do not occur for the same reasons that were explained in Chapter 11.4.1. Harvested wood products resulting from deforestation have been excluded according to Equation 2.8.3[442] and accounted on the bases of the *Tier 1* method on instantaneous oxidation.

[441] ARR2014, Table 6

[442] IPCC 2013 KP Supplement, Chapter 2.8.1.2, p. 2.116.

11.5 Article 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human induced

All forest land is considered managed in Estonia – the whole forest land in Estonia is or has been covered with forest management plans. In addition, protected forests are covered with a protection scheme.

11.5.2 Information relating to Forest management

Estonia accounts for anthropogenic greenhouse gas emissions by sources and removals by sinks resulting from the Forest management under Article 3.4 for the second commitment period.

11.5.2.1 Conversion of natural forest to planted forest

In Estonia, all natural forests are under protection, thus the conversion of natural forests to planted forests does not occur.

11.5.2.2 Forest management reference level (FMRL)

Estonia was one of the countries for which Joint Research Centre (JRC) calculated the FMRL (FCCC/TAR/2011/EST) in 2011. According to the Decision 2/CMP.7 Estonia's forest management reference level is -1.742 Mt CO2 eq. year^{-1} and, applying the first order decay function for HWP, the reference level is -2.741 Mt CO2 eq. year^{-1}. The estimated annual accumulation of -0.999 Mt CO_2 eq. year^{-1} in HWP pools included in the FMRL was estimated using the approach proposed in FCCC/KP/AWG/2010/CRP.4/Rev.4. The FMRL is based on a projection; the emissions from harvested wood products originating from forests prior to the start of the second commitment period have been included in the accounting. The current FMRL is based on a projection; the emissions from harvested wood products originating from forests prior to the start of the second commitment period have been included in the accounting.

11.5.2.3 Technical corrections of FMRL

FMRL includes above- and below-ground biomass pools, the HWP pool and emissions of CO_2 from the drainage of organic soils and of non-CO_2 GHGs from forest fires. Estonia performed a technical correction of the forest management reference level for the 2022 submission according to the Decision 2/CMP.7 and the guidance in section 2.7.6 of the IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (Table 11.8).

Table 11.8 Calculations for the technical correction of FMRL

		Model`s results	Row no	Calculation formula	av. 2000-2008	2000	2005	2010	2015	2020	av. 2013-2020
					kt CO_2 eq.						
FCCC/TAR/2011/EST*	Step 1: model`s results (only biomass)	EFISCEN	1		**-4502**	-4050	-5247	-2652	-197	2061	**466**
		G4M	2		**-1654**	-1016	-2266	-804	475	1944	**930**
		Average of models	3	=(row1+row2)/2	**-3078**	-2533	-3756	-1728	139	2003	**698**
	Step 2: ex-post processing (without HWP)	Average of country`s emissions and removals from biomass, non-biomass pools and GHG sources for the period 2000-2008 (NIR 2011)	4		**-5518**						
		Offset	5	=row4-row3	**-2440**						
		Calibrated average of models	6	=row3+row5	**-5518**	-4973	-6196	-4168	-2301	-437	**-1742**
		FMRL assuming instantaneous oxidation of HWP	7								**-1742**
	Step 3: ex-post processing (with HWP)	HWP	8		**-828**						**-999**
		FMRL applying the first-order decay function for HWP	9	=row7+row8							**-2741**
Technical correction	Step 1: ex-post calibration (without HWP)	Average of country`s emissions and removals from biomass, non-biomass pools and GHG sources (same pools as in NIR 2011) for the period 2000-2008 (NIR 2022)	10		**-2875**						
		Offset 1 (revised pools/gases already included in FMRL submission)	11	=row10-row3	**203**						
		Calibrated average of models	12	=row3+row11	**-2875**	-2330	-3553	-1525	342	2206	**901**
		Additional pools to be added (NIR 2022):									
		Mineral soils	13		**-1028**						**-1030**
		Non-CO_2 from drained organic forest soils	14		**329**						**328**
		DOM (dead wood)	15		**-176**						**-113**
		Offset 2 (new pools/gases not included in FMRL submission)	16	=sum(row13:15)	**-875**						
		Adjusted FMRL assuming instantaneous oxidation of HWP	17	=row12+row16							**25**
		HWP (NIR 2022)	18		**-777**						

