LIETUVOS RESPUBLIKOS APLINKOS MINISTERIJA

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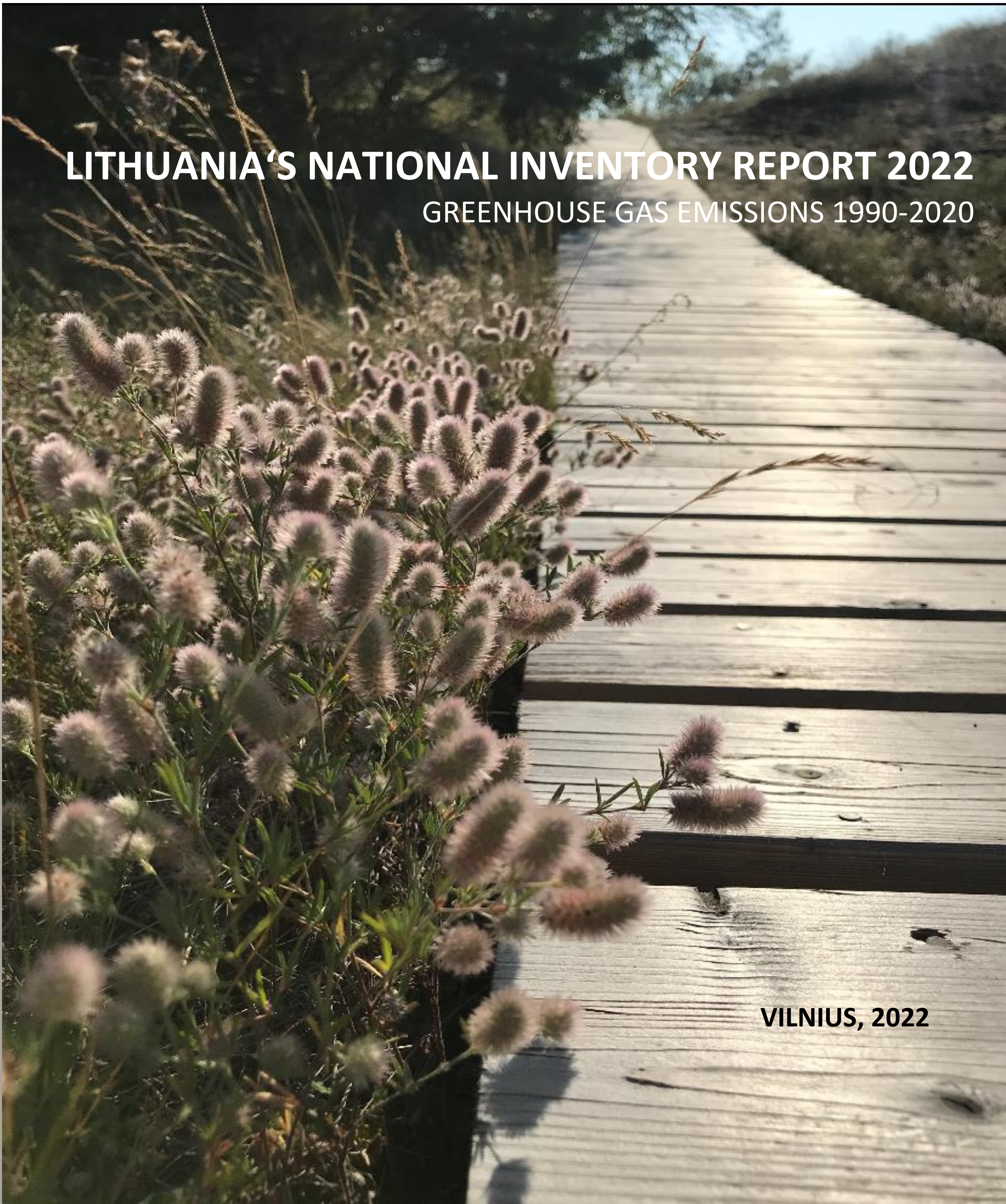
State Forest Service

LITHUANIA‘S NATIONAL INVENTORY REPORT 2022

GREENHOUSE GAS EMISSIONS 1990-2020



VILNIUS, 2022

PREFACE

Lithuania's GHG inventory submission under the UNFCCC, Kyoto Protocol and Regulation No 525/2013 of the European Parliament and of the Council of 21 May 2013 repealing Decision No 280/2004/EC contains:

- National Inventory Report (NIR);
- CRF (Common Reporting Format) data tables for years 1990-2020;
- SEF (Standard Electronic Format) tables for reporting of Kyoto units (AAUs, ERUs, CERs, tCERs, lCERs, RMUs) in the National registry during the year 2021 (CP1 and CP2).

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Cover photo: Juliana Bogdevičienė

Abbreviations

AAU	Assigned Amount Unit
AB	Stock company (SC)
AIRBC	Agricultural Information and Rural Business Centre
ARD	Afforestation, Reforestation and Deforestation
BOD	Biochemical Oxygen Demand
CC	Cropland remaining Cropland
CER	Certified Emission Reduction units
CFC	Chlorofluorocarbon
CH_4	Methane
CHP	Combined Heat and Power
CM	Cropland management
CO_2	Carbon dioxide
CO_2 eq.	Carbon dioxide equivalent
COD	Chemical Oxygen Demand
COP	Conference of the Parties
CR	CORINAIR emission factor
CRF	Common Reporting Format
CS	Country Specific emission factor
D	Default emission factor
DGSF	Directorate General of Sate Forests
DOC	Degradable Organic Carbon
EF	Emission Factor
EPA	Lithuanian Environmental Protection Agency
EPD	Lithuanian Environmental Protection Department
ERT	Expert Review Team
ERU	Emission Reduction Units
FAO	Food and Agriculture Organization of the United Nations
FF	Forest Land remaining Forest Land
FM	Forest Management
FOD	First Order Decay
FRA	Forest Resources Assessment
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GG	Grassland remaining Grassland
GHG	Greenhouse gases
GIS	Geographic Information System
GLM	Grazing land management
GPG	Good Practice Guidance
GSV	Growing Stock Volume
GWCS	Green Waste Composting Sites
HFC	Hydrofluorocarbon
HSPP	Hydro Storage Power Plant
HWP	Harvested Wood Products
IE	Included Elsewhere
IFA	International Fertilizer Industry Association
IPCC	Intergovernmental Panel on Climate Change
kt	Thousand tonnes
L	Level

LF	Land converted to Forest Land
LSFC	Lithuanian State Forest Cadaster
LULUCF	Land Use, Land-Use Change and Forestry
l-CER	long term Certified Emission Reduction units
MCF	Methane correction factor
MMS	Manure Management System
MoE	Ministry of Environment
MSW	Municipal Solid Waste
Mtoe	Million Tonnes of Oil Equivalent
N_2O	Nitrous oxide
NA	Not Applicable
NCV	Net Calorific Value
NE	Not Estimated
NF_3	Nitrogen trifluoride
NFI	National Forest Inventory
NGO	Non-governmental organization
NHF	Nature Heritage Fund
NIR	National Inventory Report
NLS	National Land Service
NMVOC	Non-methane volatile organic compounds
NO	Not Occurring
NPP	Nuclear Power Plant
PFC	Perfluorocarbon
PP	Power Plant
QA/QC	Quality Assurance/Quality Control
RES	Renewable Energy Sources
REV	Revegetation
RMU	Removal Units
RWMC	Regional Waste Management Centers
SAPS	Single Area Payment Scheme
SEF	Standard Electronic Format
SF_6	Sulphur hexafluoride
SFE	State Forest Enterprises
SFI	Standwise Forest Inventory
SFS	State Forest Service
SPD	Single Programming Document
SWDS	Solid Waste Disposal Sites
T	Trend
TOE	Tonne of Oil Equivalent
TPP	Thermal Power Plant
t-CER	temporary Certified Emission Reduction units
UAB	Joint-stock company (JSC)
UNFCCC	United Nations Framework Convention on Climate Change
WD	Wood Density

Content

EXECUTIVE SUMMARY

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

Lithuania takes part in the global climate change mitigation process and is one of the 195 countries of the world that have ratified the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC entered into force on 21st of March, 1994. The Seimas of the Republic of Lithuania ratified the UNFCCC in 1995. The Kyoto Protocol (KP) was signed in 1998 and ratified in 2002. In accordance with Kyoto Protocol Lithuania has undertaken to reduce its greenhouse gas (GHG) emissions by 8% below 1990 level during the first commitment period 2008-2012 and has fulfilled its obligation reducing more than 55% it‘s GHG emissions over this period.

At the Doha Climate Change Conference in December 2012, Lithuania as a European Union (EU) Member State together with other parties to the Kyoto Protocol to the UNFCCC adopted the Doha Amendment, establishing a second commitment period of the Kyoto Protocol, starting on 1st January 2013 and ending on 31st December 2020. The Doha Amendment amends Annex B to the Kyoto Protocol, setting out further legally binding mitigation commitments for parties listed in that Annex for the second commitment period, and amending and further laying down provisions on the implementation of parties' mitigation commitments during the second commitment period. The Union and its Member States agreed at the Doha Climate Change Conference to a quantified emission reduction commitment that limits their average annual emissions of GHGs during the second commitment period to 80% of the sum of their base year emissions.

At the Paris climate conference (COP21) in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement sets out a global action plan to put the world on track to avoid climate change by limiting global warming to well below 2°C.

Lithuania signed the Paris Agreement on 22 April 2016 and ratified on 30 December 2016. Under the Paris Agreement Lithuania jointly with the EU and its Member States took a binding target of at least a 40% domestic reduction in economy wide GHG emissions by 2030 compared to 1990, which was endorsed in the conclusions of the European Council of 23 and 24 October 2014 on the EU 2030 climate and energy policy framework. On 6 March 2015, the Council adopted this contribution of the Union and its Member States as their intended nationally determined contribution, which was submitted to the Secretariat of the UNFCCC. The target will be delivered implementing the EU legal acts on 2030 climate and energy targets by all economy sectors, with the reductions in the Emission trading system (ETS) and non-ETS sectors amounting to 43% and 30% respectively by 2030 compared to 2005.

As a Party to the UNFCCC and in accordance with Article 5, paragraph 2 of the Kyoto Protocol, Lithuania is required to develop and regularly update national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not regulated by Montreal Protocol. As a member of the European Union, Lithuania also has reporting obligations under the EU Regulation No 525/2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC.

The GHG inventory is prepared in accordance with the decision 24/CP.19 "Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to Convention" (FCCC/CP/2013/10/Add.3). GHG inventory is compiled in accordance with the methodology recommended by the Intergovernmental Panel on Climate Change (IPCC) in its *2006 IPCC*

Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), 2013 Supplement to the 2*006 IPCC Guidelines* for National Greenhouse Gas Inventories: Wetlands (IPCC, 2014), 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC, 2014) and taking into account recommendations by the UNFCCC expert review teams, provided in the Reports of the individual review of the annual submissions of Lithuania and remarks received during EU annual GHG inventory quality checks and GHG inventory technical reviews under EU Decision 406/2009/EC (Effort Sharing Decision).

The first national GHG inventory data was submitted in 1996 for the first National Communication under the UNFCCC. In 2004 first National Inventory Report (NIR) and Common reporting format (CRF) tables have been developed. In 2006 for the first time complete time series for the period 1990-2004 of the GHG inventory has been developed and submitted to European Commission and the UNFCCC Secretariat together with Lithuania's Initial Report under the Kyoto Protocol. In 2016 Lithuania submitted its Second Initial Report under the Kyoto protocol (Report to facilitate the calculation of the assigned amount for the second commitment period pursuant to Article 3, paragraphs 7bis, 8 and 8bis of the Kyoto Protocol).

In accordance with the Order of the Minister of Environment of 22nd of December 2010 (as repealed on 23-01-2014 by MoE Order No D1-61), Lithuanian Environmental Protection Agency (EPA) under the Ministry of Environment was nominated as an institution responsible for the GHG inventory preparation starting from 2011. EPA responsibilities inter alia include monitoring of environmental quality, collection and storage of environmental data and information as well as assessment and forecasting of environmental quality. Permanent GHG inventory preparation working group was established in 2011 by the Governmental Resolution No 683 (as repealed on 18-11-2021 by Climate Change Management law amendment No XI-329, by which Minister of Environment was authorised to establish GHG Inventory working group). The working group for GHG inventory preparation include members from Lithuanian Energy Institute, Centre for Physical Sciences and Technology, Institute of Animal Science of the Lithuanian University of Health Sciences, Centre for Environmental Policy, Lithuanian Research Center for Agriculture and Forestry and The State Forest Service (SFS). External experts, independent specialists providing data for the GHG inventory, may also be involved during the inventory process upon request. The Ministry of Environment is a supervisor and coordinator for preparation of GHG inventory and nominated as the National Focal Point to the UNFCCC.

The GHG inventory report presented here contains information on anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by Montreal Protocol:

- Carbon dioxide CO_2,
- Methane CH_4,
- Nitrous oxide N_2O,
- Hydrofluorocarbons HFCs,
- Perfluorocarbons PFCs,
- Sulphur hexafluoride SF_6,
- Nitrogen trifluoride NF_3.

In addition, the inventory includes emission estimates of the precursors: nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO), as well as sulphur dioxide (SO_2).

The national GHG inventory report contains detailed information about Lithuania's emissions by sources and removals by sinks for the period 1990-2020.

For the preparation of the inventory upgraded CRF Reporter inventory software (v6.0.8) has been used. The NIR includes trends of GHG emissions, description of each emission category relevant to CRF, key sources, uncertainty estimates, planned improvements and description of performed procedures of quality assurance and quality control (QA/QC).

This report also includes supplementary information in accordance with Article 7, paragraph 1 of the Kyoto Protocol:

- information on emissions and removals from the land use, land use change and forestry (LULUCF) sector under Article 3 paragraphs 3 and 4 of the Kyoto Protocol (see Chapter 11),
- information of accounting of Kyoto units (see Chapter 12),
- information on changes that have occurred in the national system comparing with the information reported in the last submission (see Chapter 13),
- information on changes that have occurred in the national registry compared with information reported in the last submission (see Chapter 14), and
- information on the minimization of adverse impacts in accordance with Article 3, paragraph 14 of the Kyoto Protocol (see Chapter 15).

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

The summary of Lithuania's GHG emissions and removals for the period 1990-2020 is presented in the table below.

Table 1. Greenhouse gas emissions/removals by sectors during the period 1990-2020, kt CO_2 eq.

Years	Energy	IPPU	Agriculture	LULUCF	Waste	Total (including LULUCF)	Total (excluding LULUCF)
1990	33,122.5	4,460.2	8,756.0	-5,531.3	1,522.1	42,329.6	47,860.9
1991	35,176.7	4,492.7	8,626.7	-5,631.5	1,547.8	44,212.4	49,843.9
1992	19,916.2	2,653.4	6,572.0	-5,358.4	1,523.0	25,306.2	30,664.5
1993	16,039.8	1,728.3	5,269.3	-6,311.5	1,549.2	18,275.2	24,586.7
1994	15,113.0	1,926.0	4,652.7	-5,824.7	1,528.3	17,395.2	23,219.9
1995	14,161.3	2,212.3	4,327.1	-4,532.6	1,532.7	17,700.9	22,233.5
1996	14,642.2	2,604.0	4,498.5	992.1	1,531.8	24,268.6	23,276.5
1997	14,189.5	2,568.3	4,533.4	-230.2	1,549.8	22,610.7	22,840.9
1998	14,887.4	2,974.9	4,408.4	-7,827.4	1,533.8	15,977.1	23,804.5
1999	12,445.7	2,911.9	4,107.6	-7,141.5	1,522.1	13,845.8	20,987.3
2000	10,916.2	3,068.3	3,936.1	-9,432.1	1,520.4	10,008.9	19,441.0
2001	11,596.5	3,315.1	3,781.4	-7,268.9	1,550.2	12,974.3	20,243.2
2002	11,660.8	3,488.1	3,925.4	-6,323.4	1,548.0	14,298.8	20,622.3
2003	11,675.0	3,571.0	4,002.1	-5,617.3	1,541.4	15,172.2	20,789.5
2004	12,287.7	3,760.7	4,049.5	-5,164.6	1,510.8	16,444.1	21,608.7
2005	13,135.6	4,037.0	4,070.5	-4,378.1	1,471.4	18,336.3	22,714.4
2006	13,186.8	4,319.1	4,061.7	-3,971.6	1,436.2	19,032.3	23,003.8
2007	13,418.0	6,141.2	4,214.3	-5,891.5	1,408.8	19,290.9	25,182.4
2008	13,293.9	5,475.9	4,110.4	-6,537.4	1,323.6	17,666.4	24,203.8
2009	12,113.6	2,299.2	4,206.0	-7,519.3	1,292.8	12,392.2	19,911.5

2010	13,094.7	2,235.4	4,156.7	-10,423.1	1,263.3	10,327.0	20,750.2
2011	12,245.0	3,714.4	4,196.7	-10,592.6	1,187.1	10,750.6	21,343.2
2012	12,278.4	3,565.0	4,271.6	-10,000.9	1,151.7	11,265.8	21,266.7
2013	11,659.6	3,000.2	4,246.1	-9,403.4	1,121.1	10,623.5	20,026.9
2014	11,278.2	3,186.3	4,467.3	-8,479.1	1,063.9	11,516.6	19,995.7
2015	11,248.4	3,507.7	4,537.7	-7,844.5	1,010.1	12,459.4	20,303.9
2016	11,578.9	3,324.3	4,431.9	-7,131.8	991.5	13,194.8	20,326.6
2017	11,508.4	3,637.4	4,390.1	-6,498.7	993.0	14,030.2	20,528.9
2018	11,872.6	3,165.8	4,248.0	-6,353.5	872.6	13,805.5	20,159.0
2019	11,890.3	3,375.1	4,256.5	-5,302.1	838.6	15,058.5	20,360.6
2020	11,816.7	3,093.5	4,450.7	-5,407.4	821.6	14,775.2	20,182.6
2020/ 1990, %	**-64.3**	**-30.6**	**-49.2**	**-2.2**	**-46.0**	**-65.1**	**-57.8**

The most significant source of GHG emissions in Lithuania is energy sector with 58.5% share of the total emissions in 2020. Agriculture is the second most significant source and accounted for 22.1% of the total emissions. Emissions from industrial processes and product use contributed 15.3% of the total GHG emissions, waste sector – 4.1%.

Main contributors in energy sector are Transport and Energy industries categories. In 2020 these categories composed 30.4% and 13.1% of the total national GHG emissions, respectively.

The composition of GHG emissions by sectors in 2020 is presented in the figure below.

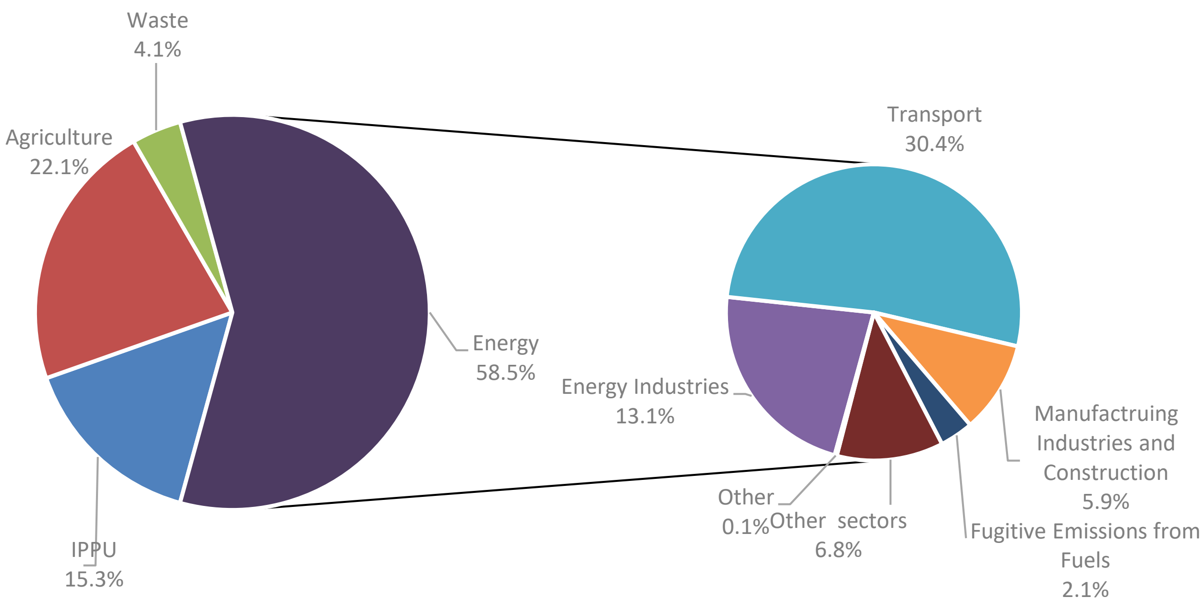


Figure 1. The composition of Lithuanian GHG emissions (CO_2 eq.) by sectors (excl. LULUCF) in 2020[1]

The total GHG emission (excl. LULUCF) amounted to 20,182.6 kt CO_2 eq. in 2020. The emissions have decreased by 57.8% comparing with the base year. The base year is 1990 for the greenhouse gases CO_2, CH_4, N_2O and 1995 for the F-gases HFC, PFC, SF_6 and NF_3.

[1] Transport, Energy Industries, Manufacturing industries and construction, Fugitive emissions from fuels, Other, Other sectors values represent emissions in percentages compared to total National GHG emissions.

The largest source of namely CO_2 emission is the energy sector that accounted 82.1% of the total national CO_2 emission (excl. LULUCF) in 2020. Transport category contribute for 54.1% and energy industries accounts 23.1% of the CO_2 emission in energy section.

Comparing with 2019 namely CO_2 emission from energy sector in 2020 have changed with a decrease of 0.2% wherein CO_2 emission from transport decreased by 2.4 %, from manufacturing industries and contruction – 8.8%, whereas emissions from the energy industries increased by 16.5%.

The most important GHG in 2020 was CO_2, it contributed 67.6% of the total national GHG emissions expressed in CO_2 eq. followed by CH_4 (14.2%) and N_2O (15.6%). HFCs, SF_6 and NF_3 together amounted 2.5% of the total GHG emissions (excl. LULUCF) in Lithuania.

Between 1990 and 2000 GHG emissions decreased significantly as a consequence of the decline in industrial production and associated fuel consumption. Once the economy started to grow again, emission rose but this was partly compensated by reductions achieved through energy efficiency and measures taken to reduce emissions.

Comparing with 2019 the total GHG emissions have decreased by 0.9% (excl. LULUCF) in 2020.

An overview of estimated GHG emissions is presented in Figure 2, which shows GHG emissions by gases, expressed in CO_2 eq. (excl. LULUCF) for the period 1995-2020.

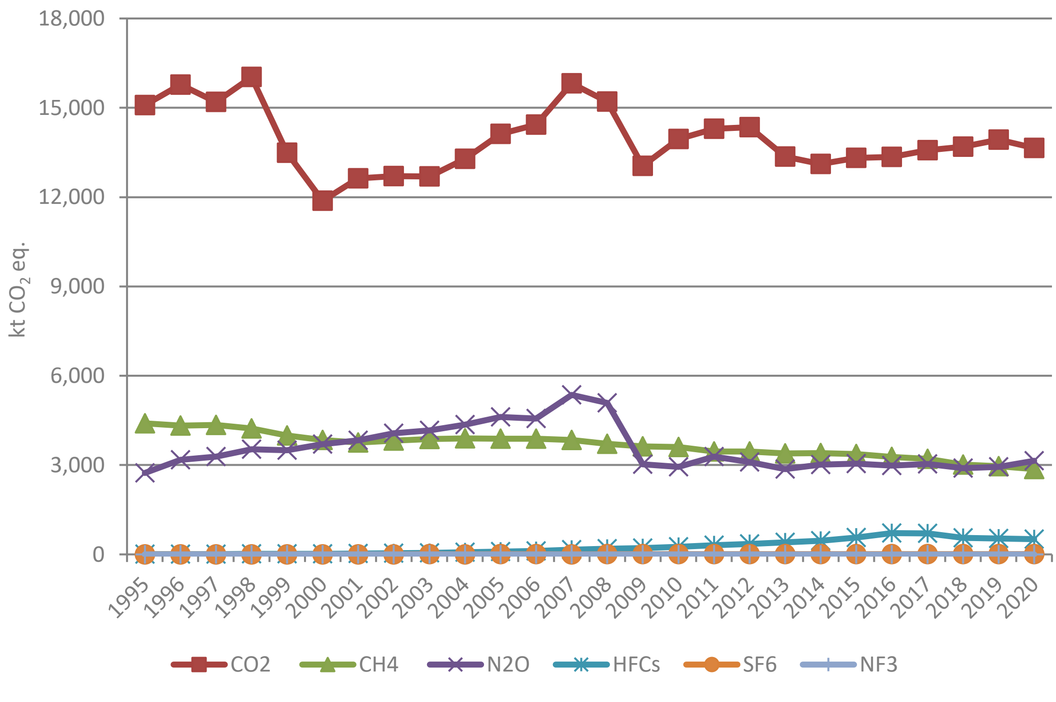


Figure 2. Trends of GHG emissions by gas (excl. LULUCF)

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

Energy sector is the most significant source of GHG emissions in Lithuania with 58.5% share of the total emissions (excl. LULUCF) in 2020. Emissions from energy sector include CO_2, CH_4 and N_2O GHG.

Namely CO_2 emission from energy sector accounted 82.1% of the total national CO_2 emissions (excl. LULUCF) in 2020. The main categories are transport and energy industries which contribute

45.0% and 19.4% to the total national CO_2 emission (excl. LULUCF), respectively. Comparing with 2019, CO_2 emissions from energy sector have decreased by 0.2% in 2020. The emissions of CH_4 have decreased by 8.8% and N_2O decreased by 0.4%.

The second most important source of GHG emissions is agriculture sector accounting for 22.1% of the total national GHG emissions (excl. LULUCF). This sector is the most significant source of CH_4 and N_2O emissions accounting for 58.6% and 87.4% of the total CH_4 and N_2O emissions, respectively. The main source of CH_4 emissions is enteric fermentation contributing 86.2% to the total agricultural CH_4 emissions. Agricultural soils are the most significant source of N_2O emissions accounting for 93.5% of the total agricultural N_2O emissions. Comparing with 2019 GHG emissions in agriculture sector have increased by 4.6% in 2020.

Emissions from industrial processes and product use sector amounted to 15.3% of the total GHG emissions (excl. LULUCF) in 2020. The main categories are: ammonia production, nitric acid production and cement production. Ammonia production is the largest source of CO_2 gas emissions in industrial processes and product use sector contributing 13.06% to the total national CO_2 emissions (excl. LULUCF) in 2020. Nitric acid production is the main source of N_2O emissions in industrial processes sector and accounts for 4.9% in the total national N_2O emissions (excl. LULUCF) in 2020. GHG emissions in 2020 from industrial processes and product use sector have decreased by 8.3% comparing with 2019.

Waste sector accounted for 4.1% of the total GHG emissions in 2020(excl. LULUCF). There was 2% decrease in CH_4 emission from waste sector in 2020 comparing with 2019. The solid waste disposal on land is the second important source of CH_4 emissions. It contributes 19.7% to the total CH_4 emissions (excl. LULUCF) in 2020.

PART 1:

ANNUAL INVENTORY SUBMISSION

1 INTRODUCTION

1.1 Background information on GHG inventories and climate change

1.1.1 Background information on climate change in Lithuania

Lithuanian climate is formed affected by global factors and local geographical circumstances. Key features of the climate depend on the country's geographical location. The territory of Lithuania lies in the northern part of the temperate climate zone. The distance from the equator (6,100 km) and from the North Pole (3,900 km) determines general solar radiation flux and atmospheric circulation patterns over the country. According to the general classification of climate, almost the entire territory of Lithuania is assigned to the south-western sub-region of the continental forest region of the middle latitudes of the Atlantic Ocean, because its climate is close to that of Western Europe; while the Baltic coast is assigned to the South Baltic sub-region.

The character of climate variations in Lithuania greatly depends on the processes of atmospheric circulation, i.e., cyclonic and anticyclone formations and air mass advection of a different nature. It was observed that a number of deep cyclones visiting Lithuania in cold seasons (November-March) was increasing, whereas a number of anticyclone formations decreasing. The changing patterns of atmospheric circulation entailed changes in other climatic indices: changes in thermal season duration, decrease in seasonal differences of air temperature and precipitation amount, decline in snow cover indices.

Rapid increase in average annual temperature in Vilnius observed in the last 30 years (Figure 1-1).

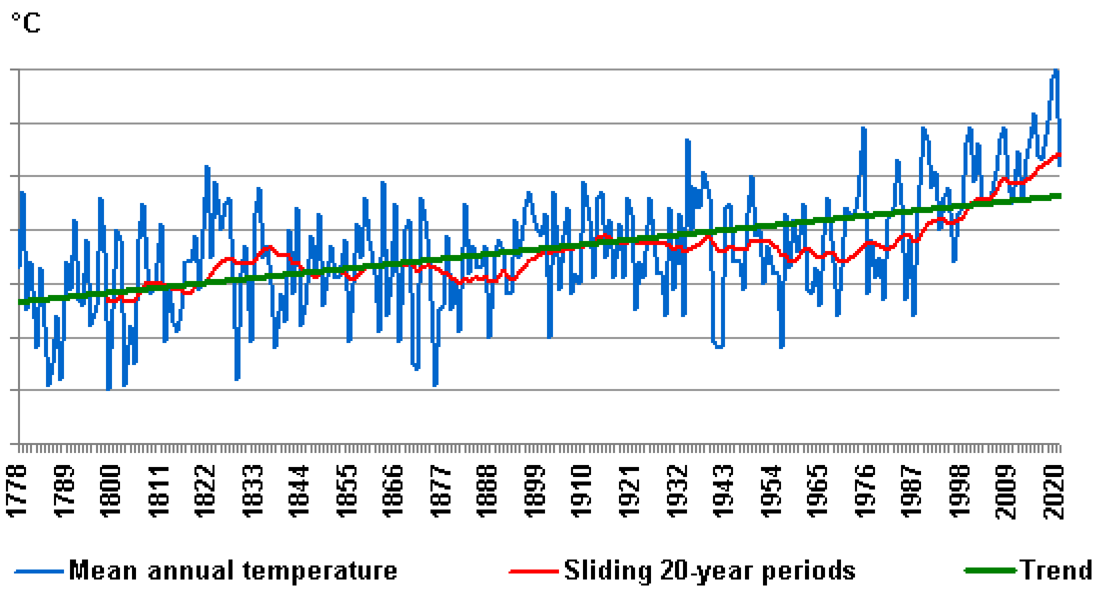


Figure 1-1. Average annual temperature in Vilnius, 1778-2021[2]

Average annual temperature, compared with the beginning of 20th century, has increased 0.7-0.9°C which leads to more frequent droughts (for example 1992, 1994, 2002, 2006 summer seasons). Changes in precipitation patterns are not homogenous – in some parts of Lithuania it

[2] Lithuanian Hydrometeorological Service under the Ministry of Environment. Available from: http://www.meteo.lt/en/web/guest/weather-temperature

is increasing, in other – decreasing. However, these changes are not very significant. There is an observed tendency of precipitation increase during cold season and decrease during warm season. Liquid precipitation is becoming more frequent in cold season.

In Lithuania climate predictions are made by downscaling COSMO-CLM, HadCM3, ECHAM5 models output data. According to the modelling results, average maximum and minimal temperature in 21st century in Lithuania should increase. Highest changes are predicted during cold season. In Vilnius, average maximum and minimum temperature could increase by 4°C in year 2100. During different months, however, this increase could be up to 7°C.

In 21st century heat waves (days when maximum temperature ≥ 30°C) will become more frequent. In 2061-2100 there could be 7 heat wave days per year more compared to 1971-2000. Cold spells, on the contrary, will become less frequent with most significant changes in January. Modelling experiments suggest that at the end of 21st century cold spells (days when minimal temperature ≤ -15°C) will occur only during January-February.

In 21st century sunshine hours will increase during August – October, and will decrease during rest of the year. This will be caused by the higher cyclonic activity during cold season.

Studies made in Lithuania assume that biggest changes in precipitation patterns will be during winter season and will not be so explicit in summer. Precipitation can double in Klaipėda – by the end of century precipitation amount can increase 16-22% compared to the end of 20th century. In Vilnius changes will be not so significant – projected increase is about 9-10%. Severe thundershowers will be more frequent on the coast (> 30%).

Changes in temperature and precipitation patterns will affect different economical activities and natural ecosystems. Coastal region is one of the most vulnerable regions in Lithuania. Lithuanian coast is in the south-eastern region of Baltic Sea which will undergo biggest changes in 21st century, due to the sink of terrain and sea level rise. Pessimistic scenario suggests that water level in this region can rise by 0.5-1.0 m. In that case, there would be high risk of flooding urban areas in Klaipėda and Palanga. Also wind surge could disturb the port activities in Klaipėda more frequently.

All information about climate condition in Lithuania is observed at Lithuanian Hydrometeorological Service.

1.1.2 Background information on greenhouse gas inventories

This National Inventory Report (NIR) covering the inventory of GHG emissions in Lithuania is being submitted to the secretariat of the UNFCCC, in compliance with the decision 24/CP.19 of the Conference of the Parties. NIR is also submitted to the European Commission and complies with EU Regulation 525/2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC.

Since 2004, inventory is prepared using common reporting format (CRF). From 2006 inventory was being prepared using CRF Reporter software, developed by UNFCCC secretariat. In 2006 for the first time complete time series 1990-2004 has been developed and submitted to the European Commission and the UNFCCC secretariat together with Lithuania's Initial Report under the Kyoto protocol. In 2016 Lithuania submitted its Second Initial Report under the Kyoto protocol (Report to facilitate the calculation of the assigned amount for the second commitment period pursuant to Article 3, paragraphs 7bis, 8 and 8bis of the Kyoto Protocol).

The GHG inventory presented here contains information on anthropogenic emissions by sources and removals by sinks for the direct (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3) and indirect (CO, NOx, SO_2, NMVOCs,) greenhouse gases. This report contains detailed information about Lithuania's GHG inventory for the period 1990-2020. NIR includes description of the methodologies and data sources used for emissions estimation by sources and removals by sinks, also description of the trends, key categories analysis, uncertainty estimates, planned improvements and description of performed procedures of QA/QC. The purpose of the report is to ensure the transparency, consistency, comparability, completeness and accuracy of GHG inventory. For the preparation of inventory upgraded CRF Reporter v.6.0.8 available as online application has been used.

The GHG inventory is prepared in accordance with the decision 24/CP.19 "Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to Convention" (FCCC/CP/2013/10/Add.3). Greenhouse gas inventory is compiled in accordance with IPCC methodology: Guidelines for National Greenhouse Gas Inventories (IPCC, 2006); 2013 Supplement to the *2006 IPCC Guidelines* for National Greenhouse Gas Inventories: Wetlands (IPCC, 2014), 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC, 2014).

1.2 A description of the national inventory arrangements

1.2.1 Institutional, legal and procedural arrangements

National system for Lithuanian GHG inventory preparation has been changing over the time. Until the year 2011, GHG inventory preparation process was performed by contracting GHG compilers on the annual basis. Aiming to increase institutional capacity for inventory preparation and continuity of the inventory preparation process in compliance with Guidelines for National systems under Article 5 paragraph 1 of the Kyoto Protocol (decision 19/CMP.1) the Government of Lithuania and the Minister of Environment have issued a number of key regulatory legal acts and assigned responsible institutions for GHG inventory preparation. The main entities participating in GHG inventory preparation process are:

- Ministry of Environment
- Environmental Protection Agency
- State Forest Service
- National Climate Change Committee
- Permanent GHG inventory working group
- Data providers
- External consultants

The principle scheme showing institutions responsibility in preparation of the GHG inventory in Lithuania and their interaction is shown in Figure 1-2.

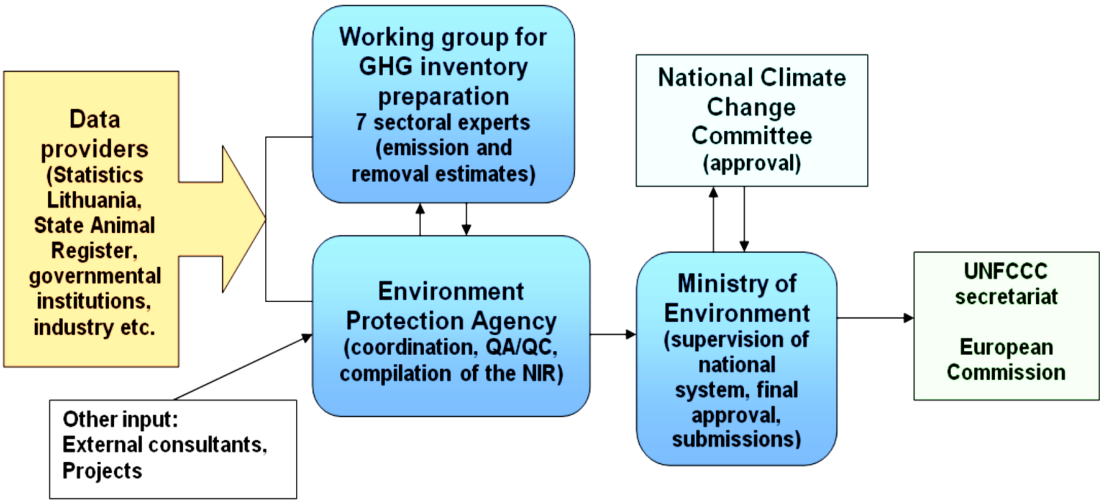


Figure 1-2. Institutional arrangement for GHG inventory

Ministry of Environment

Ministry of Environment of the Republic of Lithuania is a National Focal Point to the UNFCCC. The Ministry of Environment is designated as single national entity responsible for the national GHG inventory. It has overall responsibility for the national system of GHG inventory and is in charge of the legal, institutional and procedural arrangements for the national system and the strategic development of the national inventory. Within the ministry, the Climate Policy Group administers this responsibility by supervising the national system. The Group will continue to supervise and coordinate the preparation of the National Inventory Report, including the final review of the draft NIR. Among its responsibilities are the following:

- Overall coordination of GHG inventory process;
- Preparation of legal basis necessary for national system functioning;
- Official consideration and approval of GHG inventory;
- Approval of QA/QC plan and procedures;
- Timely submission of GHG inventory to UNFCCC Secretariat and European Commission;
- Coordination of the UNFCCC inventory reviews in Lithuania;
- Keeping of archive of official submissions to UNFCCC and European Commission;
- Informing the inventory compilers about relevant requirements for the national system.

Environmental Protection Agency

Lithuanian Environmental Protection Agency (EPA) under the Ministry of Environment starting from 2011 was nominated as an entity responsible for GHG inventory preparation by the Order of the Minister of Environment No D1-1017 (repealed by the Order of the Minister of Environment No D1-61, 23-01-2014). Before this assignment EPA was one of the main activity data and other relevant information providers for GHG inventory's Waste sector and data on F-gases.

At present EPA collects data on the use of water resources, discharges of wastewater, waste generation and treatment, pollution of ambient air and surface water, chemicals and fluorinated gases; manages the available registers, e.g. the Ambient Air Quality, the European Pollutants

Releases and Transfer Register and various databases. In 2012 Climate change division for GHG inventory preparation was established within the EPA.

As the coordinator of the GHG inventory preparation process, EPA has the following functions and responsibilities:

- Development and implementation of QA/QC plan and specific QA/QC procedures;
- Identification of data providers for specific information and collection of activity data and emission factors used to calculate emissions;
- Collaboration with sectoral experts while selecting best available methods that complying with IPCC methodology giving the priority to key categories and categories with high uncertainty;
- Documenting and archiving data related to GHG inventory and its preparation process;
- Accomplishment of cross-cutting issues: key categories analysis, overall uncertainty assessment, analysis of GHG trends;
- Preparation of CRF tables and compilation of NIR;
- Evaluation of requirements for new data, based on recommendations received during internal and external reviews.

Since 2014 submission personnel of EPA is also responsible for calculation of emissions and preparation of NIR part of the industrial processes and product use sector and agricultural soils part of the agriculture sector.

EPA establishes and operates GHG inventory archive, where GHG inventory submissions and all supporting reference material is stored and maintained. Backups are prepared on regular basis following the EPA's information management procedures. The archive is managed according to the EPA Director's Order of 26 June 2012 No AV-152 concerning the approval of the National GHG inventory data archiving procedures. The main QA/QC procedures under responsibility of EPA are performed according to the EPA Director's Order of 23 July 2012 No AV-191 concerning the approval of the National GHG inventory data quality assurance and quality control procedures.

State Forest Service

The State Forest Service (SFS) compiles the National Forest Inventory (NFI) and the forest information system, carries out monitoring of the status of the Lithuanian forests, collects and manages statistical data etc. The Service functions under the Ministry of Environment.

Since 2010 SFS in the GHG inventory preparation process is responsible for calculations of emissions and removals of LULUCF sector and Kyoto Protocol activities under Art. 3 para. 3 and 4 following the Order of the Minister of Environment 29 of July, 2010 No D1-666 (repealed by the Order of the Minister of Environment No D1-61, 23-01-2014). SFS representative is also a member of permanent working group for GHG inventory preparation under the Government Resolution No 683. In this framework, the SFS has the following responsibilities:

- Collection of activity data and emission factors used to calculate emissions and removals for LULUCF and KP-LULUCF sectors;
- Selection of methods (complying with 2006 IPCC Guidelines) for calculation of emissions and removals giving the priority to key categories and categories with a high uncertainty;

- Emission and removals estimates for LULUCF and KP-LULUCF sectors, preparation of CRF tables and NIR parts for LULUCF and KP-LULUCF and providing the final estimates for the EPA;
- Uncertainty assessment for LULUCF and KP-LULUCF sector;
- Checking and archiving of input data, prepared estimates and used materials;
- Implementation of QA/QC plan and specific QA/QC procedures related to LULUCF and KP-LULUCF;
- Evaluation of requirements for new data, based on recommendations received during internal and external reviews.

In 2012 Climate Change group responsible for LULUCF sector GHG emission and removals estimates was established within National Forest Inventory division at SFS.

Permanent GHG Inventory working group

Permanent GHG Inventory preparation working group was established by the Governmental Resolution No 683 in 2011 (as repealed on 18-11-2021 by Climate Change Management law amendment No XI-329, by which Minister of Environment was authorised to establish GHG Inventory working group) and MoE Order No D1-538 (as amended on 01-04-2022 by the Minister of Environment Order No D1-85). According to the MoE Order No D1-538, Working group for the preparation of a GHG inventory report consists of representatives from:

- Ministry of Environment (Chairman of the Working group);
- Environmental Protection Agency (Deputy Chairman of the Working group);
- Centre for Physical Sciences and Technology (energy, transport);
- Lithuanian Energy Institute (energy, except transport);
- Institute of Animal Science of the Lithuanian University of Health Sciences (agriculture);
- Lithuanian Research Center for Agriculture and Forestry (LULUCF);
- State Forest Service (LULUCF; KP-LULUCF);
- Public body Centre for Environmental Policy (waste).

Institutions, listed in the MoE Order No D1-538, nominated experts, who have experience in areas related to GHG emissions accounting.

Functions and responsibilities of the Working group for GHG inventory preparation as a whole are defined as follows:

- Evaluation of requirements for new data based on internal and external reviews;
- Search and identification of specific data providers;
- Preparation of requests for new data;
- Identification, on the basis of the *2006 IPCC* Guidelines, of methodologies for calculation of GHG emissions setting priority to the key categories and categories with high uncertainty level;
- Determination of activity data and appropriate emission factors, calculation of emissions;
- Filling in CRF tables for corresponding sectors, drafting relevant NIR sectoral chapters;

- Application of sector specific QA/QC procedures;
- Preparation of comments and answers to the questions and comments received during the EC and UNFCCC reviews;
- Collaboration with NIR compiler and QA/QC manager (EPA).

National Climate Change Committee

Before final submission to the UNFCCC Secretariat and the European Commission, National Inventory Report is forwarded to the National Climate Change Committee for the comments and final approval. The National Committee on Climate Change was set up in 2001 in the first instance and renewed in 2018. It consists of experts from government, academia and non-governmental organizations (NGOs) and has an advisory role. The main objective of the Committee is to ensure attainment of the goals related to the restriction of GHG emissions as set in the National Sustainable Development Strategy and implementation of the measures for attaining such goals. The Committee has to coordinate the issues related to formulation and implementation of the national policy on climate change management, to advise on the implementation of the provisions of the UNFCCC and coordinate compliance with the requirements of the Kyoto Protocol and the EU legal acts related to the UNFCCC. Also, the Committee submits proposals regarding the annual priorities for the financing of climate change management measures under the Program for Climate Change, which is set up by the Law on Climate Change Management adopted on 7th July 2009.

Data providers

Data providers are responsible for:

- collection of activity data;
- applying QC procedures (references in the documentation QC protocols to be provided to EPA);
- evaluation of uncertainties of the initial data.

The main providers of the data for the Lithuania's GHG inventory are:

- Statistics Lithuania publishes Lithuanian annual statistical publications (annual statistical data on energy balance, agriculture, production and commodities);
- State Forest Service under the Ministry of Environment executes National Forest Inventory (NFI), publishes annual statistical data on forestry (Lithuanian Statistical Yearbook of Forestry (2001-2015); Lithuanian Country Report on Global Forest Resources Assessment (2005, 2010));
- Annual EU Emissions Trading System (ETS) data reports by the operators;
- Environmental Protection Agency collects data and maintains database on wastewater and waste, F-gases;
- Industrial companies (nitrogen fertilizers and chemical products production company (ammonia, nitric acid production data and natural gas consumption data), oil refinery (CO_2 EFs for fuel combustion), cement production company (activity data and CaO/MgO content), lime production company (limestone composition data), glass production companies (data on dolomite, soda ash, potash and chalk use), mineral wool producer (rock wool production data, etc.));

- Center for Physical Sciences and Technology annually calculates precursors (NOx, SO_2, CO, NMVOC) emissions under the UNECE Convention on Long-range Transboundary Air Pollution;
- State Medicines Control Agency (data on metered dose inhalers, N_2O use in medicine);
- The Geological Survey of Lithuania provides data on peat extraction areas.

Aiming to set up the system to ensure a better data collection for the preparation of NIR the amendment No 1540 of the Government Resolution No 388 of 7th April 2004 was adopted in 2010. The Government Resolution determines responsibilities of other ministries and their subordinated institutions, as well as other institutions and the state science research institutes to provide data which they collect and possess and are required for the inventory compilation (Table 1-1). In the Government Resolution each ministry is assigned to collect more precise information from institutions and agencies within their jurisdiction and provide all this information to Ministry of Environment and its authorized institution – Environmental Protection Agency. The state science research institutes are authorized to perform new scientific researches, necessary for the improvement of data collection in the sectors where lack of data is identified, and to provide information required for the preparation of the NIR.

Table 1-1. Summary of institutions responsibilities to provide data under the amendment No 1540 to the Government Resolution No 388

Institution	Data
Ministry of Agriculture and it's subordinates	Information on land use and land use change areas and other relevant information Information on cattle population, age and other relevant information required for inventory's Agriculture sector's estimates preparation
Ministry of Energy and it's subordinates	All the available information required for GHG inventory's Energy sector's estimates preparation
Statistics Lithuania	All the available information required for GHG inventory preparation, including energy and fuel balance, economic development indicators, e.g. GDP, etc.
State science research institutes	All the available information required for GHG inventory preparation possessed by the Lithuanian Energy Institute, Agriculture Institute, Institute of Agrarian Economics, Institute of Animal Science, Institute of Physics, etc.
Lithuanian Transport Safety Administration	Information related to CO_2 emissions from road vehicles and other data
Ministry of Interior and it's subordinates	Information on annually registered number of vehicles, their models, types, CO_2 emissions, engine capacity and fuels used

External consultants

External experts, independent specialists providing data for the GHG inventory (data providers) may also be involved during the inventory process in preparation and upgrading of methodologies, data review and evaluation; they can also perform expertise of the whole inventory or of its separate parts. External experts can be contracted annually in the areas where specific expertise is needed and the experience and knowledge of the GHG inventory preparation working group member's is not enough.

Norway Grants partnership project "Cooperation on GHG inventory" between Lithuania and Norway under the program No 25 „Capacity-building and institutional cooperation between beneficiary state and Norwegian public institutions, local and regional authorities" has been implemented during 2015-2016. The partner of this program was Norwegian Environment Agency, which is the national entity responsible for GHG inventory preparation in Norway.

The objective of this partnership project was capacity building and improvement of the Lithuania's National system for the preparation of GHG inventory to comply with the relevant

UNFCCC and Kyoto protocol reporting requirements. The main purpose of this project was to share experiences of implementation the *2006 IPCC Guidelines* in GHG inventory. The outcomes of the project are:

- A training program for Lithuanian inventory experts to raise the technical competence in the GHG inventory and GHG emissions projections development process.
- The improvement of Quality assurance/Quality control (QA/QC) procedures and QA (Agricultural soils category and LULUCF sector) performed by Norwegian experts.
- Implementation of studies to fill in the reporting gaps in several LULUCF sector's areas:
    - Study for evaluation of carbon stocks in forest and non-forest land in soil and forest litter. This study will cover the sampling of soil and litter on the national forest inventory sample plots and analysis of these samples.
    - Study for evaluation of carbon stocks in soil and forest litter of forests that were afforested on non-forest land. The study will include determination of sample plots and sampling, analysis of samples.
    - Study for evaluation of carbon stock in dead organic matter (dead wood) analyzing various degrees of dead wood decomposition rates. The study will cover determination of sample plots and sampling, analysis of samples.
    - Study for development of the harvested wood products (HWP) accounting system and preparation of accounting methodology. This study should cover analysis of legal regulation, practices of neighboring countries and accounting principles of harvested wood products in Lithuania.
- National emission factors for energy sector development and revision study.
- Assistance in improvement of national system for GHG projections reporting. Development of proposals for fulfillment of relevant EU and UNFCCC GHG projections reporting requirements and support in modeling tools and methodologies use.

Under the planned Project activities in October 2015 two training seminars took place in Oslo, Norway: the first one was the experience sharing event on GHG inventory, and the second was dedicated to uncertainty evaluation, in which besides Norwegian and Lithuanian GHG inventory experts Latvian experts were involved. During the experience sharing seminar in break-out groups sectoral experts (energy, agriculture, industrial processes, waste and LULUCF) have discussed the most important issues and shared the experience on *2006 IPCC Guidelines* application. Additionally, during the workshop the national systems, QA/QC procedures and other cross-cutting issues were discussed. As a result of these discussions, aiming to increase the quality of Lithuania's GHG inventory, GHG inventory improvement plan will be developed. Uncertainty evaluation seminar gave an opportunity to discuss methodological and practical aspects of the uncertainty evaluation in GHG inventory, such as the collection and documentation of the expert judgement information, use of uncertainty analysis and key category analyses to prioritize inventory improvements, delimitation of uncertainty analyses, Tier 2 uncertainty evaluation (Monte Carlo method). More information about the Project ant its activities can be found at the Ministry of Environment website http://am.lrv.lt/lt/veiklos-sritys-1/klimato-kaita/norvegijos-ir-lietuvos-sesd-apskaitos-partnerystes-projektas (in lithuanian).

In 2016 the Partnership agreement between the Ministry of Environmental Protection and Regional Development of the Republic of Latvia, the Ministry of Environment of the Republic of Lithuania and the Ministry of the Environment of Estonia for the implementation of the **SEED**

Project S91 "Baltic Expert Network for Greenhouse Gas Inventory, Projections and PaMs Reporting (BENGGI)" was signed.

This network was established in order to improve the quality of inventory and projections preparation under EU and UNFCCC. Networking would allow acquiring necessary knowledge and sharing experience between experts. Baltic countries share similar natural, economical, social and political conditions that influence GHG inventory reporting procedures, as well as reported content. Under the BENGGI project following activities were implemented:

- State of the art report and assessment of GHG inventory and projections reporting to the UNFCCC and European Commission in the Baltic Sea region (BSR).
- Identifying partners for the main project - network (organizations, experts, institutes etc.)
- Organizing seminars on networking in cooperation with Scandinavian experts and holding a showcase seminar/workshop in which experts could review real issues related to reporting process and inventory preparation.
- Designing a work plan for the main project and planning indicative budget plan.

The first project seminar took place on October 24-25, 2016 in Riga (Latvia) bringing together 42 participants from 3 Baltic states and 1 participant from Sweden. The aim of the seminar was to identify strengths and weaknesses of participating countries reports and discuss how to improve the quality of reported GHG related data to the UNFCCC and European Commission. Seminar helped identify main issues within GHG inventory reporting, projections and PaMs among Baltic States. Input from Swedish expert helped frame the future network based on the Nordic experience. Experience sharing between experts added input to the research conducted by consultants.

The second project seminar took place on 22 February, 2017 in Riga (Latvia). During the workshop several issues that has potential to be solved within the cooperation network were detected. A special session was dedicated to LULUCF action issues, where experts from all Baltic states discussed the issues of LULUCF sector accounting and reporting.

As a further cooperation of Baltic experts a seminar in June 2018 was held in Vilnius. During the seminar the following GHG inventory issues among participants were discussed:

- Development of national emission factors in energy sector;
- Fugitive emissions estimation;
- Quality assurance and quality control process in energy and IPPU sectors;
- F-gases data collection systems in Baltic states;
- F-gases regulation implementation challenges.

1.2.2 Overview of inventory planning, preparation and management

Lithuania prepares National Inventory Report and fills in CRF tables according to requirements of the UNFCCC, the Kyoto Protocol and the EU greenhouse gas monitoring mechanism Regulation No 525/2013. The organization of the preparation and reporting of Lithuania's GHG inventory and the responsibilities of its different institutions are described in previous section.

The annual GHG inventory preparation follows the Work schedule for reporting. Work schedule for preparation and submission of National GHG inventory 2022 is presented in Table 1-2. Lithuania has to submit GHG inventory to the European Commission by 15th January and update estimates by 15th March annually. GHG inventory to the UNFCCC secretariat shall be submitted by 15th April annually.

Table 1-2. Work plan for preparation and submission of National GHG inventory in 2021

Activity	Responsible institutions	Deadlines
Updated QA/QC plan for 2021 inventory	EPA, MoE	August 2021
Data collection - sending of official data request letters to data providers; Methods development; QC procedures, data archiving	EPA, WG sectoral experts	June-August 2021
Meetings of all involved institutions for defining specific areas for improvements and recalculations	MoE, EPA, SFS, WG sectoral experts	September 2021
Sectoral experts input results to EPA	WG sectoral experts	August-November 2021
Filling in CRF Reporter, QC procedures, data archiving	EPA	November-December 2021
Filling in CRF and prepare NIR part on LULUCF and KP-LULUCF and sending to EPA, data archiving	SFS	December 2021
Prepare draft NIR and send to MoE and other institutions for comments	EPA	December 2021
Comments from MoE and others to EPA	MoE	December 2021
Submission of CRF tables, xml file and draft NIR to European Commission	MoE	By 15 January 2022
Possible CRF and NIR updates and final approval by MoE	EPA, WG sectoral experts, MoE	By March 2022
Sending NIR to NCCC for comments and final approval, QA procedures	MoE	By 15 March 2022
Submission of GHG inventory to European Commission	MoE	By 15 March 2022
Submission of GHG inventory to UNFCCC secretariat	MoE	By 15 April 2022

This schedule does not include timeframe for the EU inventory consistency checks, EU ESD and UNFCCC reviews and Lithuania's responses though the Work Plan may be updated during the year. Possible legislation improvements for a proper National System functioning are also not included in this scheme, but will be considered during the year and will be drafted by the Ministry of Environment, if necessary.

1.2.3 Quality assurance, quality control and verification plan

1.2.3.1 Quality assurance and quality control procedures

General Quality Control procedures applied

As a GHG inventory compiler and QA/QC manager EPA performs general QC procedures presented in the Figure below.

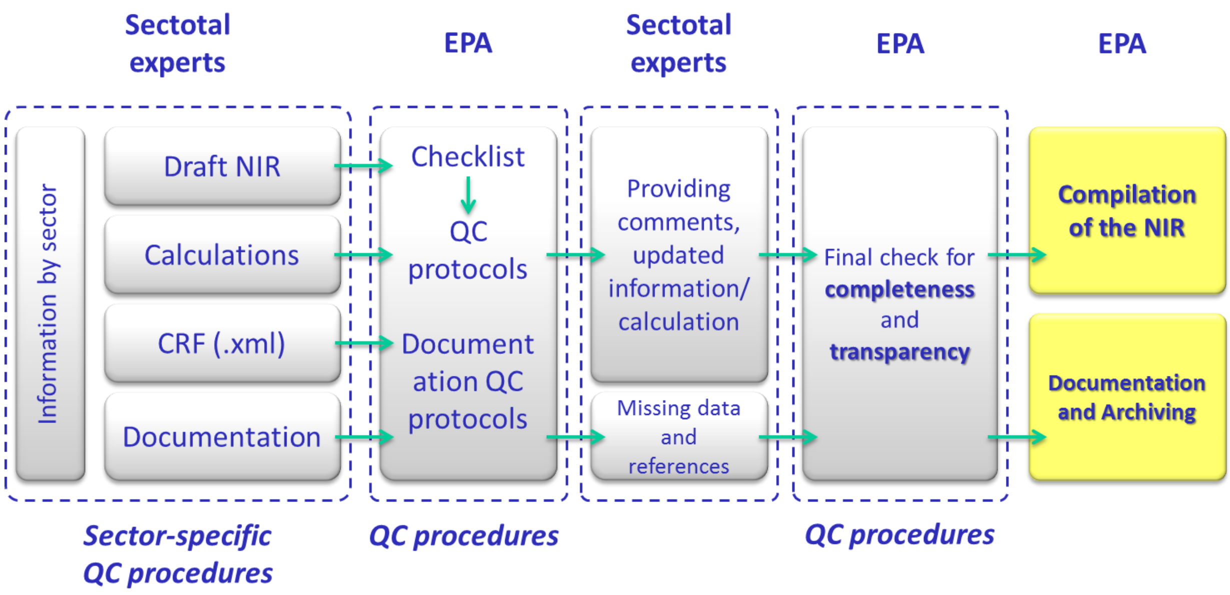


Figure 1-3. General QC procedures performed by EPA

As shown in the Figure above general procedures of the QC involves check of all the input data, assumptions and data criteria, references provided, emission calculations, units and conversion, consistency between source categories, aggregation and transcription. Besides of general check EPA fills in the Checklist for primer data check and QC protocols which record all the corrective actions taken. General control procedures also involve QC of documentation and archiving system.

QC procedures involve the *evaluation of the data collection procedure*. This covers evaluation of the following checks: if all the necessary methods, activity data and emission factors have been used; if calculations have been made correctly; if all-time series data has been provided and calculated; if comparison of current year data and calculation to the results of the previous years have been made; if the notes and comments contain all necessary information on the data sources, calculation methods, etc. Procedure also includes *evaluation of the emission calculation* by assessing the consistency of emission factors (EF) used, correctness of parameters and units, conversion factors used; correctness of data upload to CRF. Finally *general evaluation of the respective sectors* are made to establish: integrity of the inventory data structures, completeness of the inventory, consistency of the time-series, general comparison with the previous year, full correspondence of the calculations to the NIR text, all necessary information on methodology, assumptions, data sources and references are provided.

Results of the checks are recorded in the Checklists and QC protocols. After the check, the QC protocols are given back to the sectoral experts who respond to the comments of the QC Manager and, if necessary, correct the data, calculation methodology or the text in the NIR accordingly.

In addition to routine quality checks (Tier 1), source specific quality control procedures are applied, focusing on key categories and categories with high uncertainty. Source-specific QA/QC is discussed in detail in the relevant sections of the NIR.

Quality Assurance

The aim of Quality Assurance (QA) procedures is to review the complete GHG inventory by the third party which is not directly involved in preparation of inventory to assess its quality i.e.

assure that best available data and methods are used. The objective of QA implementation is to involve reviewers that can conduct an unbiased review of the inventory. Review for QA can be applied either for the whole inventory either for a certain sector. QA procedures for Lithuania's GHG inventory can be applied by performing scheduled international review (UNFCCC review, EU review) or performing national QA procedures.

National QA procedures

As QA/QC procedures are coordinated by EPA it is also under responsibility of EPA to establish a QA system comprising the procedure of the review. This procedure includes:

- Identification and prioritization of data sets for review based on key category, uncertainty analysis, conducted QC procedures, etc.;
- Identification of reviewers;
- Conclusion of findings and corrective actions based on the review results.

National review of the draft GHG inventory report takes place before the final submissions to the EC and UNFCCC secretariat (January to March) by institutions that are not directly involved to inventory preparation process. If not planned otherwise the final draft of the NIR is reviewed by Ministry of Environment, National Climate Change Committee members and, if possible, by additional institutions that are not directly involved in the preparation process.

EU level and international reviews

On the annual basis European Commission (EC) conducts quality checks of the EU member states GHG inventories. After these procedures corrections are elaborated in Lithuania's GHG inventory responding to EC quality checks and comments. Starting from 2015, EU Members states GHG inventories are also subject to review under EU Decision 406/2009/EC to check Member states' compliance with EU Effort Sharing Decision (ESD) targets. As part of the EU's effort to assist Member States in improving the quality of the GHG inventories, the checks to verify the transparency, consistency, comparability and completeness of the greenhouse gas inventory are performed. First step review checks include:

1. Assessment whether all emission source categories and gases required under Regulation (EU) No 525/2013 are reported;

2. Assessment whether emissions data time series are consistent;

3. Assessment whether implied emission factors across Member States are comparable taking the IPCC default emission factors for different national circumstances into account;

4. Assessment of the use of 'Not Estimated' notation keys where IPCC tier 1 methodologies exist and where the use of the notation key is not justified in accordance with paragraph 37 of the UNFCCC reporting guidelines on annual greenhouse gas inventories as included in Annex I to Decision 24/CP.19;

5. Analysis of recalculations performed for the inventory submission, in particular if the recalculations are based on methodological changes;

6. Comparison of the verified emissions reported under the Union's Emissions Trading System (ETS) with the GHG emissions reported pursuant to Article 7 of Regulation (EU) No 525/2013 with a view of identifying areas where the emission data and trends as submitted by the Member State under review deviate considerably from those of other Member States;

7. Comparison of the results of Eurostat's reference approach with the Member States' reference approach;

8. Comparison of the results of Eurostat's sectoral approach with the Member States' sectoral approach;

9. Assessment whether recommendations from earlier Union or UNFCCC reviews, not implemented by the Member State could lead to a technical correction;

10. Assessment whether there are potential overestimations or underestimations relating to a key category in a Member State's inventory.

UNFCCC reviews performed by the external review team (ERT) help fulfilling requirements of the Quality Assurance. By conducting annual reviews ERT indicate issues and provides recommendations where inventory needs improvements. These recommendations are taken into account in the subsequent submission by providing detailed explanation how each of the recommendation was or will be applied.

Other reviews

In 2016 review (QA) of agricultural soils category and LULUCF sector was performed by GHG inventory experts from Norwegian Environment Agency in the scope of Lithuania's and Norway's partnership project on GHG inventory. The aim of the project was capacity building and improvement of Lithuania's GHG inventory. During this QA few inconsistencies/errors in estimation of agricultural soils GHG emissions have been identified (emissions from organic soils and crop residues) and recommendations how to improve transparency of NIR were provided. All review findings and recommendations were taken into consideration and where possible implemented in this submission.

Since 2016 Lithuania participates in the "Baltic Expert Network for Greenhouse Gas Inventory, Projections and PaMs Reporting" (BENGGI) project. The purpose of the project is to develop a GHG inventory and projections expert network between the three Baltic States: Estonia, Latvia and Lithuania. The network's main objective is to increase the quality of GHG inventory reports and projections through knowledge and experience sharing. In the light of this project peer reviews in the Baltic states are foreseen.

1.2.3.2 QA/QC plan

The overall aim of the quality system is to maintain and improve the quality in all stages of the inventory work, in accordance with decision 24/CP.19. The quality objectives of the QA/QC plan and its application are an essential requirement in the GHG inventory and submission processes in order to ensure and improve the inventory principles: transparency, consistency, comparability, completeness, accuracy, timeliness and confidence in the national emissions and removals estimates for the purposes of meeting Lithuania's reporting commitments under the UNFCCC and the Kyoto protocol. In addition, one of the objectives of the quality system is to determine short-term and long-term activities for the GHG inventory improvement plan.

QA/QC plan was updated in 2020, some parts of the QA/QC plan are updated annually (e.g. list of planned improvements). EPA was responsible for the update of QA/QC plan which was approved by the MoE. EPA is responsible for the coordination and implementation of the Plan with a supervision performed by the MoE.

The QA/QC plan describes the quality objectives of the GHG inventory, the national system for inventory preparation, tasks and responsibilities. A description is provided of various formal procedures already implemented in the development of the GHG inventory and planned improvements for the period 2020-2021.

1.2.3.3 Verification activities

According to the obligations under the EU Regulation No 525/2013 on a mechanism for monitoring and reporting GHG emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC Lithuania has to evaluate and report on consistency of the reported data in GHG inventory to submitted information under other Directives, statistical databases, etc. This information includes:

- a brief assessment whether the emissions estimates of carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx) and non-methane volatile organic compounds (NMVOC), in inventories submitted by the Member State under Directive 2001/81/EC of the European Parliament and of the Council and under the UNECE Convention on Long-range Transboundary Air Pollution are consistent with the corresponding emission estimates in greenhouse gas inventories under Regulation (EU) No 525/2013;
- comparison between the reference approach calculated on the basis of the data included in the greenhouse gas inventory and the reference approach calculated on the basis of the data reported pursuant to Article 4 of Regulation (EC) No 1099/2008 of the European Parliament and of the Council and Annex B to that Regulation (EU) No 525/2013;
- consistency check of the data reported on fluorinated greenhouse gases in the greenhouse gas inventory with the data reported pursuant to Article 6(1) of Regulation (EC) No 842/2006 (referred to in Article 7(1)(m)(ii) of Regulation (EU) No 525/2013);
- consistency check of reported emissions in the greenhouse gas inventory with data of the actual or estimated allocation of the verified emissions reported by installations and operators under Directive 2003/87/EC (referred to in Article 7(1)(k) of Regulation (EU) No 525/2013).

Lithuania also conducts annual consistency checks of activity data (mainly livestock population) provided in the greenhouse gas inventory with those reported by FAO statistics.

1.2.3.4 Treatment of confidential information

There is no information in GHG inventory that would be identified as confidential.

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

No changes in the national inventory arrangements were made since the previous submission.

1.3 Inventory preparation, and data collection, processing and storage

1.3.1 Inventory preparation process

Lithuania prepares NIR and CRF tables annually according to requirements of the UNFCCC, the Kyoto Protocol and the EU greenhouse gas monitoring mechanism Regulation No 525/2013. The annual GHG inventory preparation follows the Work schedule for reporting.

Work process of preparation and submission of National GHG inventory in Lithuania is organized by performing planned activities. The Figure below shows a general overview of the NIR preparation and submission process cycle.

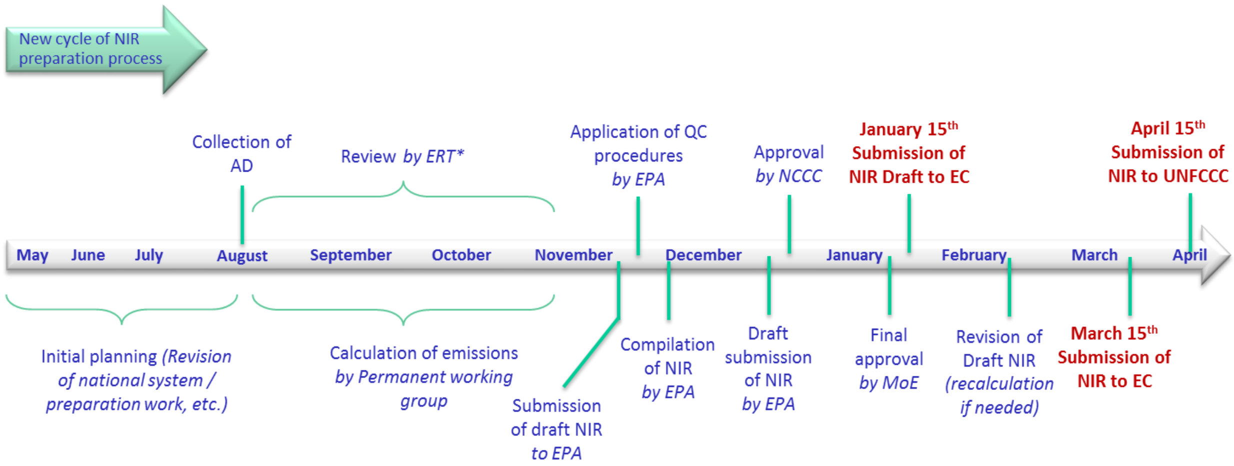


Figure 1-4. General Timeline of NIR preparation and submission process

Lithuania has to submit GHG inventory to the European Commission by 15th January and update estimates by 15th March annually. GHG inventory to the UNFCCC secretariat shall be submitted by 15th April annually.

This timeline shows only general activities overview and might be modified according to the reviews scheduled, planned projects, etc.

1.3.2 Data collection, processing and storage

Data is being collected annually from the main data sources. All data sources and data providers are described in Chapter 1.1.2 (Data providers).

Processing of data and its storage (archiving) is one of the main QC procedures. Proper documentation and archiving system is an essential part of inventory compilation and assurance of inventory transparency. Inventory documentation must be sufficiently comprehensive, clear and adequate for all present and future experts to be able to obtain and review the references used and reproduce the inventory calculations.

The archive of the GHG inventory is placed within the Environmental Protection Agency (EPA).

The manual describing common archiving procedures of Lithuania's GHG inventory (archive data structure, timing, data security etc.) was approved on 26th of June 2012 and published as EPA Director's Order No. AV-152 *Concerning the approval of the National GHG inventory data archiving procedures*. The document describes general archiving principles, timing and outlines the structure of the Lithuania's GHG inventory archive. Figure 1-5 outlines Lithuania's GHG inventory archive structure.

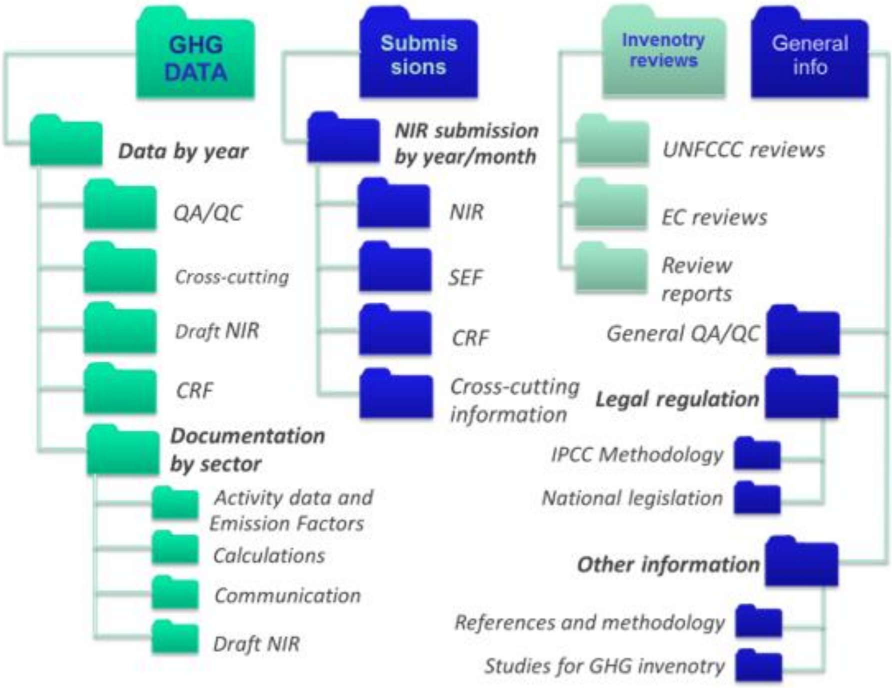


Figure 1-5. Lithuania's GHG inventory archive structure

As shown in Figure archive is organized by locating information in 5 main folders: 1) *General information* contains all related legislation (national, EU and UNFCCC decisions), IPCC methodologies and other methodological information provided by UNFCCC, all information related to QA/QC system (QA/QC plans and templates for protocols and checklists while performing QC procedures), other relevant information e.g. important sources and references, conducted studies and projects, etc. 2) *GHG data* – this is the folder were all activity data used for calculations are stored. Data in this section is stored by year of submission further allocating it by sectors. Each CRF sector contains the following information – activity data and emission factors, calculations (excel spread sheets), communication (data or other relevant information obtained through communication with external experts, companies etc.), draft versions of text part with comments and tracked changes. Besides the information on each sector each folder by year contains information on cross-cutting issues (key categories and uncertainty analysis, GHG trends), draft CRF xml files, draft versions of NIR with comments and tracked changes, quality control protocols, documentation protocols and checklists for each sector. As submission of NIR is scheduled in January, March and April information located in GHG data might be further stored by month of submission if major recalculations are applied. 3) Folder *Submissions* stores information by date of submission (NIR, its annexes and cross-cutting information, SEF tables, CRF tables and xml file). 4) *Inventory Reviews* stores information of EU and UNFCCC review process (centralized and in-country review questions and answers and review reports).

In order to assure quality of archiving system EPA performs quality control procedures for documentation and archiving system. Figure 1-6 provides main QC procedures applied for documentation placed in archive.

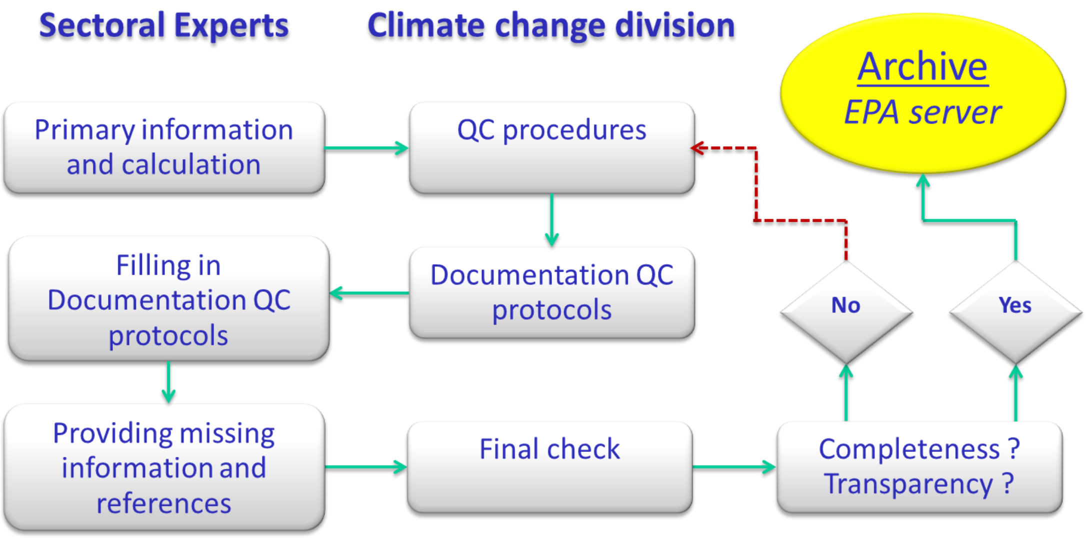


Figure 1-6. Quality control procedures applied for data archiving system

In order to assure transparency and completeness of data archived EPA developed documentation quality control protocols for each sector. Prior to each submission of NIR comprehensive quality checks are performed over each sector to identify missing references and documentation. Taking into consideration check results, sectoral experts provide missing references, documentation and/or additional explanation to the EPA. This procedure also allows EPA experts to assess the rationale for methods choice and availability of activity data. Further all relevant GHG inventory information is collected, systematized, compiled and arranged according to the established archiving system.

1.4 Brief general description of methodologies and data sources used

1.4.1 Methodologies used for preparation of GHG inventory

GHG inventory contains information on the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). Information is provided on the following indirect greenhouse gases: carbon monoxide (CO), nitrogen oxides (NOx) and non-methane volatile organic compounds (NMVOCs), as well as sulphur oxides (SOx). Information on indirect GHG emissions is provided in detail in Chapter 9.

The GHG inventory is prepared in accordance with IPCC methodology:

- *2006 IPCC Guidelines* for National Greenhouse Gas Inventories (IPPC*, 2006*);
- 2013 Supplement to the *2006 IPCC Guidelines* for National Greenhouse Gas Inventories: Wetlands (IPCC*, 2014*);
- 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC*, 2014*);
- *2019 Refinement* to the *2006 IPCC Guidelines* for National Greenhouse Gas Inventories (IPCC, 2019).

GHG inventory is prepared also taking into account requirements, provided in Regulation (EU) No 525/2013 of 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 and repealing Decision No 280/2004/EC.

Simple equations that combine activity data with emission factors are used. Different sources in the transport, agriculture, waste and LULUCF sectors necessitate the use of more complicated equations and models. Table 1-3 summarizes the most important data sources used in the inventory.

Table 1-3. Main data sources used in the greenhouse gas inventory

Sector	**Main data sources**
1.A Energy: Fuel Combustion	Energy Statistics database (Statistics Lithuania) EU ETS emission data
1.B Energy: Fugitive Emissions	Energy Statistics database (Statistics Lithuania) Lithuanian Geological Service Individual companies
2. Industrial Processes and Product Use	Individual production plants EU ETS emission data Industrial statistics database (Statistics Lithuania) F-gases database (EPA) Published literature
3. Agriculture	The Register of Agricultural Information and Rural Business Centre of Ministry of Agriculture Agricultural Statistics database (Statistics Lithuania) Regional Waste Management Centres International fertilizer association (IFA) Published literature
4. LULUCF	NFI (National Forest Inventory) State Forest inventory Lithuanian Statistical Yearbook of Forestry Published literature
5. Waste	Waste database (EPA) Water and wastewater database (EPA) Regional Waste Management Centres

A detailed description of methodologies and data sources used in the preparation of the emission inventory for each sector is outlined in the relevant chapters.

1.5 Brief description of key categories

Key categories analyses for the GHG inventory were performed according to the *2006 IPCC Guidelines* Approach 1 and Approach 2 level and trend assessment of the key categories. Level assessment with uncertainty (LU_{xt}) and trend assessment with uncertainty (TU_{xt}) were calculated using Approach 1 uncertainty analysis (Annex II).

The base year for the analysis is 1990 for the greenhouse gases CO_2, CH_4, N_2O and for the F-gases HFC, PFC, SF_6 and NF_3. The categories identified by Approach 2 that are different from categories identified by Approach 1 were treated as key categories.

The level of disaggregation used for the key category analysis was performed by taking into account country-specific issues, specifically, in energy and agriculture sectors key categories were broken down into sub-source categories in order to reflect the level at which the EFs were applied and in order to focus efforts towards methodological improvements on these most significant sub-source categories.

Approach 1 key category (level assessment) with a highest contribution to national total emission in 2020 is 1.A.3.b Road transportation contributing 17% and in 1990 is 4.A.1 Forest land remaining forest land - carbon stock change in biomass (CO_2) - 11%. The second most important source of greenhouse gas emissions in 2020 is 4.A.1 Forest land remaining forest land - carbon stock change in biomass (CO_2) accounting for 15%.

Approach 1 key category (trend assessment) with a highest contribution to national total emission in 2020 is 4.A.1 Forest land remaining forest land - carbon stock change in biomass (CO_2) accounting for 17% of the total emissions.

Key category analysis using a subset of inventory estimates was conducted. The LULUCF sector has been excluded from the analyses. Level and trend assessment of the subset identified additional categories when compared to Approach 1 analysis of total inventory. Additional categories identified by level and trend assessment are 1.A.4 Other sectors-Liquid fuels (N_2O) and 3.B.2 Manure Management – Cattle (N_2O).

Approach 2 key category (level assessment) with a highest contribution to national total emission is 4.A.1 Forest land remaining forest land - carbon stock change in biomass (CO_2) – consists 18% in 2020 and 21% in 1990.

The following categories were identified by Approach 2 using subset (Level and Trend assessment) when compared to Approach 1 and Approach 2:

- 1.A.1. Energy industries-Biomass (CH_4);
- 1.A.4 Other sectors-Liquid fuels (N_2O);
- 1.A.4 Other sectors-Solid fuels (CH_4);
- 3.B.2 Manure Management – Cattle (N_2O);
- 5.B Biological Treatment of Solid Waste (N_2O).

Results of the Approach 1 and Approach 2 Level and Trend key categories analysis are provided in Table 1-4. More detailed information on key categories calculations is provided in the Annex I.

Table 1-4. Key category analysis by Level and by Trend

IPCC Category	***Greenhouse gas***	***Identification criteria***	***Comments****
1.A.1. Energy industries-Other fossil fuels	CO_2	L1, T1	
1.A.1. Energy industries-Solid fuels	CO_2	T1	
1.A.1. Energy industries-Biomass	N_2O	T2	
1.A.1. Energy industries-Biomass	CH_4		L2sub, T2sub
1.A.1.a Public electricity and heat production - Gaseous Fuels	CO_2	L1, T1, T2	
1.A.1.a Public electricity and heat production - Liquid Fuels	CO_2	T1, T2	
1.A.1.b Petroleum refining - Liquid Fuels	CO_2	L1, T1	
1.A.1.b Petroleum refining - Gaseous Fuels	CO_2	L1, T1	
1.A.2 Manufacturing industries and construction-Gaseous fuels	CO_2	L1, T1	
1.A.2 Manufacturing industries and construction-Liquid fuels	CO_2	L1, T1, T2	
1.A.2 Manufacturing industries and construction-Solid fuels	CO_2	L1, T1	
1.A.3.b Road transportation	CO_2	L1, L2, T1, T2	
1.A.3.c Railways	CO_2	L1	
1.A.4 Other sectors-Biomass	CH_4	L1, L2, T1, T2	

1.A.4 Other sectors-Biomass	N_2O	0	L2sub, T2sub
1.A.4 Other sectors-Gaseous fuels	CO_2	L1, T1	
1.A.4 Other sectors-Liquid fuels	CO_2	L1, T1	
1.A.4 Other sectors-Liquid fuels	N_2O		T1sub, T2sub
1.A.4 Other sectors-Solid fuels	CH_4		T2sub
1.A.4 Other sectors-Solid fuels	CO_2	L1, T1, T2	
1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH_4	L1, T1	
1.B.2 Oil, natural gas and other emissions from energy production	CO_2	L1, L2, T1, T2	
2.A.1 Cement Production	CO_2	L1, T1	
2.A.2 Lime Production	CO_2	T1	
2.A.4 Other process use of carbonates	CO_2	T1	
2.B.1 Ammonia Production	CO_2	L1, T1	
2.B.2 Nitric Acid Production	N_2O	L1, T1	
2.F.1 Refrigeration and Air Conditioning Equipment	HFCs	L1, L2, T1, T2	
3.A.1 Enteric Fermentation - Cattle	CH_4	L1, L2, T1, T2	
3.B.1.1 Manure Management - Cattle	CH_4	L1	
3.B.1.3 Manure Management - Swine	CH_4	T1	
3.B.2 Manure Management - Cattle	N_2O		L1sub, L2sub
3.B.2 Manure Management - Other	N_2O	T2	
3.B.2 Manure Management - Indirect N_2O Emissions	N_2O	L1, L2, T2	
3.D.1.1 Direct N_2O Emissions From Managed Soils - Inorganic N Fertilizers	N_2O	L1, L2, T1, T2	
3.D.1.2 Direct N_2O Emissions From Managed Soils - Organic N Fertilizers	N_2O	L1, L2, T2	
3.D.1.3 Direct N_2O Emissions From Managed Soils - Urine and dung deposited by grazing animals	N_2O	L1, L2, T1, T2	
3.D.1.4 Direct N_2O Emissions From Managed Soils - Crop Residues	N_2O	L1, L2, T1, T2	
3.D.1.6 Direct N_2O Emissions From Managed Soils -Cultivation of organic soils	N_2O	L1, L2, T1, T2	
3.D.2.1 Indirect N_2O Emissions From Managed Soils - Atmospheric deposition	N_2O	L1, L2	
3.D.2.2 Indirect N_2O Emissions From Managed Soils - Nitrogen leaching and run-off	N_2O	L1, L2, T1, T2	
4.A Forest land, Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO_2	L1, L2, T1, T2	
4.A.1 Forest land remaining forest land - carbon stock change in biomass	CO_2	L1, L2, T1, T2	
4.A.1 Forest land remaining forest land - net carbon stock change in dead wood	CO_2	L1, L2, T1	
4.A.2 Land converted to forest land - carbon stock change in biomass	CO_2	L1, L2	

4.A.2 Land converted to forest land - net carbon stock change in mineral soils	CO_2	L1, L2	
4.B Cropland,Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO_2	L1, L2, T1, T2	
4.B.1 Cropland remaining cropland - net carbon stock change in mineral soils	CO_2	L1, L2, T1, T2	
4.B.2 Land converted to cropland - net carbon stock change in mineral soils	CO_2	L1, L2	
4.B.2 Land converted to cropland- carbon stock change in biomass	CO_2	L1, L2, T1, T2	
4.B.2 Land converted to cropland- net carbon stock change in dead organic matter	CO_2	L1, T1	
4.C.2 Land converted to grassland - net carbon stock change in mineral soils	CO_2	L1, L2	
4.C.2 Land converted to grassland - net carbon stock change in biomass	CO_2	T1, T2	
4.D.1 Wetlands remaining wetlands -net carbon stock change in organic soils	CO_2	L1, L2, T1, T2	
4.D.2 Land converted to wetlands	CO_2	L1, L2, T1, T2	
4.E.2 Settlements	N_2O	T2	
4.E.2 Land converted to settlements	CO_2	L1, T1, T2	
4.G Harvested wood products	CO_2	L1, L2, T1, T2	
5.A Solid Waste Disposal	CH_4	L1, L2	
5.B Biological treatment of waste	CH_4	T2	
5.B Biological treatment of waste	N_2O		T2sub
5.D Wastewater Treatment and Discharge	CH_4	L1, L2, T1, T2	

**Lsub, Tsub denote the categories that were identified by level and trend assessment for a subset without LULUCF when compared to Approach 1*

Qualitative assessment of the key categories was performed (high uncertainty, mitigation technologies, significant anticipated changes in future emission levels criteria). Application of qualitative criteria identified the same source categories already defined as key through the quantitative analysis. For example, high uncertainty criteria is considered already by using Approach 2 key categories assessment, where results of the uncertainty analysis to identify key categories are used; mitigation technologies criteria could be applied to N_2O emissions from nitric acid production, but this is already key category according to KCA Approach 1 and Approach 2; there are also no expectations to grow emissions significantly in Lithuania in the future according to national GHG emission projections developed by Lithuania and overall Lithuania's commitments and policy to reduce GHG emissions in the future.

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

Uncertainty estimation was performed using Approach 1 of *2006 IPCC Guidelines*. Quantitative uncertainties assessment was carried out for the emission level 2020 and for 1990-2020 trend in emissions for all source categories comprising emissions of CO_2, CH_4, N_2O, HFCs, SF_6 and NF_3 gases (in CO_2 equivalents). The GHG uncertainty estimates do not take into account the uncertainty of the Global Warming Potential (GWP) factors. The sources included in the uncertainty estimate cover 99.9% of the total GHG emission.

Uncertainties were estimated using combination of available default factors proposed in *2006 IPCC Guidelines* with uncertainties based on expert judgment, consultation with statistical office. Approach 1 uncertainty evaluation analysis (including and excluding LULUCF) is presented in Annex II Tables 2-1, 2-2.

Uncertainty categories are reported in line with key categories analysis and they are used for Tier 2 key categories analysis.

The uncertainty analysis was performed for each sector for all gases combined on purpose to have more detailed information for inventory improvements planning. Uncertainties of activity data of different gases and uncertainties of emission factor from the same sectors were combined using *2006 IPCC Guidelines* Equation 3.2.

$$U_{total} = \frac{\sqrt{(U_1 \cdot x_1)^2 + (U_2 \cdot x_2)^2 + \cdots + (U_n \cdot x_n)^2}}{|x_1 + x_2 + \ldots + x_n|}$$

Detailed information about uncertainty assessment is described under each sub-sector in the relevant NIR chapters.

Overall uncertainty

The total national GHG emission including LULUCF in the year 2020 is estimated with an uncertainty of ±28.1% and the trend of GHG emission 1990-2020 has been estimated to be ±6.3%.

The total national GHG emission excluding LULUCF in the year 2020 is estimated with an uncertainty of ±10.6 and the trend of GHG emission 1990-2020 has been estimated to be ±2.3%.

1.7 General assessment of the completeness

Lithuania's GHG emission inventory includes all the major emission/removal sources identified by the *2006 IPCC Guidelines* with some exceptions reported as "not estimated" (NE) (see Table 1-5). Emissions/removals are not estimated mainly due to lack of available IPCC methodologies and/or lack of activity data.

Table 1-5. Source/sinks categories reported as "NE" in the GHG inventory

GHG	Source/Sink category	Explanation
CH_4	4.F Other Land 4.F Other Land/4(V) Biomass Burning	No default methodology is provided for estimation of emissions from biomass burning in other land category therefore it is reported as NE.
CH_4	4.A Forest Land/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils/Sub_01	Under Tier 1 (*2006 IPCC Guidelines*, Chapter 7, p. 7.14) methane emissions are assumed to be insignificant in the drained peatlands.
CH_4	4.D Wetland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Peat Extraction Lands/Total Organic Soils/Drained Organic Soils	Under Tier 1 (*2006 IPCC Guidelines*, Chapter 7, p. 7.14) methane emissions are assumed to be insignificant in the drained peatlands.
CO_2	4.F Other Land 4.F Other Land/4(V) Biomass Burning	No default methodology is provided for estimation of emissions from biomass burning in other land category therefore it is reported as NE.
CO_2	4.C Grassland 4.C.2 Land converted to grassland/Carbon stock change/4.C.2.2 Wetlands converted to grassland 4.C.2 Land converted to grassland/Carbon stock change/4.C.2.2 Wetlands converted to grassland	No default values of B_{BEFORE} were provided for wetlands and settlements converted to grassland, furthermore it was assumed that all conversions to grassland occur on lands with herbaceous vegetation for which the biomass immediately before conversion (B_{BEFORE}) can be assumed to be equal to the one in grassland,

		therefore no carbon stock changes in living biomass were estimated and thus reported as NE.
N_2O	4.F Other Land 4.F Other Land/4(V) Biomass Burning	No default methodology is provided for estimation of emissions from biomass burning in other land category therefore it is reported as NE.

Summary of Lithuania's GHG inventory completeness is provided below.

Table 1-6. Summary of GHG inventory completeness

IPCC source and sink categories			CO_2	CH_4	N_2O	HFCs	PFC	SF_6	NF_3
1	**Energy**								
	A	Fuel combustion	√	√	√				
	1	Energy industries	√	√	√				
	2	Manufacturing industries and construction	√	√	√				
	3	Transport	√	√	√				
	4	Other sectors	√	√	√				
	5	Other	√	√	√				
	B	Fugitive emissions from fuels	√	√	√				
	1	Solid fuels	NO	NO	NO				
	2	Oil and natural gas	√	√	√				
	C	CO_2 Transport and storage	NO						
	D	Memo items							
	1	International Bunkers	√	√	√				
	2	Multilateral Operations	NO	NO	NO				
	3	CO_2 emissions from biomass	√						
	4	CO_2 Captured	NO						
2	**Industrial processes and product use**								
	A	Mineral products	√						
	B	Chemical industry	√	NO	√	NO	NO	NO	NO
	C	Metal production	√	NO	NO	NO	NO	NO	NO
	D	Non-energy products from fuels and solvent use	√	NO	NO				
	E	Electronics industry				NO	NO	√	√
	F	Product uses as substitutes for ODS				√	NO	NO	NO
	G	Other product manufacture and use	NO	NO	√	NO	NO	√	NO
	H	Other	√	NO	NO	NO	NO	NO	NO
3	**Agriculture**								
	A	Enteric fermentation		√					
	B	Manure management		√	√				
	C	Rice cultivation		NO					
	D	Agricultural soils		NA	√				
	E	Prescribed burning of savannahs		NO	NO				
	F	Field burning of agricultural residues		NO	NO				
	G	Liming	√						
	H	Urea application	√						
	I	Other carbon-containing fertilizers	NE						
	J	Other	NO	NO	NO				
4	**Land use, land use change and forestry**								
	A	Forest land	√	√	√				
	B	Cropland	√	√	√				
	C	Grassland	√	√	√				
	D	Wetlands	√	NO/NE	√				
	E	Settlements	√	NO	√				
	F	Other land	√	NO/NE	√				
	G	Harvested Wood Products	√						
	H	Other land	NO	NO	NO				
5	**Waste**								
	A	Solid waste disposal on land	NO/NA	√					

	B	Biological treatment of solid waste		√	√				
	C	Incineration and open burning of waste	√	√	√				
	D	Wastewater treatment and discharge		√	√				
	E	Other	NO	NO	NO				
6	**Other**		NO	NO	NO	NO	NO	NO	NO

√ – Emissions of the gas are covered under the source category

NA – Emissions of the gas are not applicable to the source category

NO – Emissions of the gas does not occur in Lithuania for the source category

NE – Emissions on the gas are not estimated for the source category

2 TRENDS IN GREENHOUSE GAS EMISSIONS

2.1 Description and interpretation of emission trends for aggregated GHG emissions

Total GHG emissions amounted to 20,182.6 kt CO_2 eq. excluding LULUCF and 14,775.2 kt CO_2 eq. including LULUCF in 2020. GHG include CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3. The emissions of GHG expressed in kt CO_2 eq. in 2020 have decreased by 57.8% comparing to the base year excluding LULUCF and by 65.1% including LULUCF. Figure 2-1 shows the estimated total GHG emissions in CO_2 eq. from 1990 to 2020.

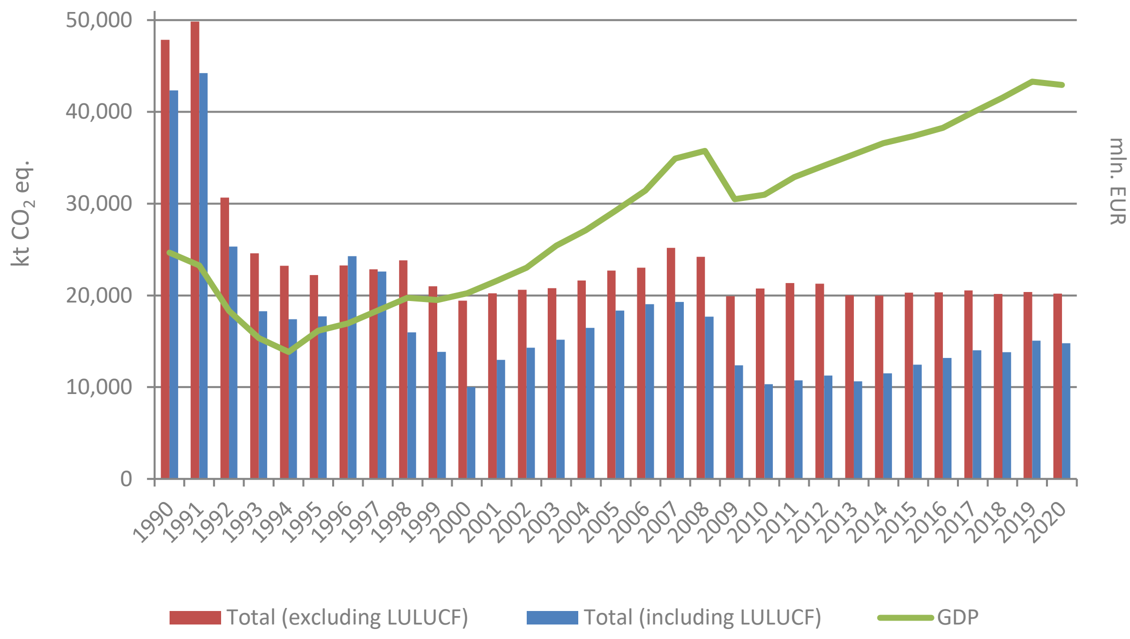


Figure 2-1. Emission trends for aggregated GHG in 1990-2020

The most important greenhouse gas is CO_2 as it contributed 67.6% to the total national GHG emissions expressed in CO_2 eq. in 2020, followed by CH_4 (14.2%) and N_2O (15.6%). PFCs, HFCs, SF_6 and NF_3 amounted together to 2.5% of the total GHG emissions (excl. LULUCF) in Lithuania.

Upon its independence from the Soviet Union in 1990, after 50 years of annexation, Lithuania inherited an economy with high energy intensity. A blockade of resources, imposed by USSR during 1991-1993 led to a sharp fall in economic activity, as reflected by the decrease of the Gross Domestic Product (GDP) in the beginning of nineties. The economic situation improved in the middle of the last decade and GDP has been increasing until 1999 (during 1999-2000, GDP decreased due to the economic crisis in Russia) and GDP continued increasing from 2001 to 2008. In 2009 GDP decreased due to the world economic crisis and after it the constant growth of GDP is observed. These fluctuations were reflected in the country's emissions of greenhouse gases.

2.2 Description and interpretation of emission trends by sector

The trends of greenhouse gas emissions by sectors are presented in Table 1 showing greenhouse gas emissions by sectors, expressed in CO_2 equivalent and taking into account greenhouse gas emissions/removals from LULUCF sector.

Energy

Energy sector is the most significant source of GHG emissions in Lithuania with 58.5% share of the total emissions (excl. LULUCF) in 2020. Emissions from energy include CO_2, CH_4 and N_2O emissions.

Emissions of total GHG from energy sector have decreased almost 3 times from 33,122.5 kt CO_2 eq. in 1990 to 11,816.7 kt CO_2 eq. in 2020 (Figure 2-2). Significant decrease of emissions was mainly due to economic slump in the period 1991-1995. During the fast economic growth over the period 2000-2008 GHG emission in energy sector was increasing about 2.5% per annum. The global economic recession had impact on GHG reduction in energy sector by 8.9% in 2009. The closure of Ignalina NPP and GDP increase had impact on greenhouse gas increase by 8.1% in 2010. Since January 2015 the liquefied natural gas (LNG) terminal started operation in Lithuania which opened the natural gas market in Lithuania. In 2015, 16.5% of total natural gas import to Lithuania was imported via LNG terminal. In 2016, the share of imported natural gas via LNG terminal increased significantly and during the period 2016-2020 it varied in the range of 35-65%.

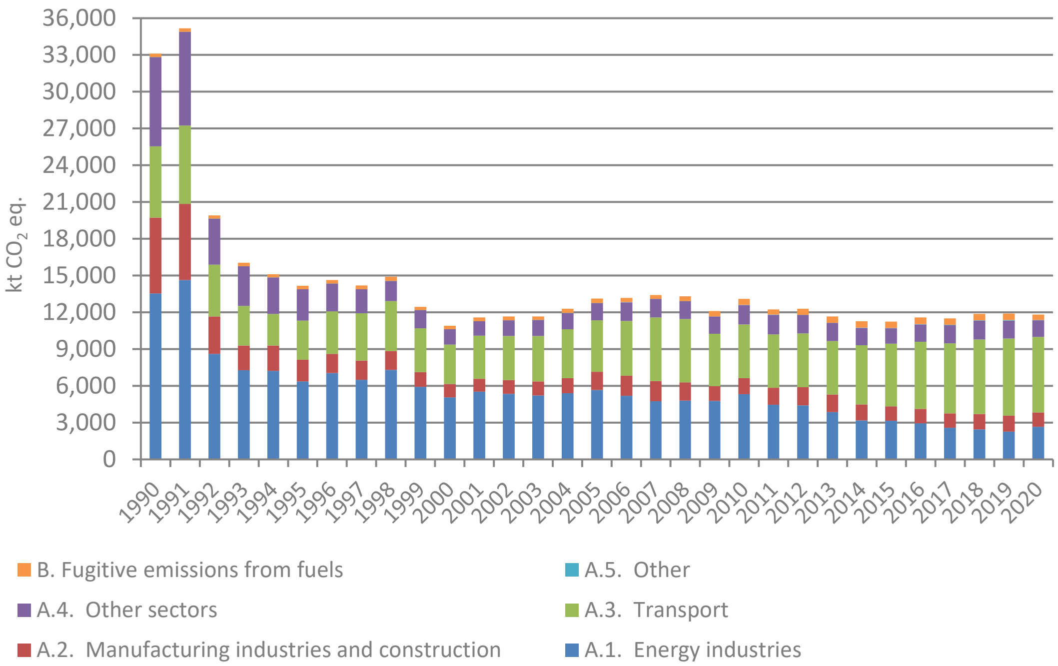


Figure 2-2. Trend of GHG emissions in energy sector during the period 1990-2020

During the period 1990-2020 the share of transport sector significantly increased. In 1990 transport sector accounted for 17.6% of total GHG emission in energy sector whereas in 2020 – 52.0%. This growth is influenced by the increase in the volume of goods transported by road, increasing number of road vehicles and greater emissions from passenger cars.

The increase of GHG emissions from fugitive sources is mainly caused by the increase of CO_2 emissions from hydrogen production in oil refinery reflecting amount of hydrogen produced. In 2007-2010 GHG emissions from hydrogen production were increasing by average 50.5% per annum.

Industrial Processes and Product Use

Emissions from industrial processes and product use sector (referred to as non-energy related ones) amount to 15.3% of the total emissions (excl. LULUCF) in 2020. Emissions from industrial processes and product use include CO_2, N_2O and F-gases emissions. Emissions of total GHG from the industrial processes and product use sector have decreased by 30.6% from 4,460.2 kt CO_2 eq. in 1990 to 3,093.5 kt CO_2 eq. in 2020 (Figure 2-3).

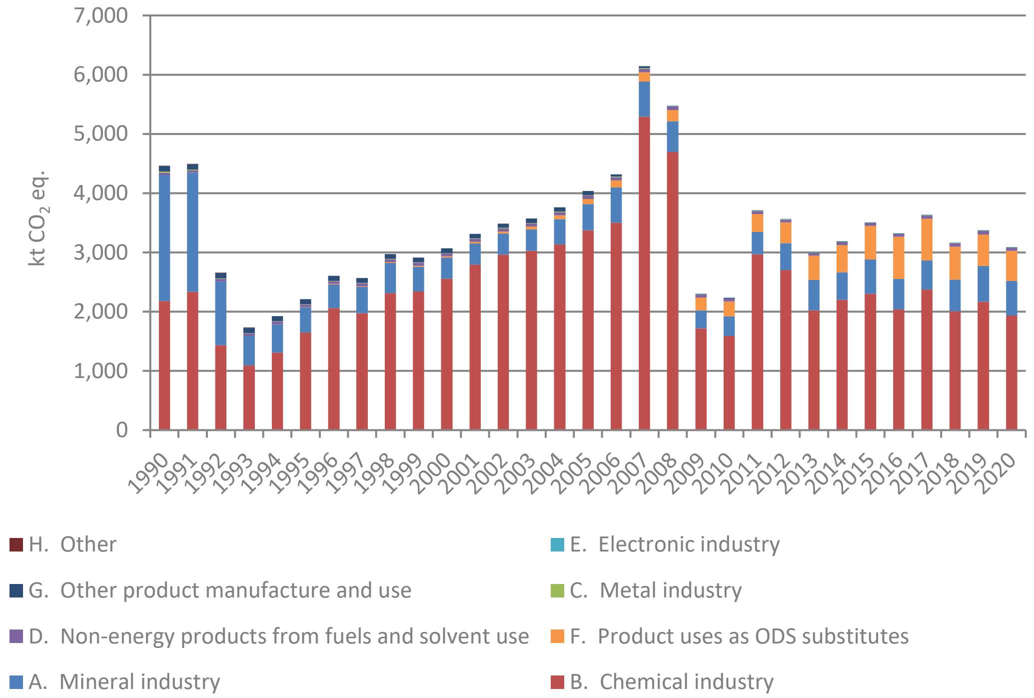


Figure 2-3. Trend of GHG emissions in industrial processes and product use sector during the period 1990-2020

CO_2 emissions from ammonia production contributed 13.1% to the total national CO_2 emissions (excl. LULUCF) in 2020. The lowest emission of CO_2 was in 1993 due to decrease of the ammonia production and the peak of CO_2 emissions was in 2007 when the ammonia production increased. Comparing with 2019 ammonia production in 2020 decreased by 5.3% and CO_2 emissions decreased by 10.4% in 2020.

Nitric acid production is the main source of N_2O emissions in industrial processes sector and accounts for 4.9% in the total national N_2O emissions (excl. LULUCF) in 2020. N_2O emissions had been increasing since 1994 and reached its peak in 2007. After the installation of the secondary catalyst in nitric acid production enterprise in 2008 the emissions of N_2O dropped drastically till 2010 and increased in 2011 because of the increase of production capacity. After 2011 emissions began to decrease because the project of catalyst installation has been finished. Comparing with 2019 nitric acid production in 2020 decreased by 4.1% and N_2O emissions decreased by 15.8%.

Agriculture

Agriculture sector is the second most important source of greenhouse gas emissions in Lithuania contributing 22.1% to the total GHG emission (excl. LULUCF). The emissions from agriculture sector include CH_4, N_2O and CO_2 emissions. Emissions of total greenhouse gases from agriculture sector have decreased almost 2 times from 8,756.0 kt CO_2 eq. in 1990 to 4,450.7 kt CO_2 eq. in 2020 (Figure 2-4).

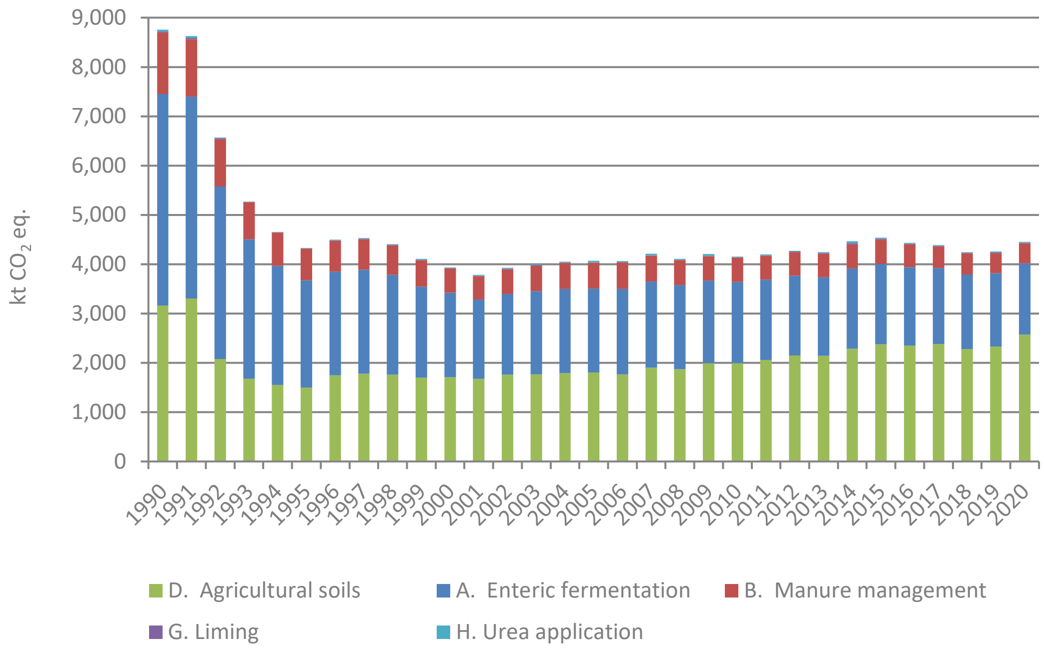


Figure 2-4. Trend of GHG emissions in agriculture sector during the period 1990-2020

Agriculture sector is the most significant source of the CH_4 and N_2O emissions accounting for 58.6% and 87.4% in the total CH_4 and N_2O emissions, respectively. The emissions of CH_4 and N_2O from agriculture sector in 2020 decreased by 66.2% and 26.5% compared to the base year, respectively. The reduction of CH_4 emissions is caused by the decrease in total number of livestock population.

The major part of the agricultural CH_4 emission originates from digestive processes. Enteric fermentation contributes 50.5%, manure management – 8.1% to the total national CH_4 emissions.

Agricultural soils are the most significant source of N_2O emissions accounting for 81.7% in the total national N_2O emissions.

LULUCF

The Land Use, Land-Use Change and Forestry (LULUCF) sector for 1990-2020 as a whole acted as a CO_2 sink except in 1996 when emission constituted to 992.1 kt CO_2 eq. (Figure 2-5). That is explained by sudden spruce dieback due to the continuous droughts and pests invasion, that caused huge losses in trees volume in Lithuania`s spruce stands, which has direct impact on biomass calculations and on CO_2 balance from this sector.

Removals in LULUCF sector in 2020 has risen compared to 2019, although removals in living biomass of Forest land remaining forest land has slightly decreased and overall, forest land removals were -6,496.4 kt CO_2 eq. in 2019 and -6,485.4 kt CO_2 eq. in 2020, but also emissions from settlements (from 772.1 kt CO_2 eq. in 2019 to 598.9 kt CO_2 eq. in 2020) and especially other land (from 352.4 kt CO_2 eq. in 2019 to 60.0 kt CO_2 eq. in 2020) has significantly decreased. To add, removals in grassland and harvested wood products categories also decreased. On the contrary, emissions from cropland category has been significantly decreasing during the recent years: from 1,299.7 kt CO_2 eq. in 2014 to 863.4 kt CO_2 eq. in 2019, but it slightly increased in 2020 to 934.9 kt CO_2 eq. Overall, total emissions and removals balance in LULUCF sector increased from -5,302.1 kt CO_2 eq. to -5,407.4 kt CO_2 eq. between 2019 and 2020. As it could be seen from the Figure below, total GHG removals in LULUCF sector have been decreasing from 2011 and one of the main factors until 2019 was significantly decreasing removals in Forest land. Declining GHG removals in Forest land is mostly related to changing age class distribution in forests, as majority of pine forests are getting older and at this age, their removal potential is decreasing.

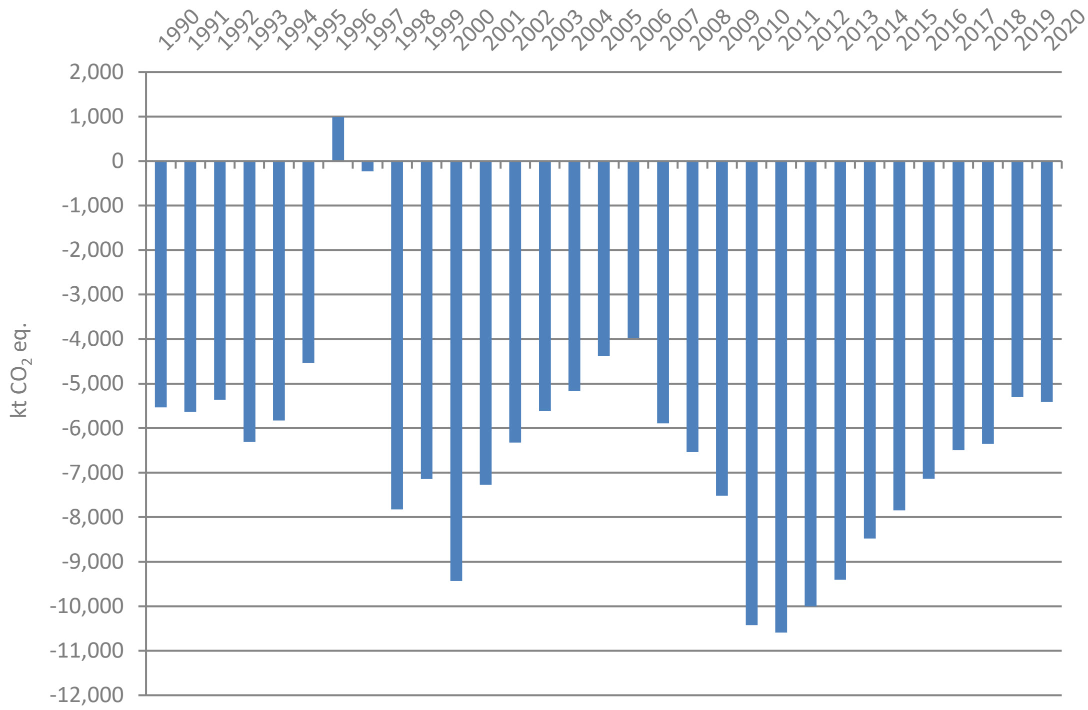


Figure 2-5. Total GHG emissions/removals from LULUCF sector for the period 1990-2020

Waste

The waste sector accounted for 4.1% of the total greenhouse gas emissions in 2020 (excl. LULUCF). The emissions from waste sector include CO_2, CH_4 and N_2O emissions. Emissions of the total GHG from waste sector have decreased from 1,522.1 kt CO_2 eq. in 1990 to 821.6 kt CO_2 eq. in 2020 (Figure 2-6).

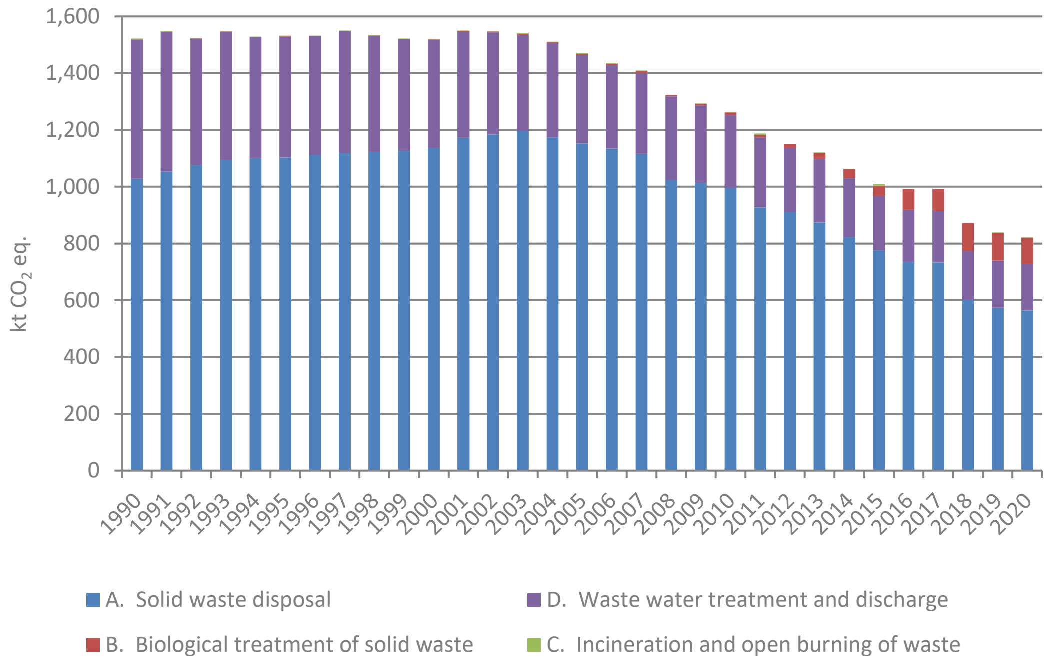


Figure 2-6. Trend of GHG emissions in waste sector during the period 1990-2020

Solid waste disposal on land including disposal of sewage sludge is the largest GHG emission source from waste sector. It contributed around 68.5% of the total GHG emission from waste sector in 2020. GHG emissions occurring due to solid waste and sewage sludge disposal on land were increasing slightly from 1990 to 2003 and then started to decrease due to reduction of disposed waste, extraction of landfill gas, anaerobic digestion of sewage sludge.

Certain increase of emissions from solid waste disposal was observed from 2000 to 2003 and was caused mainly by disposal of large amounts of organic sugar production waste. In later years the producers managed to hand this waste over to farmers for use in agriculture and GHG emissions declined.

Biological treatment of waste includes composting and anaerobic digestion. GHG emissions from biological treatment have increased substantially after establishment of the regional waste management systems in 2010 and once again after implementation of MBT facilities in 2016. Emissions from biological treatment reached 11.1% of the total waste sector emissions in 2020.

3 ENERGY (CRF 1)

3.1 Overview of the sector

Sudden political upheaval, after the collapse of the former Soviet Union, was followed by deep and complicated changes in all sectors of the Lithuanian economy, including Energy sector. Economic slump in Lithuania was comparatively large: at the end of 1994 Lithuanian Gross Domestic Product (GDP) dropped to 56.1% of the 1990 level. Since 1995 country's economy has been gradually recovering (Figure 3-1). Lithuanian GDP decreased by 1.1% in 1999 due to the financial and economic crisis in Russia. The year 2000 was a turning point because since this year the national economy has been recovering very fast. During the period 2000-2007 the average growth rate of GDP was 8.0% per annum (Database of Statistics Lithuania, 2021). The impact of global economic recession was dramatic in Lithuania. The global economic crisis had an effect on Lithuanian GDP already in 2008, but GDP growth rate in 2008 was still positive (2.4%). In 2009, GDP decreased by 14.7%. Since 2010 Lithuania's GDP has grown slightly by 1.6% in 2010, 6.1% in 2011 and 3.8% in 2012. During 2013-2014, GDP growth rates slightly slowdown and accounted 3.6% per annum. In 2015, GDP growth rate reduced by almost two times (to 2.1%). In 2016, GDP growth rate was higher and reached 2.4%. This growth was influenced by several factors. The improved global economic situation had relatively swift implications for exporters in Lithuania. International environment was not the only factor exerting strong pressure on economic activity. Economic development in Lithuania was largely influenced by domestic demand, especially private consumption, which is driven by strong shifts in the labour market.

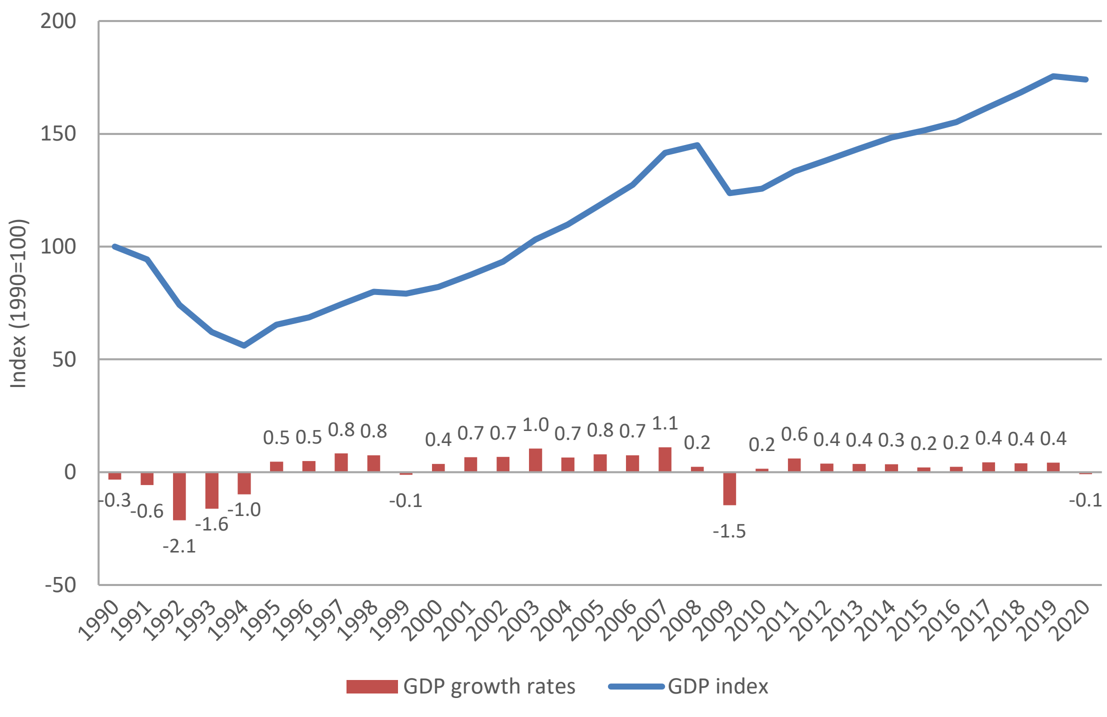


Figure 3-1. Changes of GDP annual growth rates and index in Lithuania (Statistics Lithuania, https://osp.stat.gov.lt/)

In 2017, Lithuania's economic growth has picked up notably on the back of strong support from improvements in the international economic environment (Fig. 3-1). In 2017, GDP increased by 4.4%. However, a year later, in 2018, slowing global economic development offset the relevant improvement of domestic demand, therefore, GDP growth rate reduced to 4.0%. In 2019, GDP growth rate was rather high in the context of EU countries and approximated to 4.3%. The created value added in industry, service sector (especially, freight transportation) and agriculture significantly contributed to that growth rate. In 2020, Lithuania resisted well to the COVID-19 pandemic induced global crisis, with GDP contracting by only 0.8%. The fall of the Lithuanian economy in 2020 was one of the smallest in the EU countries. The successful performance of exporters, the financial support provided by the Government and low dependence of the economy on the most restricted and affected activities caused a slight economic downturn in 2020.