	Model`s results		Row no	Calculation formula	av. 2000-2008	2000	2005	2010	2015	2020	av. 2013-2020
					kt CO_2 eq.						
	Step 2: ex-post calibration (with HWP)	Offset 3 (revised pools/gases already included in FMRL submission)	19	=row18-row8	**52**						
		Calibrated average of models	20	=row8+row19							**-947**
		Adjusted FMRL applying the first-order decay function for HWP	21	=row17+row20							**-922**
		Technical correction to FMRL**	22	=row21-row9							**1819**

*Report of the technical assessment of the forest management reference level submission of Estonia submitted in 2011

**Technical correction in accordance with paragraphs 14 and 15 of the annexes to decision 2/CMP.7. Technical Corrections = FMRLcorr – FMRL

Technical correction of FMRL was calculated due to the following reasons:

- Estimates of carbon stock change in living biomass have been updated due to revised data from the NFI. Country specific $BCEF_S$ were calculated based on NFI and research studies[443];
- CO_2 emissions from drained organic forest soils were recalculated using updated activity data and emission factors;
- Non-CO_2 GHG emissions from forest fires were recalculated and estimated according to 2006 IPCC Guidelines;
- The following additional carbon pools were included in reporting the FM for the second commitment period: CO_2 emissions from mineral soils and dead organic matter;
- Additional non-CO_2 source was included in reporting the FM for the second commitment period: CH_4 and N_2O emissions from drained organic soils.

Net emissions in the reference period 2000–2008 are significantly different in NIR 2011 and NIR 2022. The main reasons are:

- The total area of Estonia was re-estimated as 45 339 km^2 instead of 45 227 km^2;
- From 2014 onwards, more plots were measured every year (370 clusters of plots instead of 270 clusters);
- The calculation of the area of water bodies has been specified;
- Verification of historical data series has improved;
- Methodologically, the difference between the previous approach and the updated methodology is that the calculation of inventories reflects the trend of the 15-year measurement results instead of the previous 5-year trend. The new methodology is statistically significantly more accurate;
- 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.

The technical correction of HWP was minor due to the similar input data.

FMRL technical correction was recalculated using ex-post calibration model. The FMRL with a technical correction assuming instantaneous oxidation of HWP is 0.03 Mt CO_2 eq. $year^{-1}$ and applying the first-order decay function for HWP is -0.92 Mt CO_2 eq. $year^{-1}$. The FMRL technical correction is 1.82 Mt CO_2 eq. $year^{-1}$.

11.5.2.4 Information related to the natural disturbances provision under Article 3.4

In Estonia, the most important natural disturbances are extreme weather events (storms), wildfires, insect attacks and disease infestations, and other (damage done by game animals). Estonia will not apply the ND provision for the period of 2013–2020.

Perished stands

According to the Forest Act, a forest in which the canopy density, as determined based on living trees is less than 30 per cent due to biotic or abiotic damage, is deemed to be perished.

In 1998–2013, the stands, which according to the forest protection expertize were designated to salvage logging due to forest damage, were deemed as perished stands. The area and growing stock of such stands are calculated according to the data of forest protection expertize.

In 1991–1997, the area of perished stands was presented according to the data of Statistics Estonia and in 1990 according to the data of the Estonian State Forest Protection Service (no data of Statistics Estonia in 1990). In 1990–1997, the growing stock of perished stands was calculated according to the average growing stock of perished stands by different damaging agents during the period of 1998–2013.

The background level of emissions associated with natural disturbances is presented in Figure 11.3. The background level is 82.80 kt CO_2 eq. and the margin for the ND is 105.41 kt CO_2 eq., equalling twice the standard deviation of the time series of 1990–2012 which defines the background level. Background level and margin were recalculated using data from 1990–2012 according to the recommendation of ERT[444].