Dynamics of primary energy consumption in Lithuania during 1990-2020 is presented in Figure 3-2. Total primary energy consumption in 1990 amounted to 675.6 PJ (16.14 Mtoe) and in 2020 – 314.9 PJ (7.52 Mtoe). Oil and oil products were the most important fuel in Lithuania over the previous decade. Since 2000 their share in the primary energy balance has been fluctuating about 32.6% with the smallest portion of 23.7% in 2003 and the largest share of 39.2% in 2018. The major factors influencing changes in the role of oil products were decreasing consumption of heavy oil products for production of electricity and district heat and growing consumption of motor fuels in the transport sector. In 2009, due to significant reduction of motor fuel consumption, share of oil products decreased to 27.9%, but in 2010 due to the closure of Ignalina Nuclear Power Plant (NPP) the share of oil products increased to 36.2%. In 2019, the share of oil and oil products reached 38.9%. Such large share of oil products was caused by growing demand of motor fuel in transport sector. In 2020, the share of oil and oil products decreased till 37.3% due to COVID-19 crisis.

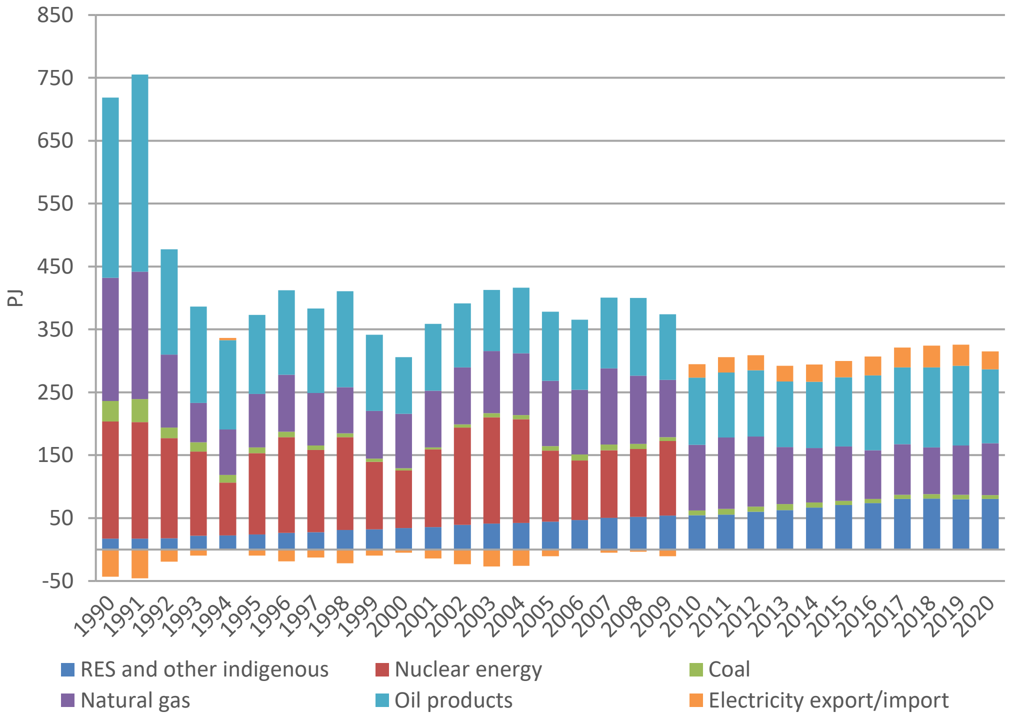


Figure 3-2. Primary energy consumption in Lithuania (Statistics Lithuania, https://osp.stat.gov.lt/)

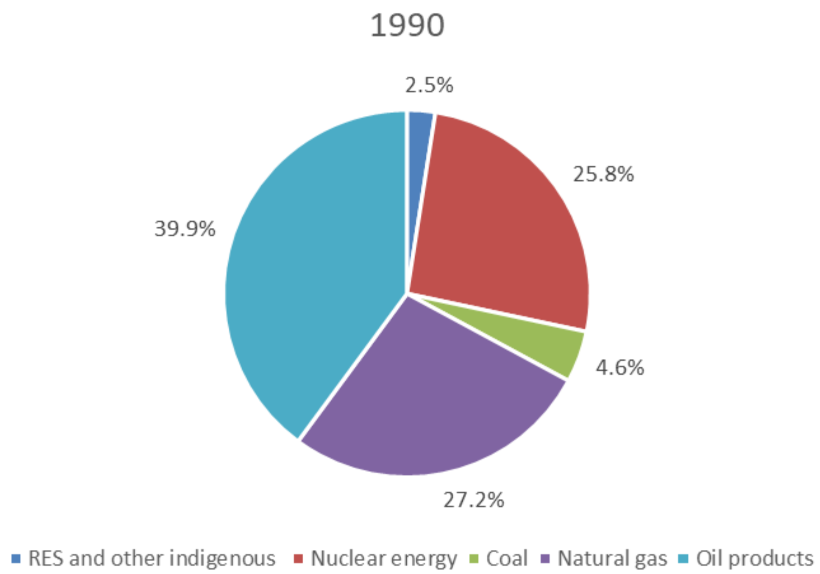
The share of natural gas was fluctuating about 27.7% over the period 2000-2020 with the lowest contribution of 22.9% in 2018 and the largest share of 37.2% in 2011. Total consumption of natural gas decreased owing to reduction of its use for non-energy needs in 2008 and 2009. Consumption of natural gas for production of mineral fertilizers in 2009 was by 1.9 times less than in 2007. Since the beginning of Lithuanian economy recovery after the global crisis, the share of natural gas increased by 12.8 percentage points, i.e., from 24.4% in 2009 till 37.2% in

2011. The consumption of natural gas started reducing by 4.6% a year since 2011 and, in 2019, its accounted to 78.1 PJ (1.87 Mtoe) in the balance of primary energy consumption. In 2020, consumption of natural gas increased to 82.6 PJ (1.97 Mtoe) due to increase of electricity production at CHPs.

During the period 1990-2009 the share of nuclear energy was very high and fluctuated about 32.1% with the lowest value of 24.6% in 1991 and the highest value of 40.9% in 2003. The role of nuclear fuel was very important in Lithuania. Nuclear fuel helped to increase the security of the primary energy supply, especially in the power sector. During the process of accession into the EU, one of the country's obligations was a decision on the early closure of Ignalina Nuclear Power Plant (NPP). It was agreed that Unit 1 of this power plant would be closed before 2005 and Unit 2 in 2009. Ignalina NPP was the main source of electricity generation during the period 1988-2009, and even after the closure of Unit 1 it was producing more than 70% of electricity generated by Lithuanian power plants. The share of nuclear energy in the primary energy balance in the year 2009 (year of final closure of Ignalina NPP) was 31.6%. It is important to note that a large portion of electricity generated by this power plant was exported. Lithuania was a net exporter of electricity and for instance in 2004 more than 37% of electricity generated by Ignalina NPP was exported to neighbouring countries. In 2014, the share of electricity generated by all Lithuanian power plants was about 37% in the balance of gross electricity consumption and 63% of electricity necessary to meet internal demand was covered by electricity import. Electricity import in the primary energy balance structure accounted 8.7% in 2015, 9.7% in 2016, 9.7% in 2017, 10.7% in 2018 and 10.3% in 2019. In 2020, the share of electricity import in the primary energy balance decrease to 9.0%.

Over the period 2000-2020 the share of coal in the primary energy balance was fluctuating about 2.4% with the lowest value of 0.8% in 2001 and the highest value of 3.3% in 2013. With reference to data of 2020, the share of coal was 1.8%.

Comparison of the primary energy consumption structure in 1990 and in 2020 is presented in Figure 3-3.



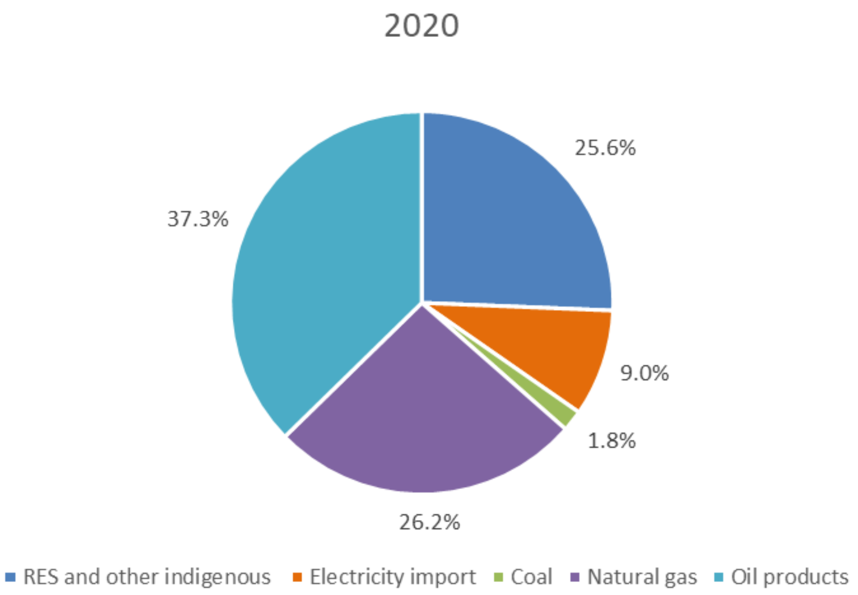


Figure 3-3. Structure of primary energy consumption in Lithuania (Statistics Lithuania, https://osp.stat.gov.lt/)

Indigenous energy resources in Lithuania are rather scarce. Certain contribution into balance of indigenous resources is originated from local oil, peat and energy of chemical processes. Contribution of non-renewable indigenous energy is presented in Figure 3-4. In 2020, non-renewable indigenous energy in total primary energy accounted only 3.6%.

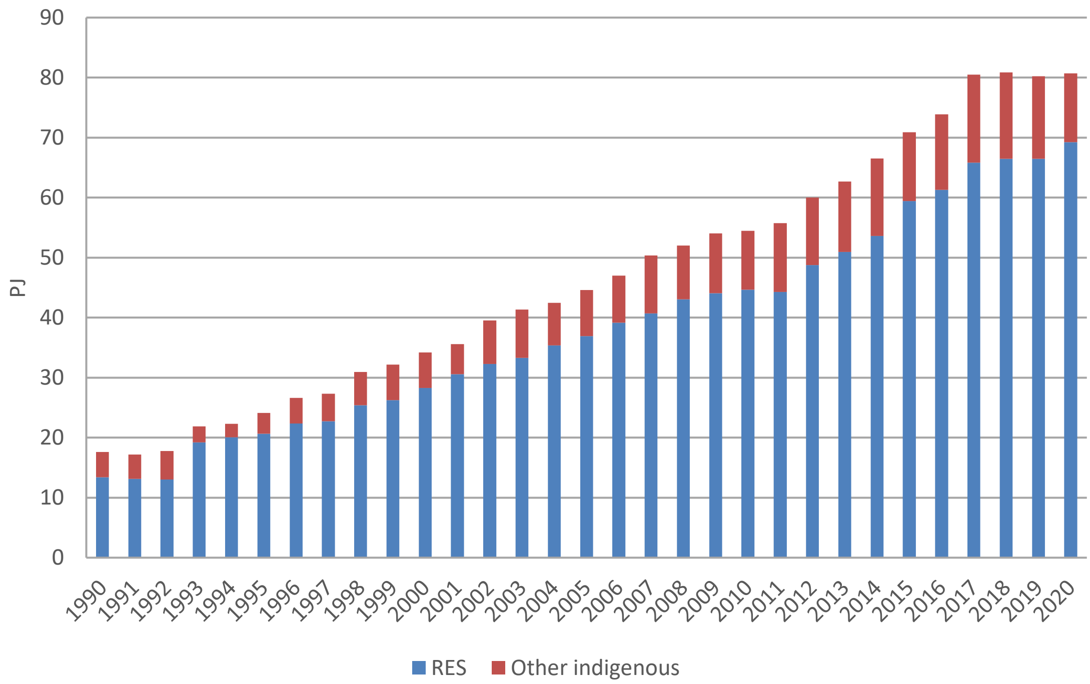


Figure 3-4. Consumption of indigenous energy sources in Lithuania (Statistics Lithuania, https://osp.stat.gov.lt/)

Contribution of renewable energy sources into the country's primary energy balance during the period 1990-2020 was increasing (Statistics Lithuania, Energy balances). During the period 1990-

2020 primary energy supply from renewable sources increased by 5 times with an average annual growth of 5.4%.

Lithuania has undertaken, according to Directive of the European Parliament and of the Council No 2009/28/EC on the promotion of the use of energy from renewable sources, to increase the renewable sources share in the final national energy consumption up to 23% by 2020. Lithuania has already reached the 23% target: in 2014, the share of renewable energy sources in the total energy balance of the country exceeded one fifth, accounting for 23.6%, and increased to 27.4% in 2020.

The consumption of renewable energy sources by energy forms are presented in Figure 3-5. Currently the main domestic energy resource is solid biomass. Solid biomass accounted for 75.6% in the balance of renewable energy sources in 2020. The second largest renewable energy source is wind energy. In 2020, a share of wind energy was 8.0%. Liquid biomass (bioethanol and biodiesel) accounted 6.1% of total renewable energy. Hydro power is fluctuating and currently provides 1.5% in the balance of renewable energy sources. The shares of ambient heat, renewable waste, municipality biogas and solar energy were 3.0%, 2.8%, 2.3% and 0.7% in 2020, respectively. Renewable energy source in the primary energy balance accounted 70.1 PJ in 2020.

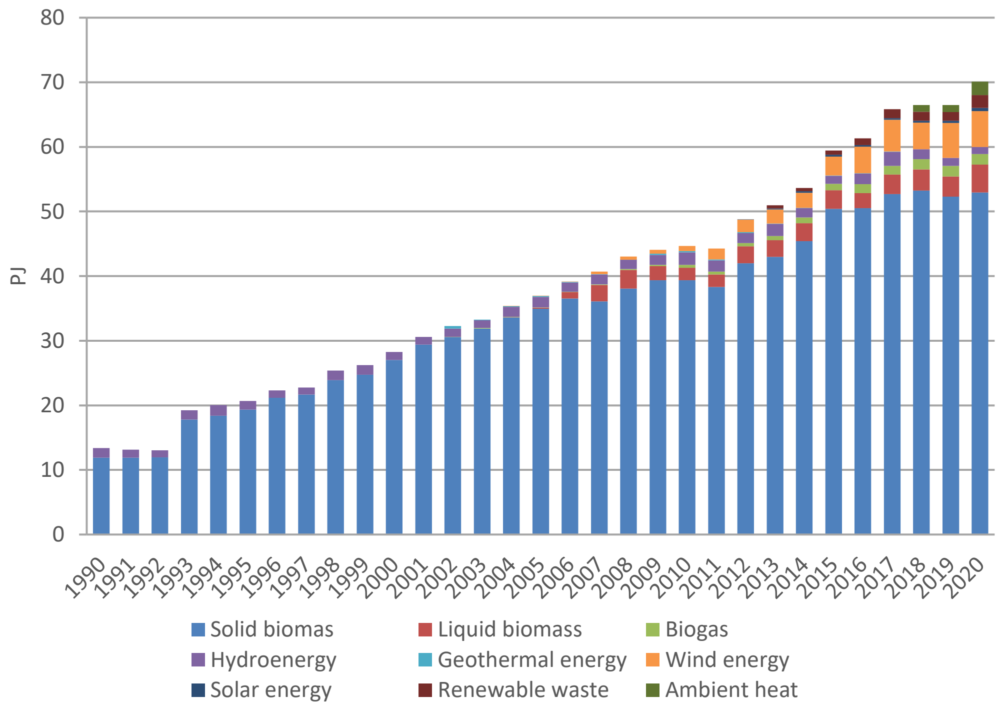


Figure 3-5. Consumption of renewable energy sources in Lithuania (Statistics Lithuania, https://osp.stat.gov.lt/)

Ignalina NPP played a key role in the Lithuanian energy sector producing up to 70-80% of the electricity. Even after the closure of Unit 1 at the end of 2004 this power plant was dominating in the electricity market – its share in the balance of gross electricity generation in 2009 has been almost 70.7%. Therefore, the most important internal changes in the Lithuanian energy sector in 2010 are related with the final closure of Ignalina NPP (Figure 3-6). After the closure of Ignalina NPP the Lithuanian Thermal Power Plant (Lithuanian TPP) became the largest electricity generation source considering the installed capacity. Lithuanian TPP can covered up to 50-60% of the gross internal consumption. But the cost of electricity production at this power plant was high due to high price of natural gas. Thus, more than half of required electricity is imported from neighboring countries. In 2019, the electricity generation in Lithuania totaled to 14.30 PJ (3.97 TWh). The volume of electricity generation from renewable energy sources accounted 48.7% of the country's total electricity generation in 2019. In 2020, the electricity generation in country increased until 19.86 PJ (5,52 TWh). Significant reduction of natural gas price allowed Lithuanian power plants to ensure a competitive price in the market in the presence of reduced electricity import due to maintenance of the electricity interconnection between Lithuania and Sweden. The share of electricity generation from renewable energy sources decreased till 35.9% in the country's total electricity generation as the share of fossil fuel-based electricity increased in 2020.

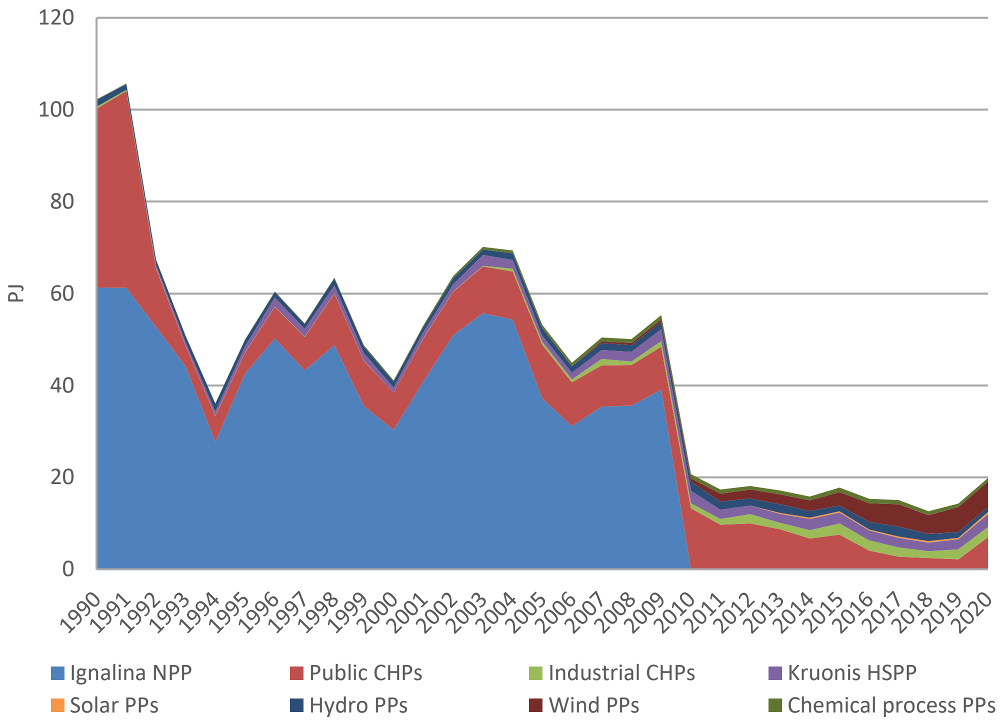


Figure 3-6. Structure of electricity generation in Lithuania (Statistics Lithuania, https://osp.stat.gov.lt/)

Baltic Energy Market Interconnection Plan (BEMIP) was signed in 2009 seeking to diversify and ensure the electricity supply to the Baltic States. Connecting Lithuania, Latvia and Estonia to neighboring EU countries and the internal market is the main priority of the BEMIP Action Plan. This priority requires the full implementation of the internal market rules in order to enable three Baltic States to participate in the EU electricity market. Interconnection between Lithuania and Poland (project LitPol Link) is fully in line with the EU energy policies and National energy strategies in the region. The 500 MW power link connecting Lithuania and Poland was put into operation in December 2015. By 2020, the LitPol Link started operating at a 1,000 MW capacity.

The European Commission through the European Energy Programme for Recovery provided funding for the construction of electricity interconnection between Lithuania and Sweden (NordBalt). NordBalt is a submarine power cable between Klaipeda in Lithuania and Nybro in Sweden. The implemented project promoted trading between Baltic and Nordic electricity markets, as also to increase the security of power supply in both markets. Submarine cable laying started in 11 April 2014. This interconnection is a high voltage direct current cable. The length of the cable is 450 kilometers. Its capacity is 700 MW. The cable was commissioned in 2016.

Taking into consideration general EU energy policy, the country's energy policy is focused on gradual increase of consumption of renewable energy resources and increase of energy efficiency.

Green electricity generation was almost stable and fully dominated by hydropower in Lithuania during the period 1990-2000 (Figure 3-7). Since 2000 green electricity generation portfolio became more diversified and renewable electricity generation volume was increasing on average by 12.0% per year, except in 2018, when renewable electricity generation reduced by 13.1% (this reduction was stipulated by decreased production of hydropower due to dry year). In 2020, electricity generation from renewable energy sources accounted 9.27 PJ (2575.1 TWh). It was dominated by wind power, generating about 60.3%, hydro power, producing 11.7%, biomass – 12.3% and biogas and municipality waste, about 10.7%, of green electricity. Solar electricity contribution to the structure of green electricity production was 5.0% in 2020.

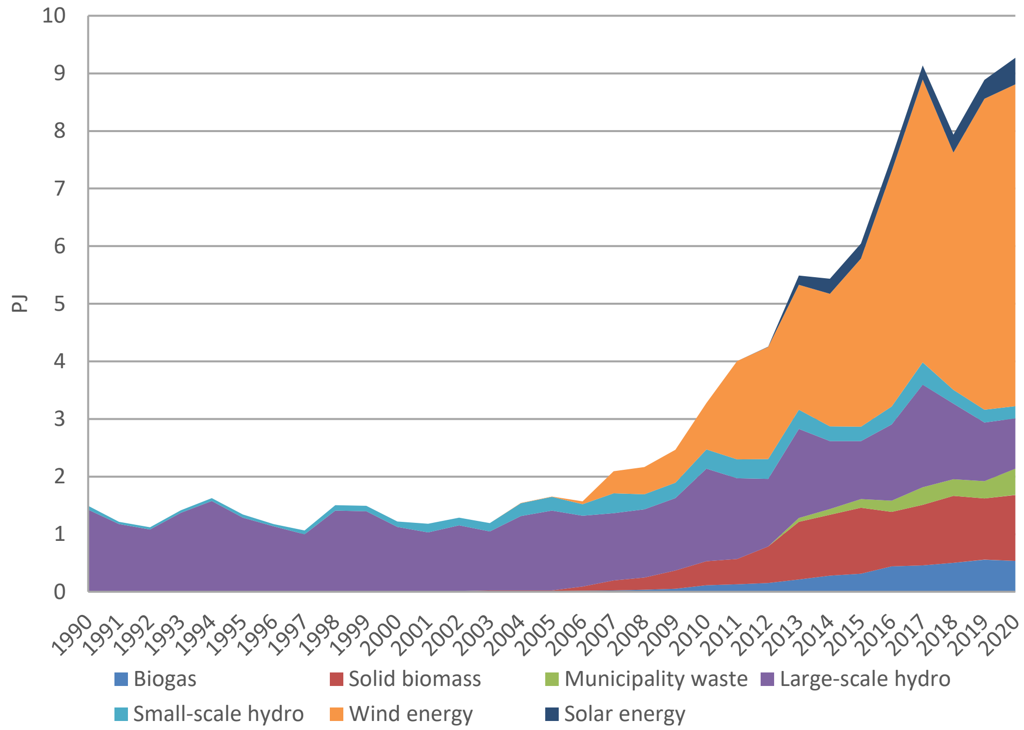


Figure 3-7. Green electricity production in Lithuania (Statistics Lithuania, https://osp.stat.gov.lt/)

Many factors had influence on changes of energy consumption: deep economic slump in 1991-1994, fast economic growth over the period 2000-2008, dramatic reduction of economic activities in all branches of the national economy and the closure of Ignalina NPP in 2009, a significant increase of energy prices, an increase of energy efficiency and other reasons.

Total final energy consumption (excluding non-energy use) in 1990 amounted to 405.26 PJ (9.68 Mtoe). In 1991-1994 final energy consumption decreased approximately by 2 times (Figure 3-8). During the period 2000-2008 the final energy consumption was increasing by 3.9% per annum, and in 2008 it was 214.7 PJ (5.1 Mtoe) (Statistics Lithuania, Energy balances). During this period the final energy consumption was increasing in all sectors of the national economy.

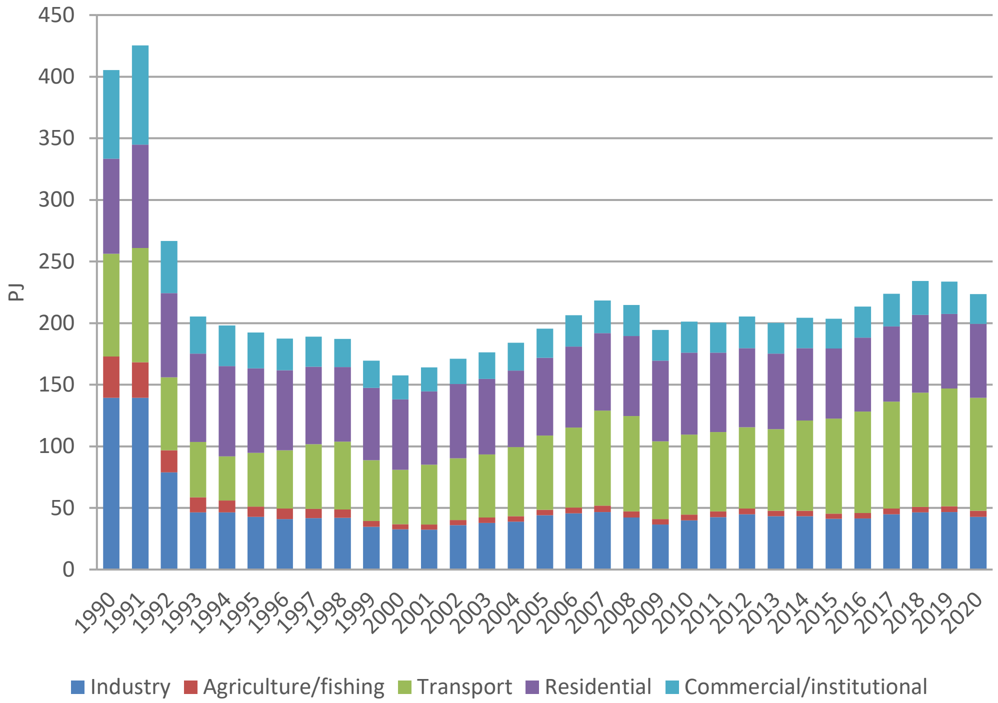


Figure 3-8. Final energy consumption in Lithuania (Statistics Lithuania, https://osp.stat.gov.lt/)

In 2009, total final energy consumption was by 9.5% less than in the previous year, and the most severe impact of the economic recession was in the construction sector where energy consumption decreased by 34.9% and in the transport sector - by 18.5%. As a result of recovering Lithuanian economy, total final energy consumption increased by 3.5% in 2010. During 2011-2015 the final energy consumption remained rather stable. In 2016, final energy consumption increased by 4.9%, in 2017 - by 4.8%, in 2018 – by 4.6%, in 2019 – reduced by 0.2% and in 2020 reduced by 4.4%. In 2020, it amounted to 223.5 PJ (5.34 Mtoe). This decrease in energy demand was influenced by COVID-19 lockdown. Due to COVID-19 energy demand significantly reduced in commercial/institutional sector, industry and transport. The transport sector remained the largest energy consuming sector. In 2020, transport sector accounted 41.0% in the total final energy consumption. Residential sector accounted 26.9% of total final energy consumption, industry – 19.2%, commercial/institutional – 10.8% and agriculture/fishing – 2.1%.

During the transition to market economy period significant improvements in the energy efficiency has been achieved due to replacement of the old energy intensive technologies by the new innovative technologies in the industry and implementation of various energy efficiency improvement measures in other sectors of the economy. During 2000-2020 period the final energy consumption and the final electricity consumption was growing slower than the GDP (Figure 3-9).

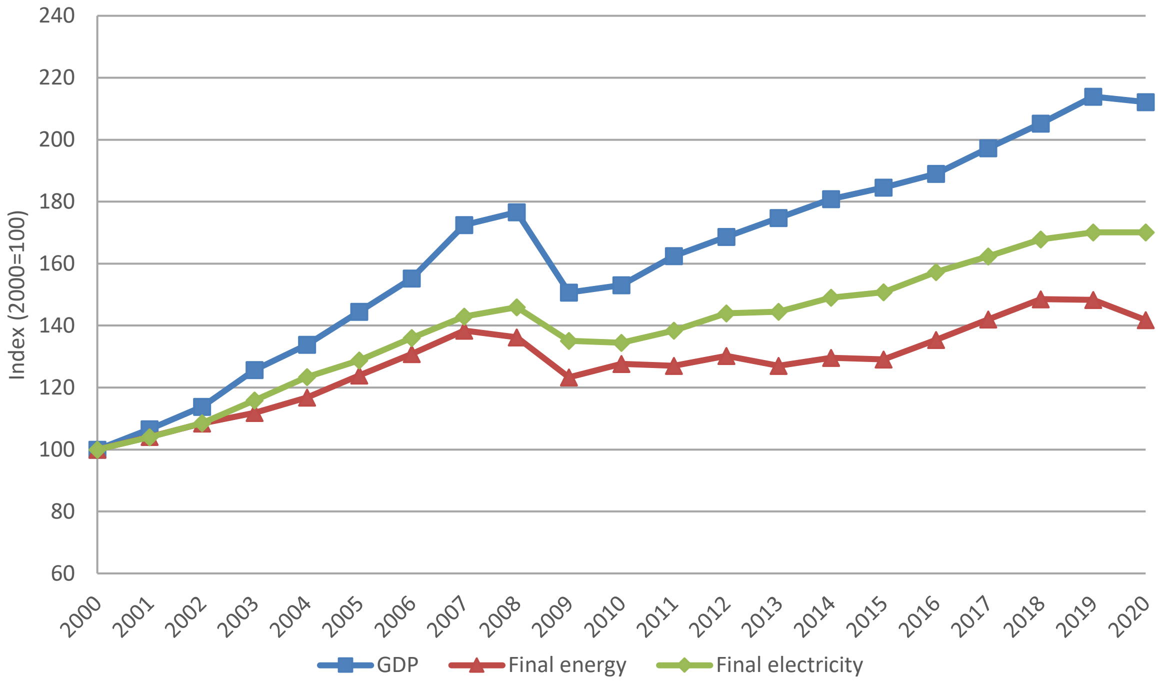


Figure 3-9. GDP, final energy and final electricity growth index (Statistics Lithuania, https://osp.stat.gov.lt/)

Energy intensity indicator mainly is used for the characterization of energy efficiency within the country and for the respective branch of the economy. Energy intensity is defined as the primary (final) energy consumption (measured in units of energy) with the performance indicators (calculated in national currency or a common currency), which is characterized by GDP. Changes in primary and final energy intensity in Lithuania are presented in Figure 3-10.

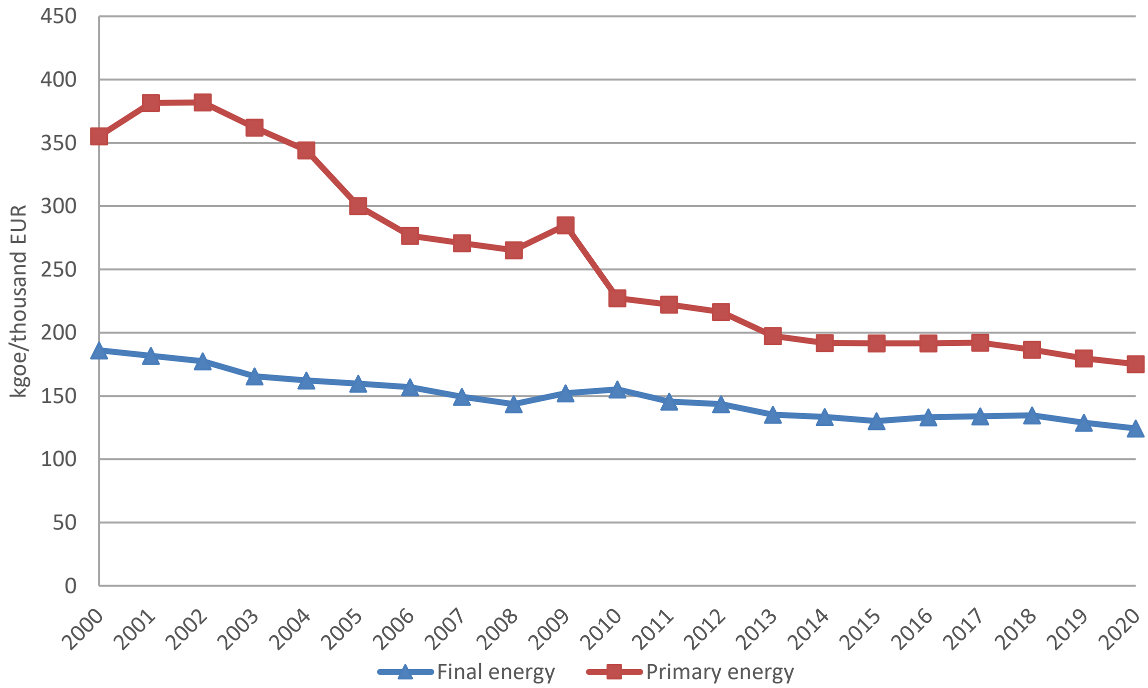


Figure 3-10. Changes in primary and final energy intensity (Statistics Lithuania, https://osp.stat.gov.lt/)

Substantial changes in the power sector and the above-mentioned changes in the primary energy balance has led to a very significant reduction in the primary energy intensity. In 2020, the primary energy intensity made 49.3% of the 2000 level and amounted 175 kgoe/thous. EUR. The final energy intensity decreased by 33.2% - from 186 kgoe/thous. EUR in 2000 to 124 kgoe/thous. EUR in 2020. A further reduction in primary energy intensity depends very much on the efforts to reduce the final energy intensity, i.e. on the successful implementation of the energy efficiency measures in the respective branches of the economy.

Several emission sources in the Energy Sector are key categories. Key categories in 2020 by level (L) and trend (T) are listed in Table 3-1.

Table 3-1. Key categories in Energy Sector in 2020

IPCC Category	*Greenhouse gas*	*Identification criteria*	*Comments**
1.A.1. Energy industries-Other fossil fuels	CO_2	L1, T1	
1.A.1. Energy industries-Solid fuels	CO_2	T1	
1.A.1. Energy industries-Biomass	N_2O	T2	
1.A.1. Energy industries-Biomass	CH_4		L2sub, T2sub
1.A.1.a Public electricity and heat production - Gaseous Fuels	CO_2	L1, T1, T2	
1.A.1.a Public electricity and heat production - Liquid Fuels	CO_2	T1, T2	
1.A.1.b Petroleum refining - Liquid Fuels	CO_2	L1, T1	
1.A.1.b Petroleum refining - Gaseous Fuels	CO_2	L1, T1	
1.A.2 Manufacturing industries and construction-Gaseous fuels	CO_2	L1, T1	
1.A.2 Manufacturing industries and construction-Liquid fuels	CO_2	L1, T1, T2	
1.A.2 Manufacturing industries and construction-Solid fuels	CO_2	L1, T1	
1.A.3.b Road transportation	CO_2	L1, L2, T1, T2	
1.A.3.c Railways	CO_2	L1	
1.A.4 Other sectors-Biomass	CH_4	L1, L2, T1, T2	
1.A.4 Other sectors-Biomass	N_2O		L2sub, T2sub
1.A.4 Other sectors-Gaseous fuels	CO_2	L1, T1	
1.A.4 Other sectors-Liquid fuels	CO_2	L1, T1	
1.A.4 Other sectors-Liquid fuels	N_2O		T1sub, T2sub
1.A.4 Other sectors-Solid fuels	CH_4		T2sub
1.A.4 Other sectors-Solid fuels	CO_2	L1, T1, T2	
1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH_4	L1, T1	
1.B.2 Oil, natural gas and other emissions from energy production	CO_2	L1, L2, T1, T2	

**Lsub, Tsub denote the categories that were identified by level and trend assessment for a subset without LULUCF*

In the Energy sector emissions of CO_2 contribute about 94.9% of total greenhouse gas emissions CO_2 eq. in 2020. Trends of total GHG emissions calculated as CO_2 equivalents from the energy sector are presented in Figure 3-11. Total greenhouse gases (GHG) from the energy sector have decreased by almost 3.0 times from 33,122.5 kt CO_2 eq. in 1990 to 11,816.8 kt CO_2 eq. in 2020. Significant decrease of emissions was mainly due to economic slump in 1991-1994 period. During the fast economic growth over the period 2000-2008 GHG emissions in Energy sector was increasing about 2.2% per annum. The global economic recession had impact on GHG reduction in energy sector by 9.0% in 2009. The closure of Ignalina NPP and GDP increase had impact on GHG increase by 8.0% in 2010. In 2011, total GHG emissions in Energy sector decreased by 6.5%. This trend was stipulated by almost 16.3% decrease of GHG emissions in public electricity and heat production sector due to increased share of electricity import from neighboring countries, increased use of renewable energy sources and natural gas. The level of total GHG emissions in Energy sectors in 2012 remain almost the same as in 2011. In 2013, total GHG emissions in Energy sector decreased by 5.0% and in 2014 by 3.3% due to high share of electricity import and increased use of renewable energy sources. In 2015, total GHG emissions in Energy sectors remain almost at the same level as in 2014. In 2016, total GHG emissions in Energy sector increased by 3.0% due to increasing trend of GHG emissions in transport sector. In 2017, total GHG emissions in Energy sectors decreased by 0.6% due to increased use of renewable energy sources and very high share of electricity import. In 2018, total GHG emissions in Energy sector increased by 3.2% and in 2019 by 0.1% due to increasing trend of GHG emissions in manufacturing industries and transport sectors. Due to COVID-19 pandemic total GHG emissions in Energy sector decreased by 0.6% in 2020.

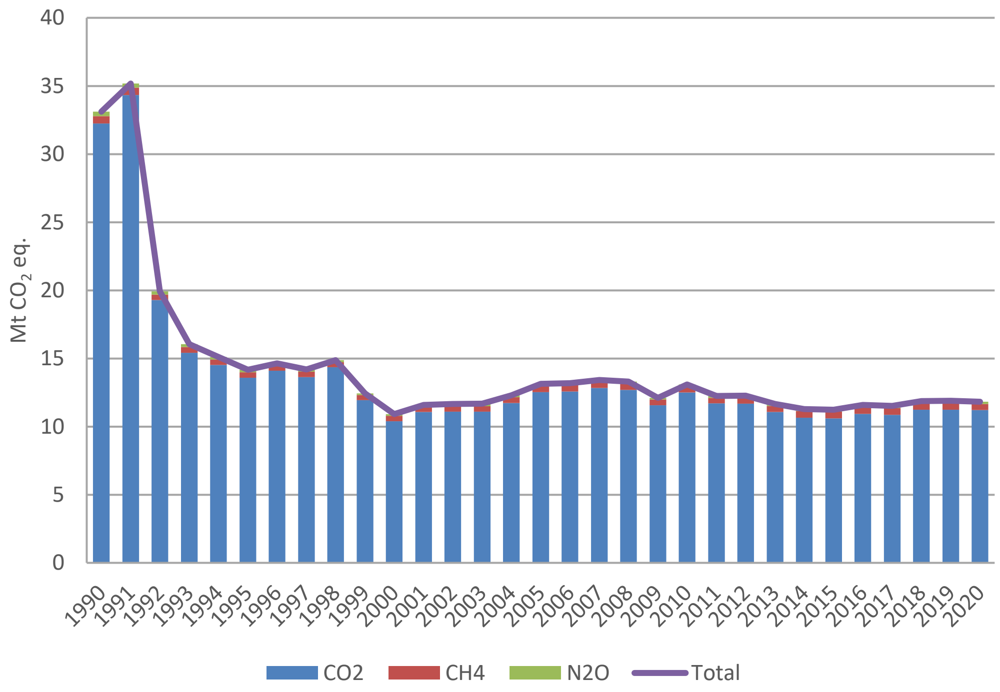


Figure 3-11. Trends of total GHG emissions from the Energy Sector (CRF 1)

Changes in structure of GHG emissions in energy sector showed in Figure 3-12. Historically the 1.A.1 Energy industries accounted for the largest share of GHG emissions from Energy Sector (41% in 1990). In 2020, this source category decreased till 22% of total GHG emissions from energy sector. During the period 1990-2020 the share of transport sector increased significantly. In 1990 transport sector accounted for 17% of total GHG emissions from Energy Sector and in 2020 – 52%. In 2020 transport accounted the largest share of GHG emissions from Energy sector.

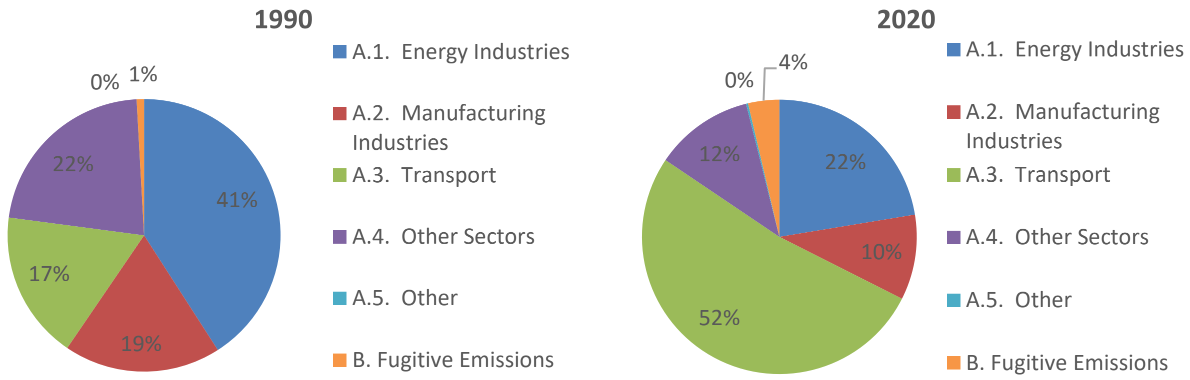


Figure 3-12. Structure of GHG emissions from Energy Sector in 1990 and 2020

The trends of GHG emissions calculated as CO_2 equivalent from different subsectors within the Energy Sector are presented in Figure 3-13.

The most important subsector regarding total emissions in the base year was Energy industries (1.A.1) and it remains to be one of the most important. The closure of Ignalina NPP in 2010 had impact on GHG emissions increase in this subsector. In 2010, GHG emissions increased by approximately 11.4% in energy industries. Between 2011 and 2019 GHG emissions in Energy industries was decreasing by 8.1% per annum due to increasing share of electricity import and renewable energy use. In 2020, GHG emissions in Energy industries increased by 16.2% due to increased electricity generation based on natural gas instead of electricity import as significant reduction of natural gas price allowed Lithuanian power plants to ensure a competitive price in the electricity market.

Since 2013 transport sector become one of the most important sources of GHG emissions in energy sector. After the global economic crisis till 2019 GHG emissions in transport sector were increasing quite significantly, about 3.7% per annum. In 2020, GHG emissions in transport sector decreased by 2.3% due to COVID-19 lockdown.

Growing activities in the Manufacturing industries and construction sector stipulated increase in GHG emissions during 2016-2019 by 2.9% per annum. In 2020, GHG emissions in the Manufacturing industries and construction sector decreased by 8.7%.

Between 2015 and 2019 GHG emissions in Other sectors (1.A.4) was growing about 3.0% per annum. Such increase was mainly stipulated by growth of natural gas and coal consumption in residential and commercial/institutional subsectors (in 2015-2018) and liquid fuels consumption in agriculture/forestry/fishery (in 2019). In 2020, GHG emissions in Other sectors decreased by 5.9% due to significant reduction of fuel consumption in commercial/institutional subsectors as the result of the COVID-19 crisis.

Fugitive emissions from fuels are increasing about 0.6% per annum from 2010 till 2019. Trends of GHG emissions from 1.B Fugitive emissions from fuels are mainly caused by the CH_4 emissions from natural gas transmission/distribution and CO_2 emissions from hydrogen production (steam reforming process). In 2020, fugitive emissions decreased by 17.8% due to significant decrease of hydrogen production and natural gas leakages in transmission/distribution networks.

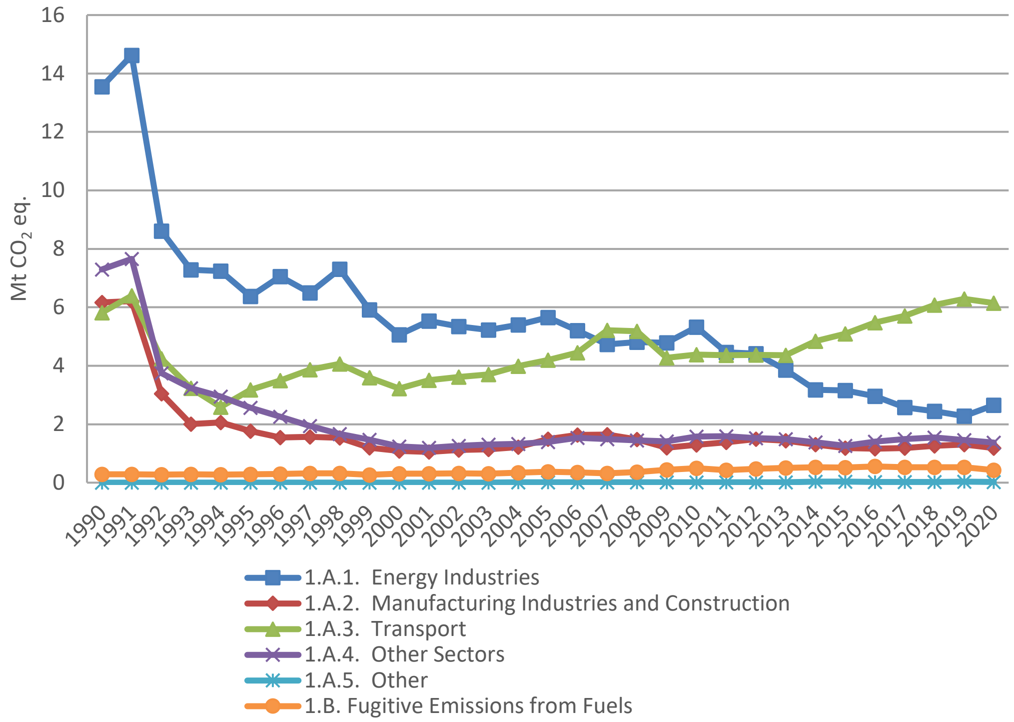


Figure 3-13. Total GHG emissions from the different subsectors within the Energy Sector (CRF 1)

3.2 Fuel combustion (CRF 1.A)

Fuel Combustion category (CRF 1.A) comprises following sources:

- Fuel Combustion – Sectoral Approach (CRF 1.A.A)
  - Energy Industries (CRF 1.A.1)
  - Manufacturing Industries and Construction (CRF 1.A.2)
  - Transport (CRF 1.A.3)
  - Other Sectors (CRF 1.A.4)
  - Non-Specified (CRF 1.A.5)
- Fuel Combustion – Reference Approach (CRF 1.A.B.)
- Difference - Reference and Sectoral Approach (CRF 1.A.C)
- Feedstocks and non-energy use of fuels (CRF 1.A.D)

This chapter gives an overview of emissions and key sources of fuel combustion activities, includes information on completeness, QA/QC, planned improvements as well as on emissions, emissions trends and methodologies applied (including emission factors). Furthermore, information on sectoral/reference approach and feedstocks/non-energy use of fuels is given in this sector. Additionally to information provided in this Chapter, energy sector related information is provided in the Annexes:

- Annex III Lithuanian energy balance;
- Annex IV Lithuanian energy consumption in manufacturing industries;
- Annex V Energy sector country specific CO_2 emission factors;
- Annex VI Summary of study on "Update of country specific GHG emission factors for Energy sector" (performed by Lithuanian Energy Institute in 2016). This study includes updated values of country specific CO_2 emission factors and default emission factors (CH_4 and N_2O) based on *2006 IPCC* methodology;

– Annex VII CO_2 emissions from the installations, participating in the EU ETS, 2020.

3.2.1 Methodological issues

Activity data

In the Energy sector all activity data for calculation of GHG emissions has been obtained from the Lithuanian Statistics database and yearly publications "Energy balance".

Fuel and energy balance has been compiled based on the data provided by legal entities (enterprises) consuming, producing or supplying fuel and energy. The data presented in the Energy balances shows domestic fuel and energy resources of the Republic of Lithuania, including their extraction, production, exports and imports, fuel consumption for generating electricity and heat, as well as final fuel and energy consumption by main economic activity and in households.

All heat generated in public power plants (CHP), public heat plants (heat only boilers), as well as energy (heat) from chemical processes, generated in chemical industry enterprises, is subsumed under the energy balance. Fuel is calculated in terms of tonnes of oil equivalent and terajoules using the net calorific value. The net calorific value (NCV) is the amount of heat which is actually available from the combustion process, i.e. excluding the latent heat of water formed during combustion.

Net calorific values (NCVs) used to convert fuel consumption from natural units into energy units are provided in the tables below. The NCV are publicly available at Lithuanian Statistics database. Net calorific values for 2017-2020 are presented in Table 3-2. The NCV values have been approved by the Order No. DĮ-228 on Fuel and energy balance preparation methodology (https://www.e-tar.lt/portal/lt/legalAct/TAR.55F2081A61B9) and amended by the Order No. DĮ-154 on 31 July 2008 (https://www.e-tar.lt/portal/lt/legalAct/TAR.4C9BF7AE2B62).

Table 3-2. Specific net calorific values (source: Lithuanian Statistics database, https://www.stat.gov.lt/)

Fuel type	TJ/tonne			
	2017	2018	2019	2020
Anthracite	0.02512	0.02512	0.02512	0.02512
Coking coal	0.02512	0.02512	0.02512	0.02512
Other bituminous coal	0.02512	0.02512	0.02512	0.02512
Sub-bituminous coal	0.02269	0.02269	0.02269	0.02269
Lignite	0.01465	0.01465	0.01465	0.01465
Coke	0.0293	0.0293	0.0293	0.0293
Peat	0.01172	0.01172	0.01172	0.01172
Peat briquettes	0.01591	0.01591	0.01591	0.01591
Peat pellets	0.0133	0.0133	0.0133	0.0133
Firewood and wood waste (m^3)	0.0082	0.0082	0.0082	0.0082
Agriculture waste	0.01465	0.01465	0.01465	0.01465
Charcoal	0.0308	0.0308	0.0308	0.0308
Fuel oil - low sulphur (<1%)	0.03977	0.03977	0.03977	0.03977
Fuel oil - high sulphur (>1%)	0.03935	0.0391	0.03914	0.04023
Liquefied petroleum gases	0.04579	0.04575	0.04575	0.04579
Motor gasoline	0.04399	0.04399	0.04395	0.04391
Bioethanol	0.027	0.027	0.027	0.027
Bio-ETBE	0.027	0.027	0.027	0.027
Diesel	0.04286	0.04286	0.04286	0.04291

Heating and other gasoil	0.04286	0.04286	0.04291	0.04291
Biodiesel (methyl-ester)	0.037	0.037	0.037	0.037
Aviation gasoline	0.04479	0.04479	0.04479	0.04479
Gasoline type jet fuel	0.04479	0.04479	0.04479	0.04479
Kerosene type jet fuel	0.04324	0.04328	0.04328	0.04328
Shale oil	0.03901	0.03901	0.03901	0.03901
Bitumen	0.04019	0.04044	0.04006	0.04086
Lubricants	0.042	0.042	0.042	0.042
Refinery feedstocks	0.04282	0.04274	0.04283	0.04283
Crude oil	0.04232	0.04232	0.04203	0.04203
Refinery gas	0.04404	0.04404	0.04492	0.04517
Petroleum coke	0.03265	0.03265	0.03265	0.03265
Paraffin waxes	0.03998	0.03998	0.03998	0.03998
Naphtha	0.045	0.045	0.045	0.045
Emulsified vacuum residue	0.03956	0.03956	0.03956	0.03956
Natural gas (MWh)*	0.00324	0.00324	0.00324	0.00324
Landfill biogas (1000 m^3)	0.02	0.02	0.02	0.02
Sludge biogas (1000 m^3)	0.02	0.02	0.02	0.02
Orimulsion	0.02763	0.02763	0.02763	0.02763
Other biogas (1000 m^3)	0.02	0.02	0.02	0.02
Industrial waste (non-renewable)	0.01014	0.01165	0.0104	0.01019
Industrial waste (renewable)	0.01213	0.01045	0.00967	0.01001
Municipal waste (renewable)	0.00874	0.01025	0.01025	0.01001
Municipal waste (non-renewable)	0.01193	0.01172	0.01022	0.01015

* Since 2016, the amount of natural gas in the national fuel and energy balance is calculated in GWh using its gross calorific value. The amount of natural gas in GWh is based on gross calorific value, and in TJ – based on net calorific value. The net calorific value for natural gas (provided by Statistics Lithuania) is 0.00324 TJ/MWh (as presented in Table 3-2). Based on data provided by natural gas transmission operator in Lithuania, its average specific calorific value was 10.672 MWh/1000 m^3 in 2020. Considering this value, the natural gas specific calorific value expressed in TJ/1000 m^3 is equal to 0.034577 TJ/1000 m^3.

Table 3-3. Conversion factors (Statistics Lithuania)

Factor	TOE	GJ	Gcal	MWh
TOE	1.000	41.861	10.000	11.628
GJ	0.024	1.000	0.239	0.278
Gcal	0.100	4.186	1.000	1.163
MWh	0.086	3.600	0.860	1.000

Brief overview of the Lithuania's Energy balance is presented below:

- *Consumption in the energy sector* refers to the quantities consumed by the energy industry to support extraction (mining, oil and gas production) or plant operations of transformation activities, as well as for pumped water storage in hydropower stations. The quantities of fuels transformed into another form of energy are excluded. Energy enterprises are those which under the international methodology of energy are subsumed under the following kinds of activity according to the national version (EVRK Rev. 2) of the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2):
    - Extraction of crude petroleum;
    - Extraction of peat;
    - Support activities for petroleum and natural gas mining;

  - Manufacture of refined petroleum products;
  - Electricity, gas, steam and air conditioning supply.
- *Non-energy use* covers energy resources used as raw materials, i.e. energy resources which are neither used as fuel nor converted into other kind of fuel.
- *Consumption in industry* refers to fuel quantities consumed by an industrial undertaking in support of its primary activities. Industrial enterprises are those which under the international methodology of energy are subsumed under the following kinds of activity according to EVRK Rev. 2 (excluding enterprises which are subsumed under the energy sector):
  - Mining and quarrying;
  - Manufacturing.
- *Consumption in the transport sector* includes fuel and energy consumed by all means of transport: railways, inland waterways (excluding fishing), air (international, domestic and military aviation), road (fuel used in road vehicles including fuel used by agricultural vehicles on highways), pipeline system and other transport, irrespective of the kind of enterprise industrial, construction, transport, agricultural, commercial or public) the transport facility belongs to. Moreover, fuel consumed by personal transport facilities is included. Fuel with which vehicles (cars, aircraft, ships, etc.) were fuelled abroad is not recorded.
- *Consumption in agriculture* encompasses fuel and energy consumption by enterprises whose economic activity is related to agriculture, hunting and forestry.
- *Consumption in fishing* encompasses fuels delivered to inland, coastal and deep-sea fishing vessels of all flags that are refuelled in the country (including international fishing) and fuel and energy used in the fishing industry.
- *Consumption in the service sector* encompasses fuel and energy consumed in other economic activities not mentioned above, i.e. for heating and lighting premises meant for trade, education, health, commercial services, administration, etc.
- *Consumption in households* encompasses fuel and energy sold to the population for heating, lighting, cooking. Fuel consumed for individual transport is subsumed under the item "Consumption in transport".
- *International marine bunkers* are defined as quantities of fuels delivered to ships of all flags that are engaged in international navigation. Consumption by ships engaged in fishing and domestic navigation vessels is excluded.

To improve transparency of the reporting in energy sector in the NIR the energy balance data according to the fuel type for 1990, 1995, 2000, 2005 and 2010-2017 are provided in the Annex III and energy consumption by the fuel type in manufacturing industries for the same time period are provided in the Annex IV. The entire time series (1990-2017) are publicly available at the databases of the Statistics of Lithuania[3]. In the Annex III and Annex IV the energy balance data are provided in Terajoule (TJ).

Methods and emission factors

GHG emissions were calculated on the basis of the amount and type of fuel combusted and its emission factor. The following equation has been used:

[3] Available from: *http://www.stat.gov.lt/lt/*

$$Emission_{GHG,fuel} = Fuel\ consumption_{fuel} \times Emission\ factor_{GHG,fuel}$$

where:

$Emission_{GHG,\ fuel}$ - emissions of GHG by type of fuel, kg GHG;

$Fuel\ consumption_{fuel}$ - amount of fuel combusted, TJ;

$Emission\ factor_{GHG,\ fuel}$ - emission factor of a given GHG by type of fuel, kg/TJ.

CO_2 emissions were calculated mostly applying Tier 2 or Tier 3, except industrial waste (Tier 1 based on 2006 IPCC Guidelines default emission factor); CH_4 and N_2O were calculated applying Tier 1, except CH_4 from the use of wood/wood waste and other solid biomass use in category 1.A.4 Other sectors, where Tier 2 was applied using country specific emission factor based on internationally referenced sources and EFs from neighbouring countries appropriate to Lithuania's national circumstances. Detailed information on methods and emission factors used is provided under each respective category description. Annex V includes all country specific CO_2 emission factors and Annex VI includes summary of study on "Update of country specific GHG emission factors for Energy sector" (fuel combustion) performed by Lithuanian Energy Institute in 2016. This study includes updated values of country specific CO_2 emission factors.

3.2.2 Comparison of sectoral approach with the reference approach

CO_2 emissions from energy sector were calculated using both sectoral and reference approaches. Reference approach is accounting for carbon, based mainly on supply of primary fuels and the net quantities of secondary fuels brought into the country. The reference approach is a top-down approach, using a country's energy supply data to calculate the CO_2 emissions from combustion of fuels.

Differences between sectoral and reference approach were estimated for fuel consumption and CO_2 emissions. Figure 3-14 shows comparison of CO_2 emissions estimates for the two approaches for the period 1990–2020.

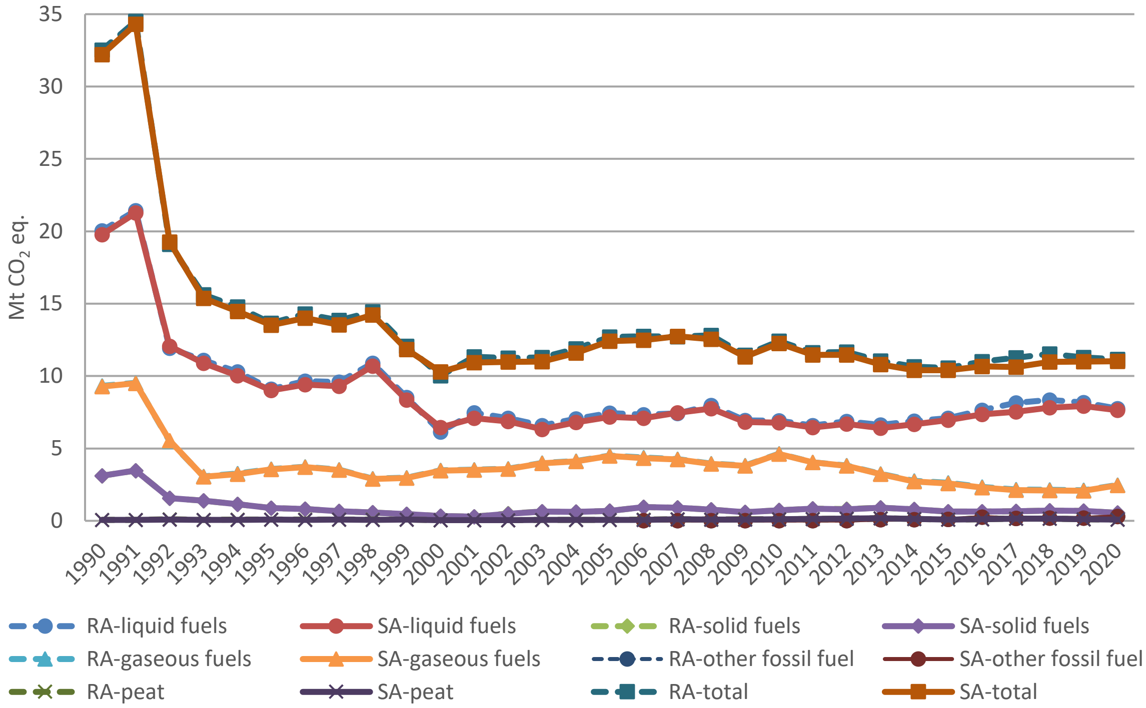


Figure 3-14. Comparison of CO_2 emissions between sectoral and reference approach

Figure 3-14 shows that the differences for CO_2 emissions are closely correlated. The bigger difference can be noticed for liquid fuel. Table 3-4 presents CO_2 emissions of sectoral and reference approach.

Table 3-4. Values of CO_2 emissions from sectoral and reference approach, kt

	Reference approach						Sectoral approach					
Year	**Liquid**	**Solid**	**Ga-seous**	**Other fossil fuel**	**Peat**	**Total**	**Liquid**	**Solid**	**Ga-seous**	**Other fossil fuel**	**Peat**	**Total**
1990	20,030	3,106	9,314	-	67	32,518	19,771	3,106	9,286	-	56	32,219
1995	9,110	884	3,571	-	97	13,663	9,012	882	3,546	-	89	13,530
2000	6,149	326	3,495	-	49	10,020	6,442	325	3,476	-	46	10,289
2005	7,438	683	4,507	-	73	12,701	7,176	683	4,479	-	70	12,408
2010	6,917	736	4,640	18	105	12,416	6,782	735	4,614	18	103	12,253
2015	7,085	647	2,617	116	89	10,553	6,962	646	2,585	116	88	10,396
2016	7,644	641	2,335	272	109	11,002	7,354	641	2,302	272	107	10,676
2017	8,141	657	2,154	175	147	11,274	7,535	657	2,121	174	142	10,629
2018	8,349	696	2,135	197	162	11,538	7,829	696	2,105	193	161	10,984
2019	8,176	681	2,108	201	119	11,285	7,936	681	2,076	196	118	11,007
2020	7,746	543	2,470	316	79	11,155	7,653	543	2,443	311	78	11,029

Table 3-5 presents percentage differences of CO_2 emissions between reference and sectoral approach.

Table 3-5. Difference of CO_2 emissions by fuel type, %

Year	Liquid fuels, %	Solid fuels, %	Gaseous fuels, %	Other fossil fuel, %	Peat, %	Total, %
1990	1.31	0.00	0.31	-	20.41	0.93
1995	1.09	0.27	0.69	-	8.79	0.98
2000	-4.55	0.27	0.57	-	7.22	-2.61

2005	3.65	0.01	0.62	-	4.60	2.36
2010	1.98	0.08	0.56	0.00	1.62	1.33
2015	1.77	0.15	1.24	0.00	1.30	1.51
2016	3.94	0.03	1.45	0.00	1.96	3.05
2017	8.04	0.00	1.55	0.53	3.46	6.06
2018	6.65	0.00	1.40	1.75	0.58	5.04
2019	3.03	0.00	1.54	2.31	0.53	2.53
2020	1.22	0.00	1.12	1.50	1.20	1.14

In reference approach emissions are estimated by excluding carbon stored in the final products from the total carbon content calculated from the apparent consumption. Feedstocks and non-energy consumption has been accounted according to the energy balances based on information provided in the Lithuanian Statistics database[4].

The differences of CO_2 emissions between these two methods can be explained by these reasons:

1. Statistical differences of energy balances contribute to some share of differences between these two methods. In 2019, statistical difference of residual fuel oil was reported as 438 TJ. This difference occurred due to different reporting of two enterprises: one enterprise in the sales invoice reported sale of dry residual fuel oil and another enterprise in their invoice reported export of wet residual fuel oil. Therefore, the residual fuel oil consumption due to this export become higher than the resources. Wherefore this difference was reported as statistical difference in Lithuanian energy statistics.
2. The differences of CO_2 emissions arise due to fuel transportation and distribution losses, which are not considered in the sectoral approach. For example, transportation and distribution losses of liquid fuels increased by 18% in 2017; losses of peat increased even 5 times in 2017 comparison to 2016; losses of other fossil fuel increased by 8 TJ times in 2017 comparison to 2016.
3. In RA CO_2 emissions from diesel and motor gasoline are fully accounted as fossil emissions, while in sectoral - the share of biofuels is accounted under liquid biomass. The share of biofuels increased by 26% in 2017 compared to 2016.
4. Mass imbalance between crude oil and other refinery feedstocks entering refinery and the petroleum products manufactured. In the Lithuanian energy statistics, the fuel input to refinery is not equal to the fuel output. In 2017, the difference was 2.3 TJ.
5. The effect of emission factors for liquid fuel in RA approach is important for countries with high import of crude oil and high export of oil products. In 2017, Lithuania imported 99.4% of crude oil and exported 81.3% of oil products produced at ORLEN Lietuva.
6. In the SA method for liquid fuels plant-specific and country-specific EFs are used, while in RA method for crude oil default EF is used (according to the 2006 IPCC Guidelines, p. 1.21, table 1.3) and for oil products country-specific EFs are used. Performed calculation showed that emission factors of liquid fuels have impact more than 4% in 2017.
7. Natural gas leakages into atmosphere for technological needs in RA method is accounted as natural gas consumption in the pipelines and in SA method natural gas leakages into atmosphere for technological needs are accounted under fugitive emissions from natural gas (1.B.2.b).
8. Refinery gas consumption for hydrogen production as intermediate process cannot be reported separately according to the international energy balance preparation principles. Emissions from hydrogen production (steam reforming process) at petroleum refining

[4] http://www.stat.gov.lt/lt/

company AB "ORLEN Lietuva" are reported under category 1.B.2.a.6 Other. By this way, their carbon is included in the RA, they are not included in the SA. To keep the consistency between the two approaches, we subtracted the CO_2 emissions from hydrogen production reported under 1.B.2.a.6 Other from RA.

In 2020, the difference in energy consumption was -1.41 per cent and in total CO_2 emissions – 1.14 per cent.

During reviews ERT noticed differences between the IEA data and the reference approach data which are provided by the Lithuanian Statistics and recommended to explain these differences in the NIR. Following this recommendation Lithuania investigated that the differences in natural gas consumption between the IEA data and the reference approach are due to the use of different types of calorific values: Lithuanian Statistics uses a net calorific value whereas the IEA data are based on a gross calorific value. The difference between net calorific value (NCV) and gross calorific value (GCV) is: 1 NCV = 0.9 GCV (IEA, 2005).

Representatives of Lithuanian Statistics explained that differences of refinery feedstock imports and refinery stocks between the IEA data and the reference approach are due to different aggregation level. The Lithuanian Statistics for refinery feedstock aggregates: refinery feedstock, semi-finished products of oil refining and additives/oxygenates. In the IEA database, refinery feedstock aggregates: refinery feedstock and semi-finished products of oil refining. Additives/oxygenates is provided separately in the IEA database.

It was investigated that crude oil import data for 1991-1994, 2000 and crude oil stock for 1990 between the IEA data and the Lithuanian statistics differ only in TJ, but are the same in specific unit (tons). This shows that these differences are due to the use of different types of calorific values.

The differences in peat briquettes consumption between the IEA data and the reference approach are due to the use of different types of calorific values: Lithuanian Statistics uses 0.01330 TJ/t and the IEA uses 0.020 TJ/t.

It is necessary to mention, that GHG emissions estimates in the sectoral approach and in the reference approach are based on activity data which is provided by the Lithuanian Statistics using the same NCV. According to the *2006 IPCC Guidelines* "fuel statistics collected by an officially recognized national body are usually the most appropriate and accessible activity data".

3.2.2 International bunker fuels

The Statistics Lithuania provides data on marine bunkers in Energy Balances (see Annex III). Country specific emission factors used to estimate CO_2 are presented in Table 3-6. Country specific CO_2 emission factors and *2006 IPCC Guidelines* default values of CH_4 and N_2O have been used.

Gas	Method used	Source of AD	EF used
CO_2	T2	Lithuanian Statistics database	CS
CH_4	T1	Lithuanian Statistics database	D
N_2O	T1	Lithuanian Statistics database	D

Table 3-6. Country specific CO_2 emission factors used for International bunkers, t/TJ

Fuel type	1990-2014	2015	2016	2017	2018	2019	2020
International navigation							

Gas/diesel oil	72.89	72.73	72.73	72.80	72.80	72.80	72.80
Residual fuel oil (RFO)	77.60	78.40	78.40	78.40	78.40	78.40	78.40
International aviation							
Jet kerosene	72.24	71.74	71.74	71.67	71.67	71.67	71.67

Annex V includes all country specific CO_2 emission factors. Summary of study on "Update of country specific GHG emission factors for Energy sector" is presented in Annex VI. Seeking to ensure higher accuracy of GHG inventory it was decided to apply the updated CO_2 emission factors for a period after 2015 and for a period 1990-2014 to use the emission factors determined in the study of 2012 (as presented in Annex VI). In 2017 the accredited Laboratory of Quality Research Centre of AB ORLEN Lietuva oil refinery performed updated measurements of CO_2 emission factors for transport fuel, therefore these updated country specific CO_2 emission factors for 2017-2020 were applied for transport fuel.

Tier 2 is used for CO_2 emissions estimates and Tier 1 for CH_4 and N_2O for International bunkers. GHG emissions and activity data from navigation assigned to international bunkers are presented in the following Table 3-7.

Table 3-7. GHG emissions and activity from 1.D International bunkers-navigation 1990-2020

Year	Activity data, TJ	CO_2, kt	CH_4, kt	N_2O, kt
1990	3,894	302.2	0.027	0.008
1995	5,780	448.5	0.040	0.012
2000	3,828	292.6	0.027	0.008
2005	5,933	456.8	0.042	0.012
2010	5,781	445.0	0.040	0.012
2015	3,196	240.7	0.022	0.006
2016	6,742	512.4	0.047	0.013
2017	7,293	554.2	0.051	0.015
2018	8,369	636.2	0.059	0.017
2019	8,100	616.1	0.057	0.017
2020	7,644	581.3	0.054	0.015

GHG emissions and activity data from aviation assigned to international bunkers are presented in the following Table 3-8.

Table 3-8. GHG emissions and activity from 1.D International bunkers-aviation 1990–2020

Year	Activity data, TJ	CO_2, kt	CH_4, kt	N_2O, kt
1990	5,522	398.9	0.003	0.011
1995	1,622	117.2	0.001	0.003
2000	972	70.2	0.000	0.002
2005	1,923	138.9	0.001	0.004
2010	2,012	145.3	0.001	0.004
2015	3,416	245.1	0.002	0.007
2016	3,999	286.9	0.002	0.008
2017	4,432	317.6	0.002	0.009
2018	5,274	378.0	0.003	0.011
2019	5,162	370.0	0.003	0.010
2020	2,268	162.5	0.001	0.005

Statistical data on use of three types of aviation fuel are collected by the Statistics Lithuania: aviation gasoline, gasoline type jet fuel and kerosene type jet fuel since 2000. Since 2000 Statistics Lithuania distinguishes aviation fuel consumption between domestic and international flights, however for 1990-1999 period only total fuel consumption data are available. In order to ensure time series consistency and comparability activity data were extrapolated and following advice from ERT it was distinguished in such a way that all aviation gasoline and part of kerosene type jet fuel is used for domestic purposes and the rest kerosene type jet fuel is used for international flights – the latter could therefore be considered as aviation bunkers.

3.2.3 Feedstocks and non-energy use of fuels

Feedstocks and non-energy use of fuel are included in national Energy balances (see Annex III). Use of fuels for feedstocks and non-energy use is dominated by natural gas (Figure 3-15). In 2020, natural gas amounted about 78.8% in the structure of feedstocks and non-energy use of fuels.

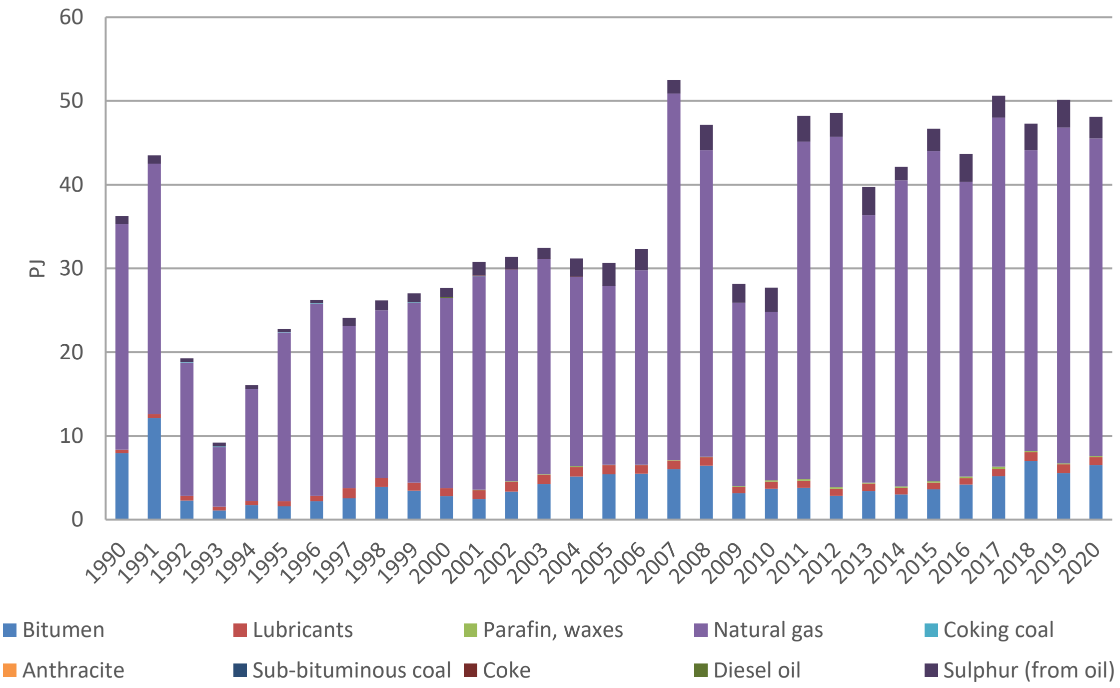


Figure 3-15. Feedstocks and non-energy use of fuels in Lithuania

The natural gas is used for ammonia, calcium ammonium nitrate, organic products and nitric acid production in the AB Achema. AB Achema is a leading manufacturer of nitrogen fertilizers and chemical products in Lithuania and the Baltic states. The ERT recommended to cross-check the data reported as non-energy use in the energy sector and the data reported under the industrial processes as the calculated CO_2 non-emitted from the use of natural gas for non-energy purpose differs from CO_2 emissions from ammonia production. A cross-check between the natural gas data used in industrial processes and the data reported as non-energy use in the energy sector showed that difference occur due to the use of different calorific values for the natural gas. In the industrial processes sector a specific calorific value is based on average annual lower calorific value of natural gas which is calculated on the basis of reports from the natural gas supplier AB Lietuvos dujos, which measure the calorific value twice a month. In the energy sector calculations are based on the data provided by the Statistics Lithuania where fuel consumption is calculated in terms of tonnes of oil equivalent and terajoules using the net calorific value. The data reported as non-energy use in the energy sector and the data reported under the industrial processes also differs because the data reported as non-energy use in the energy sector accounts not only feedstocks for ammonia production, but also feedstocks for calcium ammonium nitrate, organic products and nitric acid production. It is necessary to mentioned that AB Achema revised data for non-energy use for 2005-2014 in 2016, therefore in the 2016 submission revised data were reported in CRF 1.AD Feedstocks, reductants and other non-energy use of fuels.

The sulphur is a by-product of the oil refinery and it was included in the feedstock and non-energy use of fuels to reflect the data in the energy balance of Statistics Lithuania in the GHG inventory. Sulphur is used as a feedstock in Sulphuric acid production (CRF category 2.B.10). Pure sulphur does not contain carbon therefore GHG emissions from sulphur are not occurring.

The amounts of excluded carbon were calculated in accordance with the methodology provided in *2006 IPCC Guidelines* Volume 2 (page 6.7). The amounts of excluded carbon are reported in CRF 1.AD Feedstocks, reductants and other non-energy use of fuels and linked to the CRF 1.AB Fuel Combustion - Reference Approach as excluded carbon.

3.2.4 CO_2 capture from flue gases and subsequent CO_2 storage

CO_2 capture from flue gases and subsequent CO_2 storage is not occurring in Lithuania.

3.2.5 Country-specific issues

All country specific issues are explained in detail under relevant chapters of source categories.

Table 3-9 provides information on the status of emissions estimates of all subcategories of Category 1.A Fuel Combustion. Symbol "+" indicates that emissions from this subcategory have been estimated. "NO" indicates that the respective sector and fuel category is not relevant for Lithuanian energy balance.

Table 3-9. Overview on the status of emissions estimation of Category 1.A Fuel Combustion (CRF 1.A)

IPCC Category	**CO_2**	**CH_4**	**N_2O**
1.A.1.a Public electricity and heat production			
1.A.1.a Liquid fuels	+	+	+
1.A.1.a Solid fuels	+	+	+
1.A.1.a Gaseous fuels	+	+	+
1.A.1.a Other fossil fuels	+	+	+
1.A.1.a Peat	+	+	+
1.A.1.a Biomass	+	+	+
1.A.1.b Petroleum refining			
1.A.1.b Liquid fuels	+	+	+
1.A.1.b Solid fuels	NO	NO	NO
1.A.1.b Gaseous fuels	+	+	+
1.A.1.b Other fossil fuels	NO	NO	NO
1.A.1.b Peat	NO	NO	NO
1.A.1.b Biomass	+	+	+
1.A.1.c Manufacture of solid fuels and other energy industries			
1.A.1.c Liquid fuels	+	+	+
1.A.1.c Solid fuels	NO	NO	NO
1.A.1.c Gaseous fuels	+	+	+
1.A.1.c Other fossil fuels	NO	NO	NO
1.A.1.c Peat	+	+	+
1.A.1.c Biomass	+	+	+
1.A.2.a Iron and steel			
1.A.2.a Liquid fuels	NO	NO	NO
1.A.2.a Solid fuels	NO	NO	NO

1.A.2.a Gaseous fuels	NO	NO	NO
1.A.2.a Other fossil fuels	NO	NO	NO
1.A.2.a Peat	NO	NO	NO
1.A.2.a Biomass	NO	NO	NO
1.A.2.b Non-ferrous metals			
1.A.2.b Liquid fuels	NO	NO	NO
1.A.2.b Solid fuels	NO	NO	NO
1.A.2.b Gaseous fuels	NO	NO	NO
1.A.2.b Other fossil fuels	NO	NO	NO
1.A.2.b Peat	NO	NO	NO
1.A.2.b Biomass	NO	NO	NO
1.A.2.c Chemicals			
1.A.2.c Liquid fuels	+	+	+
1.A.2.c Solid fuels	+	+	+
1.A.2.c Gaseous fuels	+	+	+
1.A.2.c Other fossil fuels	NO	NO	NO
1.A.2.c Peat	NO	NO	NO
1.A.2.c Biomass	+	+	+
1.A.2.d Pulp, Paper and Print			
1.A.2.d Liquid fuels	+	+	+
1.A.2.d Solid fuels	+	+	+
1.A.2.d Gaseous fuels	+	+	+
1.A.2.d Other fossil fuels	NO	NO	NO
1.A.2.d Peat	+	+	+
1.A.2.d Biomass	+	+	+
1.A.2.e Food processing, beverages and tobacco			
1.A.2.e Liquid fuels	+	+	+
1.A.2.e Solid fuels	+	+	+
1.A.2.e Gaseous fuels	+	+	+
1.A.2.e Other fossil fuels	NO	NO	NO
1.A.2.e Peat	+	+	+
1.A.2.e Biomass	+	+	+
1.A.2.f Non-metallic minerals			
1.A.2.f Liquid fuels	+	+	+
1.A.2.f Solid fuels	+	+	+
1.A.2.f Gaseous fuels	+	+	+
1.A.2.f Other fossil fuels	+	+	+
1.A.2.f Peat	+	+	+
1.A.2.f Biomass	+	+	+
1.A.2.g.i Machinery			
1.A.2.g.i Liquid fuels	+	+	+
1.A.2.g.i Solid fuels	+	+	+
1.A.2.g.i Gaseous fuels	+	+	+
1.A.2.g.i Other fossil fuels	NO	NO	NO
1.A.2.g.i Peat	+	+	+
1.A.2.g.i Biomass	+	+	+
1.A.2.g.ii Transport equipment			
1.A.2.g.ii Liquid fuels	+	+	+
1.A.2.g.ii Solid fuels	+	+	+
1.A.2.g.ii Gaseous fuels	+	+	+

1.A.2.g.ii Other fossil fuels	NO	NO	NO
1.A.2.g.ii Peat	NO	NO	NO
1.A.2.g.ii Biomass	+	+	+
1.A.2.g.iii Mining and quarrying			
1.A.2.g.iii Liquid fuels	+	+	+
1.A.2.g.iii Solid fuels	+	+	+
1.A.2.g.iii Gaseous fuels	+	+	+
1.A.2.g.iii Other fossil fuels	NO	NO	NO
1.A.2.g.iii Peat	+	+	+
1.A.2.g.iii Biomass	+	+	+
1.A.2.g.iv Wood and wood products			
1.A.2.g.iv Liquid fuels	+	+	+
1.A.2.g.iv Solid fuels	+	+	+
1.A.2.g.iv Gaseous fuels	+	+	+
1.A.2.g.iv Other fossil fuels	NO	NO	NO
1.A.2.g.iv Peat	+	+	+
1.A.2.g.iv Biomass	+	+	+
1.A.2.g.v Construction			
1.A.2.g.v Liquid fuels	+	+	+
1.A.2.g.v Solid fuels	+	+	+
1.A.2.g.v Gaseous fuels	+	+	+
1.A.2.g.v Other fossil fuels	NO	NO	NO
1.A.2.g.v Peat	+	+	+
1.A.2.g.v Biomass	+	+	+
1.A.2.g.vi Textile and leather			
1.A.2.g.vi Liquid fuels	+	+	+
1.A.2.g.vi Solid fuels	+	+	+
1.A.2.g.vi Gaseous fuels	+	+	+
1.A.2.g.vi Other fossil fuels	NO	NO	NO
1.A.2.g.vi Peat	+	+	+
1.A.2.g.vi Biomass	+	+	+
1.A.2.g.vii Off-road vehicles and other machinery			
1.A.2.g.vii Liquid fuels	+	+	+
1.A.2.g.vii Solid fuels	NO	NO	NO
1.A.2.g.vii Gaseous fuels	NO	NO	NO
1.A.2.g.vii Other fossil fuels	NO	NO	NO
1.A.2.g.vii Peat	NO	NO	NO
1.A.2.g.vii Biomass	NO	NO	NO
1.A.2.g.viii Non-specified industry			
1.A.2.g.viii Liquid fuels	+	+	+
1.A.2.g.viii Solid fuels	+	+	+
1.A.2.g.viii Gaseous fuels	+	+	+
1.A.2.g.viii Other fossil fuels	+	+	+
1.A.2.g.viii Peat	+	+	+
1.A.2.g.viii Biomass	+	+	+
1.A.3. TRANSPORT			
1.A.3.a Domestic aviation			
1.A.3.a Liquid fuels	+	+	+
1.A.3.a Biomass	NO	NO	NO
1.A.3.b Road Transportation			

1.A.3.b Liquid fuels	+	+	+
1.A.3.b Solid	NO	NO	NO
1.A.3.b Gaseous fuels	+	NO	NO
1.A.3.b Other fossil fuels	NO	NO	NO
1.A.3.b Biomass	+	+	+
1.A.3.c Railways			
1.A.3.c Liquid fuels	+	+	+
1.A.3.c Solid	NO	NO	NO
1.A.3.c Gaseous fuels	NO	NO	NO
1.A.3.c Other fossil fuels	NO	NO	NO
1.A.3.c Biomass	NO	NO	NO
1.A.3.d Domestic Navigation			
1.A.3.d Liquid fuels	+	+	+
1.A.3.d Solid	NO	NO	NO
1.A.3.d Gaseous fuels	NO	NO	NO
1.A.3.d Other fossil fuels	NO	NO	NO
1.A.3.d Biomass	NO	NO	NO
1.A.3.e Other transportation			
1.A.3.e Liquid fuels	+	+	+
1.A.3.e Solid	NO	NO	NO
1.A.3.e Gaseous fuels	+	+	+
1.A.3.e Other fossil fuels	NO	NO	NO
1.A.3.e Biomass	NO	NO	NO
1.A.4.a Commercial/Institutional			
1.A.4.a Liquid fuels	+	+	+
1.A.4.a Solid fuels	+	+	+
1.A.4.a Gaseous fuels	+	+	+
1.A.4.a Other fossil fuels	NO	NO	NO
1.A.4.a Peat	+	+	+
1.A.4.a Biomass	+	+	+
1.A.4.b Residential			
1.A.4.b Liquid fuels	+	+	+
1.A.4.b Solid fuels	+	+	+
1.A.4.b Gaseous fuels	+	+	+
1.A.4.b Other fossil fuels	NO	NO	NO
1.A.4.b Peat	+	+	+
1.A.4.b Biomass	+	+	+
1.A.4.c Agriculture/Forestry/Fisheries			
1.A.4.c Liquid fuels	+	+	+
1.A.4.c Solid fuels	+	+	+
1.A.4.c Gaseous fuels	+	+	+
1.A.4.c Other fossil fuels	NO	NO	NO
1.A.4.c Peat	+	+	+
1.A.4.c Biomass	+	+	+
1.A.5 Non-specified			
1.A.5 Liquid fuels	+	+	+
1.A.5 Solid fuels	NO	NO	NO
1.A.5 Gaseous fuels	NO	NO	NO
1.A.5 Other fossil fuels	NO	NO	NO
1.A.5 Peat	NO	NO	NO

1.A.5 Biomass	NO	NO	NO

3.3 Energy industries

3.3.1 Main Activity Electricity and Heat Production (CRF 1.A.1.a)

3.3.1.1 Category description

During 1990-2010 Ignalina NPP was dominating in the internal electricity market - its share in the structure of electricity generation was fluctuating at around 80%. At the beginning of 2009 the total installed capacity of the Lithuanian power plants was 5029 MW, including Ignalina NPP with 1300 MW and Lithuanian TPP with 1800 MW of electrical capacity. After the decommissioning of Ignalina NPP (Unit 1 was closed in 2004 and Unit 2 in 2009) total available capacity of Lithuanian power plants was 3605 MW in 2010. Since 2010 Lithuanian TPP is dominating in the structure of capacities. Currently this power plant renamed to Elektrenai Complex with total installed capacity of 1055 MW: two units of the reserve power plant (300 MW each) and combined cycle unit (455 MW). About 22% of the overall installed electrical capacity is covered by renewable energy power plants. In 2020, wind PP amounted 14.0% of total installed electrical capacity in the country. Currently very high share of required electricity (share of net import to gross inland electricity consumption was 80% in 2020) is imported from neighboring countries as the cost of electricity production at Lithuanian power plants is higher.

During 2000-2017 the share of green electricity was increasing on average by 12.0% per year but it reduced by 13.1% in 2018. This reduction was stipulated by decreased production of hydropower due to dry year. In 2019, renewable electricity production increased by 12.0%, in 2020 - by 4.0%.

The key trend in public electricity and heat production sector - power generation becoming more geographically distributed due to the installation of relatively small power plants based on biomass.

Characteristics of the Lithuanian power plants in 1 January 2021 are presented in Table 3-10.

Table 3-10. Characteristics of the Lithuanian power plants in 1 January 2021 (Litgrid, 2021)

Power plant	Fuel	Installed capacity, MW
CHPs	Residual fuel oil, natural gas	1230
CHPs	Natural gas	657
Kaunas hydro PP	-	101
Kruonis hydro pumped storage PP	-	900
Small hydro PP	-	27
Wind PP	-	540
Biomass PP	Biomass	63
Biogas PP	Biogas	36
Solar PP	-	169
Waste CHP	Municipal and industrial waste	48
Other CHP	Natural gas, energy from chemical processes	37
Total	**-**	**3808**

Lithuania is a country, where living space heating season (when outside temperature is less than +10ºC) is on average 219 days per year (6-7 months). Lithuanian district heating systems are playing very important role in the heat production sector. About 75% of the residential buildings in Lithuania's towns are supplied with heat from the district heating systems.

In 2020, 32.0% of heat supplied to district heating systems was produced at Combined Heat and Power plants (CHP), 47.0% - at heat only boilers and 21.0% – at plants using energy from chemical processes.

Natural gas was the main fuel used in the district heating sector till 2012. In 2020, share of natural gas accounted to 11.1% in district heating sector. Since 2000 the share of renewable energy (biomass, wood, straw, chips, sawdust, wood pellets) increased significantly from 6.0% (2000) to 87.3% (2020) in Lithuanian district heating sector. Relevant share of residual fuel oil used for heat production in district heating systems was replaced by renewable energy sources mainly by biomass.

Category 1.A.1.a Public Electricity and Heat Production covers emissions from fuel combustion for electricity generation, combined heat and power generation and fuel combustion in heat plants.

3.3.1.2 Electricity Generation (CRF 1.A.1.a.i)

All emissions are reported as "not occurring" because entire production of electricity is carried out at CHPs and renewable energy sources power plants.

3.3.1.3 Combined Heat and Power Generation (CRF 1.A.1.a.ii)

3.3.1.3.1 Category description

Tendencies of fuel consumed and total GHG emissions in Combined Heat and Power Generation (including Electricity Generation) are provided in Figure 3-16.

As it is seen from Figure 3-16, during the 2001-2012 period the consumption of fuels in Combined Heat and Power Generation was rather stable – about 45 PJ a year. However, since 2013 fuel consumption in Combined Heat and Power Generation started to decrease by almost 10.0% per annum till 2020. This was mainly due to reduction of electricity and heat generation based on natural gas and liquid fuels and increased share of electricity import from neighboring countries. In 2020, the total fuel consumption in Combined Heat and Power Generation increased by 46.4%. This increase was due to significant reduction of natural gas prices as a result of the global COVID-19 pandemic. Significant reduction of natural gas price allowed Lithuanian power plants to ensure a competitive price in the electricity market in the presence of reduced electricity import due to maintenance of the electricity interconnection between Lithuania and Sweden.

Consumption of fuels in Combined Heat and Power Generation totalled 28.1 PJ in 2020.

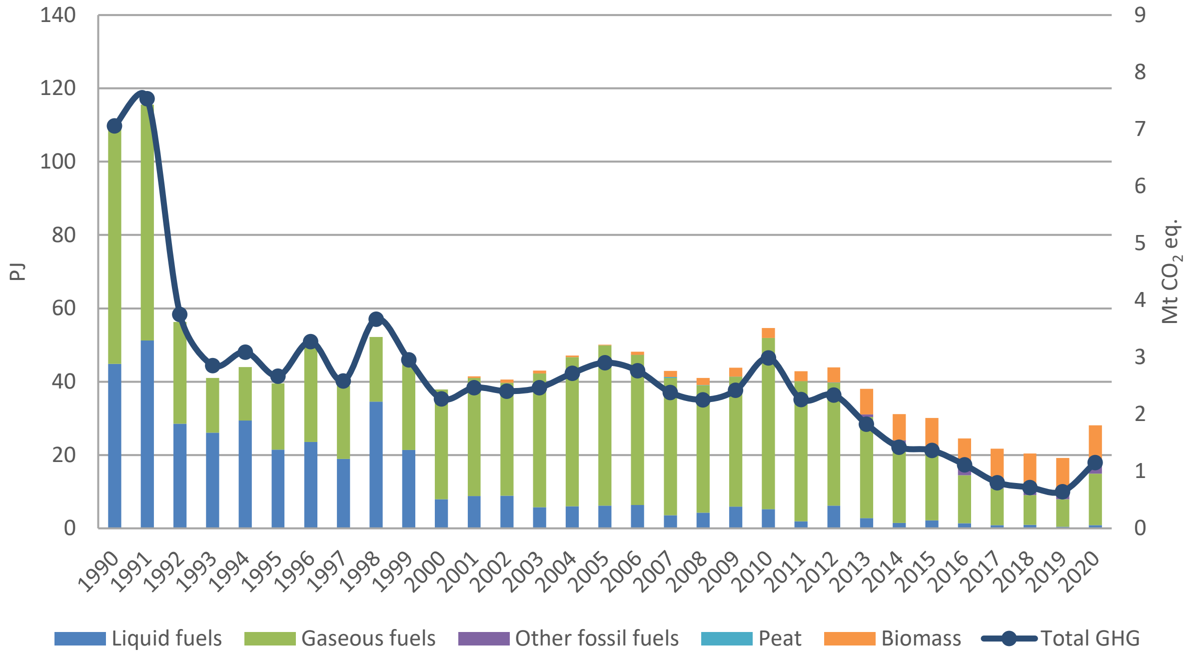


Figure 3-16. Tendencies of fuel consumed and GHG emissions in Combined Heat and Power Generation (1.A.1.a.ii)

Historically natural gas was dominating in the structure of total fuel combusted for Combined Heat and Power Generation. Since 2001 wood/wood waste started to be used for Combined Heat and Power Generation. The share of biomass (including biogas) increased from 1.1% (2001) till 51.3% (2019). In 2020, natural gas dominated in the structure (49.9%) of total fuel combusted for Combined Heat and Power Generation followed by biomass which accounted 38.6%. The share and volume of liquid fuels drastically decreased since 1990s and in 2020 accounted only 3.1% in structure of fuel combusted. In 2007, the biggest Lithuanian biomass power plant tried to switch to higher share of peat instead of wood/wood waste, but this solution was not economically and technically feasible therefore this high peak of peat consumption appeared only in 2007. The first CHPs ("Fortum Klaipeda") based on municipal (non-biomass fraction and biomass fraction) and industrial waste (non-biomass fraction and biomass fraction) started operation in 2013. Until 2017 "Fortum Klaipėda" incinerated waste and biomass, and from 2017 onwards, incinerates only waste. In 2020, the Kaunas CHP (24 MW) based on municipal and industrial waste started operation in Kaunas. Non-biomass fraction of municipal and industrial waste in the structure of total fuel combusted in Combined Heat and Power Generation increased from 1.6% (2013) till 8.5% (2020). Non-biomass fraction of municipal waste combusted in CHP consist from: fabric, textile materials, leather, rubber, soft and hard plastic etc. A quantitative assessment of biomass and non-biomass fractions of waste has been obtained from the Lithuanian Statistics database (http://www.stat.gov.lt/lt/) and is provided in the Annex III. The structure of waste depends on the quantities of waste supplied by the different waste suppliers. The carbon content factors used were derived in study "Update of country specific GHG emission factors for energy sector" (2016). They were measured from 17 samples considered to represent the non-biomass fraction and on 6 samples considered to represent the biomass fraction.

Biogas from manure management is combusted in co-generators for energy purposes which is included in subcategory 1.A.1.a.ii Combined heat and power generation. Further explanation is provided in chapter 5.3.2.2. Characterization of manure management systems.

Total GHG emissions from Combined Heat and Power Generation decreased by 6.1 times since 1990 and amounted to 1157.7 kt CO_2 eq. in 2020.

3.3.1.3.2 Methodological issues

CO_2 emissions were calculated applying Tier 2 or Tier 3, except industrial waste (Tier 1 based on *2006 IPCC Guidelines* default emission factor); CH_4 and N_2O were calculated applying Tier 1.

Emission factors and methods

Gas	Method used	Source of AD	EF used
CO_2	T1, T2, T3	Lithuanian Statistics database	D, CS, PS
CH_4	T1	Lithuanian Statistics database	D
N_2O	T1	Lithuanian Statistics database	D

Country specific CO_2 emission factors used in the calculations of emissions from Combined Heat and Power Generation (1.A.1.a.ii) have been derived in study "Determination of national GHG emission factors for energy sector" (performed in 2012 by Lithuanian Energy Institute) and study "Update of country specific GHG emission factors for energy sector" (performed in 2016 by Lithuanian Energy Institute). All country specific CO_2 emission factors are presented in Annex V. Summary of study on "Update of country specific GHG emission factors for Energy sector" is presented in Annex VI. Seeking to ensure higher accuracy of GHG inventory it is valuable to apply the updated CO_2 emission factors for a period after 2015 and for a period 1990-2014 to use the emission factors determined in the study of 2012 (as presented in Annex VI). According to the agreement with Ministry of Environment the accredited Laboratory of Quality Research Centre of AB "ORLEN Lietuva" (petroleum refining company) performed measurements for CO_2 emission factors for all oil products produced at this refinery in 2017. Country specific CO_2 emission factors applied since 2017 for oil products are based on these measurements' protocols.

Country specific CO_2 emission factor for natural gas was determined considering the chemical composition of natural gas during 2004-2014 that was provided by Central Calibration and Test Laboratory of AB Lietuvos dujos. Till 2015 natural gas in Lithuania was imported from Russia via pipelines and the country depended on natural gas import from Russia for 100%.

Since January 2015 the liquefied natural gas (LNG) terminal started operation in Lithuania which opened the natural gas market in Lithuania. LNG terminal allows the natural gas supply from different suppliers. Currently Statoil is contracted to supply LNG for five years to cover the minimum operational need of the terminal. Gas is originating from the Snohvit field in the Norwegian Sea. The chemical composition of natural gas imported through the pipeline from Russia and the LNG terminal is different. CO_2 emission factor for natural gas (55.53 kg/GJ) in 2015 was determined considering chemical composition of natural gas that was provided by ESO (Energijos Skirstymo Operatorius AB) taking into consideration gas imported via LNG terminal and via pipeline. ESO was established January 1 of 2016 merging AB Lietuvos dujos and JSC LESTO. The main activities of ESO is natural gas and electricity distribution in Lithuania.

In 2015, via LNG terminal was imported 16.5% of total natural gas import to Lithuania. In 2016, the share of imported natural gas via LNG terminal increased significantly and reached 59.8% of total natural gas import. Therefore, the CO_2 emission factor for natural gas (55.73 kg/GJ) was updated considering changes in chemical composition of natural gas for 2016.

Data on chemical composition and quality parameters since 2016 are provided by Amber Grid. JSC Amber Grid is the operator of Lithuania's natural gas transmission system. AB Amber Grid was established on 11 June 2013 pursuant to a resolution adopted by a General Meeting of

Shareholders of AB Lietuvos Dujos in implementation of requirements of legal acts of the Republic of Lithuania providing for the unbundling of the natural gas transmission activity from other activities.

In 2017, it was imported 46.0% of total natural gas import to Lithuania via LNG terminal. The CO_2 emission factor for natural gas (55.57 kg/GJ) was updated considering changes in chemical composition of natural gas for 2017. In 2018, via LNG terminal was imported 35.8%. In 2019, the share of imported natural gas increased significantly and reached 65.3% of total natural gas import. In 2020, via LNG terminal was imported the same share of natural gas (65.3%) as in 2019.

Seeking to ensure higher accuracy of GHG inventory variable yearly values of CO_2 emission factor of natural gas for a period 2004-2020 are applied and an average value (established on the basis of natural gas chemical composition imported to Lithuania from Russia during 2004-2014) for a period 1990-2003.

2006 IPCC Guidelines default emission factors were used for CH_4 and N_2O emissions estimation (Table 3-11).

Table 3-11. *2006 IPCC Guidelines* default emission factor CH_4 and N_2O emission factors used for category Combined Heat and Power Generation (1.A.1.a.ii), kg/TJ

Fuel type	**CH_4 1990-2020**	**N_2O 1990-2020**
Heating and other gasoil	3.0	0.6
Residual fuel oil (RFO)	3.0	0.6
Liquefied petroleum gases (LPG)	1.0	0.1
Refinery gas	1.0	0.1
Orimulsion	3.0	0.6
Emulsified vacuum residue	3.0	0.6
Natural gas	1.0	0.1
Wood and wood waste	30.0	4.0
Other solid biomass	30.0	4.0
Biogas	1.0	0.1
Municipal waste (non-biomass fraction)	30.0	4.0
Municipal waste (biomass fraction)	30.0	4.0
Industrial waste	30.0	4.0

Plant specific emission factors based on EU ETS data (Tier 3) for Combined Heat and Power Generation (1.A.1.a.ii) are presented in Table 3-12. Emulsified vacuum residue and refinery gas are combusted at the ORLEN Lietuva CHP: emulsified vacuum residue was combusted in 2008; refinery gas was combusted in 2012-2020. Orimulsion was combusted at the Lithuanian TPP during 1995-2008 period. The fuel composition for the most of fuels might change over time and plant specific EFs show this variation. Therefore, following recommendations given from the experts during the implementation of European Commission project "Assistance to EU Member states with KP reporting requirements", in the case of plant specific emission factor application, the average value of CO_2 emission factor was used for the period 1990-2004 and variable yearly values for the period 2005-2020.

Table 3-12. Plant specific CO_2 emission factors for category Combined Heat and Power Generation (1.A.1.a.ii) (EU ETS reports data)

Year	**CO_2, t/TJ**
Orimulsion	
1995-2004	81.74

2005	81.95
2006	81.74
2007	80.33
2008	82.95
Emulsified vacuum residue	
2008	79.41
Refinery gas	
2012	56.92
2013	57.64
2014	59.03
2015	58.72
2016	58.46
2017	57.49
2018	57.08
2019	56.37
2020	56.38

Activity data

For calculation of GHG emissions in category Combined Heat and Power Generation (1.A.1.a.ii) activity data had been obtained from the Lithuanian Statistics database (http://www.stat.gov.lt/lt/). Activity data is provided in the Annex III.

3.3.1.3.3 Uncertainties and time-series consistency

Uncertainty of activity data in Combined Heat and Power Generation is ±2.0% taking into consideration recommendations provided by *the 2006 IPCC Guidelines*. According to *the 2006 IPCC Guidelines* (Volume 2, Chapter 1, page 1.19) biomass data are generally more uncertain than other data in national energy statistics, because a large fraction of the biomass may be part of the informal economy, and the trade in these types of fuels is frequently not registered in the national energy statistics and balances. That is a reason for higher uncertainty for biomass activity data than for other fuel types. The uncertainty rage for biomass is assigned ±5.0% taking into account implementation of solid biomass accounting rules for energy sector enterprises, biomass sellers and other legal entities (after revision in 2015) and following recommendations provided by *the 2006 IPCC Guidelines*.

Uncertainties of CO_2 emission factors for liquid fuels (residual fuel oil, LPG, non-liquefied petroleum gas, orimulsion and emulsified vacuum residue) and gaseous fuels (natural gas) are ±2.0% in Combined Heat and Power Generation. Uncertainties of CO_2 emission factors for solid fuels (peat) and waste are ±5.0%. Estimated uncertainties of CO_2 emission factors for biomass are ±15%. Uncertainties of all country specific CO_2 emission factors were revised in the study "Update of country specific GHG emission factors for Energy sector" (see Annex VI).

Uncertainties of CH_4 and N_2O emission factors for liquid, solid, gaseous fuels and waste were assigned as very high about ±50%. Uncertainties of emission factors for biomass were assumed ±150%. Uncertainties were derived considering *2006 IPCC Guidelines*.

Time series of the estimated emissions are consistent and complete because the same methodology, emission factors and data sources are used for sectors for all years in the time series. All emissions are estimated or reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.3.1.3.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

The consumption of every type of fuel has been checked and compared with other available data sources (IEA, EUROSTAT). The time series for all data have been studied carefully in search for outliers.

The results are verified by calculating CO_2 emissions with the reference approach, and comparing results with the sectoral approach.

3.3.1.3.5 Category-specific recalculations

No recalculations have been done.

3.3.1.3.6 Category-specific planned improvements

Further investigation of possibilities to use the new available data provided in the EU ETS based on Tier 3, reported by the operators for the energy sector emission estimates is foreseen.

3.3.1.4 Heat plants (CRF 1.A.1.a.iii)

3.3.1.4.1 Category description

Tendencies of fuel consumed and total GHG emissions in Heat Plants are provided in Figure 3-17.

Total fuel consumption in Heat Plants reduced by 3.5 times since 1990 (Figure 3-17). During the 2004-2012 the consumption of fuels in Heat Plants was rather stable – about 20 PJ a year. During 2013–2019 the fuel consumption started to increase almost by 4.0% per annum. This is mainly due to replacement of heat production at CHP by heat production at Heat plants. In 2020, heat production at Heat plants reduced by 6.0% in comparison to 2019 due to decreased demand and increased share of heat production at CHP. Total fuel consumption in Heat plants amounted 21.59 PJ in 2020.

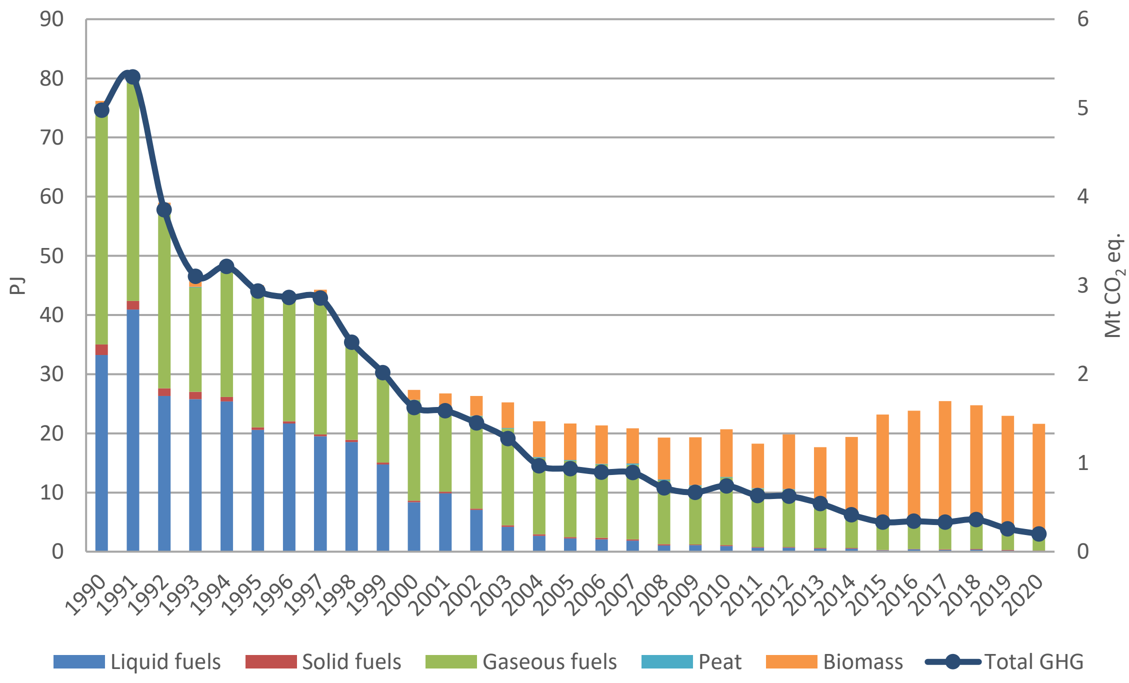


Figure 3-17. Tendencies of fuel consumed and GHG emissions in Heat Plants (1.A.1.a.iii)

Currently biomass and natural gas dominates in the structure of total fuel combusted in Heat Plants. In 2020, biomass accounted 87.3% and natural gas – 11.1%. Since 2000 wood/wood waste started to be widely used for heat generation in Heat Plants. During a last decades, the share of biomass increased from 6.0% (2000) till 87.3% (2020). In 2013, 2017 and 2018 some of heat plants tried to switch to higher share of peat instead of wood/wood waste but this solution was not economically feasible therefore this high peak of peat consumption appeared in 2013, 2017 and 2018. The share and volume of liquid fuels drastically reduced since 1990s and in 2020 accounted only 0.7% in structure of fuel combusted. Solid fuels accounted 0.9% in 2020.

Total GHG emissions from Heat Plants reduced by 25 times since 1990 and amounted 199.7 kt CO_2 eq. in 2020.

3.3.1.4.2 Methodological issues

CO_2 emissions were calculated applying Tier 2/Tier 3, CH_4 and N_2O were calculated applying Tier 1.

Emission factors and methods

Gas	Method used	Source of AD	EF used
CO_2	T2, T3	Lithuanian Statistics database	CS, PS
CH_4	T1	Lithuanian Statistics database	D
N_2O	T1	Lithuanian Statistics database	D

All country specific CO_2 emission factors are presented in Annex V.

2006 IPCC Guidelines default emission factors were used for CH_4 and N_2O emissions estimation (Table 3-13).

Table 3-13. *2006 IPCC Guidelines* default emission factor CH_4 and N_2O emission factors used for category Heat Plants (1.A.1.a.iii), kg/TJ

Fuel type	CH_4 1990-2020	N_2O 1990-2020
Heating and other gasoil	3.0	0.6
Residual fuel oil (RFO)	3.0	0.6
Liquefied petroleum gases (LPG)	1.0	0.1
Shale oil	3.0	0.6
Crude oil	3.0	0.6
Diesel oil	3.0	0.6
Refinery gas	1.0	0.1
Other bituminous coal	1.0	1.5
Anthracite	1.0	1.5
Sub-bituminous coal	1.0	1.5
Peat	1.0	1.5
Natural gas	1.0	0.1
Wood and wood waste	30.0	4.0
Other solid biomass	30.0	4.0
Biogas	1.0	0.1

Plant specific CO_2 EFs based on EU ETS data applied for refinery gas, sub-bituminous coal and anthracite for category Heat Plants (1.A.1.a.iii) are presented in Table 3-14. Refinery gas was combusted at heat plant located at the ORLEN Lietuva during 2007-2011. Sub-bituminous coal and anthracite was combusted at heat plant located in cement production plant. Sub-bituminous coal was combusted during 2000-2015 and anthracite only in 2000 and 2009, 2010. Therefore, the average value of CO_2 emission factor for sub-bituminous coal was used for the period 2000-2011 and variable yearly values for the period 2012-2015 following recommendations given from the experts during the implementation of European Commission project "Assistance to EU Member states with KP reporting requirements".

Table 3-14. Plant specific CO_2 emission factors for category Heat Plants (1.A.1.a.iii) (EU ETS reports data)

Year	CO_2, kg/GJ
Refinery gas	
2007	56.18
2008	55.07
2009	54.86
2010	57.53
2011	57.25
Sub-bituminous coal	
2000-2011	95.45
2012	96.00
2013	95.40
2014	95.50
2015	94.90
Anthracite	
2000	106.55
2009	106.00
2010	107.10

Activity data

For calculation of GHG emissions in category Heat Plants (1.A.1.a.iii) activity data had been obtained from the Lithuanian Statistics database (http://www.stat.gov.lt/lt/). Activity data is provided in the Annex III.

3.3.1.4.3 Uncertainties and time-series consistency

Uncertainty of activity data in category Heat Plants is ±2.0% taking into consideration recommendations provided by *the 2006 IPCC Guidelines*. According to *the 2006 IPCC Guidelines* (Volume 2, Chapter 1, page 1.19) biomass data are generally more uncertain than other data in national energy statistics, because a large fraction of the biomass may be part of the informal economy, and the trade in these types of fuels is frequently not registered in the national energy statistics and balances. That is a reason for higher uncertainty for biomass activity data than for other fuel types. The uncertainty rage for biomass is assigned ±5.0% taking into account implementation of solid biomass accounting rules for energy sector enterprises, biomass sellers and other legal entities (after revision in 2015) and following recommendations provided by *the 2006 IPCC Guidelines*.

Uncertainties of CO_2 emission factors for liquid fuels (crude oil, shale oil, residual fuel oil, LPG, non-liquefied petroleum gas, orimulsion, gasoil, diesel oil and emulsified vacuum residue) and gaseous fuels (natural gas) are ±2.0% in category Heat Plants. Uncertainties of CO_2 emission factors for solid fuels (peat and other bituminous coal) are ±5.0%. Estimated uncertainties of CO_2 emission factors for biomass are ±15%. Uncertainties of all country specific CO_2 emission factors were revised in the study "Update of country specific GHG emission factors for Energy sector" (see Annex VI).

Uncertainties of CH_4 and N_2O emission factors for liquid, solid and gaseous fuels were assigned as very high about ±50%. Uncertainties of emission factors for biomass were assumed ±150%. Uncertainties were derived considering *2006 IPCC Guidelines*.

Time series of the estimated emissions are consistent and complete because the same methodology, emission factors and data sources are used for sectors for all years in the time series. All emissions are estimated or reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.3.1.4.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

The consumption of every type of fuel has been checked and compared with other available data sources (IEA, EUROSTAT). The time series for all data have been studied carefully in search for outliers.

The results are verified by calculating CO_2 emissions with the reference approach, and comparing results with the sectoral approach.

3.3.1.4.5 Category-specific recalculations

No recalculations have been done.

3.3.1.4.6 Category-specific planned improvements

Further investigation of possibilities to use the new available data provided in the EU ETS based on Tier 3, reported by the operators for the energy sector emission estimates is foreseen.

3.3.1.5 CO_2 emission from carbonates use in flue gas desulphurisation (2.A.4.d)

3.3.1.5.1 Category description

In previous submission CO_2 emissions from consumption of carbonates use in flue gas desulphurisation were under 2.H.3 Other subcategory. Following the recommendation by the Expert Review Team, all emissions from limestone used in flue gas desulphurisation are under 2.A.4.d. Other (Other process uses of carbonates) in this submission. Information on CO_2 emissions from limestone used for flue gas desulphurisation is included in this chapter below.

3.3.1.5.2 Methodological issues

There is one power plant in Lithuania which used limestone for flue gas desulphurisation in the period 2008-2016. CO_2 emissions were calculated using Tier 2 method based on national data on the quantity of limestone and dolomite consumed (Equation 2.15, page 2.34) described in *2006 IPCC Guidelines*:

$$CO_2 Emissions = (M_{ls} \times EF_{ls}) + (M_d \times EF_d)$$

where:

M_{ls} *or* M_d - mass of limestone or dolomite respectively (consumption), tonnes,

EF_{ls} or EF_d - emission factor for limestone or dolomite calcination respectively, tonnes CO_2/tonne carbonate.

Activity data (limestone use) was supplied by power plant. Limestone used in the CO_2 estimation is the quantity of carbonate rock, thus a default purity of 95% is assumed as suggested by the *2006 IPCC Guidelines*. Default emission factor (0.43971 tonnes CO_2/tonne carbonate) suggested in *2006 IPCC Guidelines* Volume 3 Table 2.1 (page 2.7) was used. The limestone is used in the flue gas desulphurisation only when liquid fuel (residual fuel oil) is used and the quantity of limestone used is directly dependent on the amount of liquid fuel used (on average 0.06 tonne of limestone is used for 1 tonne of liquid fuel) (Table 3-15).

Table 3-15. CO_2 emission from limestone use in flue gas desulphurization

Year	Limestone use, t	Consumed liquid fuel, t	CO_2 emission, t
2008	4,138.0	59,993.0	1,728.5
2009	2,237.0	62,131.0	934.4
2010	3,647.0	58,351.0	1,523.4
2011	49.0	703.0	20.5
2012	10,028.0	113,865.0	4,188.9
2013	2,703.0	33,099.0	1,129.1
2014	155.0	4,685.0	64.7
2015	450.0	7,084.0	188.0
2016	179.5	2,311.0	75.0
2017-2020	NO	NO	NO

According to *2006 IPCC Guidelines*: "It is good practice to report emissions from the consumption of carbonates in the source category where the carbonates are consumed and the CO_2 emitted (…)". Where carbonates are used as fluxes or slagging agents (e.g., in iron and steel, chemicals, or for environmental pollution control etc.) emissions should be reported in the respective source categories where the carbonate is consumed." (page 2.33), therefore information on emissions calculated was provided under Energy sector (CRF 1.A.1.a) of the NIR, however, due to lack of CRF Reporter functionality emissions in CRF Reporter were reported under CRF 2.A.4.d "Other" category in Industrial processes and product use sector.

3.3.1.5.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgement:

- Activity data uncertainty is assumed to be 3%;
- Emission factor uncertainty is assumed to be 5%;
- Combined uncertainty is 5.8%.

3.3.1.5.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.3.1.5.5 Category-specific recalculations

No recalculations have been done.

3.3.1.5.6 Category-specific planned improvements

Category-specific improvements are not planned.

3.3.2 Petroleum Refining (CRF 1.A.1.b)

3.3.2.1 Category description

Refineries process crude oil into a variety of hydrocarbon products such as gasoline, kerosene and etc. In Lithuania there is the only petroleum refining company operating in the Baltic States. Oil refinery processes approximately 10 million tons of crude oil a year. The company is the most important supplier of petrol and diesel fuel in Lithuania, Latvia and Estonia. Motor gasoline, jet kerosene, gas/diesel oil, residual fuel oil, LPG and refinery gas used in Lithuania are produced by the oil refinery. Imports of the fuels specified above comprise only a minor fraction of the fuels used in Lithuania.

Tendencies of fuel consumed and total GHG emissions in Petroleum Refinery are presented in Figure 3-18.

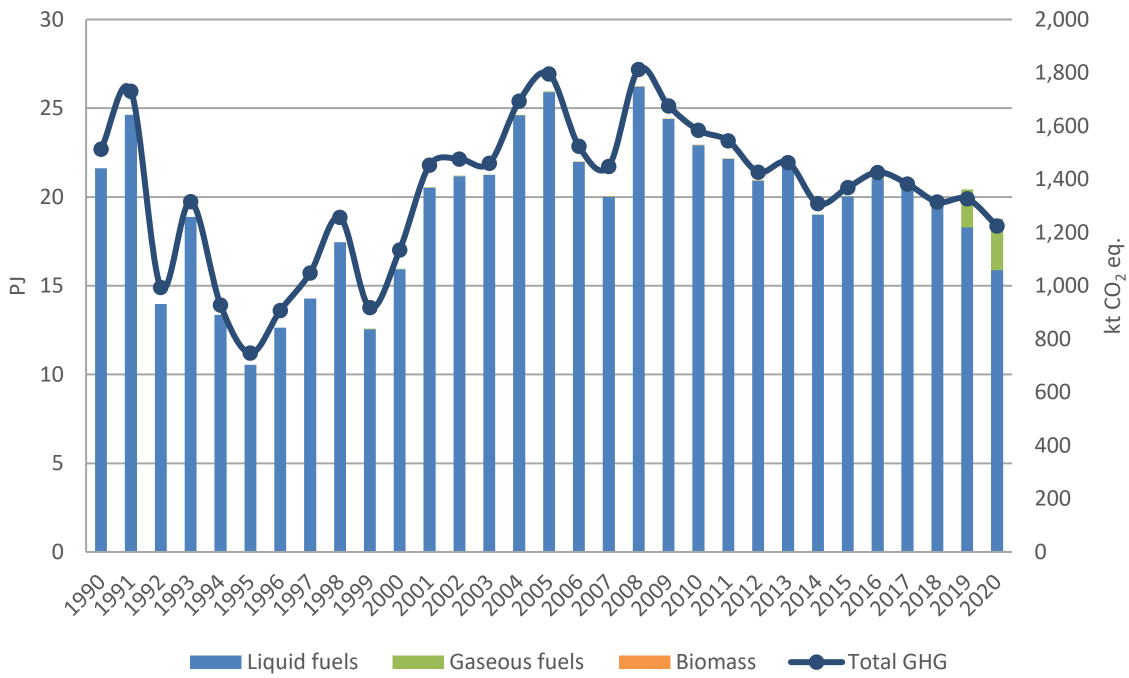


Figure 3-18. Tendencies of fuel consumed and total GHG emissions in Petroleum Refinery (1.A.1.b)

As it is seen from Figure 3-18, liquid fuels are mainly used in Petroleum Refinery industry. In 2020, liquid fuels accounted 84.7% in the total fuel structure. The share of liquid fuel decreased as the ORLEN Lietuva started to use natural gas for petroleum refinery in 2019. Historically, refinery gas made more than 50% of total fuel consumed in petroleum refinery. With reference to data of 2020, there was consumed 18.76 PJ, from which refinery gas accounted 58.2%, petroleum coke – 17.8%, residual fuel oil – 8.7% and natural gas - 15.3%.

Total GHG emissions from Petroleum Refinery were below 1990 level by 19.0% and amounted 1,224.3 kt CO_2 eq. in 2020.