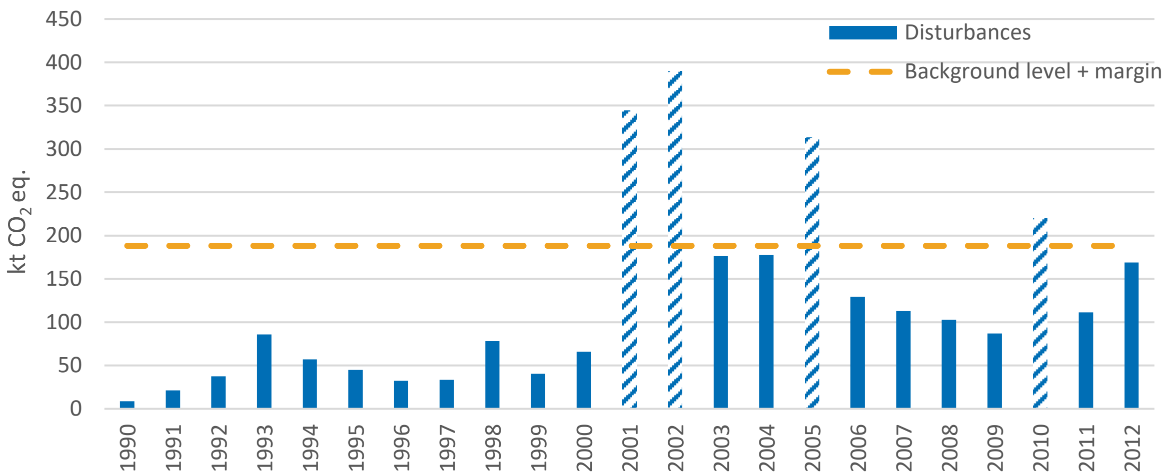

Figure 11.3. Emissions from natural disturbances in 1990 to 2012 with the obtained background level and margin (outliers are marked with diagonal-lined bars), kt CO_2 eq.

Equation 2.14 in IPCC 2006 Guidelines[445] was used to calculate the natural disturbances emissions for the annual carbon loss in biomass due to disturbances. Country-specific data was used to estimate the fraction of biomass lost in disturbances (fd) in Table 11.9. Annual emissions from wildfires are estimated according to the methodology described in Chapter 6.9. The proportion of salvage logging was estimated to be 71% (stem volume) based on the data from State Forest Management Centre (RMK)[446]. Roughly 46% of Estonian forests belong to the Estonian state and thus these forests are maintained, grown, and managed by the RMK. As Estonia does not have specific research done to estimate the percentage of salvage logging the data from RMK was used for the estimation. The salvage logging is an average of the data gathered during the period of 2016–2018.

Table 11.9 Fraction of biomass lost in disturbances for national disturbances estimation

	fd
Insect attacks and disease infestation	0.26
Extreme weather events	0.26
Other (damage done by game animal)	0.22

[444] ARR2020, KL.9, p. 34
[445] IPCC 2006 Guidelines, Volume 4, Chapter 2: Methodologies Applicable to Multiple Land-Use Categories, page 2.18, equation 2.14.
[446] https://www.rmk.ee/en

11.5.2.5 Information on Harvested wood products under Article 3.4

Estonia started to account harvested wood products in the second commitment period and all the instantaneous oxidations have been excluded according to the IPCC guidelines. Harvested wood products under Article 3.4 were calculated according to the IPCC guidelines and in the same manner as described in Chapter 6.10.

The emissions and removals resulting from changes in the harvested wood products pool do not include imported harvested wood products, irrespective of their origin. Information about foreign trade and production of Harvested wood products is provided by Statistics Estonia, NFI, Estonian Forest and Wood Industries Association, and Food and Agriculture Organization of the United Nations (FAO).

11.5.3 Information relating to Cropland management, Grazing land management, Revegetation and wetland drainage and rewetting, if elected, for base year

Estonia did not elect any other activities under Article 3.4.

11.6 Other information

The most important long-term forest strategy document is Estonian Forestry Development Plan that is compiled in every 10 years. The Estonian Forestry Development Plan (EFDP) until 2020 was approved by the Parliament on 15 February 2011. The main objective of the EFDP is to ensure forest productivity and vitality, and the diverse and efficient use of this resource. To achieve this goal, it was determined that in the long run, timber is used as renewable natural resource in timber industry and energy sector up to the amount of increment. To maintain forest productivity, forest renewal activities will be carried out on at least half of the regeneration cutting sites. To preserve good condition of threatened species and the species characteristic to Estonia, the aim is to ensure that at least 10% of the area of forest land has been taken under strict protection and representativeness of protected forests has been improved.

More precise activities and goals of EFDP until 2020 can be found in the document[447]. The Ministry of the Environment started to draw up the Forestry development plan 2021–2030 in December 2017. The EFDP is expected to be adopted by the end of 2022.