3.3.2.2 Methodological issues

CO_2 emissions were calculated applying Tier 2/Tier 3, CH_4 and N_2O were calculated applying Tier 1.

Emission factors and methods

Gas	Method used	Source of AD	EF used
CO_2	T2, T3	Lithuanian Statistics database	CS, PS
CH_4	T1	Lithuanian Statistics database	D
N_2O	T1	Lithuanian Statistics database	D

All country specific CO_2 emission factors are presented in Annex V.

2006 IPCC Guidelines default emission factors were used for CH_4 and N_2O emissions estimation (Table 3-16).

Table 3-16. *2006 IPCC Guidelines* default emission factor CH_4 and N_2O emission factors used for category Petroleum Refinery (1.A.1.b), kg/TJ

Fuel type	CH_4 1990-2020	N_2O 1990-2020
Residual fuel oil (RFO)	3.0	0.6
Liquefied petroleum gases (LPG)	1.0	0.1
Petroleum coke	3.0	0.6
Crude oil	3.0	0.6
Diesel oil	3.0	0.6
Refinery gas	1.0	0.1
Natural gas	1.0	0.1
Wood and wood waste	30.0	4.0

Plant specific CO_2 EFs based on EU ETS data applied for residual fuel oil (non-tradable) and refinery gas for category Petroleum Refinery (1.A.1.b) are presented in Table 3-17. Non-tradable residual fuel oil is combusted only at the refinery therefore the use of this residual fuel oil is reported under category Petroleum Refinery (1.A.1.b). Residual fuel oil (non-tradable) and refinery gas was combusted at the petroleum refinery company during 1990-2020: the average value of CO_2 emission factor was used for the period 1990-2007 and variable yearly values for the period 2008-2020.

Table 3-17. Plant specific CO_2 emission factors for category Petroleum Refinery (1.A.1.b) (EU ETS reports data)

Year	Refinery gas (CO_2, t/TJ)	Residual fuel oil (non-tradable) (CO_2, t/TJ)
1990-2007	57.13	81.65
2008	55.07	80.26
2009	54.86	80.21
2010	57.53	81.54
2011	57.25	83.04
2012	56.92	81.30
2013	57.64	81.78
2014	59.03	82.75
2015	58.72	82.32
2016	58.46	82.49
2017	57.49	82.00

2018	57.08	82.14
2019	56.37	82.32
2020	56.38	81.99

Activity data

For calculation of GHG emissions in category Petroleum Refinery (1.A.1.b) activity data had been obtained from the Lithuanian Statistics database (http://www.stat.gov.lt/lt/). Activity data is provided in the Annex III.

3.3.2.3 Uncertainties and time-series consistency

Uncertainty of activity data in Petroleum Refinery is ±2.0% taking into consideration recommendations provided by *the 2006 IPCC Guidelines*. According to *the 2006 IPCC Guidelines* (Volume 2, Chapter 1, page 1.19) biomass data are generally more uncertain than other data in national energy statistics, because a large fraction of the biomass may be part of the informal economy, and the trade in these types of fuels is frequently not registered in the national energy statistics and balances. That is a reason for higher uncertainty for biomass activity data than for other fuel types. The uncertainty rage for biomass is assigned ±5.0% taking into account implementation of solid biomass accounting rules for energy sector enterprises, biomass sellers and other legal entities (after revision in 2015) and following recommendations provided by *the 2006 IPCC Guidelines*.

Uncertainties of CO_2 emission factors for liquid fuels (crude oil, residual fuel oil, LPG, refinery gas, diesel oil and petroleum coke) and gaseous fuels (natural gas) are ±2.0% in Petroleum refinery. Estimated uncertainties of CO_2 emission factors for biomass are ±15%. Uncertainties of all country specific CO_2 emission factors were revised in the study "Update of country specific GHG emission factors for Energy sector" (see Annex V).

Uncertainties of CH_4 and N_2O emission factors for liquid and gaseous fuels were assigned as very high about ±50%. Uncertainties of emission factors for biomass were assumed ±150%. Uncertainties were derived considering *2006 IPCC Guidelines*.

Time series of the estimated emissions are consistent and complete because the same methodology, emission factors and data sources are used for sectors for all years in time series. All emissions are estimated or reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.3.2.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

The results are verified by calculating CO_2 emissions with the reference approach, and comparing results with the sectoral approach.

3.3.2.5 Category-specific recalculations

No recalculations have been done.

3.3.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

3.3.3 Manufacture of Solid Fuels and Other Energy Industries (CRF 1.A.1.c)

3.3.3.1 Category description

Emissions in this sector arise from fuel combustion in Manufacturing of Solid Fuels and Other Energy Industries. Under 1.A.1.c.i are reported: extraction of peat and under 1.A.c.ii are reported activities: extraction of crude oil; electricity, gas, steam and air condition supply (including operation of LNG terminal).

3.3.3.1.1 Manufacture of solid fuels (CRF 1.A.1.c.i)

Tendencies of fuel consumption and total GHG emissions in Manufacture of Solid Fuels are presented in Figure 3-19.

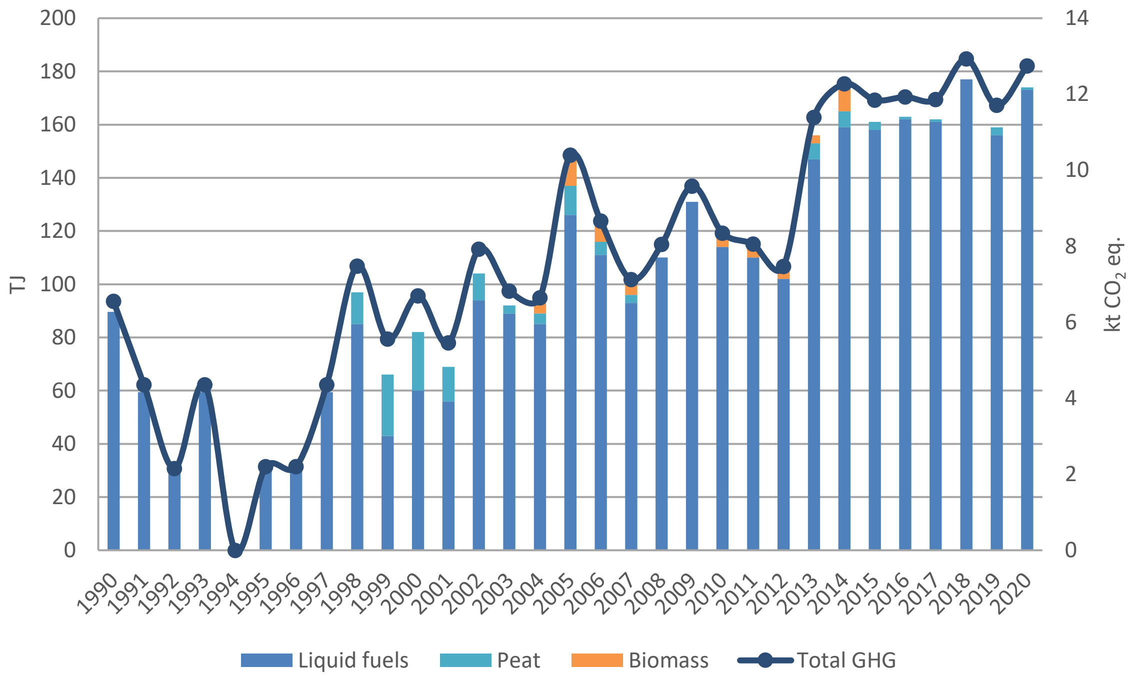


Figure 3-19. Tendencies of fuel consumption and total GHG emissions in Manufacture of Solid Fuels (1.A.1.c.i)

As it is seen from Figure 3-19, fuel consumption in Manufacture of Solid Fuels accounted 174 TJ in 2020. Liquid fuels accounting about 99% of total fuel consumed in Manufacture of Solid Fuels (extraction of peat). With reference to data of 2020, diesel accounted 98.9%, motor oil – 0.6% and peat - 0.6%.

In 2020, total GHG emissions from Manufacture of Solid Fuels were about 2 times higher than in 1990 and amounted 12.7 kt CO_2 eq.

3.3.3.1.2 Other Energy Industries (CRF 1.A.1.c.ii)

Tendencies of fuel consumption and total GHG emissions in Other Energy Industries are presented in Figure 3-20.

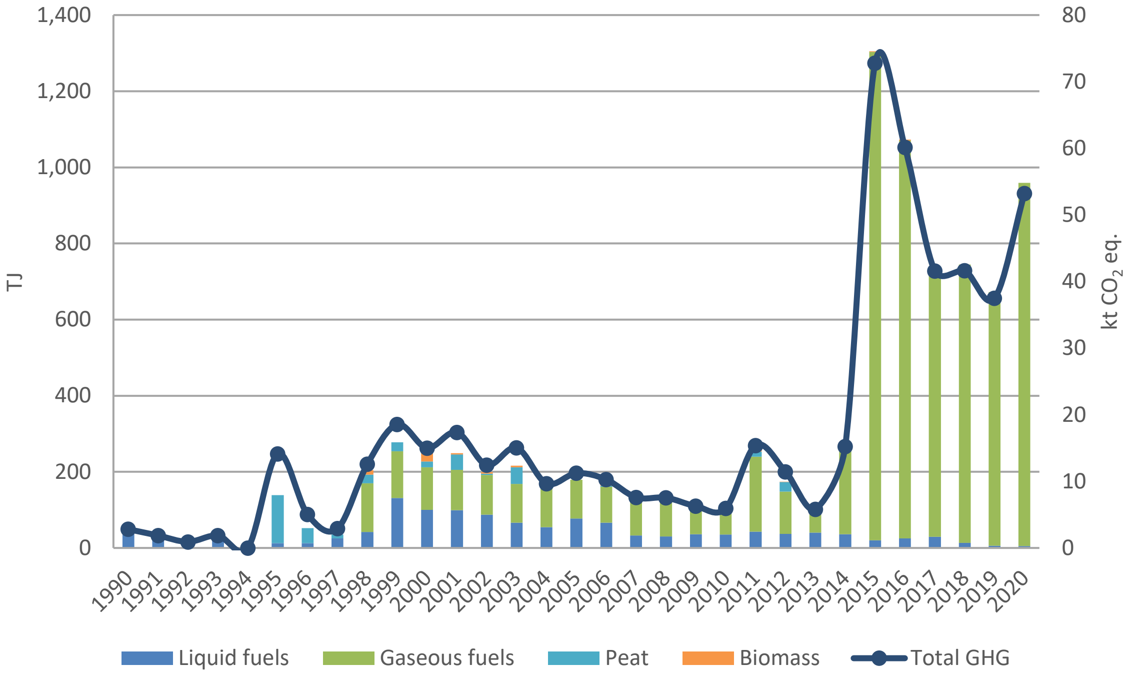


Figure 3-20. Tendencies of fuel consumption and total GHG emissions in Other Energy Industries (1.A.1.c.ii)

As it is seen from Figure 3-20, historically fuel consumption fluctuation depended on Other energy industries activities but fuel consumption increased significantly due to start of LNG terminal operation since January 2015. In 2015, 1,281 TJ of natural gas was combusted at LNG terminal for operational needs. Improvements and optimization of LNG terminal operation allowed reducing fuel consumption till 666 TJ in 2019. In 2020, natural gas consumption increased by 43% in comparison to 2019. Natural gas use has increased due to start of the new Kaunas CHP operation. Kaunas CHP used natural gas for own needs during the starting activities.

The total fuel consumption in Other Energy Industries amounted to 959 TJ in 2020. With reference to data of 2020, natural gas accounted 99.5% and liquid fuels – 0.5%.

In 2020, total GHG emissions from Other Energy Industries were about 19 times higher than in 1990 and amounted 53.2 kt CO_2 eq.

3.3.3.2 Methodological issues

CO_2 emissions were calculated applying Tier 2, CH_4 and N_2O were calculated applying Tier 1.

Emission factors and methods

Gas	Method used	Source of AD	EF used
CO_2	T2	Lithuanian Statistics database	CS
CH_4	T1	Lithuanian Statistics database	D
N_2O	T1	Lithuanian Statistics database	D

All country specific CO_2 emission factors are presented in Annex V.

2006 IPCC Guidelines default emission factors were used for CH_4 and N_2O emissions estimation (Table 3-18).

Table 3-18. *2006 IPCC Guidelines* default emission factor CH_4 and N_2O emission factors used for category Manufacture of Solid Fuels and Other Energy industries (1.A.1.c), kg/TJ

Fuel type	CH_4 1990-2020	N_2O 1990-2020
Heating and other gasoil	3.0	0.6
Liquefied petroleum gases (LPG)	1.0	0.1
Motor gasoline	3.0	0.6
Diesel oil	3.0	0.6
Peat	1.0	1.5
Natural gas	1.0	0.1
Wood and wood waste	30.0	4.0
Other solid biomass	30.0	4.0

Activity data

For calculation of GHG emissions in category Manufacture of Solid Fuels and Other Energy industries (1.A.1.c) activity data had been obtained from the Lithuanian Statistics database (http://www.stat.gov.lt/lt/). Activity data are provided in the Annex III.

3.3.3.3 Uncertainties and time-series consistency

Uncertainty of activity data in Manufacture of Solid Fuels and Other Energy Industries is ±2.0% taking into consideration recommendations provided by *the 2006 IPCC Guidelines*. According to *the 2006 IPCC Guidelines* (Volume 2, Chapter 1, page 1.19) biomass data are generally more uncertain than other data in national energy statistics, because a large fraction of the biomass may be part of the informal economy, and the trade in these types of fuels is frequently not registered in the national energy statistics and balances. That is a reason for higher uncertainty for biomass activity data than for other fuel types. The uncertainty rage for biomass is assigned ±5.0% taking into account implementation of solid biomass accounting rules for energy sector enterprises, biomass sellers and other legal entities (after revision in 2015) and following recommendations provided by *the 2006 IPCC Guidelines*.

Uncertainties of CO_2 emission factors for liquid fuels (motor gasoline, gasoil, LPG, diesel oil) and gaseous fuels (natural gas) are ±2.0% in Manufacture of solid fuels and Other Energy Industries. Estimated uncertainties of CO_2 emission factors for biomass are ±15%. Uncertainties of all country specific CO_2 emission factors were revised in the study "Update of country specific GHG emission factors for Energy sector" (see Annex VI).

Uncertainties of CH_4 and N_2O emission factors for liquid and gaseous fuels were assigned as very high about ±50%. Uncertainties of emission factors for biomass were assumed ±150%. Uncertainties were derived considering *2006 IPCC Guidelines.*

Time series of the estimated emissions are consistent and complete because the same methodology, emission factors and data sources are used for sectors for all years in time series. All emissions are estimated or reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.3.3.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

The results are verified by calculating CO_2 emissions with the reference approach, and comparing results with the sectoral approach.

3.3.3.5 Category-specific recalculations

No recalculations have been done.

3.3.3.6 Category-specific planned improvements

Category-specific improvements are not planned.

3.4 Manufacturing Industries and Construction (CRF 1.A.2)

3.4.1 Category description

3.4.1.1 Iron and Steel (CRF 1.A.2.a)

There are no Iron and Steel industries in Lithuania. All emissions are reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.4.1.2 Non-Ferrous Metals (CRF 1.A.2.b)

There are no Non-Ferrous Metals industries in Lithuania. All emissions are reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.4.1.3 Chemicals (CRF 1.A.2.c)

The Chemicals industry is one of the largest manufacturing industries in Lithuania. It produces a number of different products among which the most important are the following: sulphur acid (SO_2), ethyl alcohol, fermented preparations, ammonium nitrate, urea, diammonium phosphate, amino resins, phenolic resins and polyurethanes in primary form, toilet and washing soap, preparations for use on hair and yarn of cellulose acetate. During the latter decade it has been noticed an intensive development of this industry. According to the data of 2020, chemicals industry produced 9,425.0 thousand decaliters of ethyl alcohol, 1,247.0 thousand tons of sulphur acid, 578.5 thousand tons of diammonium phosphate and other chemicals in smaller numbers[5].

Tendencies of fuel consumption and total GHG emissions in Chemicals industry are presented in Figure 3-21.

[5] Lithuanian Statistics (2021). Manufacturing of products in Lithuania during 2000-2020 // https://osp.stat.gov.lt/pramone.

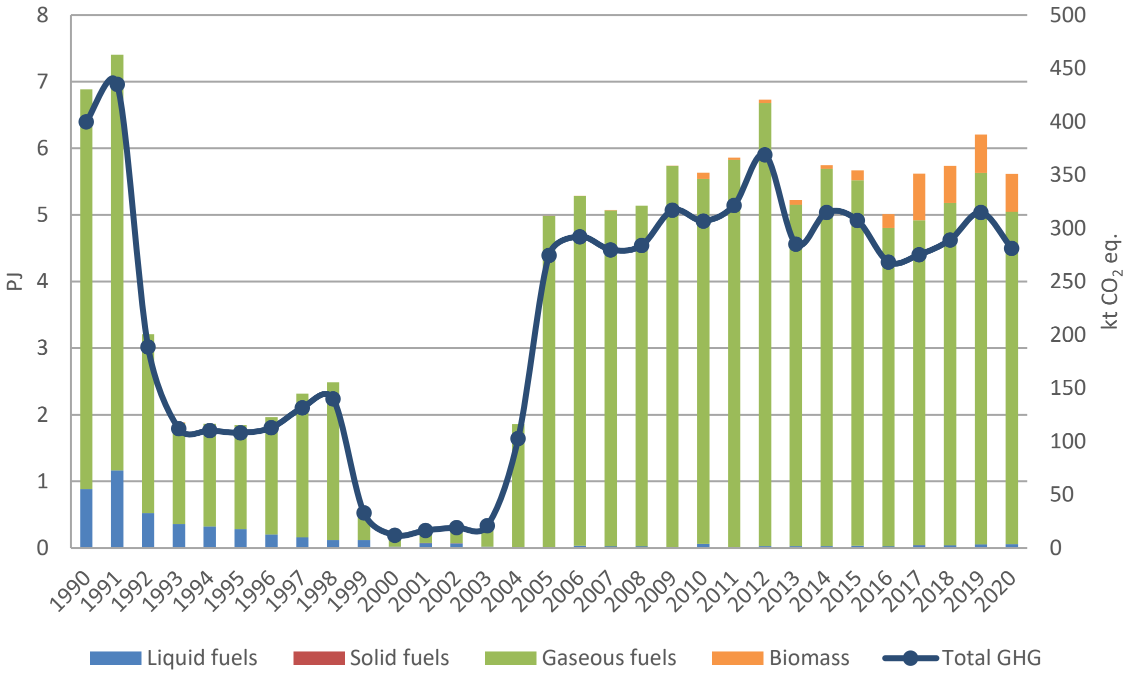


Figure 3-21. Tendencies of fuel consumption and total GHG emissions in Chemicals industry (1.A.2.c)

Natural gas is the main fuel used in chemical industry in Lithuania. During 1990-2020 period, it has contained 71-99% of total fuel used in industry. During economic recession and "recovery" period (1990-2002) fuel consumption in Lithuania's chemical industry has had a tendency to decrease by 22.5% a year with a large decrease of natural gas consumption (Figure 3-21). Since 2003, when economy has started to grow at very fast rates, energy consumption in Chemical industries began to increase. In 2020, energy consumption in Chemical industries decreased by 9.5% (in comparison to 2019) and amounted 5.6 PJ. With reference to data of 2020, natural gas accounted 88.9% in the structure of total fuel consumption in Chemical industry, biomass - 10.1% and liquid fuels – 10.0%.

In 2020, total GHG emissions from Chemical industries were about 1.4 times lower than in 1990 and amounted to 281.2 kt CO_2 eq.

3.4.1.4 Pulp, Paper and Print (CRF 1.A.2.d)

The Pulp, Paper and Print industries is a small branch of manufacturing industry in Lithuania. In 2020, Pulp, Paper and Print industry produced 128.5 thousand tons of paper and paperboard, as well 231.2 thousand tons of corrugated paper and paperboard, cartons, boxes and cases of corrugated paper or paperboard.

Tendencies of fuel consumption and total GHG emissions in Pulp, Paper and Print industries are presented in Figure 3-22.

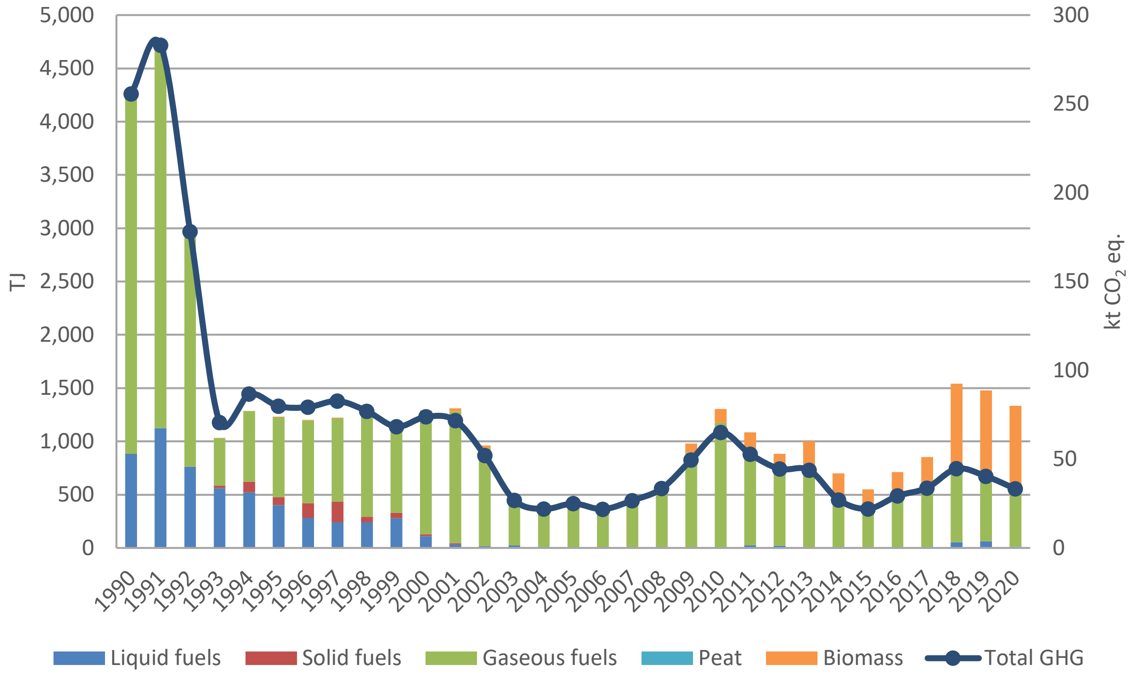


Figure 3-22. Tendencies of fuel consumption and total GHG emissions in Pulp, Paper and Print industries (1.A.2.d)

In 2020, total fuel consumption amounted to 1,335 TJ in Pulp, Paper and Print industries. Historically natural gas was the main fuel used in Pulp, Paper and Print industries, but during 2009-2020 biomass consumption increased by almost 9 times. Thus, in 2020, the share of biomass already accounted 57.4%, natural gas – 41.6%, liquid fuels – 0.8% and solid fuels - 0.2% in the structure of fuel used in Pulp, Paper and Print industries. Pulp, Paper and Print industries are distinguished as energy intensive industry branch therefore fuel consumption significantly depends on economic activity and shows corresponding fluctuation.

In 2020, total GHG emissions from Pulp, Paper and Print industries were even 7.7 times lower than in 1990 and amounted to 33.3 kt CO_2 eq.

3.4.1.5 Food Processing, Beverages and Tobacco (CRF 1.A.2.e)

Food Processing, Beverages and Tobacco industries has old traditions in Lithuania. Currently this branch of the manufacturing industry consists of the following important structural parts – production of meet and its products, preparation and processing of fish and its products, preparation, processing and preservation of fruits, berries and vegetables, production of dairy products, production of grains, production of strong and soft drinks as well tobacco. Till the beginning of last economic crisis Food Processing, Beverages and Tobacco industries met a slow decrease in the structure of value added created, i.e. from 43.2% (1995) till 26.2% (2008), but remained the largest manufacturing industry in Lithuania. During the last decade food processing industry, has passed a rapid restructuring process, when number of active economic entities in the main branches of food industry (except in fruit and berries industry) has noticeably decreased. However, the share of large companies has increased. Food processing industry has kept a stable share in terms of value added in the structure of national economy and rapid growth rates in the export structure (Kaunas Technology University, 2009). In 2020, industry produced 225.2 thousand tons of meat and offal, 128.6 thousand tons of food fish, 43.1 thousand tons of prepared preserved vegetables, fruits and nuts, 8.2 thousand liters of fruits and vegetables juices, 260.4 thousand tons of milk, 559.3 thousand tons of flour, 138.1 thousand tons of bread and pastry products, 32,020.8 thousand decaliters of beer, 20,310.3 thousand decaliters of natural mineral and aerated waters without sugar and non-flavoured, 8,512.9 thousand decaliters of non-alcoholic beverages and other.

Tendencies of fuel consumption and total GHG emissions in Food processing, beverages and tobacco industries are presented in Figure 3-23.

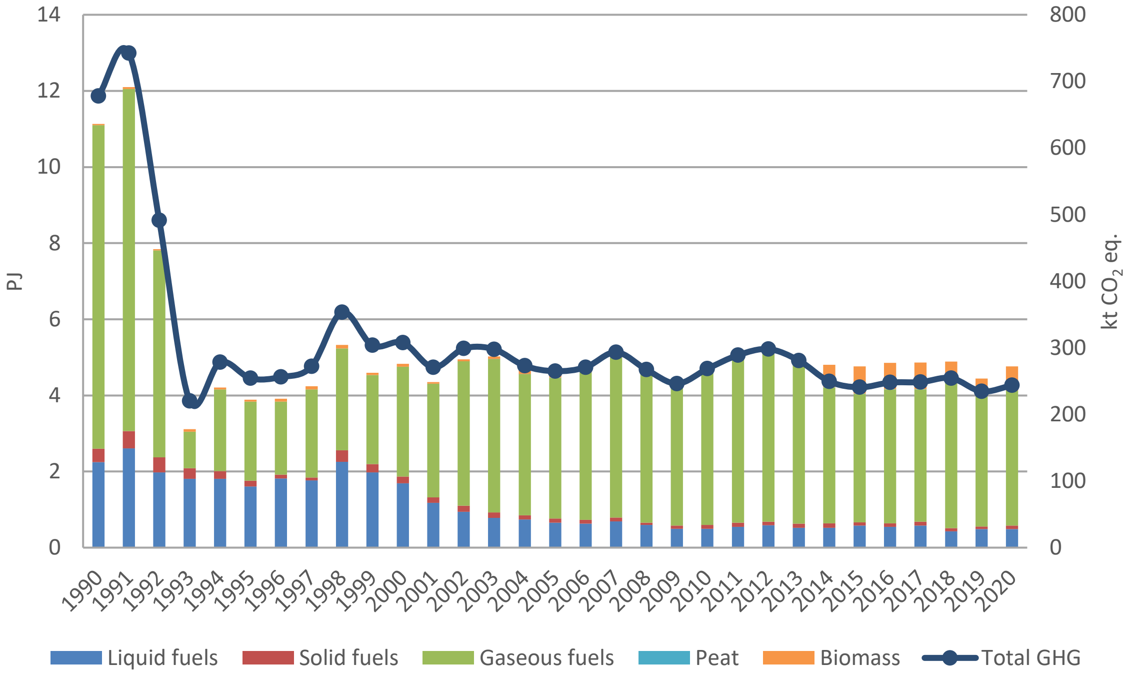


Figure 3-23. Tendencies of fuel consumption and total GHG emissions in Food Processing, Beverages and Tobacco industries (1.A.2.e)

Fuel consumed in Food Processing, Beverages and Tobacco industries has become more diversified compared to the structure that have existed in 1990. Instead of three fuels (residual fuel oil, other bituminous coal and natural gas) that have been widely used in industry in early 1990s, currently LPG, gasoil, peat, wood/wood waste and biogas penetrate the market (Figure 3-23). In 2020, natural gas accounted 74.2%, liquid fuels – 10.2%, biomass – 13.6% and solid fuels – 2.0% in the total structure of fuel combusted Food Processing, Beverages and Tobacco industries.

In 2020, total GHG emissions from Food Processing, Beverages and Tobacco industries were 2.8 times lower than in 1990 and amounted to 243.6 kt CO_2 eq.

3.4.1.6 Non-Metallic Minerals (CRF 1.A.2.f)

The category of Non-Metallic Minerals takes into account production and processing of glass, building material from clay (mole), pottery, cement and their products. In 2020, there were produced 1,939.8 thousand m^2 of multiple-walled insulating units of glass, 165.8 million of bottles of colourless and coloured glass, 6.5 thousand m^3 of clay building bricks, 226.0 thousand t of silicate bricks and blocks, 1,220.8 thousand t of cement, 8.3 mill. m^2 of sheets from non-asbestos cement and 998.6 thousand t of prefabricated structural components for building or civil engineering.

Tendencies of fuel consumption and total GHG emissions in Non-Metallic Minerals industries are presented in Figure 3-24.

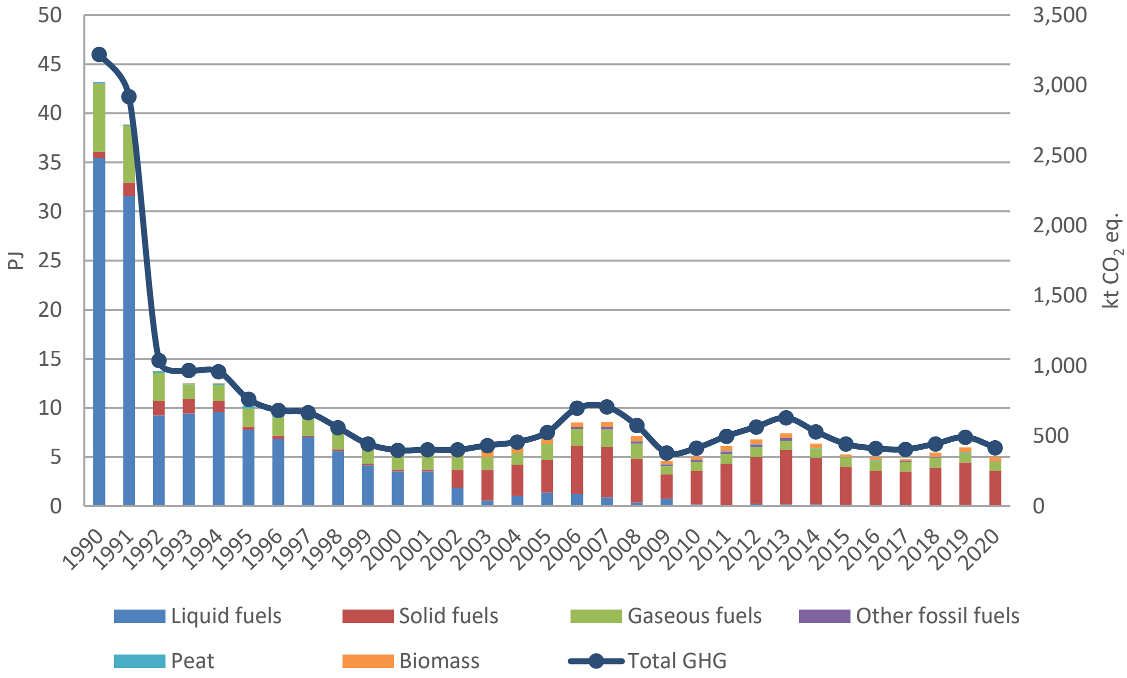


Figure 3-24. Tendencies of fuel consumption and total GHG emissions in Non-Metallic Minerals (1.A.2.f)

Due to significant economic slump after restoration of independence fuel consumption in Non-Metallic Minerals industries reduced by almost 7.6 times during 1990-2000. In 1990 liquid fuels dominated in the structure of total fuel consumed in Non-Metallic Minerals industries and since 2003 solid fuels started to dominate. In 2020, the share of solid fuels was 69.6%, natural gas – 17.5%, biomass – 9.0%, liquid fuels – 2.6% and waste – 1.3%.

In 2020, total GHG emissions from Non-Metallic Minerals industries were 7.7 times lower than in 1990 and amounted to 417.4 kt CO_2 eq.

3.4.1.7 Machinery (CRF 1.A.2.g.i)

The category of Machinery takes into account manufacture of fabricated metal products, machinery and equipment, manufacture of computer, electronic and optical products, manufacture of electrical equipment and manufacture of machinery and equipment. The most important goods produced within the Machinery industry in Lithuania are as follows: windows, doors, their frames and thresholds from iron (101.1 thous. in 2020), metallic containers (less than 50 l) (35.1 thous.), electric wires and cables (4,482.4 tons), chandeliers and other electric ceiling or wall lighting fittings (5,874.8 thous.), refrigerators and freezers (220.4 thous.).

Tendencies of fuel consumption and total GHG emissions in Machinery industries are presented in Figure 3-25.

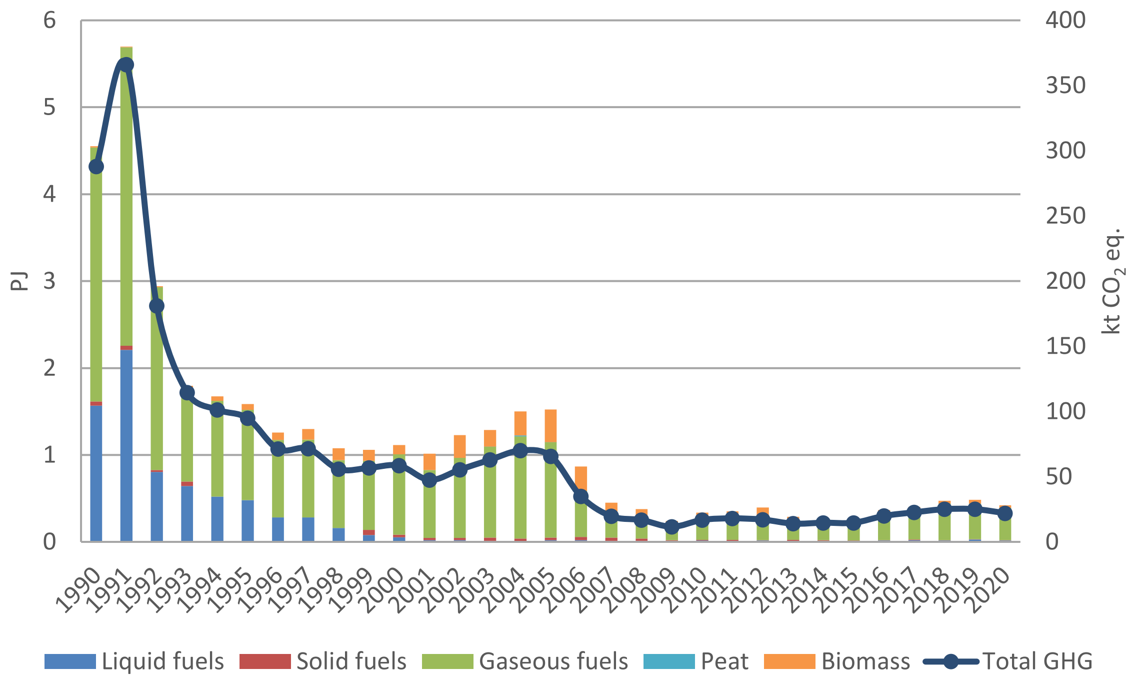


Figure 3-25. Tendencies of fuel consumption and total GHG emissions in Machinery industries (1.A.2.g.i)

Since 1990 fuel consumption in Machinery industries reduced by 10 times from 4,553 TJ in 1990 till 420 TJ in 2020. The share and volume of liquid fuels drastically reduced and in 2020 accounted only 3.8% in structure of fuel combusted. In 2020, the share of natural gas was 88.6%, solid fuels accounted 0.7% and biomass – 6.9% in the structure of fuel used in Machinery industries.

In 2020, total GHG emissions from Machinery industries were almost 13 times lower than in 1990 and amounted to 22.1 kt CO_2 eq.

3.4.1.8 Transport Equipment (CRF 1.A.2.g.ii)

The category of Transport Equipment takes into account manufacture of motor-vehicles, trailers and semi-trailers, as well manufacture of other transport equipment. Since 2007 manufacturing volume of aforementioned goods was reducing. Especially manufacturing of bicycles decreased. In 2016, volume of manufactured bicycles made 26.9% of 2007 level, however in 2017 production of bicycles increased by 56.9 thousand in comparison to 2016. In 2020, there were manufactured 2.1 thousand of trailers and semi-trailers, 17.3 thousand tons of insulated ignition wiring sets and 184.9 thousand of bicycles. Currently Transport Equipment industry is one of the smallest in the country.

Tendencies of fuel consumption and total GHG emissions in Transport Equipment industries are presented in Figure 3-26.

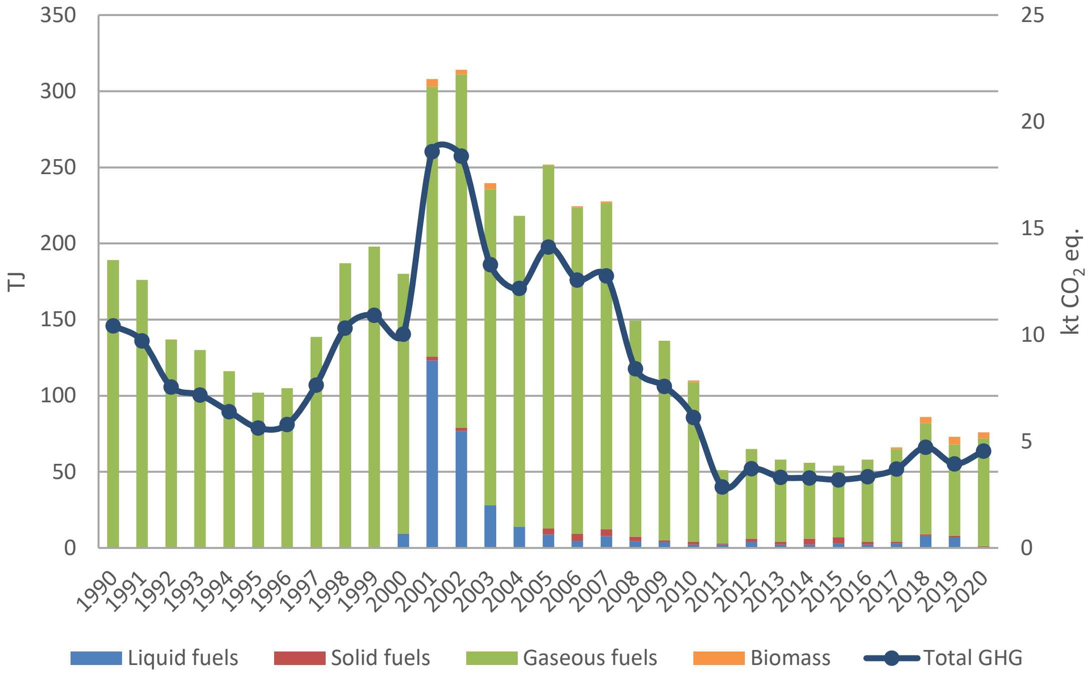


Figure 3-26. Tendencies of fuel consumption and total GHG emissions in Transport Equipment industries (1.A.2.g.ii)

Historically natural gas was the main fuel used in Transport Equipment industries. In 2020, the share of natural gas was 85.6%, liquid fuels – 8.4%, solid fuels – 1.2% and biomass accounted 4.8% in the structure of fuel used in Transport Equipment industries.

In 2020, total GHG emissions from Transport Equipment industries were 2.3 times lower than in 1990 and amounted to 4.5 kt CO_2 eq.

3.4.1.9 Mining and Quarrying (CRF 1.A.2.g.iii)

The category of Mining and Quarrying takes into account mining and quarrying of silica sand, construction sand, gravel, pebbles, shingle and silica, crushed dolomite, crushed granite and extraction of peat in Lithuania. In 2020, there were mined 13,1028.5 thousand tons of aforementioned resources (42.5% of construction sand, 52.3% of gravel, pebbles, shingle and silica). This is by 26.7% less than in 2019.

Tendencies of fuel consumption and total GHG emissions in Mining and Quarrying industries are presented in Figure 3-27.

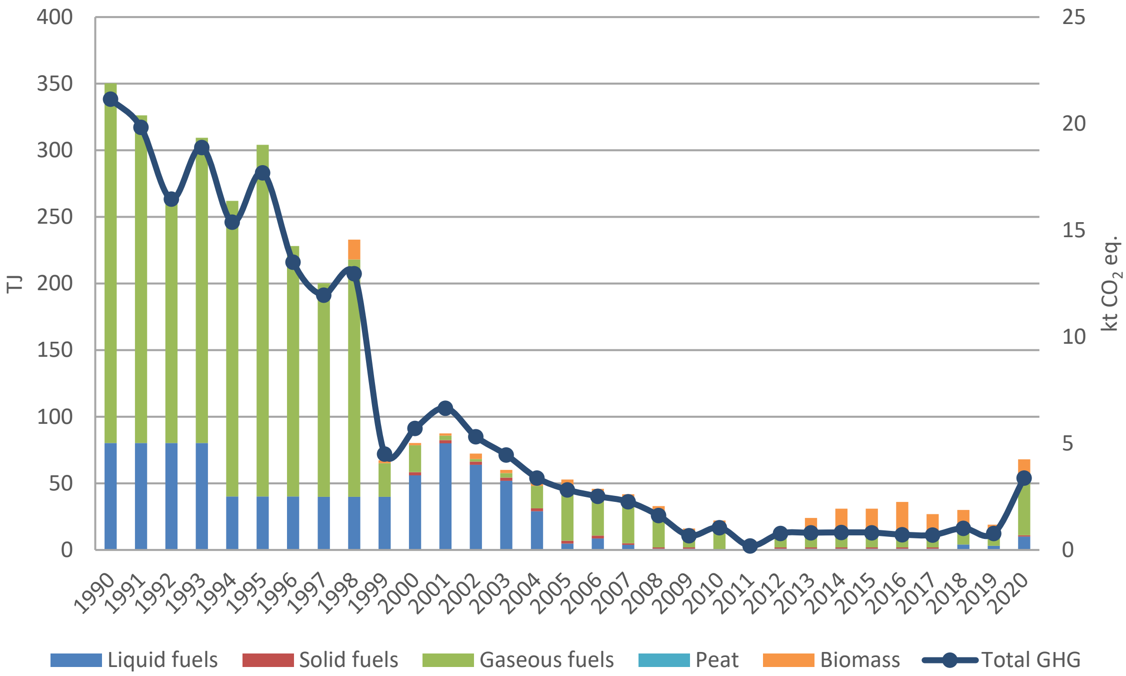


Figure 3-27. Tendencies of fuel consumption and total GHG emissions in Mining and Quarrying industries (1.A.2.g.iii)

Since 1990 fuel consumption in Mining and Quarrying industries reduced significantly from 350.3 TJ in 1990 till 19.0 TJ in 2019. In 2020, fuel consumption increased by 3 times till 68.0 TJ (in comparison to 2019). This increase was due to changes in company's "Naujasis kalcitas" activities: from non-metallic minerals to mining and quarrying. In 2020, the share of biomass accounted about 17.6%, natural gas – 64.7% and liquid – 14.7% in the structure of fuel used in Mining and Quarrying industries.

In 2020, total GHG emissions from Mining and Quarrying industries were 6 times lower than in 1990 and amounted to 3.4 kt CO_2 eq.

3.4.1.10 Wood and Wood Products (CRF 1.A.2.g.iv)

The category of Wood and Wood Products takes into account manufacture of plywood and similar laminated wood, particle board of wood, fiber board, windows and their frames and doors and their frames of wood in Lithuania. In 2020, Wood and Wood Products industry manufactured 791.7 thousand m^3 of plywood and similar laminated wood, 732.7 thousand m^3 of particle board of wood, 121.0 million m^2 of fiber board, 221.6 thousand of windows and their frames and 620.0 thousand of doors and their frames of wood.

Tendencies of fuel consumption and total GHG emissions in Wood and Wood Products industries are presented in Figure 3-28.

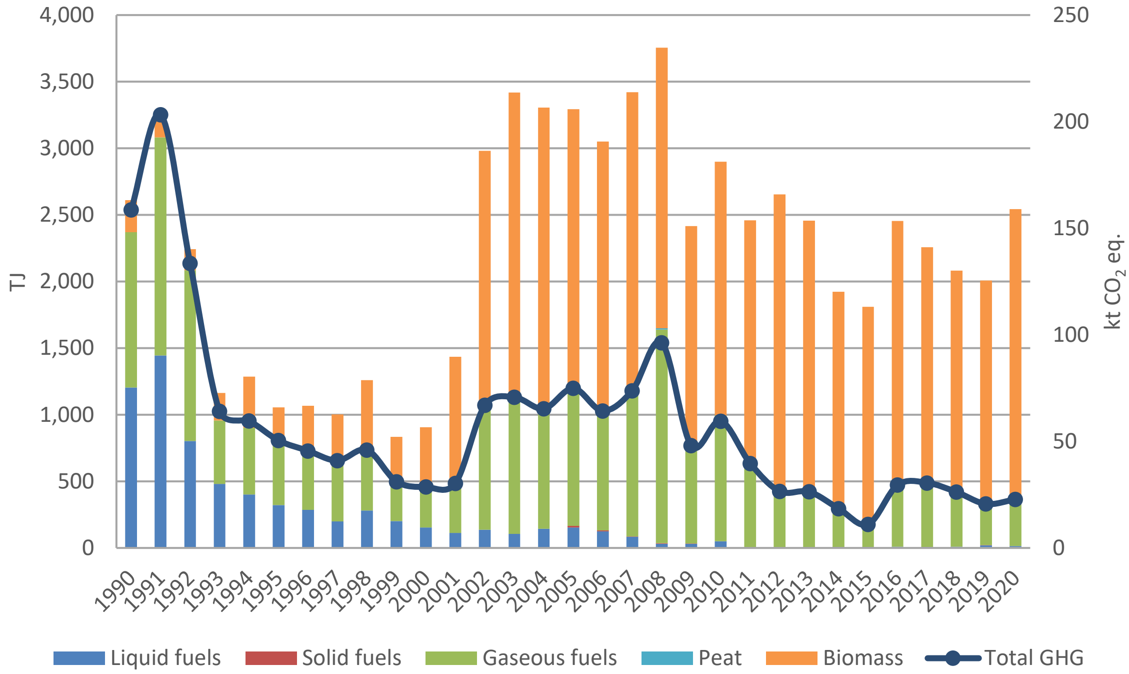


Figure 3-28. Tendencies of fuel consumption and total GHG emissions in Wood and Wood Products industries (1.A.2.g.iv)

The share of liquid fuels has reduced from 46.1% (1990) till 0.6% (2020) in the structure of fuel consumed in Wood and Wood Products industries. In general liquid and gaseous fuels were replaced by biomass. Since 2000 the share of biomass increased from 51.4% till 87.0% in 2020. In 2020, the share of natural gas accounted 12.4%.

In 2020, total GHG emissions from Wood and Wood Products industries were about 7 times lower than in 1990 and amounted to 22.8 kt CO_2 eq.

3.4.1.11 Construction (CRF 1.A.2.g.v)

Construction sector of Lithuania has approximately 5 thousand of enterprises of which 39% are specialized in constructing buildings and their parts. Small enterprises (the personnel are less than 49) are prevailing in this sector. The largest concentration of construction enterprises is in Vilnius and Kaunas counties. This situation was mainly caused by unequal distribution of investments within the territory of Lithuania. Till the last crisis, construction sector was one of the most developing industry branches in Lithuania. It created 7.3% (2005) – 9.9% (2008) of total value added in the country. This was mainly caused by the growth of national industry, good credit terms, possibilities given by EU Structural Funds, a larger demand for residential, commercial and industrial buildings, increasing selection of new building materials and technologies (Analysis of Lithuanian Construction Market, 2011). However, already in 2009 value added significantly reduced and in 2010 it made only 51.0% of 2008 level. In 2020, Construction sector created about 7.3% of total value added.

Tendencies of fuel consumption and total GHG emissions in Construction are presented in Figure 3-29.

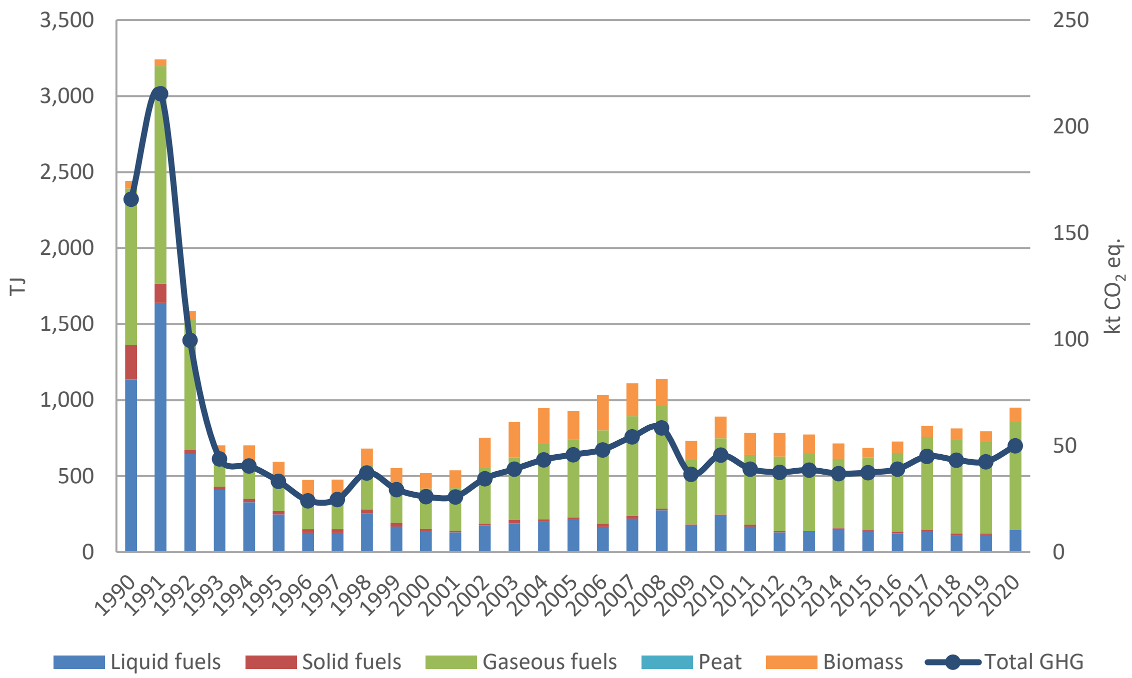


Figure 3-29. Tendencies of fuel consumption and total GHG emissions in Construction (1.A.2.g.v)

The final energy consumption was increasing during the period 2000-2008 by 10.0% per annum in Construction, but the most severe impact of the economic recession was in this sector where energy consumption decreased by 35% in 2009. In 2020, the share of natural gas accounted 75.0%, liquid fuels – 15.2%, biomass – 9.5% and solid fuels – 0.3% in the total fuel structure used for the Construction.

In 2020, total GHG emissions from Construction industries were 3 times lower than in 1990 and amounted to 50.0 kt CO_2 eq.

3.4.1.12 Textile and Leather (CRF 1.A.2.g.vi)

Textile and Leather industry in Lithuania integrates 3 branches of the industry, i.e., production of textile products, sewing of clothes and manufacture of leather and leather articles. The industry is considered as one of the most important industries in the country. Below is presented the most important products and their production volumes of Textile and Leather industry in 2020: 1,556.7 thousand of trousers, overalls, breeches and shorts, 935.4 thousand of women and girls' blouses, 833.6 thousand of dresses, 635.1 thousand of jackets and blouses and other.

Tendencies of fuel consumption and total GHG emissions in Textile and Leather industries are presented in Figure 3-30.

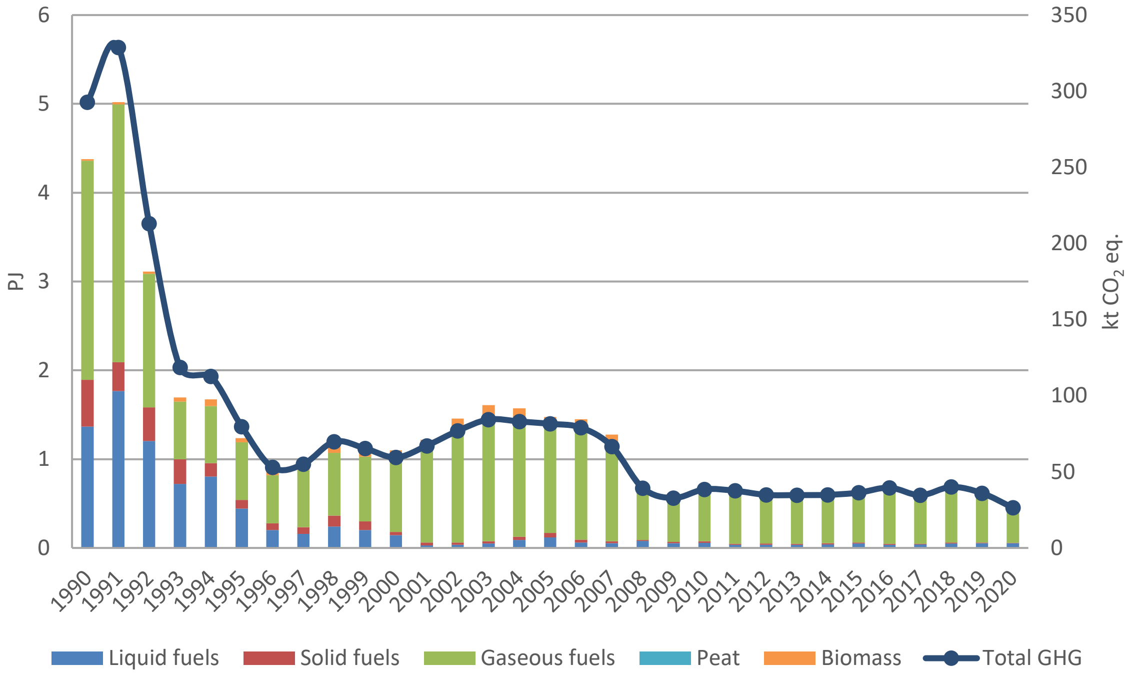


Figure 3-30. Tendencies of fuel consumption and total GHG emissions in Textile and Leather industries (1.A.2.g.vi)

The fuel consumption in Textile and Leather industries reduced almost 9 times since 1990. In 2020, the natural gas accounted 82.4%, liquid fuels – 11.0%, solid fuels – 1.2% and biomass about 5.4% in the structure of fuel used in Textile and Leather industries.

In 2020, total GHG emissions from Textile and Leather industries were 11 times lower than in 1990 and amounted to 26.4 kt CO_2 eq.

3.4.1.13 Non-Specified Industry (CRF 1.A.2.g.viii)

Non-Specified Industries in Lithuania include the following activities:

- manufacturing of rubber and plastic goods;
- manufacturing of furniture;
- manufacturing of other goods and others not included above industries.

In 2020, there were produced 31,494.2 ton of polystyrene, 4,738.3 million of plastic bottles, 9,458.6 thous. units of various type of furniture.

Tendencies of fuel consumption and total GHG emissions in Non-Specified industry are presented in Figure 3-31.

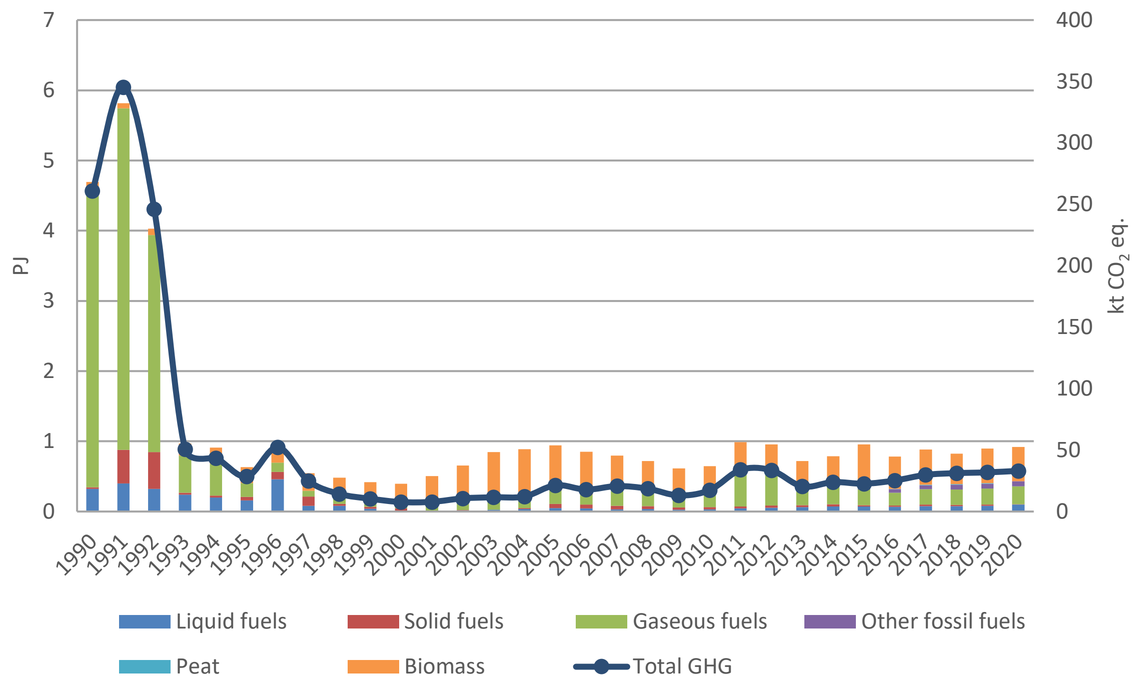


Figure 3-31. Tendencies of fuel consumption and total GHG emissions in Non-Specified Industry (1.A.2.g.viii)

Fuel consumed in the Non-Specified industry has become more diversified compared to the structure that has existed in 1990. In 2020, biomass accounted 52.9%, natural gas – 27.8%, liquid fuels – 10.7%, waste (medical and hazardous) – 8.2% and solid fuels – 0.4% in the total structure of fuel combusted in the Non-Specified industry.

In 2020, total GHG emissions from Non-Specified industry were almost 8 times lower than in 1990 and amounted to 33.1 kt CO_2 eq.

3.4.2 Methodological issues

CO_2 emissions were calculated applying Tier 2/Tier 3 (except industrial waste (medical and hazardous waste) - Tier 1 based on *2006 IPCC Guidelines* default emission factor), CH_4 and N_2O were calculated applying Tier 1.

Emission factors and methods

Gas	Method used	Source of AD	EF used
CO_2	T1, T2, T3	Lithuanian Statistics database (except AD of medical and hazardous waste provided by JSC "Toksika")	D, CS, PS
CH_4	T1	Lithuanian Statistics database	D
N_2O	T1	Lithuanian Statistics database	D

All country specific CO_2 emission factors are presented in Annex V.

2006 IPCC Guidelines default emission factors were used for CH_4 and N_2O emissions estimation (Table 3-19).

Table 3-19. *2006 IPCC Guidelines* default emission factor CH_4 and N_2O emission factors used for category Manufacturing industries and construction (1.A.2), kg/TJ

Fuel type	CH_4 1990-2020	N_2O 1990-2020

Heating and other gasoil	3.0	0.6
Residual fuel oil (RFO)	3.0	0.6
Liquefied petroleum gases (LPG)	1.0	0.1
Shale oil	3.0	0.6
Petroleum coke	3.0	0.6
Coke	10.0	1.5
Other bituminous coal	10.0	1.5
Anthracite	10.0	1.5
Sub-bituminous coal	10.0	1.5
Peat	2.0	1.5
Natural gas	1.0	0.1
Wood and wood waste	30.0	4.0
Other solid biomass	30.0	4.0
Biogas	1.0	0.1
Industrial waste	30.0	4.0

CO_2 EF based on EU ETS data applied for industrial waste (used tires) for subcategory Non-metallic Minerals Industry (1.A.2.f) are presented in Table 3-20. This type of industrial waste was combusted at cement production plant during 2006-2013 and in 2017-2020 therefore the variable yearly CO_2 EF values was used for CO_2 estimation.