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

The basis for the assessment of key categories under Article 3.3 of the KP is the same as for the assessment made for the UNFCCC inventory. Key category analysis for KP-LULUCF was carried out in accordance with Chapter 2.3.6 of the IPCC 2013 KP supplement – the key categories for the Kyoto Protocol activities can be derived from the identified key categories in the UNFCCC inventory as follows. Whenever a category is identified as a key category in the UNFCCC inventory, the associated activity under the Kyoto Protocol can be considered as a key category in reporting under the Kyoto Protocol. According to this approach, all categories under Article 3.3 of the Kyoto Protocol (Afforestation and Reforestation, Deforestation) and Forest management under Article 3.4 can be regarded as key categories.

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[447] Estonian Forestry Development Plan until 2020. [www] https://www.riigiteataja.ee/aktilisa/3180/2201/1003/Eesti_%20metsanduse_arengukava.pdf (10.01.2022).

11.7 Information relating to Article 6

No projects in this sector under Article 6 are implemented in Estonia.

12. INFORMATION ON ACCOUNTING OF KYOTO UNITS

12.1. Background information

The contents of the Standard Electronic Format report (hereinafter as SEF) for 2021 can be found as Annex 5 of this document. The SEF tables include information about AAU, ERU, CER, t-CER, l-CER and RMU in Estonian National Registry (hereinafter as NR) standing 31st of December 2021. In addition, the SEF includes information on transfers of the units during the year 2021.

12.2. Summary of information reported in the SEF tables

The total amount of AAUs in the party holding account at the end 2021 was 51,056,976.

12.3. Discrepancies and notifications

Information about discrepant transactions is included in SIAR report Appendix 2 and 3. Neither discrepancies nor notifications occurred in 2021. No actions were necessary to be taken as no discrepancies occurred during the reported period.

12.4. Publicly accessible information

Publicly accessible information is available on the webpage of Ministry of the Environment, under information about Kyoto protocol (https://envir.ee/kliima/kliima/rahvusvaheline-aruandlus#kyoto-protokolli-ala) as well as on the European Union registry webpage (https://ets-registry.webgate.ec.europa.eu/euregistry/EE/public/reports/publicReports.xhtml).

According to Annex to the Decision 13/CMP.1, II Registry requirements, point E the required public information includes:

- account information;
- JI projects in Estonia;
- information about unit holdings and transactions;
- information about entities authorized to hold units.

Public information required by Commission regulation (EC) No 389/2013 (in addition to the above-mentioned public information) is also available on the webpage of Estonian Environmental Board, under information about greenhouse gases (https://keskkonnaamet.ee/keskkonnakasutus-keskkonnatasu/ohk-ja-kliima/kasvuhoonegaasid as well as on the European Union Transaction Log webpage (http://ec.europa.eu/environment/ets/).

It includes:

- information about installations and permit details;
- information about verified emissions, surrenders and compliance status of installations;

- National allocation plan for Estonia and NIMs list.

12.5. Calculation of the commitment period reserve (CPR)

Parties are required by decision 11/CMP.1 under the Kyoto Protocol and paragraph 18 of Decision 1/CMP.8 to establish and maintain a commitment period reserve as part of their responsibility to manage and account for their assigned amount. The commitment period reserve equals the lower of either 90% of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis) or 100% of its most recently reviewed inventory, multiplied by 8.

For the purposes of the joint fulfilment, the commitment period reserve applies to the EU, its Member States and Iceland individually.

Both methods to calculate Estonia's commitment period reserve are presented hereinafter:

1. 90% of a Party's assigned amount

90% from 51 056 976 = 45 951 278.4 tonnes of CO_2 equivalent.

2. 100% of most recently reviewed inventory multiplied by 8 (Estonia has interpreted the 'most recently reviewed inventory' as the 2020 inventory submission and has used the the 15th of April 2020 submission in the calculations. FCCC/ARR/2020/EST)

19 974 140*8 = 159 793 120 tonnes of CO_2 equivalent.

Consequently, the commitment period reserve for Estonia is **45 951 278.4** tonnes of CO_2 equivalent.

12.6. KP-LULUCF accounting

The results of accounting procedure for the activities under Articles 3.3 and 3.4 of the Kyoto Protocol are presented in Table 12.1.

The main factors generating the accounted quantity (the difference in net emissions between reporting of FM during CP2 and the FMRL) are increased forest increment compared to the projections used in FMRL, and higher area of protected forests. Sustainable forest management measures implemented in the framework of the in Estonian Forestry Development Plan until 2020 aim to increase the forest increment and carbon capture ability via the relevant forest management activities (i.e. thinning) and fast renewal of forests with tree species appropriate for the habitat type. The Nature Conservation Development Plan until 2020, adopted in 2012, includes measures for maintaining biological processes in Estonian forests. As a result, the share of strictly protected forests from total forest land has increased from 8.7% in 2012 to 13.1% in 2020. Forest areas that have recently been taken under protection are generally middle-aged and have high productivity, thus also contributing somewhat to the increased C uptake by forests. In addition, models used in the FMRL construction predicted the decrease in FM area compared to 2008; however, the decrease has been lower than projected due to smaller deforestation rates.

Table 12.1. Accounting quantities for activities under Articles 3.3 and 3.4, kt CO_2 eq.

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Base Year	NET EMISSIONS/REMOVALS									Accounting parameters	Accounting quantity
		2013	2014	2015	2016	2017	2018	2019	2020	Total		
	(kt CO_2 eq)											
A. Article 3.3 activities												
A.1. Afforestation/reforestation		-292.73	-282.28	-268.57	-253.37	-235.86	-218.85	-202.73	-187.29	-1941.68		-1941.68
Excluded emissions from natural disturbances		NO	NO	NO	NO	NO	NO	NO	NO	NO		NO
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
A.2. Deforestation		554.74	588.09	617.03	679.23	679.47	647.76	548.16	478.20	4792.69		4792.69
B. Article 3.4 activities												
B.1. Forest management										-22553.76		-15176.90
Net emissions/removals		-3484.03	-3000.67	-3659.37	-3505.08	-2973.21	-3430.89	-2135.12	-365.38	-22553.76		
Excluded emissions from natural disturbances		NO	NO	NO	NO	NO	NO	NO	NO	NO		NO
Excluded subsequent removals from land subject to natural disturbances		NO	NO	NO	NO	NO	NO	NO	NO	NO		NO
Any debits from newly established forest (CEF-ne)												
Forest management reference level (FMRL)											-2741.00	
Technical corrections to FMRL											1818.89	
Forest management cap											11199.08	-11199.08
B.2. Cropland management (if elected)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
B.3. Grazing land management (if elected)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
B.4. Revegetation (if elected)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA

13. INFORMATION ON CHANGES IN NATIONAL SYSTEM

No changes in national system were carried out in 2022.

14. INFORMATION ON CHANGES IN NATIONAL REGISTRY

The following changes to the national registry of Estonia have occurred in 2021.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32. (a) Change of name or contact	No change of name or contact occurred during the reporting period. National administrator is: Ms. Annika Konovalov khgregister@keskkonnaamet.ee tel. +372 5694 4935
15/CMP.1 annex II.E paragraph 32. (b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32. (c) Change to database structure or the capacity of national registry	There has been 6 new EUCR releases (versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2) after version 11.5 (the production version at the time of the last Chapter 14 submission). No changes were applied to the database, whose model is provided in Annex A. No change was required to the application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32. (d) Change regarding conformance to technical standards	The changes that have been introduced with versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2 compared with version 11.5 of the national registry are presented in Annex B. It is to be noted that each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and are carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security were introduced.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change to the registry internet address during the reported period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	No change during the reported period.

15. INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

Estonia has provided information on minimization of adverse impacts in accordance with Article 3, paragraph 14 in its previous national inventory reports under the Kyoto Protocol. The information is provided in accordance with the guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol (Decision 15/CMP.1, Section H.).

15.1. Information on how Estonia is striving, under Article 3, paragraph 14, of the Kyoto Protocol, to implement the commitments mentioned in Article 3, paragraph 1, of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention

Estonia strives to implement its commitments under the Kyoto Protocol in a way that social, environmental, and economic impacts on other countries, including developing countries, are minimised.

Estonia is acting together with other Parties in the European Union to fulfil the commitments under the Kyoto Protocol.