Table 3-20. CO_2 emission factors for used tires for subcategory Non-metallic Minerals Industry (1.A.2.f)

Year	**CO_2, kg/GJ**
Industrial waste (used tires)	
2006	86.50
2007	85.50
2008	84.20
2009-2012	85.00*
2013	84.80
2017	84.40
2018-2020	88.70**

** Country specific emission factor (see Annex V)*

*** Justification of EF calculation provided by JSC "Akmenės cementas". Methodology from: Wuppertal Institute for Climate, Environment and Energy "EEFA GmbH" FKZ 204 42 203/02 Use of secondary fuels. Determination of the CO_2 emission factor of used tires. Final report*

Activity data

For calculation of GHG emissions in category Manufacturing industries and construction activity data had been obtained from the Lithuanian Statistics. The Lithuanian Statistics provided data on energy consumption in manufacturing industries and construction according to the type of economic activity based on special request for the 1990-2007 period. Since 2008 activity data are available at the Lithuanian Statistics database (http://www.stat.gov.lt/lt/). Activity data are provided in the Annex IV.

3.4.3 Uncertainties and time-series consistency

Uncertainty of activity data in Manufacturing industries and construction is ±2.0% taking into consideration recommendations provided by *the 2006 IPCC*. According to *the 2006 IPCC Guidelines* (Volume 2, Chapter 1, page 1.19) biomass data are generally more uncertain than other data in national energy statistics, because a large fraction of the biomass may be part of the informal economy, and the trade in these types of fuels is frequently not registered in the national energy statistics and balances. That is a reason for higher uncertainty for biomass activity data than for other fuel types. The uncertainty rage for biomass is assigned ±5.0% taking into account implementation of solid biomass accounting rules for energy sector enterprises, biomass sellers and other legal entities (after revision in 2015) and following recommendations provided by *the 2006 IPCC Guidelines*.

Uncertainties of CO_2 emission factors for liquid fuels (shale oil, residual fuel oil, LPG, and gasoil) and gaseous fuels (natural gas) are ±2.0% in Manufacturing industries and construction. Uncertainties of CO_2 emission factors for solid fuels (peat, other bituminous coal and coke) are ±5.0%. Estimated uncertainties of CO_2 emission factors for biomass are ±15%. Uncertainties of all country specific CO_2 emission factors were revised in the study "Update of country specific GHG emission factors for Energy sector" (see Annex VI).

Uncertainties of CH_4 and N_2O emission factors for liquid, solid and gaseous fuels were assigned as very high about ±50%. Uncertainties of emission factors for biomass were assumed ±150%. Uncertainties were derived considering *2006 IPCC Guidelines.*

Time series of the estimated emissions are consistent and complete because the same methodology, emission factors and data sources are used for sectors for all years in time series. All emissions are estimated or reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.4.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

The results are verified by calculating CO_2 emissions with the reference approach and comparing results with the sectoral approach.

3.4.5 Category-specific recalculations

Following recalculations have been done in Manufacturing industries and construction sectors (1.A.2):

- correction of activity data in 1.A.2.f Non-Metallic Minerals for other fossil fuel (waste non-biomass fraction) in 2018 and 2019 as well for waste (biomass fraction) in 2019 based on information provided by Statistics Lithuania;
- correction of activity data in 1.A.2.g.viii Non-Specified Industry for other fossil fuel (medical and hazardous waste) in 2019 based on revised information provided by JSC "Toksika";
- correction of activity data in 1.A.2.g.iv Wood and wood products for other bituminous coal (in 2014) due to previously made mistake;
- correction of CO_2 EF in 1.A.2.g.i Manufacturing of machinery for other bituminous coal (2015-2019) due to previously made mistake.

Impacts of these recalculations on GHG emissions are presented in Tables 3-21 to 3-24.

Table 3-21. Impact of recalculation on GHG emissions from 1.A.2.f Non-Metallic Minerals, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2018	449.9	444.9	-4.99	-1.12
2019	495.5	492.7	-2.82	-0.57

Table 3-22. Impact of recalculation on GHG emissions from 1.A.2.g.viii Non-Specified Industry, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2019	31.0	31.9	0.91	2.86

Table 3-23. Impact of recalculation on GHG emissions from 1.A.2.g.iv Wood and wood products, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2014	18.52	19.86	1.34	6.74

Table 3-24. Impact of recalculation on GHG emissions from 1.A.2.g.i Manufacturing machinery, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2015	14.69	14.69	0.001	0.007
2016	19.93	19.93	0.001	0.004
2017	22.68	22.68	0.002	0.007
2018	25.10	25.10	0.001	0.003
2019	25.11	25.12	0.001	0.002

3.4.6 Category-specific planned improvements

It is planned to include medical and hazardous waste (category 1.A.2.g.viii Non-specified industry) into the energy balance as non-biomass fraction of industrial waste in order to increase the consistency between the energy statistics and the GHG inventory activity data.

3.5 Transport (CRF 1.A.3)

The source category 1.A.3 comprises the sources presented in Table 3-25. The source category Civil Aviation only includes emissions from domestic civil aviation, i.e., civil aviation with departure and arrival in Lithuania. In the same manner, the source category Water-borne Navigation only includes emissions from domestic inland navigation.

Table 3-25. Description of categories in the 1.A.3 Transport sector

CRF source category	Description	Remarks
CRF 1.A.3		
1.A.3.a *Civil Aviation*	Jet and turboprop powered aircraft (turbine engine fleet) and piston engine aircraft	
1.A.3.b *Road Transportation*	Transportation on roads by vehicles with combustion engines: Passenger Cars, Light Duty Vehicles, Heavy Duty Vehicles and Buses, Mopeds and Motorcycles. Farm and forest tractors are included in CRF 1.A.4.c Agriculture/Forestry/Fishing (1.A.4.c.ii Off-road vehicles and other machinery, 1.A.4.c.iii Fishing). Fuel consumption and emissions from off-road vehicles are included in categories 1.A.2.g.vii Off-road Vehicles and Other Machinery and 1.A.4 Other Sectors (Off-road).	

1.A.3.b.i	Passenger cars (PC)	Emissions from vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.
1.A.3.b.ii	Light duty trucks (LD)	Emissions from vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 tonnes.
1.A.3.b.iii	Heavy duty trucks and Buses (HD)	Emissions from any other vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 tonnes (heavy duty trucks) and vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat (buses).
1.A.3.b.iv	Motorcycles (M)	Emissions from any light two-four wheel powered vehicles.
2.D.3	Urea-based catalysts	CO_2 emissions from use of urea-based additives in catalytic converters (non-combustive emissions)
1.A.3.c *Railways*	Railway transport operated by diesel locomotives	Emissions from railway transport for both freight and passenger traffic routes.
1.A.3.d *Water-borne Navigation*	Merchant ships, passenger ships, container ships, cargo ships, technical ships, tourism ships and other inland vessels.	Fishing emissions are included in the CRF 1.A.4.c.iii
1.A.2.g.vii; 1.A.3.e; 1.A.4*;* 1.A.5.b	Transport of gases via pipelines, military activity and off-road transport.	1.A.2.g.vii Off-road Vehicles and Other Machinery 1.A.4 Other Sectors (Off-road): 1.A.4.a.ii Commercial/Institutional 1.A.4.b.ii Residential 1.A.4.c Agriculture/Forestry/Fishing: 1.A.4.c.ii Off-road Vehicles and Other Machinery 1.A.4.c.iii Fishing

Methods and emission factor information for category 1.A.3 Transport are presented in table 3-26.

Table 3-26. Methods and emissions factors used to estimate emissions from transport category

CRF	Source	Emissions reported	Methods	Emission factor
1.A.3.a	Civil aviation	CO_2	Tier 1	CS
		CH_4	Tier 1	D
		N_2O	Tier 1	D
1.A.3.b	Road transportation	CO_2	Tier 1, Tier 2	D, CS
		CH_4	Tier 3	CR
		N_2O	Tier 3	CR
2.D.3	Urea-based catalysts	CO_2	Tier 3	D
1.A.3.c	Railways	CO_2	Tier 1, Tier2	D, CS
		CH_4	Tier 1	D
		N_2O	Tier 1	D
1.A.3.d	Water-borne navigation	CO_2	Tier 1	D, CS
		CH_4	Tier 1	D
		N_2O	Tier 1	D
1.A.3.e.i	Pipeline transport	CO_2	Tier 2	CS
		CH_4	Tier 1	D
		N_2O	Tier 1	D

Emissions from motorized mobile road traffic in Lithuania includes traffic on public roads within country, except for agricultural and forestry transports. The source categories Road transportation and Railways include all emissions from fuel sold to road transport and railways in Lithuania. CO_2 emissions from 1.A.3.b Road transportation are dominant in this source category. Fuel consumption in 1.A.3 Transport sector accounted for 60,486 TJ and 86,663 TJ in

2005 and 2020, respectively. The sector emissions increased from 4,440.3 in 2005 to 6,344.3 kt CO_2 equivalent in 2020. In 2020 the most important source of GHGs was road transport, with a share of 93.7% in fuel consumption (Figure 3-32). Lithuania's railway system is mainly driven by diesel oil (~2.6% of total fuel consumption in transport sector). Fuels used by ships on inland waterways have a share of ~0.2% in transport fuel consumption. In 2020 about 0.03% of transportation fuel consumption arose from civil aviation sector. However, emissions from international transport at inland waterways are excluded from the national total and reported as marine bunkers.

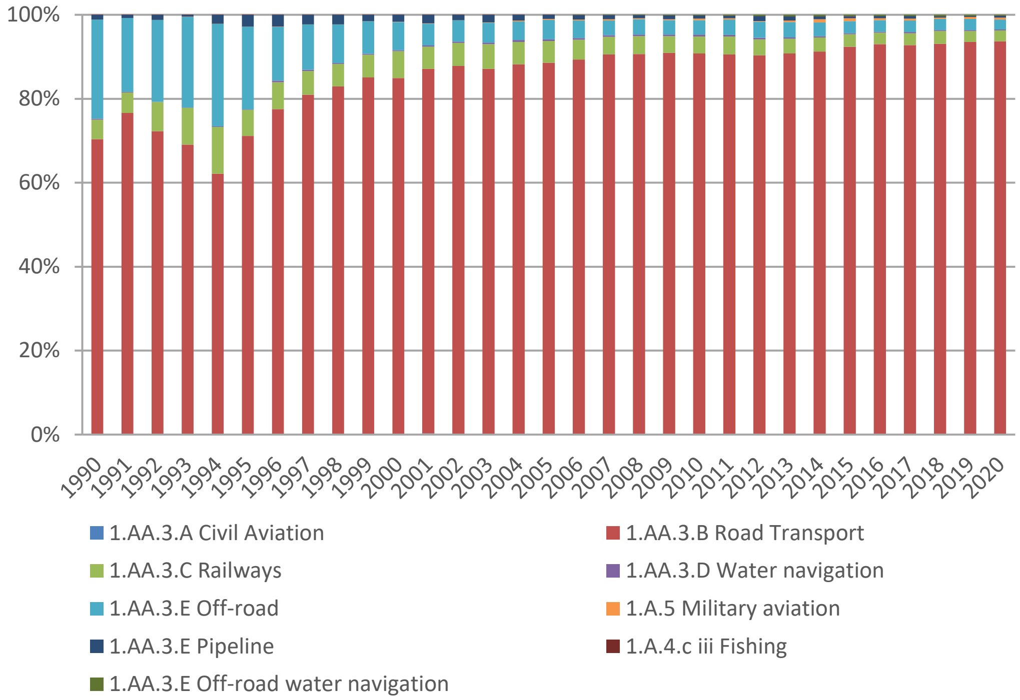


Figure 3-32. Fuel consumption distribution in Transport sector

Activity Data

Speed mode of vehicles and fuel consumption are supplied by the Lithuanian Transport Safety Administration, and the Lithuanian Statistics yearly publications "Energy balance" (Statistics Lithuania, 2018). Meteorological data is obtained from Lithuanian Hydrometeorological Service under the Ministry of Environment of the Republic of Lithuania (LHMS). The number of registered cars in Lithuania was obtained on the basis of the officially published number of vehicles with Vehicle Registration Certificate provided by State Enterprise Regitra.

According to the information provided by Lithuanian Statistics, data collection methodology of fuel use in road transport is part of the annual energy and fuel statistics survey. Functional enterprises are surveyed irrespective of their kind and ownership form. Statistical survey covers enterprises producing, supplying and consuming fuel and (or) energy.

Statistical information about oil products (motor gasoline, diesel, liquefied petroleum gas (LPG)) consumption in road transport is reported by the following enterprises:

- Enterprises producing oil products;
- Enterprises importing and exporting oil products;
- Oil products wholesale trade enterprises;

- Enterprises, which according to Law on State's oil and oil products reserve are obliged to store and manage State's oil and oil products reserve;
- Enterprises consuming fuel and energy and belonging to the following economic activities: agricultural (with 10 and more employees), forestry and fishing, mining and quarrying, manufacturing industry, construction, transport and storage (except for road transportation) (with 20 and more employees).

Energy balance statistical report EN-01 and Oil/ Oil products balance statistical report EN-06 are the sources for statistical data.

In the statistical reports respondents are providing statistical data about each fuel and energy type: changes in stocks at the beginning and end of the year, production, inter-product transfer processes, import and export, purchase and sale in the internal market, consumption allocated by consumption purposes.

Statistical indicator "Consumption in road transport" is based on the territorial principle, not on the resident, i.e. the fuel sold (purchased) in Lithuania's territory is accounted, regardless of the country the vehicle originates.

In the balance row "Consumption in road transport" fuel used by all commercial and passenger vehicle's engines, i.e. consumed in industry, construction, transportation, service and other sectors is included.

For fuels in common circulation, the carbon content of the fuel and net calorific values were obtained from fuel suppliers in accordance with the *2006 IPCC Guidelines.*

3.5.1 Civil aviation (CRF 1.A.3.a)

3.5.1.1 Category description

Civil International airports in Lithuania (Vilnius, Kaunas and Palanga) are operated by State owned assets of the enterprises under the supervision of the Ministry of Transport and Communications. The Resolution No 1355 dated 28 October 2004 of the Government of the Republic of Lithuania approved the Šiauliai Airport as military, granting the right to use it for international civil air transport.

Domestic civil aviation is essentially narrow in Lithuania. Aviation gasoline (avgas) is used for piston-type powered aircraft engines, while the jet fuel used in turbine engines for aircraft and diesel engines.

Figure 3-33. Map of aerodromes in Lithuania

Aviation gasoline is more common as fuel for private aircrafts, while the jet fuel used in aircrafts, airlines, military aircrafts and other. Net calorific values (NCVs) used to convert fuel consumption in natural units into energy units are provided in the Table 3-27.

Table 3-27. Specific net calorific values (conversion factors) (Statistics Lithuania)

Type of fuel	Tonne	TJ/tonne
Aviation gasoline and gasoline type jet fuel	1.0	0.04404
Kerosene type jet fuel	1.0	0.04320

During 2020, Lithuanian Airports served 1.8 million passengers and 30 thousand flights, which is -52% less than in 2019. During the year, 15 airline companies organized flights to 72 directions. Based on data of the Airports Council International (ACI Europe), Lithuanian Airports contribute to the GDP of Lithuania by 2.5 percent.

The majority of passengers arrived from and departed to the United Kingdom (21%), Norway (10%), Germany (9%), Denmark (5%) and Latvia (5%). In 2020, freight and mail loaded and unloaded at Lithuanian airports amounted to 19.9 thousand tonnes.

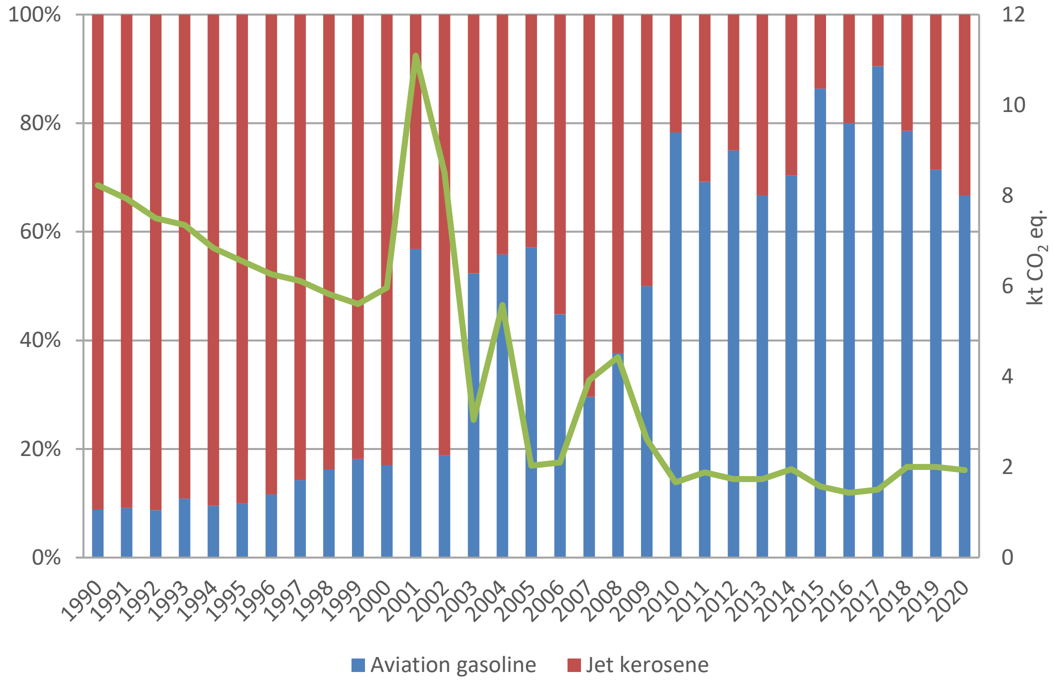


Figure 3-34. Trend of GHG emissions in Civil Aviation sector

A peak of total CO_2 eq. is related to increased aviation gasoline consumption in 2001.

3.5.1.2 Methodological issues

The aviation gasoline and jet kerosene consumption and GHG emissions were based on Tier 1 approach (*2006 IPCC Guidelines*) as this method should be used to estimate emissions from aircraft that use aviation gasoline which is only used in small aircraft and generally represents less than 1% of fuel consumption from aviation. Tier 1 method is also used for jet-fuelled aviation activities when aircraft operational use data are not available.

It should be noted that the reporting of emissions from military aircraft is under CRF code 1.A.5, not 1.A.3.a. Military activity is defined in this report as those activities using fuel purchased by or supplied to the military authorities of the country.

Activity data

Following advice from ERT (ICR Lithuania 17-21st May, 2004) it was decided to distinguish GHG emissions from aviation bunkers in such a way that all aviation gasoline and part of kerosene type jet fuel is used for domestic purposes and the rest kerosene type jet fuel is used for international flights – the latter could therefore be considered as aviation bunkers. Activity data on aviation gasoline split between domestic and international aviation is available only from 2000. Following the recommendation of ERT in 2011, the estimates of aviation gasoline consumption were linearly interpolated for the period 1996-1999 since effect of annual fluctuations was considered negligible. Emissions were estimated by assuming a constant annual rate of growth in fuel consumption from 1995 to 2000 (*2006 IPCC Guidelines,* Volume 1*)*. Trend extrapolation of GHG from jet kerosene for 1990-2002 was evaluated in combination with surrogate data. To improve the accuracy of estimates, changes in total jet kerosene consumption during 1990-2010 were used as underlying activity for simulation of trend in GHG emissions (*2006 IPCC Guidelines,* Volume 1).

Following the recommendation of ERT (ICR Lithuania 1-6 October, 2012) the extrapolation procedure was explained. In a case when we have very sharp annual fluctuations in time-series, the partial correlation can be done. Bearing in mind that the relationship between emissions and surrogate can be developed on the basis of data for a single year, the use of multiple years might provide a better estimate. Two underlying activities for surrogate data were used: average length of carriage per tonne, km, and international fuel consumed, TJ. The extrapolation was made using its own extrapolation algorithm and surrogate data was used as parameters for comparison (for example Average length of carriage per tonne, km) (Fig. 3-35).

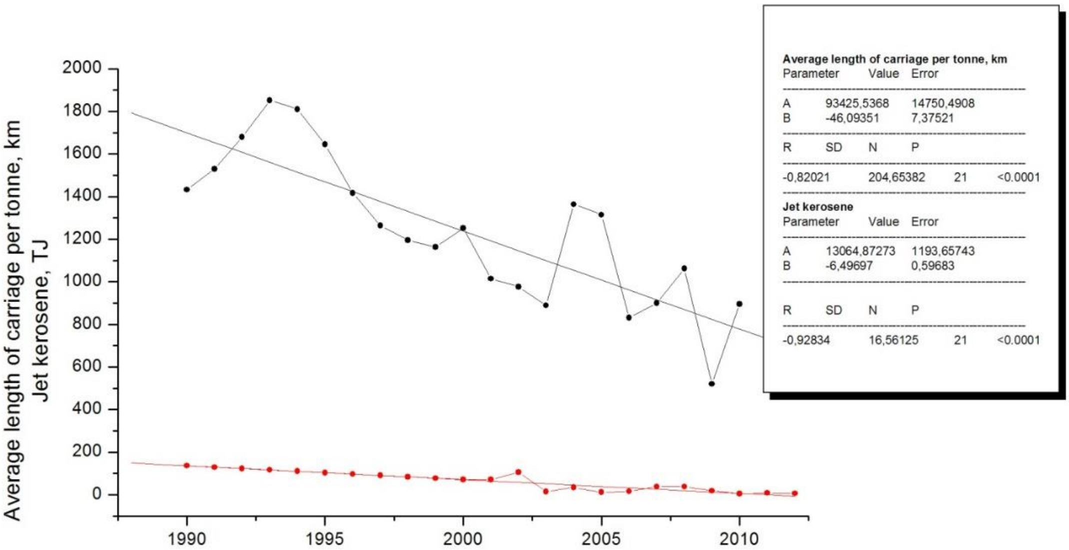


Figure 3-35 The intercomparison between surrogate data and trend of civil aviation emissions

The underlying algorithm used in the SLOPE functions is different from the underlying algorithm used in the EXTRAPOLATION function. The difference between these algorithms can lead to different results when data is undetermined and collinear. For this reason, the tendency of surrogate data was compared to tendency of time-series after extrapolation was applied.

Data on jet kerosene used for military in Lithuania is available starting from 2001. Data for 1990-2000 was extrapolated.

Additionally, special inquiry has to be made annually for data on consumption of aviation fuels for international bunkering and inland consumption, because this data is not published in the National Energy Balances and Annual Yearbooks, i.e. data of aviation fuels is given in total and is not split into national and international use.

Emission factors

Emission factors for *Civil aviation* sources used in the Lithuanian national GHG inventory are provided in Annex V and Table 3-28. Country-specific CO_2 EFs were applied based on the results of the study "Determination of national GHG emission factors for energy sector", which was prepared by Lithuanian Energy Institute in 2012 and 2016. Values of country-specific CO_2 EFs for gasoline, diesel, gasoil, jet kerosene and liquefied petroleum gas were determined on the basis of measurements performed by the accredited Laboratory of Quality Research Centre of JSC "ORLEN Lietuva".

Table 3-28. CH_4 and N_2O emission factors for Civil aviation sector used in the Lithuanian GHG inventory

Fuel	CH_4	N_2O

	CH_4, kg/TJ	EF	Method	N_2O, kg/TJ	EF	Method
Aviation gasoline and gasoline type jet fuel	0.5	D	T1	2	D	T1
Jet kerosene	0.5	D	T1	2	D	T1

3.5.1.3 Uncertainties and time-series consistency

Uncertainty of activity data of aviation fuel consumption in civil aviation is ±10% influenced mainly by domestic and international fuel split and extrapolation procedure. In fuel combustion activity, the CO_2 emission factor mainly depends on the carbon content of the fuel instead of on combustion technology. CO_2 emission factor (uncertainty 2%) was estimated according physical characterization of used fuels in country based on results of 2016 study "Update of country specific GHG emission factors for energy sector". Uncertainty of activity data of fuel consumption for 1990-2000 in civil aviation is influenced by data based on extrapolation (jet kerosene).

The current limited knowledge of CH_4 and N_2O emission factors, more detailed methods do not significantly reduce uncertainties for CH_4 and N_2O emissions, so uncertainty was assigned to about -57%/+100% and -70%/+150%, respectively. The time series for all data have been studied carefully in search for outliers.

As stated in the ARR 2017, based on a comparison of Lithuania's submission to UNFCCC and IEA data for domestic aviation, IEA data on jet kerosene differ by up to 57% (higher) from CRF data for the period 2000-2008, although quantities are low (e.g. for 2004, IEA data were 9.00 TJ higher (43.00 TJ compared with 34.00 TJ), which was 0.65 kt CO_2 eq or 0.00003 per cent of national total GHG emissions excluding LULUCF). Statistics Lithuania explained that differences could occur due to data extrapolation, data correction and due to conversion of units, for example to separate military and civil aviation during 2000-2003.

3.5.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.5.1.5 Category-specific recalculations

No recalculations have been done.

3.5.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

3.5.2 Road transportation (CRF 1.A.3.b)

3.5.2.1 Category description

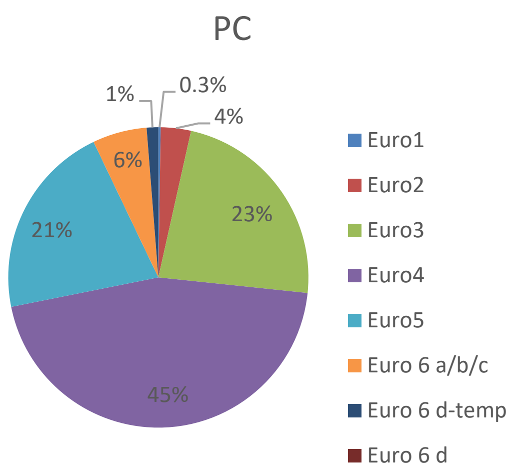
Lithuania has a well-developed road network. At the end of 2020, the length of roads amounted to 84,769 kilometers; the length of E-roads amounted to 1,742 kilometers, of which motorways – 400 km and urban streets – 6,681 km (Ministry of Transport and Communications, 2021).

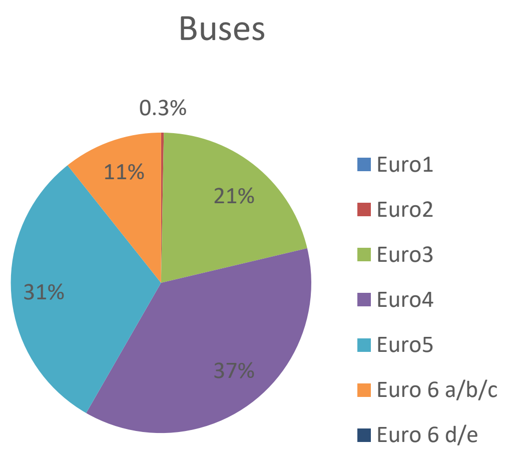
Road transportation is the most important emission source in the Transport sector. This sector includes all types of vehicles on roads (passenger cars (PC), light duty vehicles (LD), heavy duty trucks and buses (HD), motorcycles and mopeds (2-wheels)) (Table 3-29). The source category does not cover farm and forest tractors driving occasionally on the roads because they are included in other sectors as off-roads.

Implementing the amendment to Order No 260 of 25 May 2001 of the Minister of the Interior of the Republic of Lithuania on the approval of the Rules for the Registration of Motor Vehicles and Their Trailers, made by Order No IV-445 of 30 June 2014, the state enterprise Regitra deregistered vehicles whose compulsory technical inspection or vehicle owner's compulsory civil liability insurance expired by 1 July 2014. For this reason, in 2014, against 2013, the number of all vehicles registered in the country markedly decreased. 44% of mopeds and motorcycles, 18.7% of passenger cars, 20.6% of buses, 18.5% of heavy-duty vehicles were produced over 20 years ago (Figure 3-36).

Table 3-29. Number of vehicles in road transport sector by UNECE classification (thousands) (Passenger Cars-M1, Light Duty Vehicles-N1, Heavy Duty Vehicles-N2, N3, Urban Buses & Coaches-M2, M3, Two Wheelers-L1, L2, L3, L4, L5, State Enterprise Regitra)

	L1, L2, L3, L4, L5	M1	N1, N2, N3, M2, M3	Total
1990	21.14	502.83	95.18	619.15
1995	19.76	482.03	78.14	579.92
2000	17.88	619.00	78.16	715.04
2005	18.11	844.60	90.98	953.69
2010	23.92	1,009.20	91.95	1,125.07
2015	35.95	1,165.50	114.72	1,316.16
2016	40.00	1,245.68	121.62	1,407.30
2017	42.07	1,363.59	129.92	1,535.58
2018	45.54	1,442.33	140.07	1,627.94
2019	53.28	1,512.78	151.59	1,717.65
2020	58.68	1,573.36	158.67	1,790.71





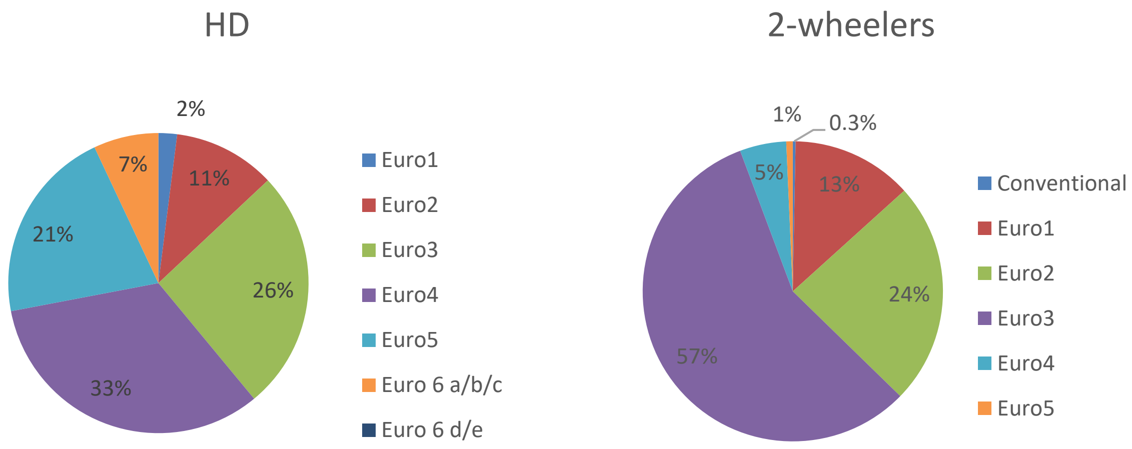


Figure 3-36. Vehicles by standarts, 2020 (SE Regitra)

In 2020, GHG emissions from road transport decreased by 2.3% from 6,053.5 to 5,913.5 kt CO_2 eq. This decrease is primarily caused by a 2.2% decrease in diesel oil fuel and 2.2% in gasoline consumption by road transportation (Table 3-30). The lowest emission level in the road transportation was achieved in 1994 because of the economic depression in Lithuania. The greenhouse gas emissions from the road transport sector are summarized in Fig. 3-37.

Table 3-30. Fuel consumption (Statistics Lithuania), [TJ]

Year	Motor gasoline	Transport diesel	LPG	Bioethanol*	Bio-ETBE*	Biodiesel*	CNG
1990	41,840	29,275.61	920	-	-	-	-
1995	25,887	11,133	1,058	-	-	-	-
2000	16,337	18,366	5,032	-	-	-	-
2005	14,685	29,262	9,593	26	-	119	-
2010	12,405	36,894	7,275	436	-	1,452	97
2012	9,656	40,157	6,400	365	4	2,064	121
2015	8,356	52,428	5,573	405	-	2,349	321
2016	9,032	57,320	5,254	269	-	2,029	325
2017	8,890	60,843	4878	344	-	2,582	327
2018	9,729	65,089	4572	334	-	2,843	323
2019	10,148	68,150	4,405	409	-	2,665	312
2020	9,922	66,669	4,058	659	-	3,551	351

*Carbon from biofuel (except fossil part of biodiesel) is reported as a memo item but not included in national CO_2 totals, as required by the *2006 IPCC Guidelines, Volume 2, Chapter 3: Mobile Combustion, 3.13 p*.

Net calorific values (NCVs) used to convert fuel consumption in natural units into energy units are provided in the Table 3-31.

Table 3-31. Specific net calorific values for Road transportation (conversion factors) (Statistics Lithuania)

Type of fuel	Tonne	2017	2018	2019	2020
		TJ/tonne			
Liquefied petroleum gases	1.0	0.04579	0.04575	0.04575	0.04579
Motor gasoline	1.0	0.04399	0.04399	0.04395	0.04391

Transport diesel	1.0	0.04286	0.04286	0.04286	0.04291
Bioethanol	1.0	0.02700	0.02700	0.02700	0.02700
Biodiesel (methyl ester)	1.0	0.03700	0.03700	0.03700	0.03700
CNG (MWh)	1.0	0.00324*	0.00324*	0.00324*	0.00324*

* Expressed as TJ per MWh

CO_2 emissions depend directly on fuel consumption. CO_2 emissions can be estimated from the mileage; however, it is usually best to estimate the total emissions from the fuel consumption (as this is more reliable data) and then allocate these emissions to the vehicle types by vehicle mileage data and relative fuel efficiencies. In 2000-2007 these emissions increased, since growth in mileage travelled outweighed improvements in vehicle fuel consumption. Road traffic is an important source of N_2O from fuel combustion and in 1994-2008 emissions increased in line with the increasing share of catalyst-controlled vehicles in the national fleet (exception is 2000 and 1999 when the consumption of motor gasoline noticeably decreased). The use of liquefied petroleum gas (LPG) is strongly influenced by the fluctuation of fuel prices.

Since 1990 the density of transport routes as well as the number of road vehicles has increased rapidly. Since 1995, the number of personal cars almost increased by a factor of 3 over the last years (Table 3-29). 93.9% of the fuel in transport sector is consumed by road transport.

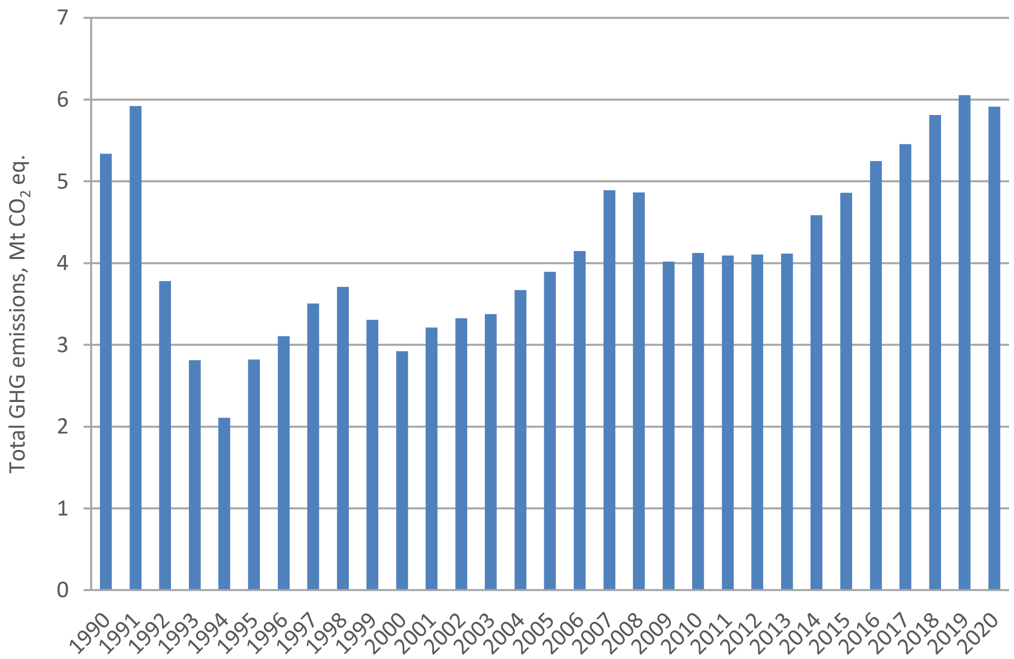


Figure 3-37. Development of GHG emissions from road transport

CH_4 emissions in Road transport are presented in Figure 3-38.

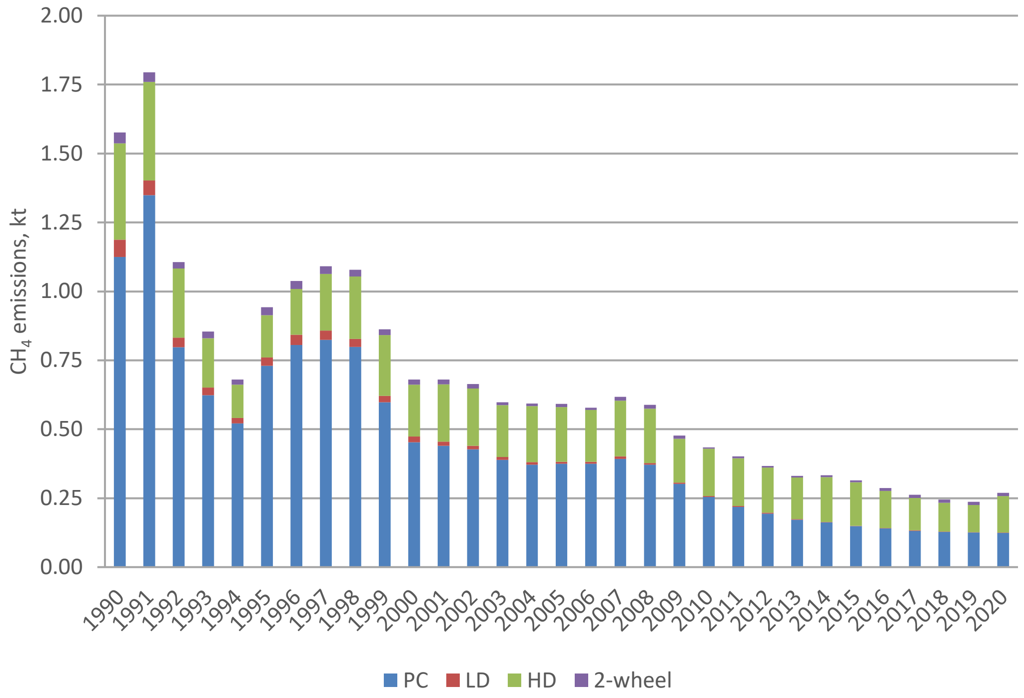


Figure 3-38. CH_4 emissions in Road transport

A higher share of passenger cars with petrol engines have catalysers installed. N_2O emissions result primarily from incomplete reduction of NO to N_2 in 3-way catalytic converters. N_2O emissions depend on driving cycle variables, catalyst composition, catalyst age, catalyst exposure to variable levels of sulphur compounds. Transport N_2O emissions are not limited by any restrictions. Initially, growth in numbers of cars with the first-generation catalyst converters (Euro 1) caused increases in N_2O emissions in comparison to the 1990 level. Newer catalytic converters are optimized to produce only small amounts of N_2O (Figure 3-39).

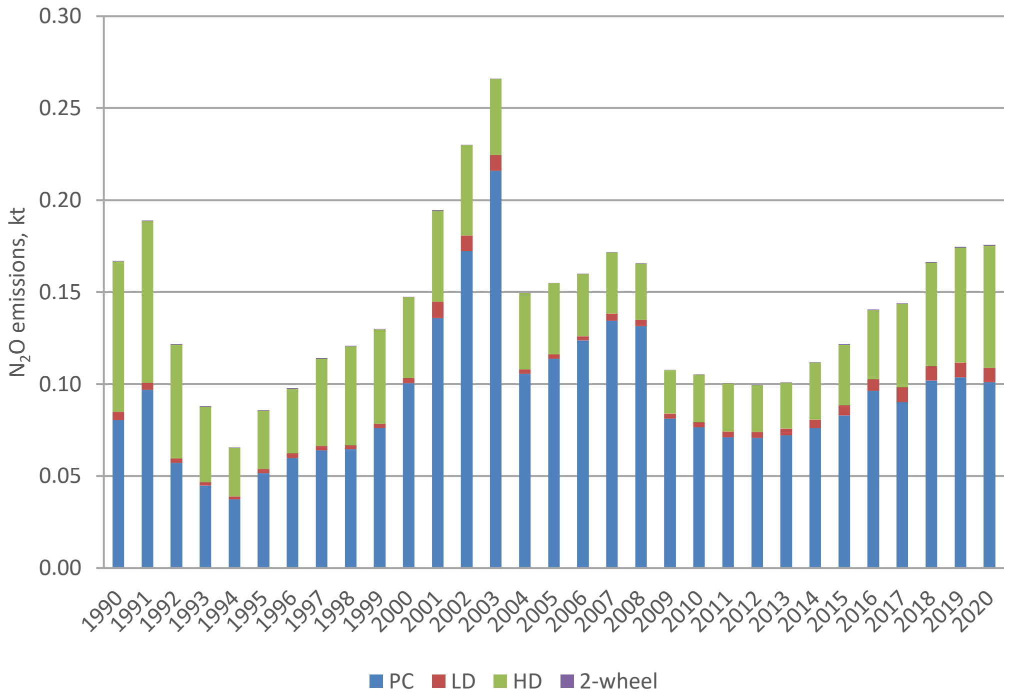


Figure 3-39. N_2O emissions in Road transport

Emissions from lubricants in two-stroke engines are considered as insignificant, as these emissions do not exceed the threshold of significance. According to Copert 5.0 data, 116-146 TJ of petrol were used for two-stroke engines in 2016-2020. In accordance with *2006 IPCC Guidelines* (Volume 2, Chapter 3, box 3.2.4), a two-stroke petrol engine should be lubricated by a mixture of lubricating oil and petrol in suitable proportion according to the manufacturer's recommendations. Depending on the engine type, mixtures of 1:25, 1:33 and 1:50 are common. Based on these proportions, lubricants use in two-stroke engines in 2019 amounts only to 3.07-6.15 TJ, consequently emissions are equal to 0.2-0.4 kt of CO_2 and do not exceed threshold of significance.

There is a marked switch from petrol engines to diesel (Table 3-30). The number of petrol engines (all vehicle types) and as a result petrol fuel consumption has dropped between 1990 and 2020, while the number of diesel engines increased significantly from ~13 thousand to over 1 million for the same period.

Passenger cars represent the most fuel-consuming vehicle category, followed by heavy-duty vehicles, light duty vehicles and 2-wheelers, in decreasing order (Figures 3-40 and 3-41).

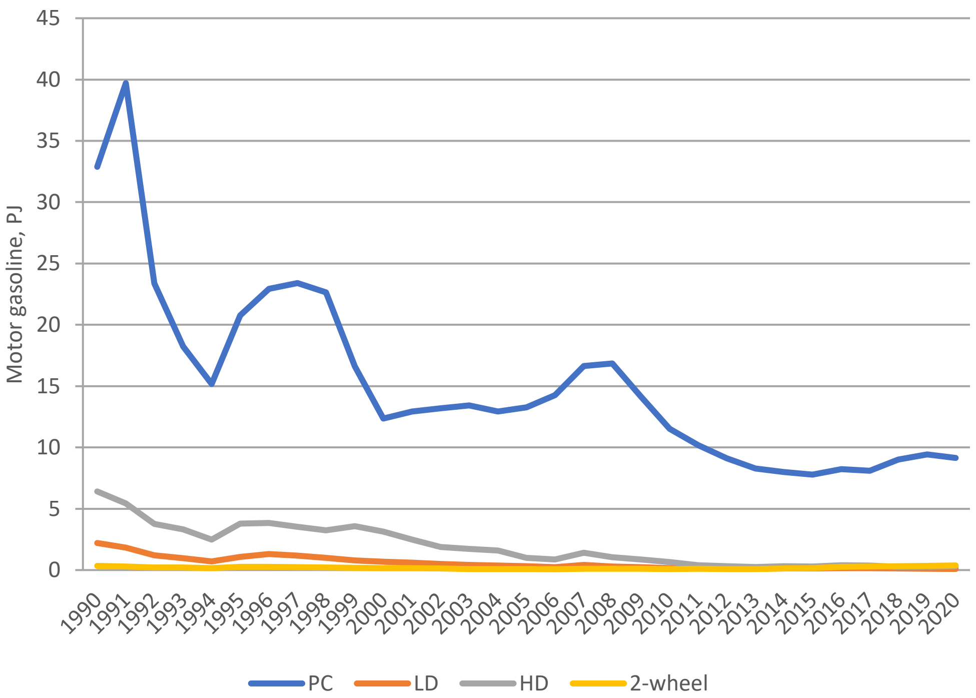


Figure 3-40. Gasoline fuel consumption per vehicle type for road transport

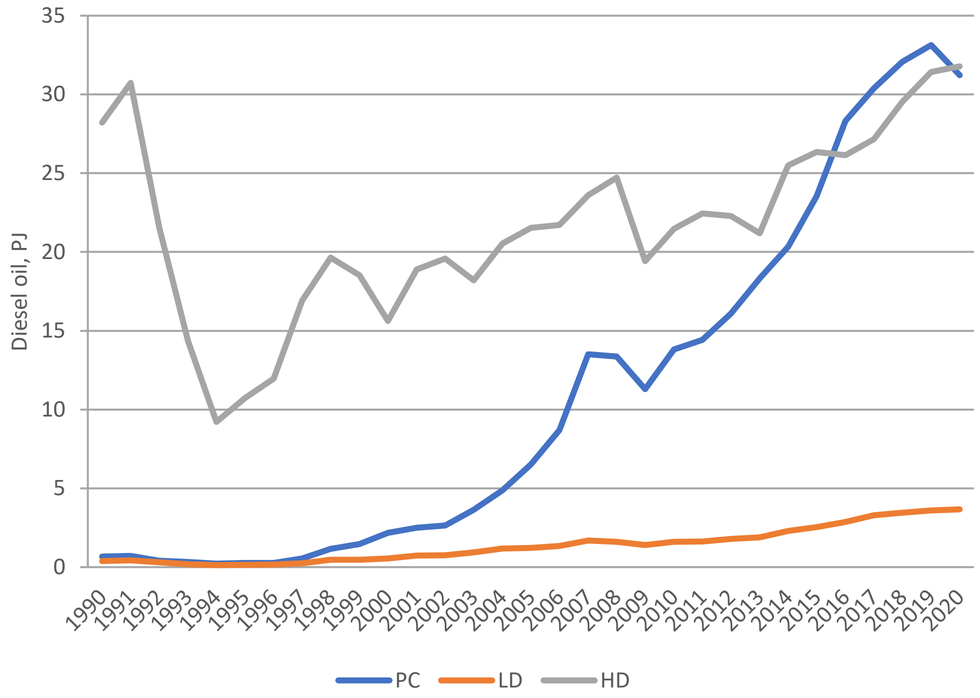


Figure 3-41. Diesel oil consumption per vehicle type for road transport

In 2020, fuel consumption shares for diesel passenger cars, diesel heavy-duty vehicles, gasoline passenger cars, LPG cars, diesel light duty vehicles were 38.5%, 39.2%, 11.3%, 5.0%, 4.5%, respectively (Figure 3-42).

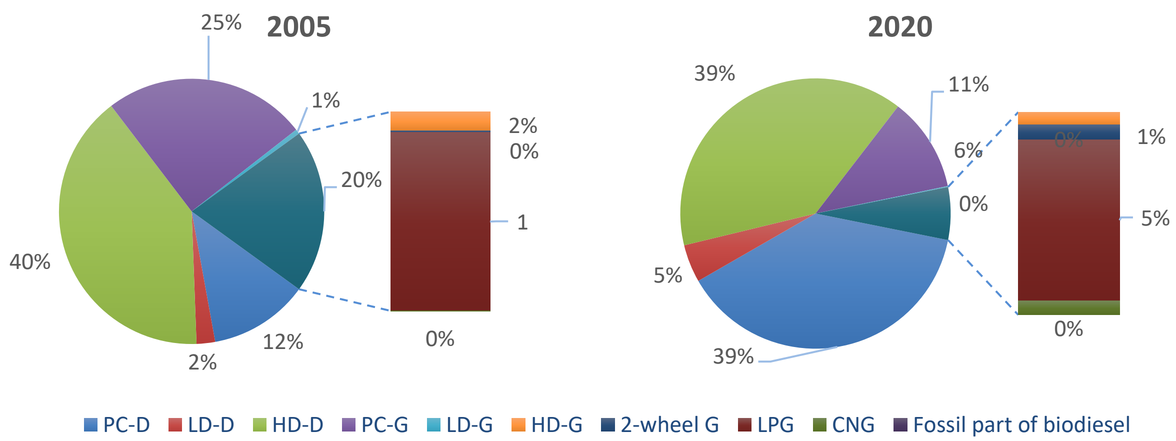


Figure 3-42. Fuel consumption share (TJ) per vehicle type and fuel type for road transport in 2005 and 2020. PC-D – diesel passenger cars, LD-D – diesel light-duty vehicles, HD-D – diesel heavy-duty vehicles, PC-G – gasoline passenger cars, LD-G – gasoline passenger cars, HD-G – gasoline heavy-duty vehicles, 2-wheel G – gasoline 2-wheelers, LPG – LPG passenger cars, CNG – CNG passenger cars.

As seen from Figure 3-43, most of GHG emissions from road transport sector are mainly emitted from passenger cars and heavy-duty vehicles.

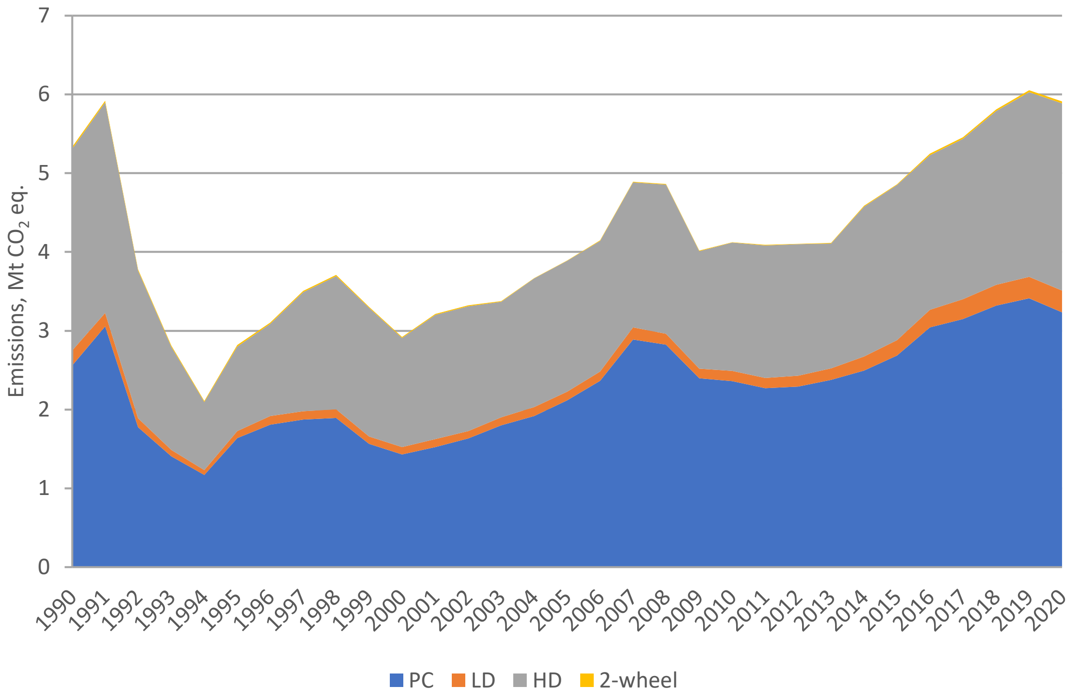


Figure 3-43. Emissions from road transportation by vehicle type

CO_2 emissions associated with the fossil carbon content in biofuels

According to the *2006 IPCC Guidelines* (vol. 2, chapter 3, section 'CO_2 emissions from biofuels', p. 3.17): "it is important to assess the biofuel origin so as to identify and separate fossil from biogenic feedstocks". In other words, a part of the carbon of biofuels (and the associated CO_2 emissions) may have a fossil origin. The following biofuels are used to replace fossil diesel: hydrotreated vegetable oil (HVO) and fatty acid methyl esters (FAME). HVO is produced through the hydro-treatment of the triglyceride-containing feedstocks (vegetable oil or animal fat), therefore all carbon can be considered of biogenic origin (no fossil part). Vegetable oils or animal fats are reacted with methanol in the presence of catalysts to form glycerol and FAME. The fossil carbon of FAME originates from the methyl group of methanol. Fossil CO_2 emissions from biodiesel were included for the first time in this submission. Estimated CO_2 emissions were disaggregated between and included respectively in the subsectors using biodiesel (1.A.3.b Road transportation, 1.A.3.c Railways, 1.A.3.d Domestic navigation).

3.5.2.2 Methodological issues

Emissions from road transportation are estimated using the *2006 IPCC Guidelines* Tier 2 method (for CO_2 emissions) and for CH_4 and N_2O emissions are based on the COPERT 5.0 model (best practice) which corresponds to the 2006 *IPCC Guidelines* Tier 3 method. In order to apply the CORINAIR methodology the vehicle categories were broken down into so-called *vehicle layers* with the same emissions technology behaviour, by type of fuel used, vehicle size (heavy duty trucks and buses by weight class, passenger cars and motorcycles by engine displacement) and pollution control equipment used, as defined by EU directives for emissions control ("EURO norms"), and by regional traffic distribution (urban, rural and highways). The classification of vehicles was done according to the UNECE. The main vehicle categories were allocated to the UNECE classification as follows:

Passenger Cars	M1
Light Duty Vehicles	N1
Heavy Duty Vehicles	N2, N3
Urban Buses & Coaches	M2, M3
Two Wheelers	L1, L2, L3, L4, L5

In the Tier 3 method, emissions are calculated using a combination of firm technical data and activity data. The activity data of road transport was split and filled in for a range of parameters including:

- Fuel consumed, quality of each fuel type;
- Emission controls fitted to vehicle in the fleet;
- Operating characteristics (e.g. average speed per vehicle type and per road)
- Types of roads;
- Maintenance;
- Fleet age distribution;
- Distance driven (mean trip distance), and
- Climate

The program calculates vehicle mileages, fuel consumption, exhaust gas emissions, evaporative emissions of the road traffic. The balances use the vehicle stock and functions of the km driven per vehicle and year to assess the total traffic volume of each vehicle category. The production year of vehicles in this category has been taken into account by introducing different classes, which reflects legislative steps ('ECE', 'Euro') applicable to vehicles registered in each Member State. The technology mix in each particular year depends on the vehicle category and the activity dataset considered.

For the period between 1990 and 2020, it was necessary to estimate the figures with the aid of numerous assumptions. The total emissions were calculated by summing emissions from different sources, namely the thermally stabilized engine operation (hot) and the warming-up phase (cold start) (EEA 2000; MEET, 1999). For Tier 3 approaches cold start emissions were estimated:

$$E_{COLD;i,k} = \beta_{i,k} \times N_k \times M_k \times E_{HOT;i,k} \times (e_{COLD} / e_{HOT} \big|_{i,k} - 1)$$

where:

$E_{COLD;i,k}$ - cold start emissions of pollutant *i*(for the reference year), produced by vehicle technology *k*;

$E_{HOT;i,k}$ - emissions (g) during stabilized (hot) engine operation;

$\beta_{i,k}$ - fraction of mileage driven with a cold engine or the catalyst operated below the light-off temperature for pollutant *i* and vehicle [veh] technology *k*;

N_k - number of vehicles of technology *k* in circulation;

M_k - total mileage per vehicle [km veh^{-1}] in vehicle technology *k*;

e_{COLD}/e_{HOT} - cold/hot emission quotient for pollutant *i* and vehicle of *k* technology.

$$E_{TOTAL} = E_{HOT} + E_{COLD},$$

where:

E_{TOTAL} - total emissions (g) of compound for the spatial and temporal resolution of the application;

E_{HOT} - emissions (g) during stabilized (hot) engine operation;

E_{COLD} - emissions (g) during transient thermal engine operation (cold start).

The β-parameter depends upon ambient temperature t_a (for practical reasons the average monthly temperature was used). Since information on average trip length is not available for all vehicle classes, simplifications have been introduced for some vehicle categories. According to the available statistical data (André *et al.*, 1998), a European value of 12.4 km has been established for the l_{trip} value and used in estimations in Lithuania.

Concentrations of some pollutants during the warming-up period are many times higher than during hot operation. In this respect, a distinction is made between urban, rural and highway driving modes. Cold-start emissions are attributed mainly to urban driving (and secondarily to rural driving), as it is expected that a limited number of trips start at highway conditions. Therefore, as far as driving conditions are concerned, total emissions were calculated by means of the equation:

$$E_{TOTAL} = E_{URBAN} + E_{RURAL} + E_{HIGHWAY}.$$

where:

E_{URBAN}, E_{RURAL} *and* $E_{HIGHWAY}$ - the total emissions (g) of any pollutant for the respective driving situations.

Fuel was distributed to transport categories, types, ecology standards and driving modes according to data taken from State Enterprise Transport and Road Research Institute under the Ministry of Transport and Communications of the Republic of Lithuania.

Emissions were estimated from the fuel consumed (represented by fuel sold) and the distance travelled by the vehicles. The first approach (fuel sold) was applied for CO_2 and the second (distance travelled by vehicle type and road type) for CH_4 and N_2O.

Emissions of CO_2 were calculated on the basis of the amount and type of fuel combusted (equal to the fuel sold) and its carbon content (*2006 IPCC Guidelines*. Volume 2, p. 3-10):

$$Emission = \sum [Fuel_a \cdot EF_a]$$

where:

Emission - emissions of CO_2, kg;

$Fuel_a$ - fuel sold, TJ;

EF_a - emission factor, kg/TJ. This is equal to the carbon content of the fuel multiplied by 44/12;

a - type of fuel (petrol, diesel, natural gas, etc).

Emission factor assumes full oxidation of the fuel. Emission equation for CH_4 and N_2O for Tier 3 is:

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

where:

Emission - emission of CH_4 or N_2O;

$EF_{a,b,c,d}$ - emission factor, kg/km;

$Distance_{a,b,c,d}$ - distance travelled during thermally stabilized engine operation phase, km;

$C_{a,b,c,d}$ - emission during transient thermal engine operation (cold start), kg;

b - vehicle type;

c - emission control technology;

d - driving situation (urban, rural, highway).

Mileage data

The annual mileage driven by the stock of vehicle per year is an important parameter in emission calculation as it affects both the total emissions calculated and the relative contributions of the vehicle types considered. Calculations demand annual mileage per vehicle technology and the number of vehicles. They were supplied by the Lithuanian Road Administration and study funded by the European Commission – DG Environment and executed in collaboration with KTI, Renault, E3M-Lab/NTUA, Oekopol, and EnviCon. The sources for this data are various European measurement programmes. Fuel consumption, calculated on the basis of appropriate assumptions for annual mileage of the different vehicle categories, can be balanced with available fuel statistics (Ntziachristos et al., 2008). In general, the COPERT V data are transformed into trip-speed dependent fuel consumption and emission factors for all vehicle categories and layers. The calculated fuel consumption in COPERT V must equal the statistical fuel sale totals according to the UNFCCC and UNECE emissions reporting format. The statistical fuel sales for road transport are derived from Statistics Lithuania.

For example, if a country has bulk fuel sold but does not have fuel use by vehicle type, they may allocate total fuel consumption across vehicle types based on the consumption patterns of their fleet (TRB's National Cooperative Highway Research Program (NCHRP) project report, Greenhouse Gas Emission Inventory Methodologies for State Transportation Departments). By applying a trial-and-error approach, it was possible to reach acceptable estimates of mileage. For each group, the emissions were estimated by combining vehicle type and annual mileage with hot emission factors, cold/hot ratios and evaporation factors.

Emission factors

Country specific CO_2 EF was developed based on the results of 2016 study "Update of country specific GHG emission factors for energy sector". Motor gasolines, diesel oil and LPG used in the country are produced by the oil refinery UAB "ORLEN Lietuva". Imports of the fuels listed above comprise only a minor fraction of the fuels used in Lithuania.

All mileage dependent emission factors for diesel and motor gasoline are listed in the EMEP/EEA Guidebook, 2016 (Road transport, June 2017). Correction factors were applied to the baseline emission factors for gasoline cars and light-duty vehicles to account for different vehicle age (COPERT V).

Emission factors for Road transportation used in the Lithuanian national GHG inventory are provided in Table 3-32 and Annex V.

Table 3-32. Emission factors for Road transportation sector used in the Lithuanian GHG inventory

Fuel	CO_2			CH_4			N_2O		
	CO_2, kg/GJ	EF	Method	CH_4, kg/TJ	EF	Method	N_2O, kg/TJ	EF	Method
Motor gasoline	See Annex V	CS	T2	-	CR	T3	-	CR	T3
Diesel oil	See Annex V	CS	T2	-	CR	T3	-	CR	T3
LPG	See Annex V	CS	T2	-	CR	T3	-	CR	T3
Bioethanol	70.8	D	T1	3.0	D	T1	0.6	D	T1
Bio-ETBE	70.8	D	T1	3.0	D	T1	0.6	D	T1
Biodiesel	75.81	D*	T1	3.0	D	T1	0.6	D	T1
Fossil part of biodiesel	75.81	D*	T1	3.0	D	T1	0.6	D	T1
CNG	See Annex V	CS	T2	92	D	T1	3	D	T1

Abbreviations:

CS - country specific emission factors based on the results of the study "Determination of national GHG emission factors for energy sector", which was prepared by Lithuanian Energy Institute in 2012 and updated in 2016 study "Update of country specific GHG emission factors for energy sector";

D - default emission factors (*2006 IPCC Guidelines*);

*D - default emission factors (*Note on fossil carbon content in biofuels, Ioannis Sempos et al., 2018);*

CR – values modelled using COPERT.