European Union has agreed a forward-looking political agenda to achieve its core energy objectives of sustainability, competitiveness, and security of supply, by reducing greenhouse gas emissions by 20%, increasing the share of renewables in the energy consumption to 20% and improving energy efficiency by 20%, all of it by 2020. The 2030 climate and energy policy framework build on and further strengthens the existing policy framework for the reduction of greenhouse gases setting out a binding, economy-wide reduction target of at least 40% domestic reduction in greenhouse gas emissions.

On 11 December 2020, the European Council endorsed a binding EU target of a net domestic reduction of at least 55% in GHG emissions by 2030 compared to 1990.

To ensure that European Union’s new policy initiatives potential adverse social, environmental, and economic impacts on various stakeholders, including developing country Parties, are identified and minimized, an impact assessment of new policy initiatives has been established. Specific guidelines for the impact assessment have been adopted in 2009, called “Impact Assessment Guidelines”. The Impact Assessment guidelines were revised in May 2015, since then called “Better Regulation Guidelines”.

In Estonia, impact assessments (which include the environmental impacts) are carried out in the early stages of the policy making process.

Please see previous years NIRs for further information as no changes have been made with respect to this information.

15.2. Information on how Estonia gives priority, in implementing the commitments under Article 3, paragraph 14, to specific actions

Estonia reports activities that are related to the actions specified in the subparagraphs (a) to (f) of paragraph 24 of the reporting requirements in the Annex to decision 15/CMP.1.

a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities

Several fiscal measures have been introduced in Estonia to support sustainable energy consumption and reduce GHG emissions. For example, excise duties on fuels and pollution charges. Current tax rates are stipulated in the Alcohol, Tobacco, Fuel and Electricity Excise Duty Act.

Excise duties

In recent years, Estonia's tax policy has proceeded from the principle that the tax burden is shifted towards taxation of consumption of natural resources and pollution of the environment. At the same time, it seeks to keep the tax system simple and transparent, with as few exceptions as possible. The following fuels are subject to excise duty in Estonia: unleaded petrol, leaded petrol, aviation spirit, kerosene, diesel fuel, diesel fuel for specific purposes, light heating oil, heavy fuel oil, shale-derived fuel oil, motor liquid petroleum gas and motor natural gas (hereinafter together motor fuel and fuel oil), coal, lignite, coke and oil shale, liquid petroleum gas, natural gas and specialty and unconventional fuel-like mineral oil, liquid combustible substances and biofuel. Excise duty is exempt from biogas, including biomethane.

Excise duty exceptions have been introduced in Estonia to ensure the competitiveness of large energy consumers. Estonia is applying an EU-wide excise duty (0.5 €/MWh) to electricity-intensive consumers whose energy management system complies with the principles set out in ISO 50001. As of 01.01.2019, the amendments to the Alcohol, Tobacco, Fuel and Electricity Excise Duty Act introduce an excise duty exception on natural gas for intensive natural gas consumers (11.30 €/1000 m^3). This does not apply to companies that supply electricity, gas, steam and air conditioning.

Pollution charges

Pollution charges are a second fiscal measure in Estonia with an impact on GHG emissions. The Government's tax policy is based on objectives aimed at reducing environmental impact by increasing the rates of charges on pollution and resource use. The Environmental Charges Act provides the grounds for determining the natural resource charges, the rates of the pollution charge, the procedure for calculation and payment thereof, and the grounds and specific purposes for using state budget revenue obtained from environmental use. Environmental charges are established and imposed based on the need for environmental protection, the economic and social situation of the state and, in the events specified in the Act, also based on the value created by natural resources subject to the charge, as well as the purpose and manner of use of the environment. A mineral resource extraction charge that exceeds the minimum rates provided for in the Act is established based on the state's goal of earning revenue. In the case of an energy mineral resource, the added value generated by the energy mineral resource is relied upon in addition to the goal of earning revenue.