Due to fact that fuel prices in Lithuania usually are higher than in neighbouring countries, the fuels used in Lithuania include fuels purchased in other countries and brought into the country as "grey" imports. At present, no precise data are available on this phenomenon, which is significant for truck and vehicle traffic in country border regions and which is referred to as "refuelling tourism".

CO_2 emissions associated with the fossil carbon content in biofuels

In order to estimate the fossil CO_2 emissions from biodiesel, the step by step approach proposed in the "Note on fossil carbon content in biofuels" (prepared by EU experts to establish an accorded point of view among EU MS to agree on a common understanding and define possible ways how to estimate the associated CO_2 emissions to the fossil carbon content in biofuels) was used. The HVO is not associated to fossil CO_2 emissions. As no CS information is available about FAME/HVO split, following the guidance, it was considered that all biodiesel used in Lithuania is FAME. The total carbon content (CC) of FAME (both bio and fossil origin) was estimated using 76.5% kgC/kg FAME as default value (it is estimated by considering that FAME composition is 50% rapeseed/30% sunflower/20% palm oil). The fossil part of carbon content of FAME was estimated using 5.4% as default value of carbon content fossil part (it is estimated by considering that FAME composition is 50% rapeseed/30% sunflower/20% palm oil). Fossil CO_2 emissions associated to FAME were calculated by applying the following equation:

Fossil origin CO_2 (kt) = (kt FAME) * (carbon content of FAME) * (fossil part of C of FAME) * 44/12

IEF value estimation

In Lithuania newer than conventional diesel vehicles (passenger cars and light duty vehicles) were not common during the last decade of the XX century. Most diesel vehicles were bought second-hand in Central Europe and brought to Lithuania. Thus, only after a few years after Euro 1 standard was established (1992), the vehicles entered the market in Lithuania. Copert V model was used for N_2O emission calculations. However, Copert V does not determine N_2O emissions for vehicles that are older than Euro 1 standard. This is in line with *2006 IPCC Guidelines*, table 3.2.5. Consequently, relatively low N_2O IEF values for period 1996-2004 are due to the fact that emissions are calculated only for the Euro 1 standard vehicles although the IEF values are calculated using the emissions only from newer categories (Euro 1, Euro 2, etc) and total amount of consumed fuel by all categories (conventional, Euro1, Euro 2, etc). Similar tendencies were observed in neighbouring and Baltic countries: Latvia, Estonia, Poland, which provided relatively low N_2O IEF values for the period 1996-2004. In the table and figures below, there are N_2O IEF values provided by Lithuania, the neighbouring countries and mean IEF values in European countries for Passenger Cars for period 1996-2004.

Table 3-33. N_2O IEF values provided by Lithuania, the neighbouring countries and mean IEF values in European countries for Passenger Cars (UNFCCC EF database)

Year	Passenger Cars Diesel Oil Implied emission factor for N_2O, kg/TJ					Passenger Cars Gasoline Implied emission factor for N_2O, kg/TJ				
	Lithuania	Latvia	Estonia	Poland	Average in other Europe countries	Lithuania	Latvia	Estonia	Poland	Average in other Europe countries
1996	0.01	0.97	0.19	0.69	1.73	2.60	2.28	3.18	4.81	5.55
1997	0.02	1.05	0.26	0.76	1.82	2.73	2.36	3.15	5.14	5.91
1998	0.40	1.06	0.33	0.88	1.95	2.72	2.44	3.23	5.41	5.99
1999	0.62	1.06	0.35	0.97	2.06	4.16	2.53	3.25	4.83	5.69
2000	0.69	1.12	0.76	0.83	1.56	7.03	2.50	3.67	5.84	5.36
2001	0.84	1.23	0.87	1.13	1.65	9.19	2.62	3.82	6.14	5.07
2002	0.93	1.24	1.18	1.31	1.79	11.41	2.72	3.85	5.91	4.41
2003	1.07	1.44	1.47	1.45	1.91	14.14	2.87	3.68	4.33	4.26
2004	1.22	1.53	1.33	1.56	2.01	5.35	2.97	3.66	4.19	3.85

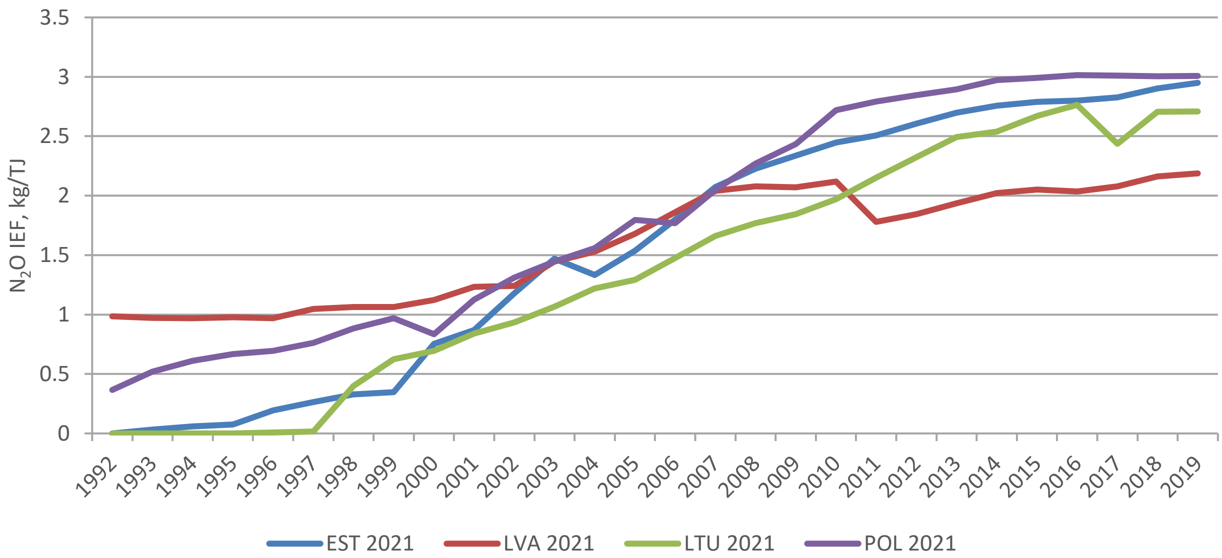


Figure 3-44. N_2O IEF values provided by Lithuania and the neighbouring countries for diesel Passenger Cars

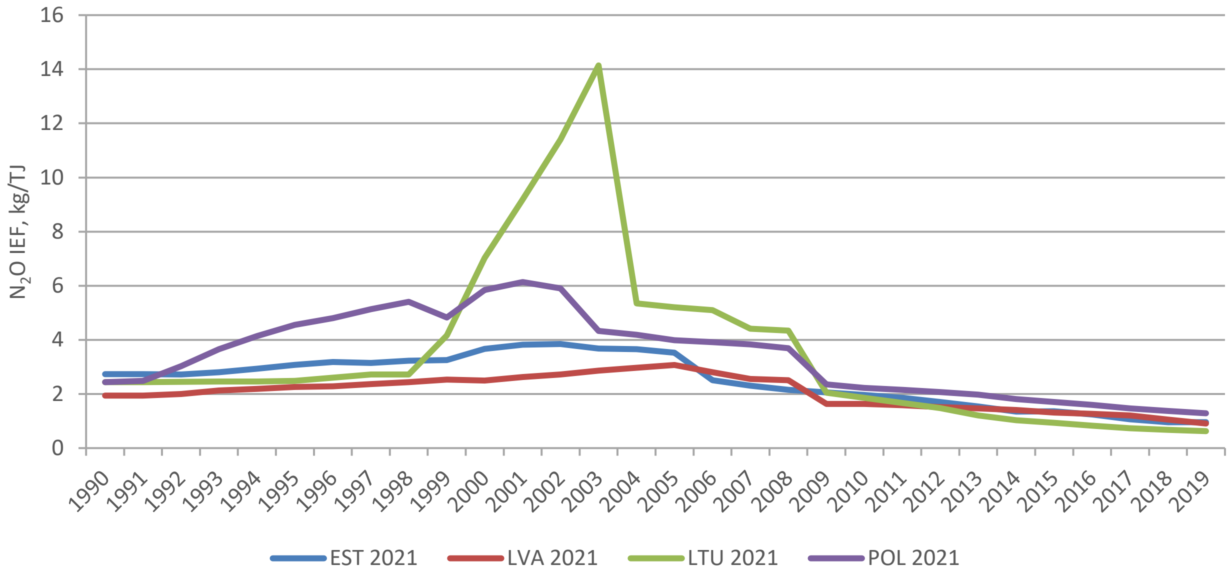


Figure 3-45. N_2O IEF values provided by Lithuania and the neighbouring countries for gasoline Passenger Cars

In 2021, CH_4 and N_2O emissions were recalculated using Tier 3 method and COPERT V input parameters were improved (sold fuel share by vehicle categories and fluctuations of fleet for every Euro standard were updated due to different data provided before) for 1990-2018.

The basis for emission calculations in COPERT V are fuel consumed, numbers of vehicles and mean annual mileage. The fuel consumption change between different vehicle categories was the main reason why IEFs have changed. The change in fuel consumption led to auto-correction performed by COPERT for mileage (which directly influences CH_4 and N_2O emissions). Other important variables are:

- CS meteorological information
- EU average information about driver behaviour (trip length, trip duration, average speed on different roads etc.)
- Technical parameters of vehicles (technologies for emissions reduction, A/C in vehicles, tank size, number of axles...)
- Fuel quality and composition of fuel
- Calorific value of fuels
- H:C and O:C ratios
- Share of fossil fraction in biodiesel
- ETBE content in biogasoline

The 2021 submission consisted of several changes/improvements to the disaggregated fleet data:

- Petrol hybrid passenger cars, along with petrol and diesel PHEV passenger cars were incorporated as a separate category within the COPERT model for the first time.

- Climatic conditions e.g. monthly relative country-specific humidity values were incorporated for the first time.

- There was a slight correction in the distribution of passenger cars within all classes when REGITRA announced about a drop-off of not operating vehicles in 2014. These datasets have been back extrapolated, this affected the fleet number distribution among the all technologies for the 5 years before drop-off.

3.5.2.3 Uncertainties and time-series consistency

The activity data for fuels used in road transportation is very accurate due to accurate total fuel sales statistics. Uncertainty in the activity data is 2%. The uncertainty on activity data for CO_2 emissions from road transport is given in *2006 IPCC Guidelines*, which mentions that this is the main source of uncertainty for CO_2. The uncertainty of road transport CO_2 emission factor is estimated to be ±2%. The uncertainty of annual N_2O emissions from road transport is estimated to be ±50%. The estimated uncertainty of the CH_4 emissions from road transport is ±40%. The time series for all data have been studied carefully in search for outliers.

The Tier 3 CH_4 and N_2O emission factors have been derived from experimental (measured) data collected in a range of scientific programmes. The emission factors for old-technology passenger cars and light commercial vehicles were taken from earlier COPERT/CORINAIR activities (Eggleston et al., 1989), whilst the emissions from more recent vehicles are calculated on the basis of data from the Artemis project (Boulter and Barlow, 2005; Boulter and McCrae, 2007). The emission factors for mopeds and motorcycles are derived from the study on impact assessment of two-wheel emissions (Ntziachristos et al., 2004). Also, the emission factors of Euro 4 diesel passenger cars originate from an ad-hoc analysis of the Artemis dataset, enriched with more measurements (Ntziachristos et al., 2007).

Emission factors proposed for the Tier 3 methodology are functions of the vehicle type (emission standard, fuel, capacity or weight) and travelling speed. These have been deduced on the basis of a large number of experimental data, i.e. individual vehicles which have been measured over different laboratories in Europe and their emission performance has been summarized in a database. Emission factors per speed class are average emission levels of the individual vehicles. As a result, the uncertainty of the emission factor depends on the variability of the individual vehicle measurements for the particular speed class. This uncertainty has been characterized in the report of Kouridis et al. (2009) for each type of vehicle, pollutant, and speed classes. In general, the variability of the emission factors depends on the pollutant, the vehicle type, and the speed class considered. The standard deviations range from a few percentage units of the mean value to more than two times the emission factor value for some speed classes with limited emission information.

The distribution of individual values around the mean emission factor for a particular speed class is considered to follow a log-normal size distribution. This is because negative emission factor values are not possible and the log-normal distribution can only lead to positive values. Also, the lognormal distribution is highly skewed with a much higher probability allocated to values lower than the mean and a long tail that reaches high emission values.

Emissions of N_2O are a function of many complex aspects of combustion and mileage dynamics as well as the type of emission control systems used. During the last decades the stock of Lithuanian diesel passenger cars and heavy-duty vehicles has intensively grown. In the period from 1990 to 2000 the number of diesel-powered vehicles increased by about 13% per year. As was expected, the linear regression analysis did not provide statistically significant linear relationship between total diesel fuel consumption and N_2O IEF values for the reason that the variation from year to year between sub-sectors and technology differ due to changes in abatement technologies and mileage. For the period between 1990 and 2000, it was necessary to estimate the figures with the aid of numerous scientific assumptions regarding mileage distribution between subsectors. In conjunction with decreasing fuel consumption in 1990-1994 the number of diesel-powered vehicles increased. We had to make fuel correction by reduce/increase mileage from our initial calculations to match the statistical fuel consumption. The correction for fuel consumption within ± one standard deviation of the official value is very critical as it reduces the uncertainty of the N_2O calculation, conversely good knowledge of the statistical fuel consumption and comparison with the calculated fuel consumption was necessary to improve the quality of the inventory. The uncertainty in annual N_2O emissions from road transport is estimated to be ±50%.

Developing emission factors for CH_4 and N_2O is more difficult because these pollutants require technology-based emission factors rather than aggregate default emission factors. Over 1990-2013 period the number of passenger cars (dominant gasoline consumers) increased despite the fact of economic crisis. Therefore, decreasing fuel consumption was balanced by mileage, although N_2O emission exceptionally differ according to the fuel sulphur level (Figure 3-46) since a regression line of nitrous oxide emission factors against mileage for passenger vehicles yielded a slight not significant slope (Barton and Simpson, 1994):

$$EF_{N_2O} = (a \times M_{j,k} + b) \times EF_{BASE}$$

where:

a, b, EF_{BASE} - depend on technology level for gasoline PCs & LCVs;

a, b - *depend on fuel sulphur content.*

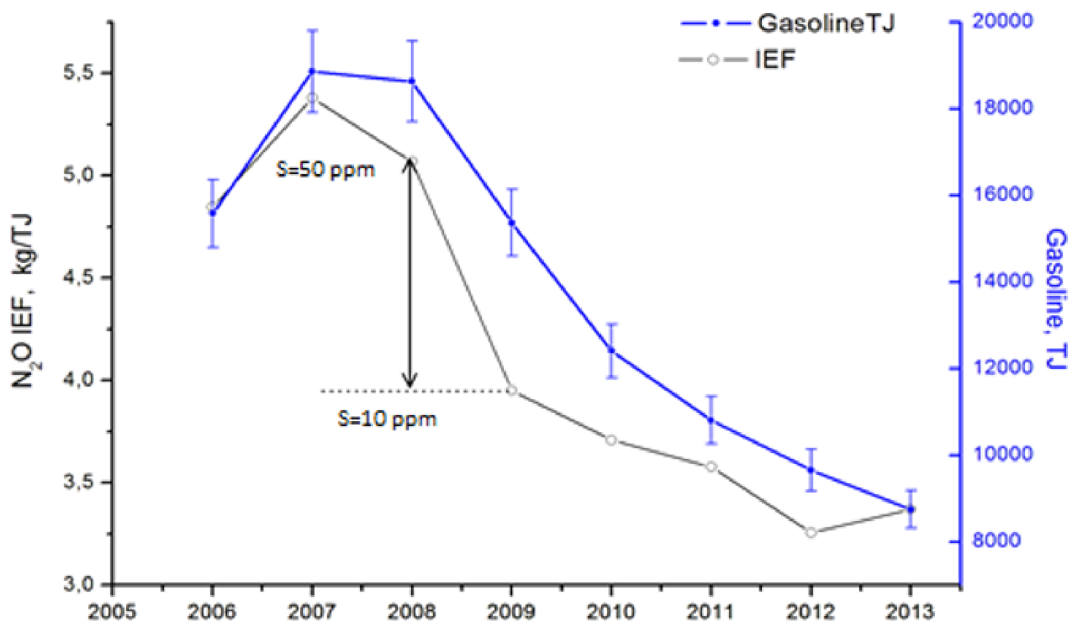


Figure 3-46. Dynamic of implied emission factors of N_2O for gasoline (prepared by expert)

A sharp decrease in N_2O IEF can be explained by several factors (Fig. 3-46). While the gasoline consumption was slightly decreasing in 2007-2013, the amount of vehicles remained increasing with a large share of 16–20-year-old cars (31.3%). This means that one of the determining factors is the large proportion of petrol cars fitted with a three-way catalyst. The effect of fuel sulphur is the second significant factor that influences the formation of N_2O over the catalyst (Baronick et al., 2000). Since January 2008, Lietuva group's company ORLEN started producing and supplying gasoline which already meets the EU requirements to be effective on January 1st, 2009 with sulphur content less than 10 ppm. The implementation of regulations reducing fuel sulphur levels across the EU in 2008 also reduced N_2O emissions for vehicles of all technology categories[6] .

The shift to higher Euro standards is one of the factors having effect on N_2O emissions. Standards requiring the use of catalytic converters on petrol cars first came into force in 1993 with EURO I. Even stricter standards have been agreed with EURO III and EURO IV, coming into force in 2001 and 2006 for passenger cars. Catalytic converters result in marked reductions of CO, NO_x and hydrocarbon emissions from petrol-driven cars, but can increase emissions of N_2O.

Increase of N_2O can be observed, but it should be noted that N_2O EF for EURO I and EURO II standard is highest in comparison with later EURO standards. In Lithuania the share of EURO I and EURO II standards were dominating during 2004-2013 (Figure 3-47). This is an explanation why IEF for N_2O emissions start to decrease with bigger share of Euro III – Euro VI which has lower N_2O EF.

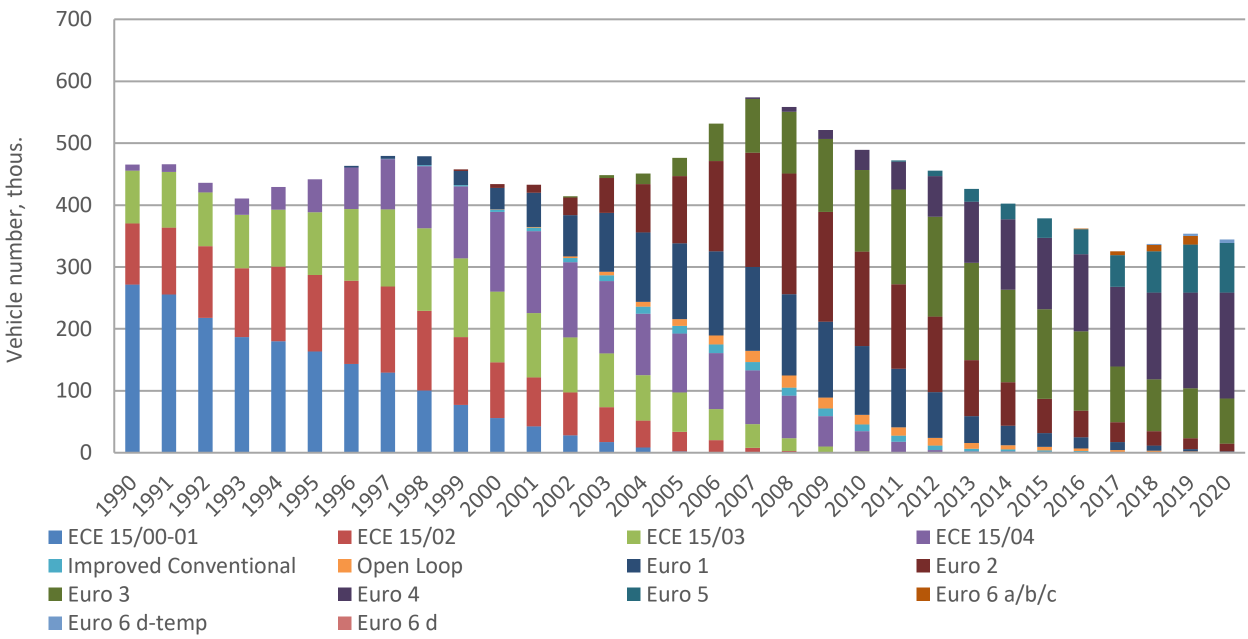


Figure 3-47. Disaggregation of PC petrol driven vehicles by standards (SE Regitra).

One more parameter influenced N_2O IEF decrease – Sulphur content in gasoline fuel. In case when fuel consumption and number of vehicles is similar, the shift to lower percentage of sulfur leads to decrease of N_2O IEF. This is primarily due to a decrease in consumption of motor gasoline, but also because emission factors for petrol-driven vehicles have decreased substantially, reflecting the improved control of N_2O emissions (TNO, 2002; Riemersma et al., 2003) in more modern vehicles.

Additional parameter needs to be considered - dieselization of fleet from 2004 until now. During the last decades the stock of Lithuanian diesel passenger cars and heavy-duty vehicles has intensively grown, on the contrary petrol fuel consumption was decreasing from 2007. At the same time share of EURO I and EURO II standard domination in national fleet is also decreasing.

[6]TNO, 2002; Riemersma et al., 2003

All these parameters (sulfur content, dieselization, EURO standards) together lead to lower N_2O IEF.

3.5.2.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.5.2.5 Category-specific recalculations

Recalculation was done for PC diesel cars in 2019 due to the correction of previously made mistake.

Table 3-34. Impact of recalculation on GHG emissions from Road transport, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2019	6,050.83	6,053.52	2.69	0.04

3.5.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

3.5.3 CO_2 emissions from urea-based catalysts (CRF 2.D.3)

3.5.3.1 Category description

"AdBlue" urea solution reduces nitrogen oxide emission from auto exhaust system (fitted with SCR technology). The solution is injected to diesel engine exhaust systems before selective reduction catalyst, consequently due to the solution reaction with nitrogen oxide gasses emissions are converted to water vapour and nitrogen. This technology optimizes engine performance by reducing particle emission and maximizing fuel energy generation. Another significant effect of the process is reduced fuel consumption (on average 5%).

AdBlue is produced according to the German standard DIN 70070 and European standard ISO/PAS 22,241-1. Only the product meeting the aforementioned standards may be marked with the AdBlue trademark. AdBlue produced by AB "Achema" and distributed by "Gaschema", the branch of "Achema", is the only certified product of such type in Baltic region.

The Euro V step was introduced in October of 2008 and the Euro VI step in September of 2013. Euro V introduced SCR to the majority of heavy-duty engines.

3.5.3.2 Methodological issues

Tier 3 category specific method is assuming 1-3% of diesel consumption for vehicles using urea as a selective catalytic reduction agent (SCR) supplemented by guidance for ammonia emissions from the EMEP-EEA Guidebook 2016. This requires detailed knowledge of the diesel fleet to estimate the number of SCR vehicles and their fuel use. COPERT and TREMOVE provided defaults for the necessary detail of fleet make-up for European fleets. The *2006 IPCC Guidelines* suggest urea consumption can be estimated as 1-3% of diesel consumed by vehicles using urea (as an SCR agent), however, EMEP Guidebook 2016 (Road transport, 2017 June) states ~5-7% of fuel consumption at a Euro V level and ~3-4% of fuel consumption at a Euro VI level.

$$E_{CO2} = Activity \cdot \frac{12}{60} \cdot Purity \cdot \frac{44}{12},$$

where:

E_{CO2} - CO_2 emissions from urea-based additive in catalytic converters (kt CO_2);

Activity - amount of urea-based additive consumed for use in catalytic converters (kt);

Purity - the mass fraction (= percentage divided by 100) of urea in the urea-based additive.

The factor (12/60) captures the stoichiometric conversion from urea ($CO(NH_2)_2$) to carbon, while factor (44/12) converts carbon to CO_2. Thirty two and half percent can be taken as default purity in case country-specific values are not available (Peckham, 2003). As this is based on the properties of the materials used, there are no tiers for this source.

3.5.3.3 Uncertainties and time-series consistency

Expert judgement suggests that the uncertainty of the CO_2 estimate is approximately ±10%, based on studies with reliable fuel statistics. The primary source of uncertainty is the activity data rather than emission factors.

3.5.3.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.5.3.5 Category-specific recalculations

No recalculations have been done.

3.5.3.6 Category-specific planned improvements

Category-specific improvements are not planned.

3.5.4 Other transport

3.5.4.1 Railways (CRF 1.A.3.c)

3.5.4.1.1 Category description

In 2020, the operational length of railways amounted to 1,910 km. The length of electrified lines remained unchanged (317 km). Emissions from producing electricity used in electric trains are not included in this category, but in category 1.A.1.

Lithuanian Railways (*lithuanian*: "Lietuvos Geležinkeliai") is the national, state-owned railway company of Lithuania. Lithuanian's trains operate frequent services across the whole of Lithuania (Fig. 3-48).

Figure 3-48. Lithuanian railways network

In 2020, goods transport by rail amounted to 53.4 million tonnes. National goods transport by rail amounted to 15.6 million tonnes. (Official Statistics Portal)

Fuel consumption 1990-2020 for railways, based on energy statistics from Statistics Lithuania is shown in Figure 3-49.

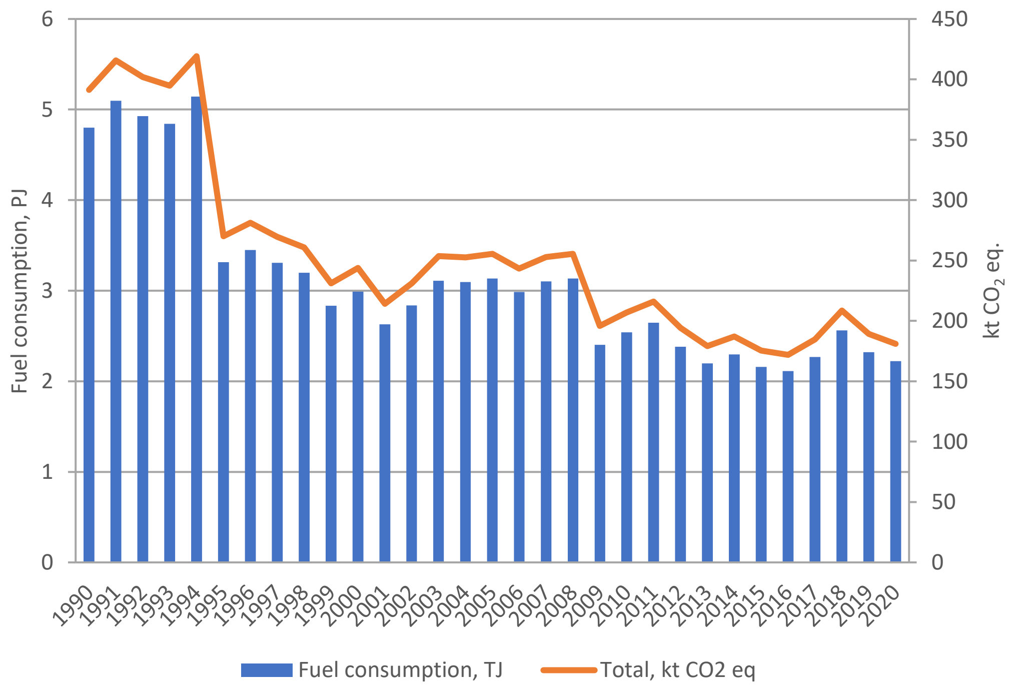


Figure 3-49. Trend of total GHG emissions in Railways sector

The trend of GHG emissions follows in general the fuel consumption trend in the railway transportation sector. The Lithuanian railway transport has suffered two obvious downturns within the last decades, the first relating to Lithuania's separation from the Soviet Union with following freight transportation decrease in 1990–1995 and the second one – to the global financial and economic crisis (2009-2010).

3.5.4.1.2 Methodological issues

CO_2 emission calculations of diesel oil are based on the Tier 2 methodology with country specific emission factors and CH_4 and N_2O - on default Tier 1 methodology (*2006 IPCC Guidelines*). Currently, the Tier 2 methodology for CH_4 and N_2O emissions will not be used throughout the lack of activity data. Emissions of railway transport sector are calculated by multiplying the statistical fuel consumption by respective emission factors assuming that for each fuel type the total fuel is consumed by a single locomotive type. Tier 2 uses equation with country-specific data on the carbon content of the fuel (2006 *IPCC Guidelines,* Volume 2, p. 3.41):

$$Emission = \sum_j (Fuel_j \cdot EF_j),$$

where:

Emission - emissions, kg;

$Fuel_j$ - fuel type j consumed (as represented by fuel sold), TJ;

EF_j - emission factor for fuel type j, $kg \cdot TJ^{-1}$;

j - fuel type.

Activity data

The data on fuel consumption of diesel are obtained from official statistics (Statistics Lithuania).

Emission factor

The emission factors used in the calculation of emissions from Railway transportation are presented in Table 3-35 and Annex V.

Table 3-35. Emission factors for Railways sector used in the Lithuanian GHG inventory

Fuel	CO_2			CH_4			N_2O		
	CO_2, kg/GJ	EF	Method	CH_4, kg/TJ	EF	Method	N_2O, kg/TJ	EF	Method
Diesel oil	72.89 72.73* 72.80**	CS	T2	4.15	D	T1	28.6	D	T1
Fossil part of biodiesel	75.81	D*	T1	3.0	D	T1	0.6	D	T1

CS - country specific emission factors based on the results of the study "Determination of national GHG emission factors for energy sector", which was prepared by Lithuanian Energy Institute in 2012;
D - default emission factors (*2006 IPCC Guidelines*);
*D - default emission factors (*Note on fossil carbon content in biofuels, Ioannis Sempos et al., 2018);*
*applied from 2015 based on the results of 2016 study "Update of country specific GHG emission factors for energy sector" (Summary of the study is presented in Annex VI).
** applied from 2017 based on the results of ORLEN laboratory analysis

Emissions from electricity used in electric trains are not included in this category, but in category 1.A.1. In 2019 emissions of railway transportation were 181.0 kt (CO_2 eq.). Substantial decrease from the year 2008 was caused by the economic depression (Figure 3-49).

3.5.4.1.3 Uncertainties and time-series consistency

The uncertainty of activity data (fuel use) is 5%. Uncertainties of CH_4 and N_2O emission factors are larger than those of CO_2 (±2%) obtained by study "Update of country specific GHG emission factors for energy sector", 2016. *2006 IPCC Guidelines* refers that the uncertainty range for the default factors for Tier 1 method is estimated to be +50%/-100%. The time series for all data have been studied carefully in search for outliers.

3.5.4.1.4 Category-specific recalculations

No recalculations have been done.

3.5.4.2 Domestic navigation (CRF 1.A.3.d)

3.5.4.2.1 Category description

There are 822 km of inland waterways of national importance of the Republic of Lithuania, 435 km of them are being operated. In 1997 the Republic of Lithuania signed European Agreement on Main Inland Waterways of International Importance (AGN agreement), according to which inland waterways of the River Nemunas and the Curonian Lagoon from Kaunas to Klaipeda are inland waterways of international importance E41 (the length – 291.2 km). All navigation period along the E41way there have to be maintained indicators as it is defined by waterways network main standards and parameters description TRANS / SC.3 / 144 of the United Nations Economic Commission. For the E41 waterway section from Klaipėda to Jurbarkas there are set measurements: length of vessel – 100m, beam – 10m, depth of the waterway – 1,5m (draught not more than 1.3m); for the section from Jurbarkas to Kaunas: length of vessel – 100m, beam – 10m, depth of waterway – 1,2m (draught not more than 1,00m). In 2020, transport of goods by inland waterways amounted to 1.2 million tonnes, the number of passengers carries – 2.5 million.

Figure 3-50. Main inland waterways in Lithuania

As seen in Figure 3-51, fuel consumption decreased by 30.9% between 2005 and 2020. GHG emissions show a decreasing trend since 2010 due to the impact of the decreased fuel consumption in inland waterways (41.0%).

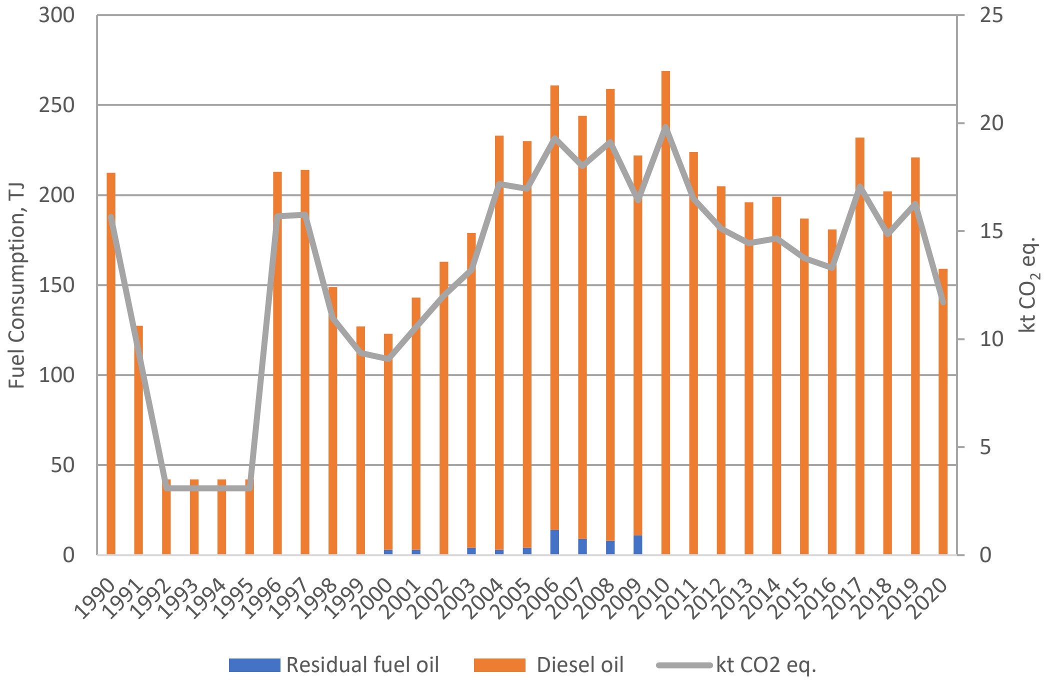


Figure 3-51. Trend of fuel consumption and GHG emissions in Domestic navigation sector

Inland waterways are navigable rivers, canals, lakes, man-made water bodies, and part of the Curonian Lagoon belonging to the Republic of Lithuania. Emissions of domestic navigation were 11.7 kt CO_2 eq. in 2020, 28.1% less than in 2019.

3.5.4.2.2 Methodological issues

Tier 1 method was applied with default emission factors for N_2O and CH_4 and country specific values for CO_2, except for biodiesel (see sections 3.5.2.1 and 3.5.2.2 for CO_2 emissions associated with the fossil carbon content in biofuels):

$$Emission = \sum (FuelConsumed_{ab} \cdot EF_{ab}) ,$$

where:

Emission - emissions, kg;

EF_{ab} - emission factor, kg·TJ^{-1};

a - fuel type;

b - domestic navigation type. At Tier 1 fuel used differentiation by type of vessel can be ignored (*2006 IPCC Guidelines*, Volume 2, p. 3.47).

Activity data

Data on fuel consumption for *Domestic navigation* and *Fishing sectors* are obtained from official statistics (Statistics Lithuania, 2020). Diesel oil consumed in Fisheries sector was assumed as consumed by fishing ships and presented in 1.A.4.c.iii sector. Differences between the CRF data and the IEA data occurs due to rounding of number and conversion of units. LT data on fuel consumption provided to Eurostat and IEA in natural measurement units coincides. Within country published data is provided in thousand tonnes to decimal point and converted to tentative fuel with the use of a certain conversion coefficient. Statistics Lithuania provide fuel consumption to Eurostat and IEA in measurement units (thousands tons) rounding digits to whole numbers. Eurostat uses conversion coefficients provided by Statistics Lithuania, but IEA uses average values of the coefficients.

Emission factors

Emission factors used in the calculation of emissions from *Domestic navigation* are presented in Annex V and Table 3-36. Up to 2014 EFs values are based on the results of 2012 study "Update of country specific GHG emission factors for energy sector.

Table 3-36. CH_4 and N_2O Emission factors for Domestic navigation and Fishing sectors used in the Lithuanian GHG inventory

Fuel	CH_4			N_2O		
	CH_4, kg/TJ	EF	Method	N_2O, kg/TJ	EF	Method
Residual Fuel Oil	7.0	D	T1	2.0	D	T1
Gasoil and Diesel oil	7.0	D	T1	2.0	D	T1

3.5.4.2.3 Uncertainties and time-series consistency

The uncertainty in activity data (fuel use) is 5%. The uncertainty value of CO_2 emission factor is ± 3%. The uncertainty of the N_2O emission factor is -40 – +140% and for CH_4 is ± 50% (2006 *IPCC Guidelines*).

3.5.4.2.4 Category-specific recalculations

No recalculations have been done.

3.5.4.3 Other (CRF 1.A.3.e)

3.5.4.3.1 Natural gas transportation in pipelines (CRF 1.A.3.e.i)

3.5.4.3.1.1 Category description

In Lithuania, natural gas is transported via gas transmission and distribution systems (Fig. 3-53). Statistics Lithuania started collecting data on consumption of natural gas used for gas transportation in pipeline compressor stations from 2001.

AB Amber Grid is the operator of Lithuania's natural gas transmission system and is in charge of transmission of natural gas (transportation of natural gas through high pressure pipelines) to system users, and operation, maintenance and development of natural gas transmission system. AB Amber Grid started its operations on 1 August 2013, when the fixed-term natural gas transmission licence (issued to AB Amber Grid by the National Control Commission for Prices and Energy) came into effect. On 10 April 2015, AB Amber Grid was issued with an open-ended gas transmission business license and was designated as the Transmission System Operator (Table 3-37). The gas transmission system operated by AB Amber Grid is comprised of gas transmission pipelines, gas compressor stations, gas metering and distribution stations, cathodic protection installations (protecting gas transmission pipelines from corrosion), as well as data transmission and telecommunications systems. Customers of AB Amber Grid are large companies (power plants, district heating plants and industrial companies) as well as medium sized companies operating in Lithuania and gas supply companies, to which AB Amber Grid renders natural gas transmission services. Employees of AB Amber Grid have long-term experience in the field of gas system operation and maintenance and the necessary management skills and qualifications.

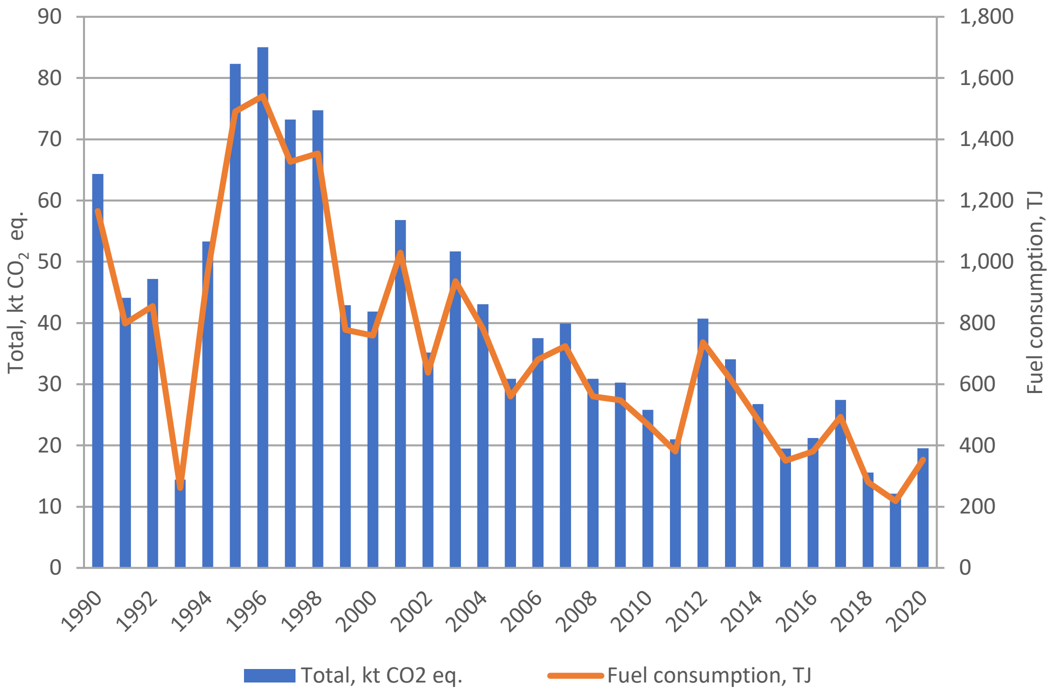


Figure 3-52. Trend of GHG emissions and fuel consumption in sector Natural gas transportation in pipelines

Table 3-37. Lithuanian natural gas transmission system (Operator of Lithuania's natural gas transmission system)

Gas transmission pipelines	**Gas distribution stations**	**Gas metering stations**	**Gas compressor stations**
2 113 km	65 stations	3 stations + 1 (owned by "ORLEN Lietuva")	2 stations

Figure 3-53. Gas distribution network in Lithuania

Transport via pipelines includes transport of gases via pipelines.

3.5.4.3.1.2 Methodological issues

Activity Data

Statistics Lithuania has started collecting data on consumption of natural gas used for gas transportation in pipeline compressor stations from 2001. For the period prior to 2001 data on use of natural gas for transmission are not available.

The surrogate method to estimate unavailable data during 1990-2000 was used since the extrapolation approaches should not be done to long periods and inconsistent trend. To evaluate more accurate relationships the regression analysis was developed by relating emissions to more than one statistical parameter. The relationship between gas pipeline emissions and surrogate data was developed on the basis of underlying activity data of total natural gas consumption in public electricity and heat production during multiple years.

Emission factors

Emission factors used in the calculation of emissions from *Natural gas transportation in pipelines* are presented in Annex V and Table 3-38.

Table 3-38. CH_4 and N_2O emission factors for Natural gas transportation in pipelines sector used in the Lithuanian national GHG inventory

Fuel	CH_4			N_2O		
	CH_4, kg/TJ	**EF**	**Method**	**N_2O, kg/TJ**	**EF**	**Method**
Natural gas	1.0	D	T1	0.1	D	T1

3.5.4.3.1.3 Uncertainties and time-series consistency

The uncertainty of activity data (fuel use) is 5%. CO_2 emission factor uncertainty is ±2% based on results of 2016 study "Update of country specific GHG emission factors for energy sector". The uncertainty of the N_2O and CH_4 emission factor is ± 50% (*2006 IPCC Guidelines*).

3.5.4.3.1.4 Category-specific recalculations

Recalculations were done for 2019 due to updated activity data in Fugitive emissions.

Table 3-39. Impact of recalculation on GHG emissions from Pipeline transport, kt CO_2 eq.

Year	Submission 2021	Submission 2022	Absolute difference, kt CO_2 eq.	Relative difference, %
2019	12.23	12.13	-0.10	-0.80

3.5.4.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.5.4.5 Category-specific planned improvements

Category-specific improvements are not planned.

3.5.5 Off-road vehicles and other machinery (CRF 1.A.2.g.vii, 1.A.3.e.ii, 1.A.4.a.ii, 1.A.4.b.ii, 1.A.4.c.ii)

3.5.5.1 Category description

The off-road category includes vehicles and mobile machinery used within the agriculture, forestry, industry (including construction and maintenance), residential, and sectors, such as agricultural tractors, chain saws, forklifts, snowmobiles (*2006 IPCC Guidelines*). New allocation by sectors was applied. Off-road activity data and emissions were allocated by sectors: 1.A.2.g.vii Off-road Vehicles and Other Machinery; 1.A.3.e.ii Other, 1.A.4 Other Sectors (1.A.4.a.ii Commercial/Institutional, 1.A.4.b.ii Residential, 1.A.4.c Agriculture/Forestry/Fishing: 1.A.4.c.ii Off-road Vehicles and Other Machinery, 1.A.4.c.iii Fishing).

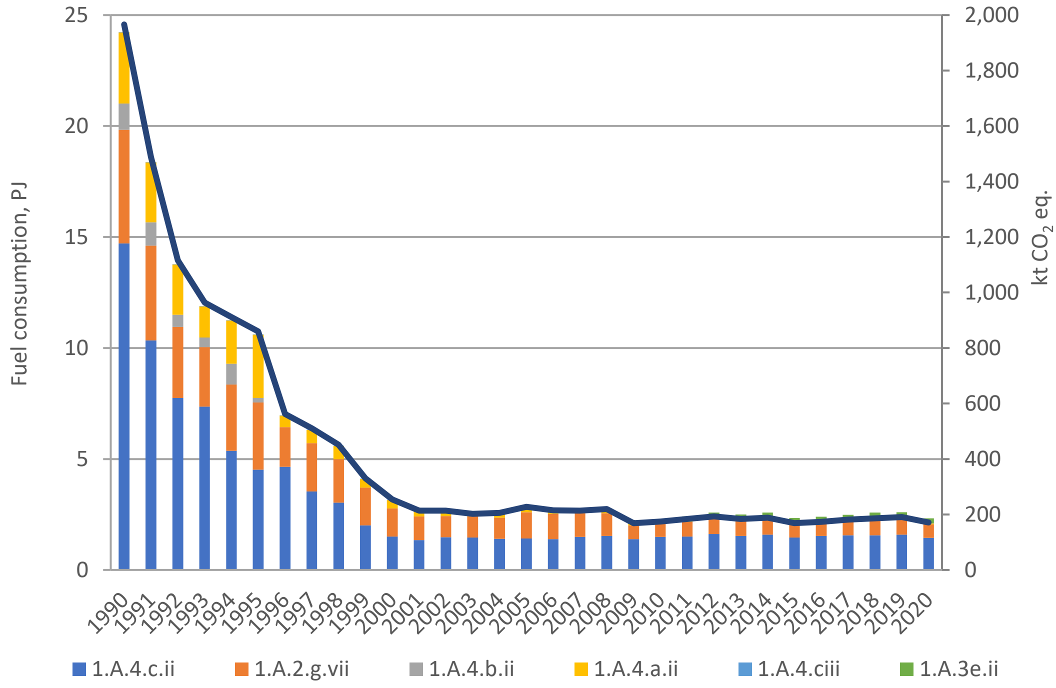


Figure 3-54. Trend of GHG emissions and fuel consumption in Off-road sector

Fuel consumption in off-road sector decreased in 1990-1993 due to reorganizations after the collapse of Soviet Union. During 1999-2000 and 2008-2009 activity was influenced by GDP decrease due to the economic crisis in Russia and world economic crisis in 2008-2009, respectively, as mentioned in Energy chapter. GHG emissions fluctuations from the Off-road sector as in Energy sector refer national economy variation.

3.5.5.2 Methodological issues

2006 IPCC Guidelines Tier 2 (for CO_2) and Tier 1 (for CH_4 and N_2O) sectoral approach was used to calculate GHG emissions from Off-road machinery sector. It was investigated that there is a possibility to apply Tier 2 method, but a study will be firstly initiated in CLRTAP emissions inventory.

Activity Data

Data on fuel consumption by off-road vehicles and machinery in industry, construction, agriculture, fishery, forestry and residential zones are not collected separately and provided in statistical reports but included in overall fuel consumption by separate sectors (industry, construction, agriculture, fishery, commercial and public services). Consumption of motor gasoline and diesel oil in these sectors as shown in energy balances provided by the Statistics Lithuania should be assigned to consumption by off-road machinery. Therefore, consumption of motor gasoline and diesel oil can be separated from other fuels and emissions caused by off-road vehicles can be calculated from these data. Off-road machinery engine on diesel oil provides better fuel efficiency, excellent oxidation resistance, higher engine reliability. In this reason dieselisation from about 1999 occurred.

Emission factors

Emission factors for off-road vehicles and machinery sector used in the Lithuanian GHG inventory are provided in Annex V and Table 3-40.

Table 3-40. CH_4 and N_2O Emission factors for Off-road vehicles and other machinery sector used in the Lithuanian national GHG inventory

Sector	CH_4, kg/TJ				N_2O, kg/TJ			
	Motor gasoline	Diesel oil	EF	Method	Motor gasoline	Diesel oil	EF	Method
Agriculture	80.00	4.15	D	T1	2.00	28.60	D	T1
Industry (including construction) and commercial maintenance	50.00	4.15	D	T1	2.00	28.60	D	T1
Household	120.00	4.15	D	T1	2.00	28.60	D	T1
Other transportation	-	4.15	D	T1	-	28.60	D	T
Fishing	-	7.00	D	T1	-	2.00	D	T1

3.5.5.3 Uncertainties and time-series consistency

GHG emissions from off-road sources are typically much smaller than those from road transportation, but activities in this category are diverse and are thus typically associated with higher uncertainties because of the additional uncertainty in activity data. Uncertainty of activity data is determined by the accuracy of the surveys - 10%. Despite the relatively larger uncertainty of CH_4 and N_2O emissions, the uncertainty of total greenhouse gas emissions (in CO_2 eq.) is dominated by CO_2 emissions. The estimated uncertainty is affected mostly by the activity data. The uncertainty of CO_2 emission factor (±2%) is based on the results of 2016 study "Update of country specific GHG emission factors for energy sector", CH_4 and N_2O (-50/+150 %) emission factors from off-road transport are given in *2006 IPCC Guidelines*. The time series for all data have been studied carefully in search for outliers.

3.5.5.4 Source-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.5.5.5 Source-specific recalculations

No recalculations have been done.

3.5.5.6 Source-specific planned improvements

Category-specific improvements are not planned.

3.6 Other sectors (CRF 1.A.4)

3.6.1 Category description

3.6.1.1 Commercial/institutional (CRF 1.A.4.a.i)

Commercial and institutional sector encompasses the following activities in Lithuania: wholesale and retail trade, maintenance of motor vehicle and motorbikes, repairing of household equipment, hotels and restaurants, financial intermediation, real estate management and rent, public management and defense, mandatory social security, education, health treatment and social work, other public, social and individual services, as well private households related activities. Analysis of the structure of value added has showed that commercial and institutional sector creates more than half of the total value added created in the country. Since 1995 the share has been annually increasing from 57.4% (1995) till 69.4% (2009). In 2020, the share of value added in commercial / institutional sector accounted 68.6%. Retail, wholesale trade, transport, accommodation and catering services' sectors are the largest sector prescribed to this category.

Tendencies of fuel consumption and total GHG emissions in Commercial / institutional sector are presented in Figure 3-55.

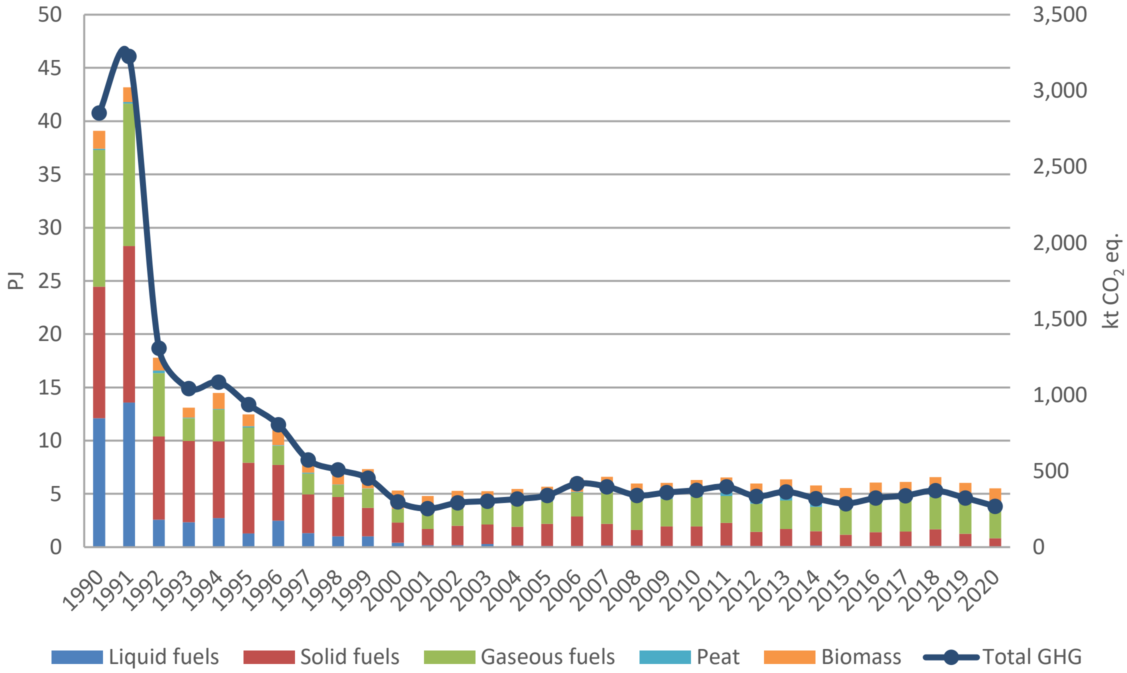


Figure 3-55. Tendencies of fuel consumption and total GHG emissions in Commercial / institutional sector (1.A.4.a)

After the drastically reduced fuel consumption volume in Commercial/institutional sector during 1990-2000, later (2001-2007) fuel consumption volumes were increasing by 5.5% a year. During the time of global economic crisis fuel consumption volumes were reduced by 4.8%. Since 2009 fuel consumption remained quite stable and accounted about 6 PJ till 2020. In 2020, fuel consumption in Commercial / institutional sector reduced by 9% due to COVID-19 pandemic. In 2020, natural gas accounted 52.6% in the fuel structure, solid fuels - 17.3%, biomass - 29.0% and liquid fuels - 1.1%.

In 2020, total GHG emissions from Commercial/institutional sector were 10 times lower than in 1990 and amounted to 268.8 kt CO_2 eq.

3.6.1.2 Residential sector (CRF 1.A.4.b.i)

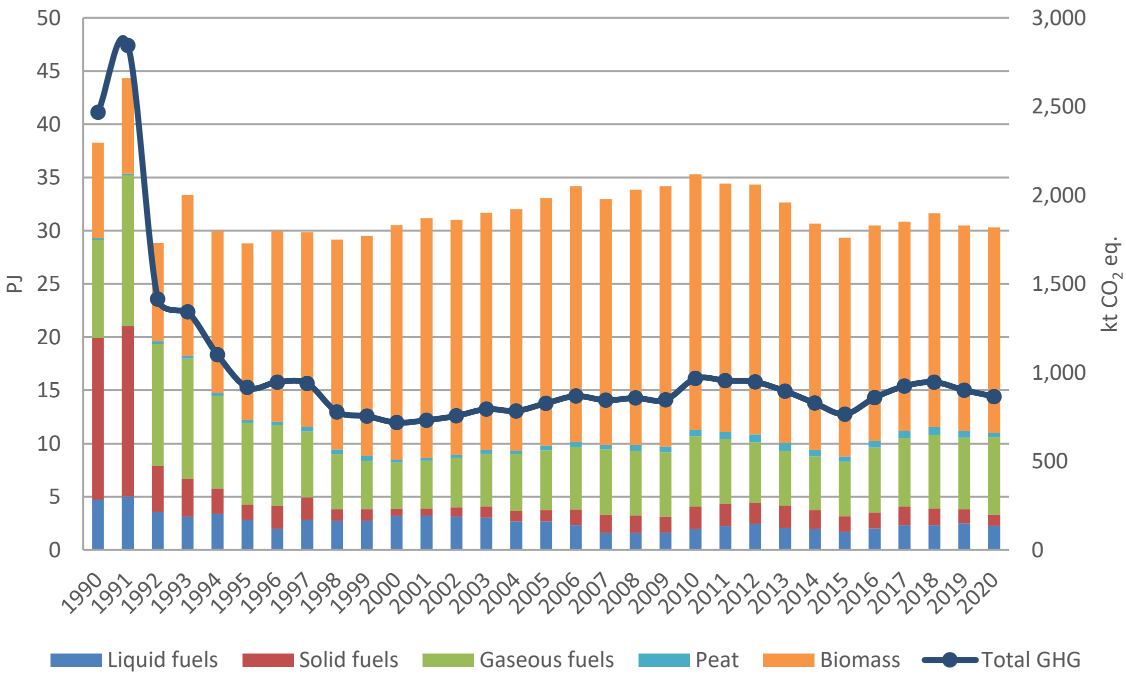
The number of dwellings remains quite stable during last decade and on average there are 1.3 million dwellings in Lithuania. Increase of the number of dwellings in Lithuania depends very much on demographical situation in the country. Since 1992 the number of inhabitants has decreased in Lithuania. The average floor area per each dwelling increases annually: in 2004, the average area of useful floor for each dwelling was 60.8 m^2, 2020 – 69.6 m^2. With reference to data of 2020, 60.5% of all dwellings are situated in Lithuanian cities, where large multifamily buildings dominate in urban areas.

Taking into account actual heat consumption, Lithuanian District Heating Association grouped Lithuanian multifamily houses according to kWh/m^2 during a month into three categories taking into account undergoing renovation process of old buildings[7]:

- Multifamily houses of new construction and with high thermal isolation - 9 kWh/m^2/month. Dwelling of this type of multifamily house consumes 540 kWh/60 m^2 of energy per month. This corresponds to 54 kgoe of fuel combusted for energy production per month. There are 128 thousand dwellings and 0.36 million people live in the dwellings (in 2020).
- Multifamily houses of new construction, partly renovated - 15 kWh/m^2/month. Dwelling of this type of multifamily house consumes 900 kWh/60 m^2 of energy per month. There are 47 thousand dwellings and 0.13 million people live in the dwellings (in 2020).
- Multifamily houses of old construction and still not renovated - 21 kWh/m^2/month. Dwelling of this type of multifamily house consumes 1260 kWh/60 m^2 of energy per month. There are 409 thousand dwellings and 1.15 million people live in the dwellings (in 2020).
- Multifamily houses of old construction and with poor thermal isolation - 35 kWh/m^2/month. Dwelling of this type of multifamily house consumes 2,100 kWh/60 m^2 of energy per month. This corresponds to 210 kgoe of fuel combusted for energy production per month. There are 118 thousand dwellings and 0.33 million people live in the dwellings (in 2020).

90.8% of dwellings located in urban areas had central heating systems in 2009, while only 42.8% of Lithuanian dwellings set in rural territories can take advantage of this service. On average in 77% of Lithuanian dwellings piped water is installed, but only 62% can profit from convenience which hot water provides (Lithuanian Statistics, 2010).

Tendencies of fuel consumed and total GHG emissions in Residential sector are presented in Figure 3-56.



[7] Lietuvos šilumos tiekėjų asociacija. Heat consumption // https://lsta.lt/silumos-ukis/silumos-suvartojimas/.

Figure 3-56. Tendencies of fuel consumption and total GHG emissions in Residential sector (1.A.4.b)

As it is seen from Figure 3-56, biomass dominates in the structure of fuel consumed in Residential sector. In 2015, fuel consumption in Residential sector decreased significantly due to climatic conditions. In 2020, there was consumed 30.3 PJ of fuel in Residential sector. Biomass accounted 63.6%, natural gas - 24.1%, solid fuels - 4.8%, liquid fuels - 7.5% of fuel structure in 2020.

In 2020, total GHG emissions from Residential sector were almost 2.9 times lower than in 1990 and amounted to 865.1 kt CO_2 eq.

3.6.1.3 Agriculture/Forestry/Fisheries sector (CRF 1.A.4.c.i)

Agricultural, forestry and fisheries sector has developed at very moderate rates in Lithuania during 1995-2009. Value added created has been increasing by 0.2% a year. The global economic crisis adjusted growth rates at a negative direction, i.e., value added has decreased by 6.8% in 2010. Value added in agricultural, forestry and fisheries sector increased by 6.9% in 2011. With reference to data of 2013-2020, this sector created 3.0–3.9% of total GDP.

Tendencies of fuel consumed and total GHG emissions in Agriculture/forestry/fishing sector - Stationary are presented in Figure 3-57.