In Estonia a pollution charge for releasing CO_2 into the ambient air was introduced in 2000. Currently, the Environmental Charges Act (enforced in 2006) obliges the owners of combustion equipment to pay pollution charges for several pollutants emitted into the air. The pollution charge in the case of emissions into ambient air must be paid by all enterprises that are required to have an air pollution permit or integrated environmental permit. According to the regulation of the Minister of the Environment[448] the air pollution permit is obligatory for all enterprises which own and operate combustion equipment (utilizing solid, liquid or gas fuel) with a rated capacity equal to or higher than 1 MW in one location. As an exception, the CO_2 charge must only be paid by enterprises producing heat. Since 2009 the rate of the CO_2 charge has been 2 EUR/t. Installations that emit nitrogen oxides, SO_2, particular matter, and heavy metals into the ambient air also pay a pollution charge. CH_4 and fluorinated gases (HFC – hydrofluorocarbons, PFC and SF_6) are not subject to pollution charges. As an exception, the Environmental Charges Act provides the option of replacing the pollution charge (incl. the CO_2 charge) with environmental investment by enterprises. The financing replaces the pollution charge if the polluter implements, at its own expense, environmental protection measures that reduce pollutants or waste by 15% from their initial value.

With the revenues from the environmental charges, the state has been financing environmental projects through the Environmental Investment Centre for the last 20 years (including replacement of fossil fuel boilers with renewable fuel boilers, reconstruction of district heating systems, etc.).

b) Removing subsidies associated with the use of environmentally unsound and unsafe Technologies

No subsidies for environmentally unsound and unsafe technologies have been implemented. Estonia's tax system is presented shortly above (Paragraph 24a) and through this tax system Estonia promotes sustainable production and technologies.

c) Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end

Estonia does not have any cooperation activities in this field currently.

d) Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non- Annex I Parties in this effort

Estonia has done research for enhancing technologies that emit less GHGs but at the moment there is no cooperation with developing countries in this field.

e) Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities

Since 2009 Estonia has contributed to the Eastern Europe Energy Efficiency and Environment Partnership Fund. The E5P Fund has supported energy efficiency and environmental sustainability projects mainly in Ukraine, but since 2013 the activities of the Fund have been extended also to Georgia, Moldova and Armenia and in 2018 also to Belarus. Estonia has taken a long-term commitment to support Ukraine with 160 000 euros, during the period 2013-2018

[448] https://www.riigiteataja.ee/akt/114122017010?leiaKehtiv

to support Moldova with 200 000 euros and Georgia with 150 000 euros, between 2018-2019 Estonia has committed to support Belraus with 60 000 euros.

f) Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

Estonian Ministry of the Environment adopted in June 2018 a regulation aiming to support developing country cooperation and stipulating specific rules for international climate cooperation. Estonia aims to support both, adaptation, and mitigation actions in developing countries, for example by supporting renewable energy sources, energy efficiency or transport and industry efficiency projects, as well as by strengthening administrative capacity regarding climate action or supporting solutions of adapting to climate change.

On the mitigation side there has been two projects approved.

Reverse Resources OÜ received a grant for the promotion of a software product for the recycling of clothing waste. Reverse Resources develops software for mapping and recycling textile waste at Asian clothing production factories. They have successfully completed two pilot projects with the world's largest global clothing brands and their factories. The support received helps to develop these solutions for the Bangladesh market.

NGO Mondo received a grant for the development of sustainable and affordable solar solutions for rural communities in Myanmar. As a result of the project, two affordable and sustainable solar-powered solutions developed in Estonia are brought to the local market because of the project, in view of the development needs of rural Myanmar Shan state. One provides a permanent electrical connection to local organizations and public buildings, the other provides home users with a suitable solution in areas where electricity has so far been unavailable. The project will also raise the environmental awareness of local people.

In 2019, there was a second application round, which was open from October 8 to December 8. A total of 12 applications were received for a total amount of 1 984 702.14. Total grant for this call was 800 000 euros, of which 3% is administrative expenditure. Financing decisions were made in 2020.

On the mitigation side there was five projects approved, e.g.

ClearLife OÜ wants to alleviate the water shortage problem in Burkina Faso. The company is developing a shower system with a closed system powered by renewable energy, where water is in constant circulation. The sustainable use of water resources is important in areas where droughts are a major problem.

TarkVent OÜ received a grant to further develop building energy management software SmartVent to improve the energy efficiency of buildings in South Africa (South Africa). As the world's sixth largest producer of anthracite, the environmental impact of electricity generation in the South Africa ranks second in the OECD's ranking after India.

Dieselland-Equipment OÜ wants to reduce the consumption of fossil fuels, air emissions and soot particles in the Republic of Kenya. A modular workroom built in Estonia for the repair of diesel engines will be moved to the destination country.

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