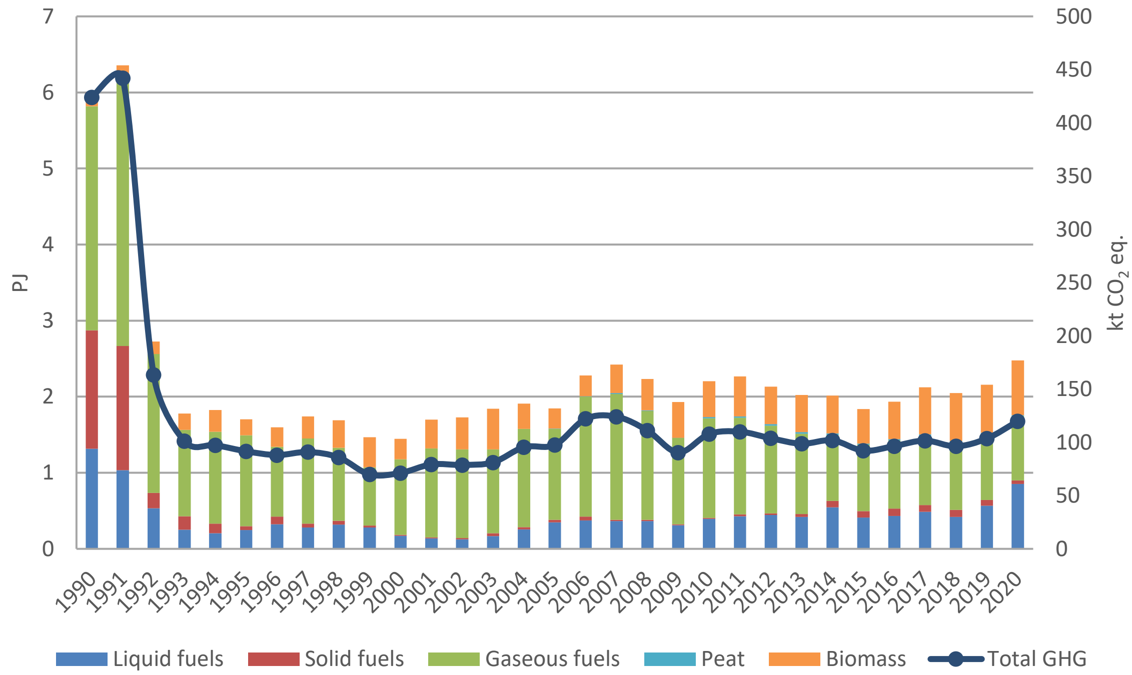


Figure 3-57. Tendencies of fuel consumed and total GHG emissions in Agriculture/forestry/fishing sector - Stationary (1.A.4.c.i)

Figure 3-57 showed that during the rapid economy development period (2000-2007) fuel consumption had a tendency to increase by 4.2% a year. During the time of global economic crisis (2008-2009) fuel consumption in Agriculture/forestry/fishing sector (1.A.4.c.i) reduced by 11.7%. In 2020 fuel consumption increased by 15.0% in comparison to 2019 as more fuel was used for grain drying. In 2020, liquid fuel made the largest share in the structure of fuel - 34.4%. The share of natural gas was 34.3%, biomass - 29.1%, and solid fuel - 2.2%.

In 2020, total GHG emissions from Agriculture/forestry/fishing sector (1.A.4.c.i) were 3.5 times lower than in 1990 and amounted to 119.9 kt CO_2 eq.

3.6.2 Methodological issues

CO_2 emissions were calculated applying Tier 2, CH_4 and N_2O were calculated applying Tier 1 or Tier 2 for CH_4 wood/wood waste and other solid biomass.

Emission factors and methods

Gas	Method used	Source of AD	EF used
CO_2	T2	Lithuanian Statistics database	CS
CH_4	T1/T2	Lithuanian Statistics database	D/CS
N_2O	T1	Lithuanian Statistics database	D

All country specific CO_2 emission factors are presented in Annex V.

2006 IPCC Guidelines default emission factors were used for CH_4 and N_2O emissions estimation except CH_4 from the use of wood/wood waste and other solid biomass use in category 1.A.4 (Table 3-41, marked *)**.** These CS emission factors are based on internationally referenced sources and EFs from neighbouring countries appropriate to Lithuania's national circumstances. These emission factors were estimated following recommendation provided by ERT in ARR 2013 (Report of the individual review of the annual submission of Lithuania submitted in 2013, paragraph 31).

Table 3-41. *2006 IPCC Guidelines* default emission factor CH_4 and N_2O emission factors used for category Other sectors (1.A.4), kg/TJ

Fuel type	1.A.4.a.i		1.A.4.b.i		1.A.4.c.i	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Heating and other gasoil	10.0	0.6	10.0	0.6	10.0	0.6
Residual fuel oil	10.0	0.6	10.0	0.6	10.0	0.6
Liquefied petroleum gases	5.0	0.1	5.0	0.1	5.0	0.1
Shale oil	10.0	0.6	-	-	10.0	0.6
Other bituminous coal	10.0	1.5	300.0	1.5	300.0	1.5
Anthracite	10.0	1.5	300.0	1.5	300.0	1.5
Sub-bituminous coal	10.0	1.5	300.0	1.5	300.0	1.5
Lignite	10.0	1.5	300.0	1.5	-	-
Peat	10.0	1.4	300.0	1.4	300.0	1.4
Natural gas	5.0	0.1	5.0	0.1	5.0	0.1
Charcoal	200.0	1.0	-	-	-	-
Wood and wood waste	250.0*	4.0	260.0*	4.0	250.0*	4.0
Other solid biomass	300.0*	4.0	260.0*	4.0	300.0*	4.0
Biogas	5.0	0.1	-	-	5.0	0.1

Activity data

For calculation of GHG emissions in category Other sectors (CRF 1.A.4) activity data had been obtained from the Lithuanian Statistics database (http://www.stat.gov.lt/lt/). Activity data are provided in the Annex III.

3.6.3 Uncertainties and time-series consistency

Uncertainty in activity data in Other sectors is ±3.0% taking into consideration recommendations provided by *the 2006 IPCC Guidelines*. According to *the 2006 IPCC Guidelines* (Volume 2, Chapter 1, page 1.19) biomass data are generally more uncertain than other data in national energy statistics, because a large fraction of the biomass may be part of the informal economy, and the trade in these types of fuels is frequently not registered in the national energy statistics and balances. The uncertainty rage for biomass activity data (±10.0%) in Other sectors is assigned higher than in other fuel combustion sectors because biomass accounting in small sources are more uncertain (*2006 IPCC Guidelines,* Volume 2, Chapter 2, table 2.15).

Uncertainties of CO_2 emission factors for liquid fuels (residual fuel oil, LPG, and gasoil) and gaseous fuels (natural gas) are ±2.0% in Other sectors. Uncertainties of CO_2 emission factors for solid fuels (peat, other bituminous coal and lignite) are ±5.0%. Estimated uncertainties of CO_2 emission factors for biomass are ±15%. Uncertainties of all country specific CO_2 emission factors were revised in the study "Update of country specific GHG emission factors for Energy sector" (see Annex VI).

Uncertainties of CH_4 and N_2O emission factors for liquid, solid and gaseous fuels were assigned as very high about ±50%. Uncertainties of emission factors for biomass were assumed ±150%. Uncertainties were derived considering *2006 IPCC Guidelines.*

Time series of the estimated emissions are consistent and complete because the same methodology, emission factors and data sources are used for sectors for all years in time series. All emissions are estimated or reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.6.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

The consumption of every type of fuel has been checked and compared with other available data sources (EUROSTAT). The time series for all data have been studied carefully in order to search for outliers.

The results are verified by calculating CO_2 emissions with the reference approach, and comparing results with the sectoral approach.

3.6.5 Category-specific recalculations

Following recalculations have been done in Other sectors (1.A.4):

- correction of activity data in 1.A.4.a.i and 1.A.4.b.i for peat in 2018 based on information provided by Statistics Lithuania.

Impact of these recalculations on GHG emissions from 1.A.4.a.i Commercial / institutional sector is presented in Table below.

Table 3-42. Impact of recalculation on GHG emissions from 1.A.4.a.i Commercial / institutional industry, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2018	372.40	371.45	-0.95	-0.25

Impact of these recalculations on GHG emissions from 1.A.4.b.i Residential sector is presented in Table below.

Table 3-43. Impact of recalculation on GHG emissions from 1.A.4.b.i Residential sector, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %

2018	944.96	945.97	1.01	0.11

3.6.6 Category-specific planned improvements

Category-specific improvements are not planned.

3.7 Other (CRF 1.A.5)

3.7.1 Military aviation (CRF 1.A.5.b)

3.7.1.1 Category description

Military activity is defined here as those activities using fuel purchased by or supplied to the military authorities of the country.

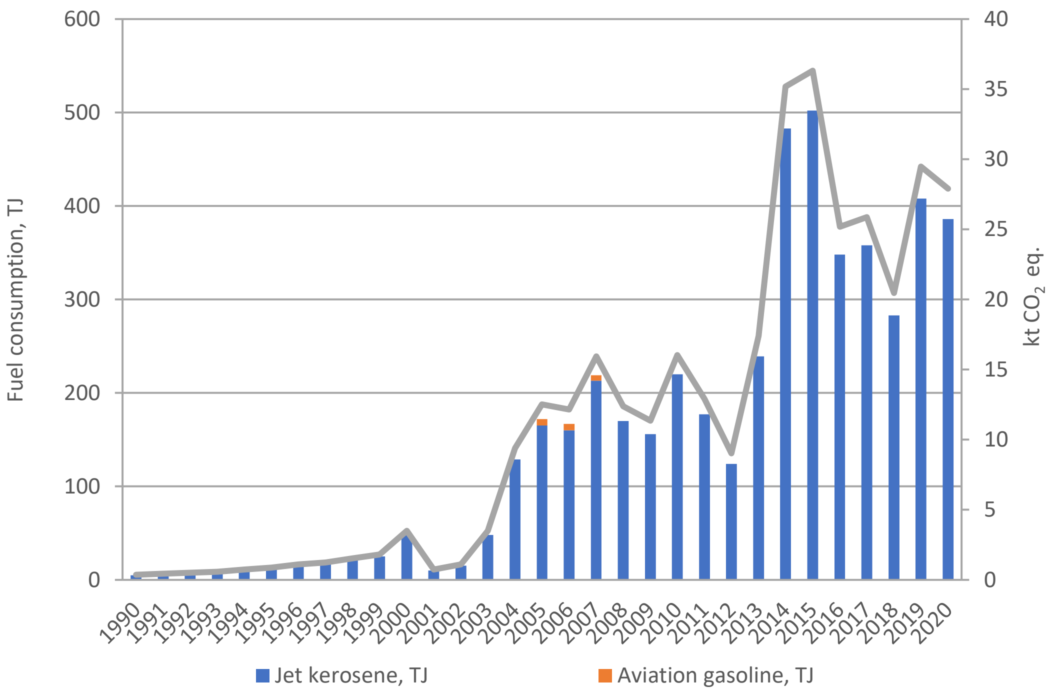


Figure 3-58. Trend of GHG emissions in Military aviation sector

3.7.1.2 Methodological issues

The *2006 IPCC Guidelines* Tier 2 (for CO_2) and Tier 1 (for CH_4 and N_2O) approach has been applied. Emission factors for aviation sources used in the Lithuanian national GHG inventory are provided in Annex V and Table 3-28. Country specific CO_2 EF was developed based on the results of 2016 study "Determination of national GHG emission factors for energy sector" and (from 2017) based on the results of ORLEN laboratory analysis. Jet kerosene used in the country is produced by the oil refinery UAB "ORLEN Lietuva".

Activity data

Statistical reports are based on information provided by the fuel suppliers. No statistical data are available for fuel consumption for military mobile sources up to 2000. Data on jet kerosene for 1990-1999 were extrapolated.

Emission factors

Emission factors used in the calculation of emissions from *Military aviation* transportation are presented in Annex V and Table 3-28 (chapter 3.5.1).

3.7.1.3 Uncertainties and time-series consistency

Uncertainty of activity data of aviation fuel consumption in military aviation is ±2%. According to expert judgment, CO_2 emission factors for fuels are generally well determined as they are primarily dependent on the carbon content of the fuel (*2006 IPCC Guidelines*). CO_2 emission factor (uncertainty 2%) was estimated according to physical characterization of used fuels in country based on average NCV and emission factors of jet kerosene reported by "ORLEN Lietuva". CH_4 and N_2O emission factors used in estimation of emissions were taken from 2006 IPCC Guidelines so uncertainties were assigned to -57/+100% for CH_4 and -70/+150% for N_2O. The time series for all data have been studied carefully in search for outliers.

3.7.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.7.1.5 Category-specific recalculation

No recalculations have been done.

3.7.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

3.8 Comparison of the verified CO_2 emissions in GHG Registry and NIR

The Lithuanian GHG emission Registry had been completely operational since 2005 until 20 June 2012 when the EU Member States' national GHG registries were consolidated to the Union Registry. The managing institution (competent authority) of the Registry is the Ministry of Environment and administrating institution - the Lithuanian Environment Investment Fund which was reorganized into the Environmental Project Management Agency in 2018.

In 2021 the Agency provided information on verified CO_2 emissions for 87 fuel combustion installations[8] (see Annex VII). CO_2 emissions from fuel combustion and production process are included in the registry for the installations, covered by activities, listed in Annex I of the EU Directive 2003/87/EC (mineral oil refinery, production of cement clinker, manufacture of glass, ceramic and paper, rockwool and etc.).

For the purpose of comparison of verified emissions of the GHG Registry with the CO_2 emissions in the NIR, installations were allocated to a certain CRF sector (sectoral approach). Comparison of the verified CO_2 emissions and NIR is provided in Table 3-44.

Table 3-44. Comparison of the verified CO_2 emissions and NIR (sectoral approach), 2020

IPPC category	Verified CO_2 emissions, kt	Calculated CO_2 emissions, kt	Absolute difference, kt	Relative difference, %
1.A.1.A Public Electricity and Heat Production	1,226.64	1,296.29	69.6	5.4
1.A.1.B Petroleum Refining	1,224.21	1,222.28	-1.9	-0.2
1.A.1.C.iii Other energy industries	62.05	53.16	-8.9	-16.7

[8] https://www.apva.lt/wp-content/uploads/2021/05/Atsiskaitymas-uz-2020-m.pdf

1.A.2.C Chemicals	165.40	280.08	114.7	40.9
1.A.2.D Pulp, Paper and Print	20.47	31.76	11.3	35.5
1.A.2.E Food Processing, Beverages and Tobacco	42.32	242.11	199.8	82.5
1.A.2.F Non-metallic Minerals	395.21	413.84	18.6	4.5
1.A.2.G.iv Wood and Wood Products	15.72	18.48	2.8	14.9
1.A.3.E.i Pipeline transport	0.26	19.53	19.3	98.6
1.A.4.A Commercial/Institutional	3.94	257.38	253.4	98.5
1.B.2.A.6 Other (Fugitive emissions from oil)	179.77	179.77	0.0	0.0
Total	**3,335.99**	**4,014.68**	**678.7**	**16.9**

Total CO_2 emissions calculated in NIR sectoral approach are by 16.9% higher as compared to verified fuel combustion emissions in the GHG Registry in 2020. The differences mainly occur due to application of different emission factors and due to different coverage and thresholds in EU ETS.

3.9 Fugitive emissions (CRF 1.B)

3.9.1 Fugitive emissions from solid fuels (CRF 1.B.1)

There are no mining activities in Lithuania and hence no fugitive emissions from coal mines occur. All emissions are reported as not occurring/not applicable therefore there are no "not estimated" sectors.

3.9.2 Fugitive emissions from oil (CRF 1.B.2.a)

3.9.2.1 Category description

Fugitive emissions from oil activities include all emissions from the exploration, production, processing, transport, and use of oil and from non-productive combustion. Fugitive emissions consist of emissions of methane, carbon dioxide and nitrous oxide. Emissions from hydrogen production (steam reforming process) at petroleum refining company AB "ORLEN Lietuva" are reported under category 1.B.2.a.6 Other.

3.9.2.2 Methodological issues

GHG emissions were calculated applying a Tier 1. The application of a Tier 1 is done using equation presented below:

$$E_{oil,gas\ industry\ segment} = A_{industry\ segment} \times EF_{industry\ segment}$$

where:

$E_{oil,\ gas\ industry\ segment}$ - annual emissions, kt;

$A_{industry\ segment}$ - activity value, units of activity;

$EF_{industry\ segment}$ - emission factor, kt/unit of activity.

Emission factors

Emissions from oil were calculated by using emission factors provided in the *2006 IPCC Guidelines* Volume 2 (table 4.2.4) and are presented in Table 3-45.

Table 3-45. Emission factors for fugitive emissions from oil (1.B.2.a)

Category	Subcategory		Emission factors	Units of measure

		Emission type	CH_4	CO_2	N_2O	
Wells	Drilling	Flaring and venting	3.3E-05	1.0E-04	0	kt per 10^3 m^3 total oil production
	Testing	Flaring and venting	5.1E-05	9.0E-03	6.8E-08	kt per 10^3 m^3 total oil production
	Servicing	Flaring and venting	1.1E-04	1.9E-06	0	kt per 10^3 m^3 total oil production
Oil production	Conventional oil	Fugitives (onshore)	1.5E-06	1.1E-07	0	kt per 10^3 m^3 conventional oil production
		Venting	7.2E-04	9.5E-05	0	kt per 10^3 m^3 conventional oil production
		Flaring	2.5E-05	4.1E-02	6.4E-07	kt per 10^3 m^3 conventional oil production
Oil transport	Pipelines	All	5.4E-06	4.9E-07	0	kt per 10^3 m^3 oil transported by pipeline
Crude oil refining	All	All	2.6E-06	0	0	kt per 10^3 m^3 oil refined

CO_2 emissions from hydrogen production (steam reforming process) were calculated applying a Tier 3 based on plant specific emission factors and activity data provided in EU ETS reports of the refinery. Refinery gas consumption for hydrogen production as intermediate process cannot be reported separately according to the international energy balance preparation principles. AB ORLEN Lietuva confirmed that refinery gas and hydrogen are not final products and not purchased as raw materials. Refinery gas and hydrogen are involved in chemical reactions at various facilities during the oil refining process therefore they cannot be included separately in national energy balance. As EU ETS reports data is available only since 2005, for historical time series 1990-2004 activity data provided by petroleum refining company AB "ORLEN Lietuva" and the estimated average EF was used (2.87 tCO_2/t refinery gas).

Plant specific CO_2 emission factors and refinery gas used for hydrogen production are presented in Table 3-46.

Table 3-46. Plant specific CO_2 emission factors and refinery gas used for hydrogen production (1.B.2.a.6)

Year	Refinery gas, kt	CO_2, t CO_2/t
1990	8.07	2.870
1995	17.21	2.870
2000	31.91	2.870
2004	35.11	2.870
2005	37.32	2.688
2006	35.38	2.684
2007	27.59	2.671
2008	50.50	2.639
2009	77.52	2.851
2010	84.58	2.970
2011	79.69	2.980
2012	76.60	2.961
2013	87.74	2.969
2014	83.19	2.961
2015	68.77	2.950
2016	83.74	2.950

2017	74.87	2.951
2018	85.22	2.944
2019	81.24	2.850
2020	64.25	2.798

Activity data

Activity data for fugitive emissions from oil have been obtained from database of the Lithuanian Statistics: oil production and refining data (see Annex III), transportation of crude oil in pipelines (see http://www.stat.gov.lt). It is necessary to mention that refinery gas received from petroleum refining processes and used as feedstock for hydrogen production is not included in the Lithuanian Statistics "Fuel and energy balance". Hydrogen production is only intermediate process and it is impossible to distinguish it according to the principles of preparation of energy balance. Activity data for hydrogen production were obtained directly from petroleum refining company AB "ORLEN Lietuva".

3.9.3 Fugitive emissions from natural gas (CRF 1.B.2.b)

3.9.3.1 Category description

Fugitive emissions from natural gas activities include all emissions from transportation and distribution, and from non-productive combustion. Fugitive emissions consist mainly of emissions of methane and carbon dioxide.

3.9.3.2 Methodological issues

Fugitive emissions from natural gas calculated applying a Tier 2 considering activity data on natural gas leakages obtained from AB "Lietuvos dujos" and Amber Grid AB. The company ESO was established in January 2016 by merging AB "Lietuvos dujos" and LESTO AB. Currently ESO is the operator of Lithuania's natural gas distribution and electricity distribution systems therefore activity data on natural gas leakages in distribution system for 2015-2020 were obtained from ESO. Amber Grid AB is the operator of Lithuania's natural gas transmission.

The application of a Tier 2 is done using equation presented below:

$$E_{oil,gas\ industry\ segment} = A_{industry\ segment} \times EF_{industry\ segment}$$

where:

$E_{oil,\ gas\ industry\ segment}$ - annual emissions, kt;

$A_{industry\ segment}$ - activity value, units of activity;

$EF_{industry\ segment}$ - emission factor, kt/unit of activity.

Emissions from natural gas transmission and distribution were calculated taking into consideration amount of natural gas leakages in transmission and distribution networks and chemical composition of natural gas provided by ESO and Amber Grid AB. Natural gas leakages in transmission and distribution networks are estimated by gas companies based on methodology of natural gas consumption for technological needs in transmission and distribution networks. According to this methodology natural gas release into the atmosphere for technological needs related to the natural gas consumption for the newly installed gas pipeline before commissioning; natural gas release into the atmosphere prior to repairs or other work where the pipeline should to be emptied; natural gas consumption for blowing pipelines after repair, installation or other work when the pipeline has been emptied; natural gas consumption by venting gas to the atmosphere via safety valves; natural gas leaks from damaged pipelines during accidents; natural gas leaks through distribution pipelines leakage and etc. Calculated amounts of natural gas leakages depend on volume of the gas pipeline, gas pressure, gas temperature and other technical parameters.

Tier 2 for fugitive emissions from natural gas started to be applied since 2016 submission as AB "Lietuvos Dujos" provided data on natural gas leakages in transmission and distribution networks for the time period 2005-2014. The data on natural gas leakages for the time period 1990-2004 was based on expert judgement. For the time period 1990-2004 data on natural gas leakages were estimated taking into consideration relation between the total natural gas consumption and leakages in transmission and distribution networks for 2005-2014. Performed analysis showed that leakages accounted about 0.4% in transmission system and about 2% in distribution system from total natural gas consumption in 2005-2014 period. Experts from AB "Lietuvos dujos" approved that this share can be applied for leakages estimates in period 1993-2004 but recommended to adjust activity data for 1990-1992 taking into consideration technical network conditions and applying regression analysis. Estimated values on natural gas leakages in transmission and distribution networks for period 1990-2004 were coordinated and agreed with experts from AB "Lietuvos dujos".

Data is converted into TJ using country specific natural gas NCVs and into tonnes using natural gas density values (Table 3-48). The natural gas leakages are presented in Table 3-47 and chemical parameters of natural gas are presented in Table 3-48.

Table 3-47. Amount of natural gas leakages (data provided by ESO and Amber Grid AB)

Year	Distribution network, kt	Transmission network, kt
1990	8.65	2.01
1995	7.44	1.62
2000	6.21	1.15
2005	7.55	2.76
2010	8.09	1.45
2015	8.41	4.17
2016	8.53	4.20
2017	7.93	4.51
2018	8.42	2.69
2019	8.49	3.65
2020	8.04	2.34

Table 3-48. Chemical parameters of natural gas (data provided by Amber Grid AB)

Year	CH_4, %	CO_2, %	Natural gas density, kg/m^3
1990-2003	97.77	0.05	0.68
2004	98.08	0.04	0.68
2005	98.05	0.04	0.68
2006	97.91	0.04	0.68
2007	97.96	0.05	0.68
2008	97.94	0.05	0.68
2009	97.64	0.05	0.69
2010	97.90	0.04	0.68
2011	97.87	0.04	0.68
2012	97.69	0.06	0.68
2013	97.35	0.07	0.69

2014	97.09	0.08	0.69
2015	95.45	0.07	0.70
2016	93.79	0.05	0.71
2017	95.05	0.07	0.70
2018	95.23	0.09	0.70
2019	94.86	0.06	0.71
2020	95.17	0.07	0.70

CH_4 and CO_2 emissions are calculated directly from the amounts leaked therefore it was assumed that emissions from natural gas transmission and distribution cover all fugitive emissions from natural gas.

Since January 2015 the liquefied natural gas (LNG) terminal started operation in Lithuania. Fugitive emissions due to liquefaction and gasification at LNG terminal estimated using Tier 1 based on *2006 IPCC Guidelines* default yearly emission factors for LNG plant (Chapter 4, table 4.2.8). The storage and transfer processes at LNG terminal are subject to the most stringent standards possible. Gas leakages can occur only in connection with maintenance work and the gas quantities can be extremely small therefore fugitive emissions estimated using default yearly emission factor – 0.005% of throughput. Amount of natural gas import and amount of estimated leakages at LNG terminal are presented in Table 3-49.

CH_4 and CO_2 emissions from LNG terminal are calculated directly from the amounts leaked (Table 3-49) and chemical parameters of natural gas (Table 3-48). Lithuanian Statistics provides data on total natural gas import and the share of natural gas import via LNG terminal is provided by National Energy Regulatory Council. Fugitive emissions due to liquefaction and gasification at LNG terminal are reported under 1.B.2.b.6 Other.

Table 3-49. Natural gas import and estimated leakages at LNG terminal

	Units	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Natural gas import via LNG terminal*	kt	310.04	1,088.32	842.47	600.21	1,324.16	1,368.12
Yearly emission factor (IPCC 2006, table 4.2.8)	% of throughput	0.005	0.005	0.005	0.005	0.005	0.005
Estimated leakages at the LNG terminal	kt	0.02	0.05	0.04	0.03	0.07	0.07

* Share of natural gas import via LNG terminal is provided by National Energy Regulatory Council.

Emissions from natural gas storage were not estimated due to there are no natural gas storage facilities in Lithuania.

3.9.4 Uncertainties and time-series consistency

Uncertainty of activity data for fugitive emissions is ±5.0% taking into consideration recommendations provided by *2006 IPCC Guidelines*.

Uncertainty of CO_2, CH_4 and N_2O emission factors for fugitive emissions from oil and natural gas systems are provided in the Table 3-50.

Table 3-50. Uncertainties of emission factors for fugitive emissions from oil and natural gas systems

Category	**Subcategory**	**Emission type**	**Uncertainty of emission factors, %**		
			CH_4	**CO_2**	**N_2O**
Oil production	Conventional oil	Fugitives (onshore)	±100	±100	NA
		Venting	±50	±50	NA
		Flaring	±50	±50	±50

Wells	Drilling	Flaring and venting	±100	±50	NA
	Testing	Flaring and venting	±50	±50	±50
	Servicing	Flaring and venting	±50	±50	NA
Oil transport	Pipelines	All	±100	±100	NA
Crude oil refining	All	All	±100	NA	NA
Gas transmission	All	All	±10	±10	NA
Gas distribution	All	All	±10	±10	NA
LNG terminal	All	All	±10	±10	NA
Hydrogen production	All	All	NA	±10	NA

Time series of the estimated emissions are consistent and complete due to the same methodology, emission factors and data sources are used for sectors for all years in time series. All emissions are estimated or reported as "not occurring/not applicable" therefore there are no "not estimated" categories.

3.9.5 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.9.6 Category-specific recalculations

Following recalculations have been done in Fugitive emissions from natural gas (1.B.2.b):

- correction of activity data in 1.B.2.b.4 for natural gas leakages (transmission network) in 2015, 2017 and 2019 based on updated information provided by Amber Grid AB.

Impact of these recalculations on GHG emissions from 1.B.2.b.4 Transmission and storage is presented in Table 3-51.

Table 3-51. Impact of recalculation on GHG emissions from 1.B.2.b.4 Transmission and storage, kt CO_2 eq.

Year	**Submission 2021**	**Submission 2022**	**Absolute difference, kt CO_2 eq.**	**Relative difference, %**
2015	289.4	300.4	11.00	3.66
2017	295.7	295.6	-0.03	-0.01
2019	287.0	287.9	0.88	0.30

3.9.7 Category-specific planned improvements

Category-specific improvements are not planned.

4 INDUSTRIAL PROCESSES AND PRODUCT USE (CRF 2)

4.1 Overview of sector

Lithuanian industry sector accounts for a significant share of gross value added in the country's economy. Division of the country's economy as per the classifier of economic activity indicates that on the first level industry consists of four activities: manufacturing; extracting industry (mining and quarrying); supply of electricity, gas and steam; supply of water, sewerage, waste management and remediation activities. After the economic recession in early 1990s, Lithuania's industrial production and economy started to grow, as reflected by the growth of the GDP. Lithuania was struck by the global economic crisis causing significant reduction in industrial production in 2009. From 2010 country economy started to recover which led to increase of the industrial production (Figure 4-1).

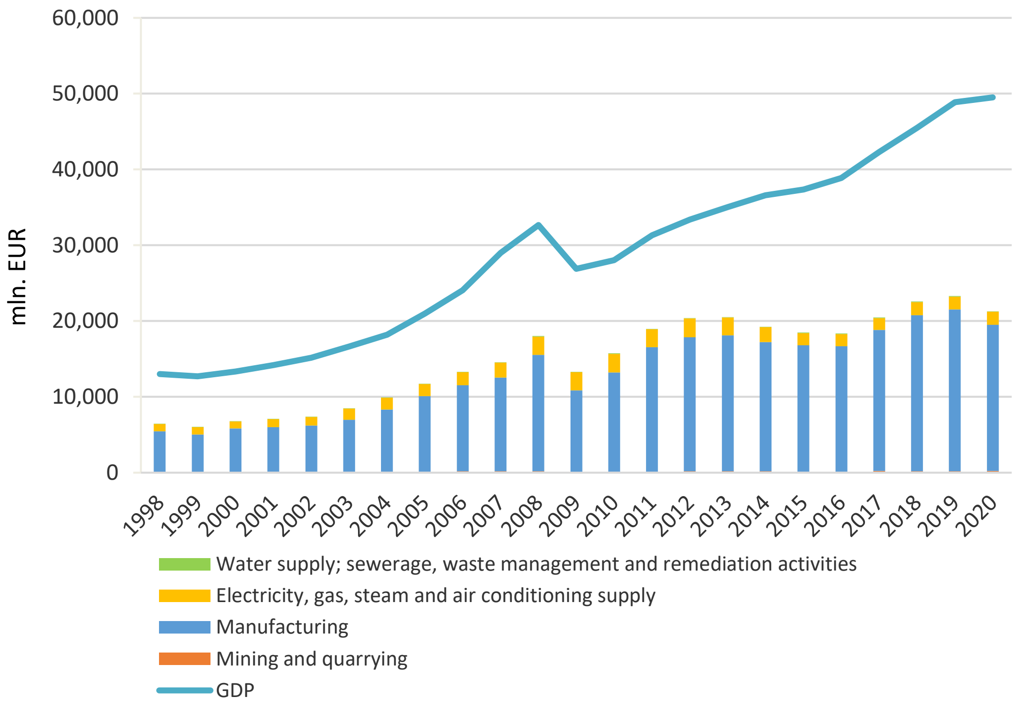


Figure 4-1. Industrial production (except construction) and GDP during production at constant prices

Dominating industry in Lithuania is manufacturing. Manufacturing constituted 91% of the total industrial production (excluding construction) in 2020.

In 2020 four most important subsectors within manufacturing cumulatively produced 60% of production:

- manufacture of refined petroleum products (13%);
- manufacture of food products and beverages (20%);
- manufacture of wood products and furniture (16%);
- manufacture of chemicals and chemical products (11%).

Share of the main sectors in production of manufacturing products in Lithuania is presented in Figure 4-2.

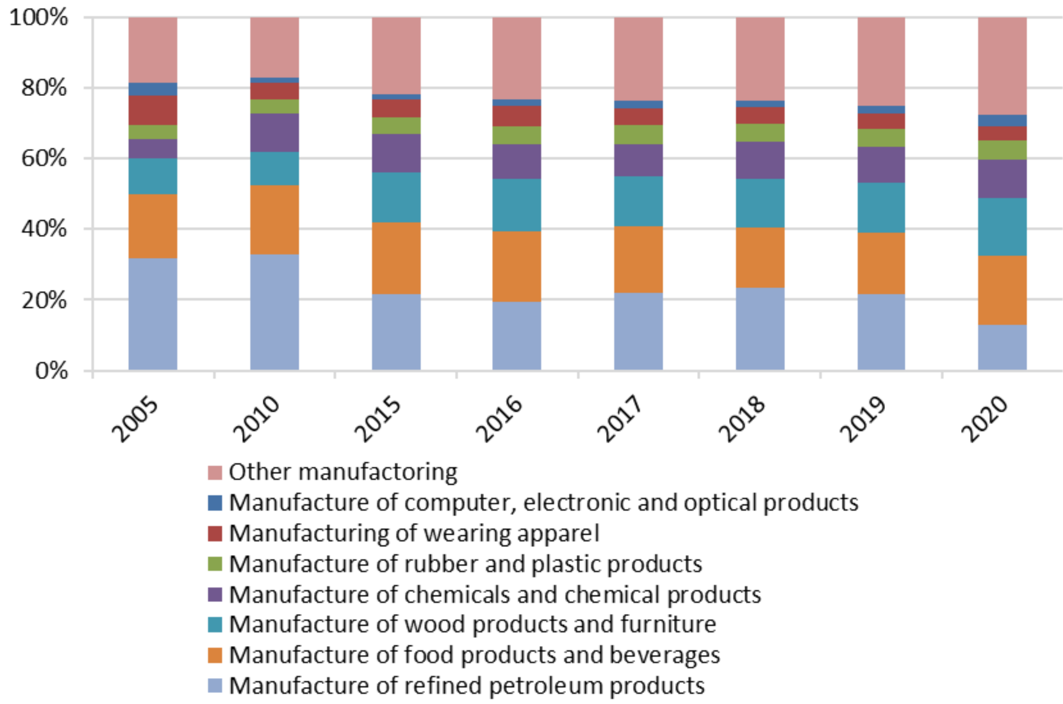


Figure 4-2. Share of the main sectors in production of manufacturing products

Greenhouse gas emissions from industrial processes contributed 15.3% to the total greenhouse gas emissions in Lithuania in 2020, amounting 3,093.5 kt CO_2 eq. (Figure 4-3).

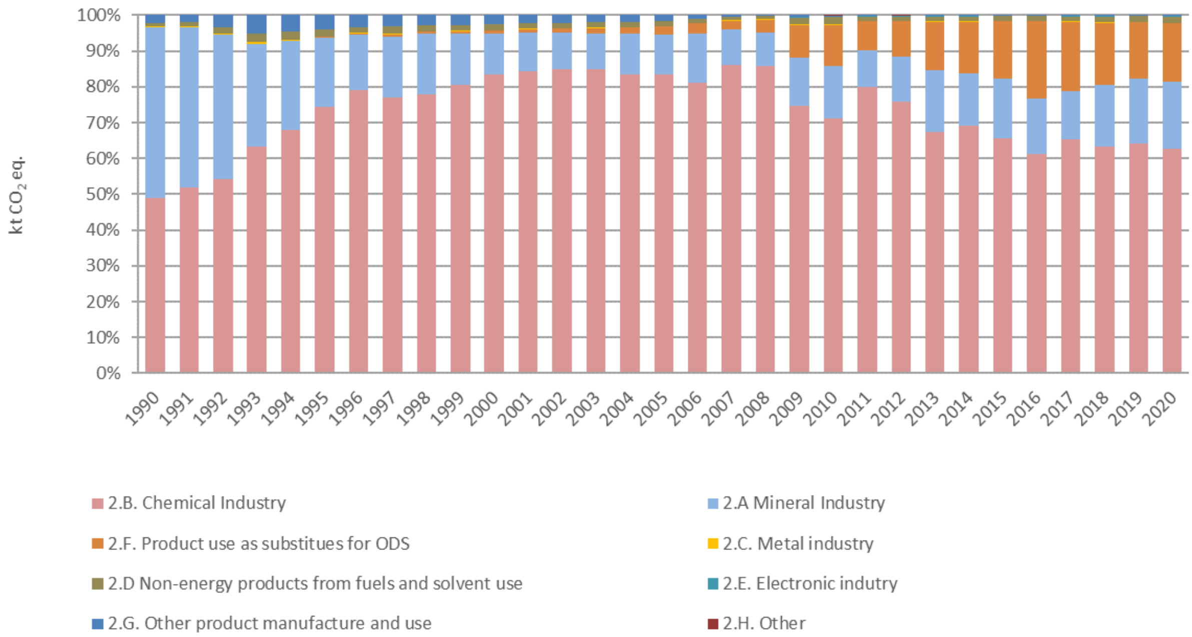


Figure 4-3. GHG emissions from industrial processes

Lithuanian GHG emissions from industrial processes consist from the following emission categories:

- Mineral Industry (CRF 2.A) include CO_2 emissions from:
  - cement production (CRF 2.A.1);
  - lime production (CRF 2.A.2);

  - glass production (CRF 2.A.3);
  - ceramics (CRF 2.A.4.a);
  - other uses of soda ash (CRF 2.A.4.b);
  - mineral wool production (CRF 2.A.4.d).
- Chemical industry (CRF 2.B) include:
  - CO_2 emissions from ammonia production (CRF 2.B.1) and methanol production (CRF 2.B.8.a);
  - N_2O emissions from nitric acid production (CRF 2.B.2);
  - CH_4 emissions from methanol production (CRF 2.B.8.a).
- Metal industry (CRF 2.C) include CO_2 emissions from the cast iron production (CRF 2.C.1).
- Non-energy products from fuels and solvent use (CRF 2.D) include CO_2 emissions from:
  - lubricant use (CRF 2.D.1);
  - paraffin wax use (CRF 2.D.2);
  - solvent use (CRF 2.D.3);
  - asphalt production and use (CRF 2.D.3);
  - urea-based catalyst (CRF 2.D.3).
- Electronics industry (CRF 2.E) include NH_3 and SF_6 emissions from:
  - semiconductor (2.E.1);
  - photovoltaics (2.E.3).
- Product uses as substitutes for ozone depleting substances (CRF 2.F) include F-gases emissions from:
  - refrigeration and air conditioning (2.F.1);
  - foam blowing agents (2.F.2);
  - fire protection (2.F.3);
  - metered dose inhalers (2.F.4.a).
- Other product manufacture and use (CRF 2.G) include emissions from:
  - SF_6 emissions from electrical equipment (2.G.1);
  - SF_6 emissions from accelerators (2.G.2.b);
  - N_2O emissions from medical applications (CRF 2.G.3.a)
  - N_2O emissions from propellant for pressure and aerosol products (CRF 2.G.3.b).
- Other (CRF 2.H) include:
  - SO_2, NOx, NMVOC and CO_2 emissions from pulp and paper industry (CRF 2.H.1);
  - CO_2 emissions from consumption of carbonates in flue gas desulphurisation (CRF 2.H.3).

Several emission sources in the industrial processes sector are key categories. The key categories in 2020 by level and trend are listed in Table 4-1.

Table 4-1. Key category from industrial processes and product use in 2020

IPCC Category	***Greenhouse gas***	***Identification criteria***
2.A.1 Cement Production	CO_2	L1, T1
2.A.2 Lime Production	CO_2	T1
2.A.4 Other process use of carbonates	CO_2	T1
2.B.1 Ammonia Production	CO_2	L1, T1
2.B.2 Nitric Acid Production	N_2O	L1, T1
2.F.1 Refrigeration and Air Conditioning Equipment	HFCs	L1, L2, T1, T2

4.2 Mineral Industry (CRF 2.A)

This category includes emissions from cement production, lime production, glass production, ceramics (bricks and tiles), other uses of soda ash and mineral wool production (Table 4-2).

Table 4-2. Reported emissions under the category mineral industry

CRF	Source	Emissions reported	Methods	Emission factor
2.A.1	Cement production	CO_2	Tier 2	PS
2.A.2	Lime production	CO_2	Tier 2	D
2.A.3	Glass production	CO_2	Tier 2	D
2.A.4.a	Ceramics	CO_2	Tier 2	CS
2.A.4.b	Other uses of soda ash	CO_2	Tier 1	D
2.A.4.d	Mineral wool production	CO_2	Tier 2	PS
2.A.4.d	Consumption of carbonates use in flue gas desulphurisation	CO_2	Tier 2	D

Emissions of the mineral industry category were 47.7% of the emissions of the industrial processes sector in 1990 and 18.7% in 2020. Amount of emissions were 2,129.6 kt CO_2 eq. in 1990 and 579.5 kt CO_2 eq. in 2020 (Figure 4-4, 4-5).

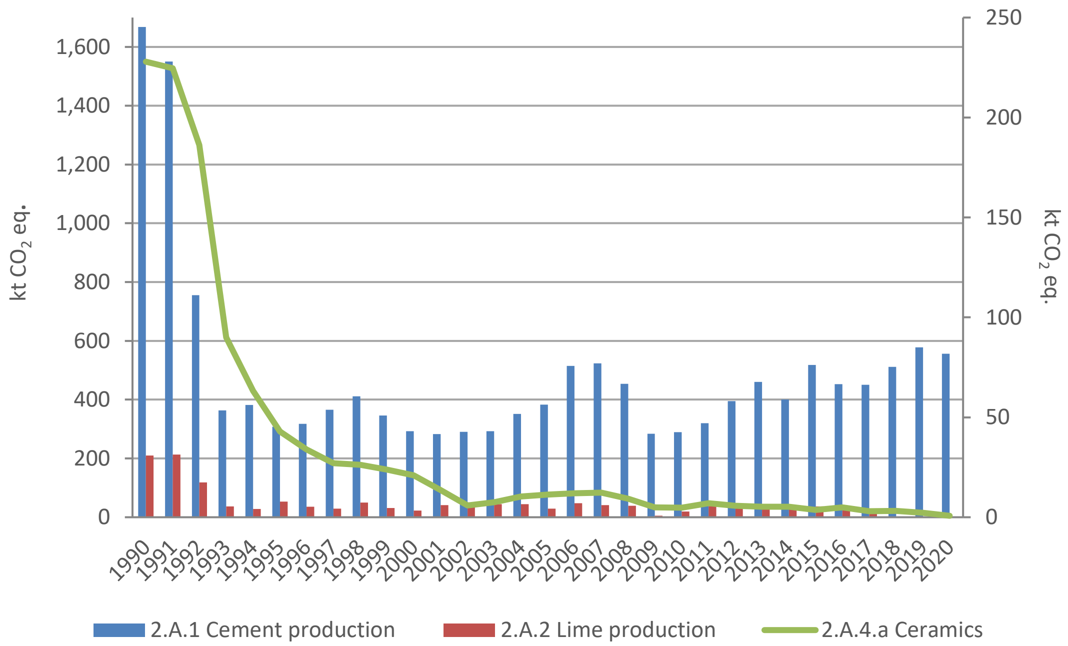


Figure 4-4. Greenhouse gas emission from mineral industry: cement production, lime production and ceramics

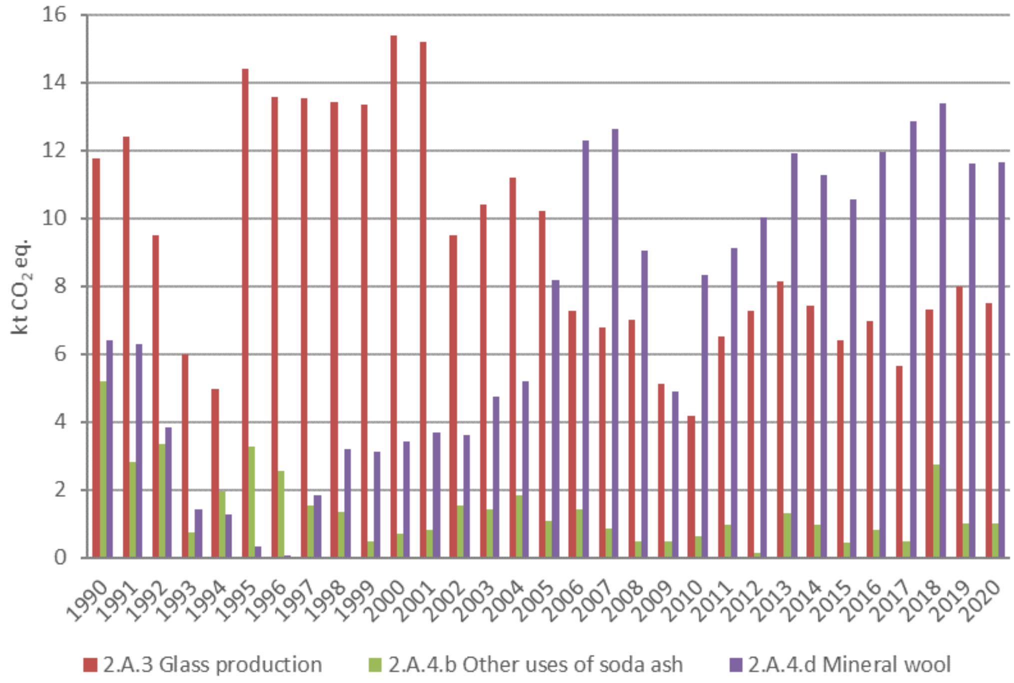


Figure 4-5. Greenhouse gas emissions from mineral industry: glass production, soda ash use and mineral wool production

Cement production is the biggest source of greenhouse gas emissions in the mineral industry category, being 556.6 kt in 2020 (96%). Emissions from cement production were 37% in 1990 and 18% in 2020 of the emissions in the industrial processes sector. There was a rapid decrease in the production volume in 1990-1993 after gaining independence. The output has had a slight growing trend in 2003-2007 fuelled by the boost in construction industry. Emissions from other mineral processes are a minor source in the category mineral products.

4.2.1 Cement Production (CRF 2.A.1)

4.2.1.1 Category Description

Category covers CO_2 emissions from cement production. Emissions of CO_2 occur during the production of clinker that is an intermediate component in the cement manufacturing process. High temperatures in cement kilns chemically change calcium carbonate into lime and CO_2. During the production of clinker, limestone, which is mainly calcium carbonate ($CaCO_3$), is heated, or calcinated, to produce lime (CaO) and CO_2 as a by-product.

Portland cement is produced in a single company, which is situated in the North Western part of Lithuania. The plant was constructed in Soviet times (1947-1974), cement produced in the factory was exported to other former Republics of USSR, Hungary, Cuba and former Yugoslavia. The company produces more than 1 million tonnes of portland cement per year. The data on clinker production and composition were provided by the plant. Activity data is collected on company level. Since 2005 the data are gathered via EU ETS reports.

Clinker production has fallen sharply after the declaration of independence from more than 3 million tonnes annually in 1990 to about 500 to 600 kt in 2000 (Figure 4-6). Sharp decline in cement production in 1990-1993 is mainly due to loss of market in former USSR. Demand of the cement in the local market has also dropped due to structural changes in industry and economy.

Since the opening of the plant cement has been produced using wet production technology. In 2006 the company has made a strong innovation step and decided to build new 4,500 t/d dry process clinker production line. The construction and installation of new dry clinker production line was completed at the end of 2013 and have started the operatation of dry clinker production line since 2014 of August (https://www.youtube.com/watch?v=kb-oKLyN3NY). During the transition of production technologies from wet process to dry, clinker production in wet line was terminated for some time until the new line was launched, which resulted in a decrease in clinker production observed in 2014.

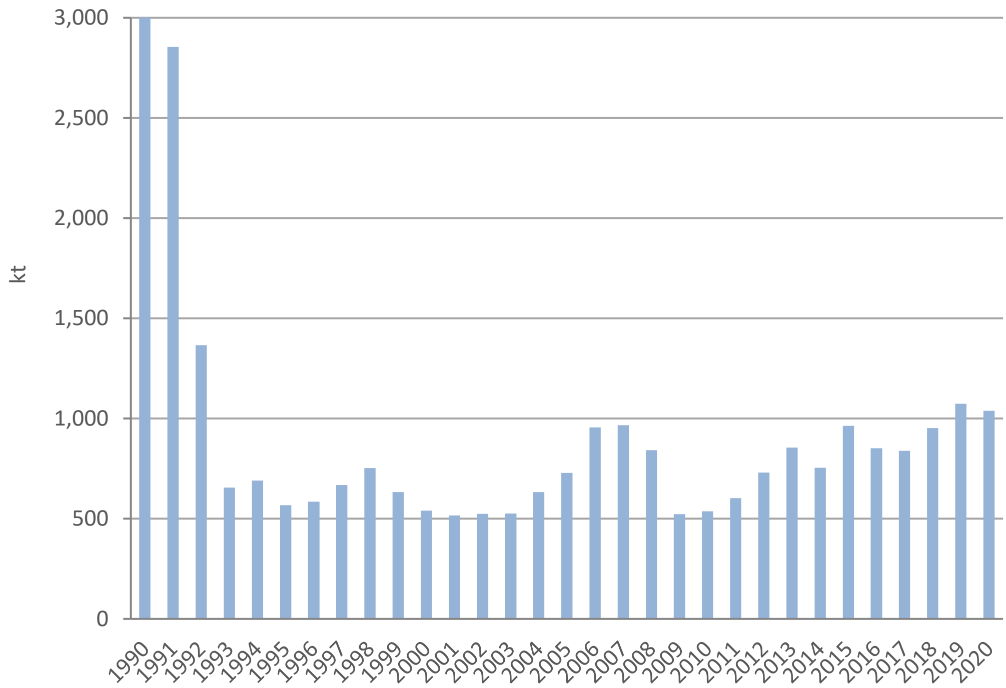


Figure 4-6. Clinker production

4.2.1.2 Methodological issues

For the period 1990-2004 CO_2 emission was calculated using Tier 2 method using specific production data provided by the production company. CO_2 emissions were calculated from material mass balance assuming that all carbon contained in raw materials (limestone) was released to the atmosphere as CO_2. Actual CO_2 emission was calculated from the data on clinker production and composition. In addition, it was assumed that CO_2 was released from calcinated fraction of kiln dust. According to the company, only about 5% of the CKD is calcinated.

CO_2 emission was calculated using the following equation:

$$Emission = CP \times (C_{CaO} \times (MCO_2/M_{CaO}) + C_{MgO} \times (MCO_2/M_{MgO})) +$$

$$+ CKD \times CF \times (C_{CaO} \times (MCO_2/M_{CaO}) + C_{MgO} \times (MCO_2/M_{MgO}))$$

where:

CP	- clinker production, kt;
CKD	- cement kiln dust generation, kt;
CF	- calcinated fraction of the CKD, the time-series of the CKD correction factor is provided in Table 4-3;

C_{CaO} and C_{MgO} - CaO and MgO fractions in clinker;

MCO_2, M_{CaO}, M_{MgO} - molecular weights of CO_2, CaO and MgO.

For the period 2005-2020 CO_2 emission data have been accessed via the verified EU ETS reports of the production plant. CO_2 emissions were calculated using plant specific data on production of clinker and CKD, and plant specific emission factors (t CO_2/t clinker, t CO_2/t CKD). In 2005 during the manufacture process removed dust was sold and shipped to the quarry, therefore the highest percent of CKD was recorded. The following years CKD value has declined due to increase of production of less alkaline clinker (the content of alkalis less than 0.85% in the clinker). Since August 2014 company operates dry clinker production line, where cement kiln dust is returned to the kiln, therefore CKD does not occur. The company has confirmed that after changing the production line from wet to dry CKD became zero.

Estimated CO_2 emissions from cement production are shown in the table below.

Table 4-3. Estimated CO_2 emissions (kt/year) from cement production

Year	Emission	CKD fraction
1990	1,668.1	1.3%
1995	308.0	1.3%
2000	292.5	1.3%
2005	383.3	2.3%
2010	289.0	0.2%
2011	319.8	0.3%
2012	395.2	0.3%
2013	460.8	0.4%
2014	400.8	0.4%
2015	518.3	NO
2016	452.4	NO
2017	450.4	NO
2018	511.3	NO
2019	578.1	NO
2020	556.7	NO

4.2.1.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Activity data uncertainty is assumed to be 2%. Data on clinker production provided by the single production company is considered reliable;
- Emission factor uncertainty is assumed to be 5%;
- Combined uncertainty is 5.4%.

CaO content in clinker fluctuated from 62.3% to 65.3% (from 1990 to 2013), the average value being 64.2%, standard deviation 0.8%.

Data on MgO content in clinker were available for the periods 2000 to 2009 and 2012 to 2013 (provided by the producer). MgO content fluctuated in the range from 3.33% to 4.13%, average value was 3.82%, standard deviation 0.26%. For GHG calculation for the period 1990 to 1999 average MgO content value was used.

Data on generation of cement kiln dust (CKD) (fraction not recycled to the kiln) were available for period 2005-2014. 2005-2007 average value was used for period 1990-2004 when the data were not available (CKD fluctuated from 0.5% to 2.3% of clinker production (average value 1.3%)). It is noted that due to changes in the production method since 2015 CKD does not occur.

4.2.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

As the producer reports CO_2 emissions for EU ETS, it was decided to perform a quality control by comparing the two estimates (*2006 IPCC Guidelines* Tier 2 versus EU ETS). Comparison of CO_2 emissions (Tier 2 versus EU ETS) for 2005-2009 is provided below:

Table 4-4. Comparison of CO_2 emissions from cement production (Tier 2 versus EU ETS)

	2005	2006	2007	2008	2009
CO_2 emissions Tier 2, kt	383.4	516.4	523.8	454.1	283.7
CO_2 emissions EU ETS, kt	383.3	515.3	524.1	453.8	284.0
ETS share, %	99.97	99.78	100.04	99.94	100.11

The difference between the Tier 2 estimations based on plant-specific data (annual clinker and CKD data, CaO and MgO content in clinker) and EU ETS data was less than 1%. Therefore, it is concluded that the estimates for the period 1990-2004 and 2005-2020 are consistent.

In GHG inventory cement production emissions for the period 2005-2020 are taken from EU ETS reports of cement production company. Company's ETS reports of 2015-2020 do not include any data on CKD due to the reasons mentioned in chapter 4.2.1.2.

4.2.1.5 Category-specific recalculations

No recalculations have been done.

4.2.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.2.2 Lime Production (CRF 2.A.2)

4.2.2.1 Category Description

After restoration of independence lime production decreased from approximately 300 thous tonnes annually to 50 thous tonnes in 1993 and is fluctuating about this value. Exceptionally low production of lime – only 5.6 kilo tonnes was observed in 2009. In 2018 the biggest lime producing company in Lithuania have almost stopped the production of lime (Figure 4-7). Data on lime production were provided by Statistics Lithuania[9] covering the whole reporting period.

Data on hydrated lime production are provided by Statistics Lithuania for the period 1999-2020. The fraction of hydrated lime fluctuated from 0% to 4%.

[9] Database of Statistics Lithuania

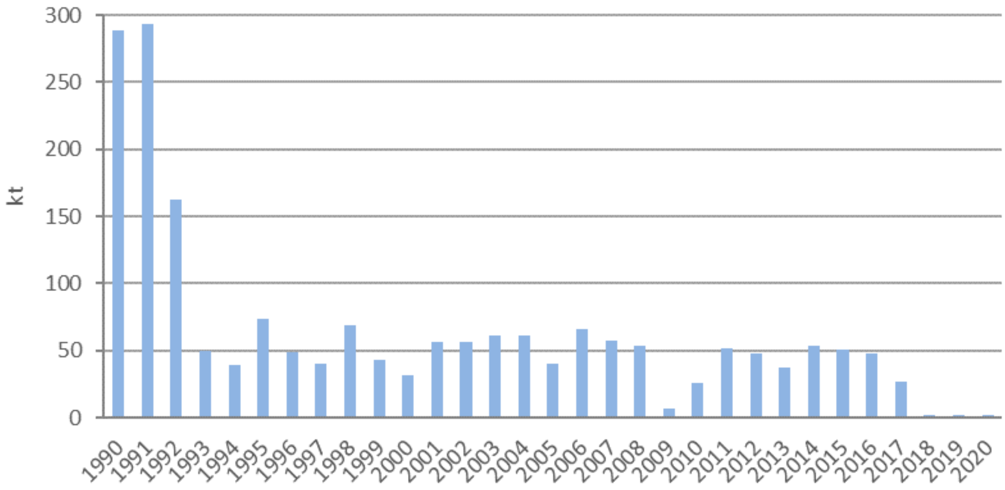


Figure 4-7. Lime production

Lime production in sugar industry

For the completeness of the activity data, the data on non-marketed lime production was collected. Lime auto produced by the sugar producing companies is not covered by the national statistics therefore the quantities of the lime produced were obtained directly from the sugar producing companies for the years 1990-2020.

4.2.2.2 Methodological issues

CO_2 emission from lime production was calculated using production data provided by Statistics Lithuania and limestone composition data provided by the lime production company. The limestone extraction in Lithuania is concentrated in one region in northern part of Lithuania, therefore available data on limestone composition from biggest lime producer data was used. According to the data provided by the lime production company, which is the main lime producer in Lithuania, limestone used for lime production contains 90% to 92% of $CaCO_3$ and 4% to 5% of $MgCO_3$. Based on these data it was assumed that products contain 91.1% of CaO, 3.9% of MgO and 5% of impurities. Actual hydrated lime production data were used for emission calculation in 1999-2016 and it was assumed that during 1990-1999 there was no hydrated lime production. In the period of 2017-2020 no hydrated lime production occurred. In the base year (as no hydrated lime production occured) and for 2017, 2018-2020 only the amount of produced quick lime was used for calculation of the emissions. The amount of produced hydrated lime is taken into account and the national correction factor for hydrated lime is used (the national correction factor is estimated according *2006 IPCC Guidelines* vol. 3, p. 2.24 correction for the proportion of hydrated lime). The emission from hydrated lime is about 1% of all emission from lime production (Table 4-5). CO_2 emissions were calculated by Tier 2 method using following equation (*2006 IPCC Guidelines*, Volume 3, Part 1, p. 2.21):

$$\text{Emission}=\sum(EF_{lime} \times M_l \times CF_{lkd} \times C_h)$$

where:

EF_{lime} - emission factors for quick and hydrated lime, tonnes CO_2/tonne lime (EFs calculated using eq. 2.9 from *2006 IPCC Guidelines*, Volume 3, Part 1, p. 2.23);

M_l - quick and hydrated lime production, tonnes;

CF_{lkd} - correction factor for LKD (default 1.02 (*2006 IPCC Guidelines*, Volume 3, Part 1, p. 2.24));

C_h - the national correction factor for hydrated lime (*2006 IPCC Guidelines*, Volume 3, Part 1, p. 2.24, correction for the proportion of hydrated lime)).

Table 4-5. Estimated country-specific correction factor for hydrated lime

Year	The country-specific correction factor for hydrated lime
1990-1998	NO
1999	0.989
2000	0.990
2001	0.997
2002	1.0
2003	1.0
2004	1.0
2005	1.0
2006	1.0
2007	0.996
2008	0.997
2009	0.990
2010	0.998
2011	0.999
2012	0.997
2013	0.997
2014	0.997
2015	0.999
2016	1.0
2017-2020	NO

Lime production in sugar industry

For determining activity data and emissions of CO_2 within the sugar industry, the amounts of limestone for the production of quicklime are used. The quantities were obtained directly from the sugar producing companies for the years 1990-2020.

According to the producers the used limestone consists to 90-92% of $CaCO_3$. In the production of sugar, lime is used for purification of the juice. Lime is added to the raw juice and some impurities are precipitated. In the carbonization step CO_2 is bubbled through the juice and most of the remaining lime is precipitated as $CaCO_3$. The precipitated "limestone" is sold and used within agricultural activities.

CO_2 emissions from lime production in sugar refining plants were estimated assuming that 86% of CaO is recovered as $CaCO_3$. This assumption is based on the data provided by the sugar producing companies:

- $CaCO_3$ content of the limestone used in sugar refineries is on average 97%;
- $CaCO_3$ content of the lime after the saturation/carbonation process is on average 83.9%.

Based on this data it was asumed that 14% of CaO is not recovered as $CaCO_3$. Only the part of CaO which is not recovered as $CaCO_3$ is reported as activity data.

In Table 4-6 the used amounts of limestone, the amounts of produced lime and emitted CO_2, the precipitated $CaCO_3$, and the reported activity data and CO_2 emissions from lime production within the sugar industry is presented. Following the recommendation by the Expert Review Team, precipitated amount of lime reported in 2.H.2 food and beverage.

Table 4-6. Lime production and estimated CO_2 emissions from sugar industry

Year	Used amount of limestone, kt	Amount of lime produced, kt	CO_2 from lime production, kt	Precipitated share of lime, %	Precipitated amount of lime, kt	Reported activity data (lime), kt	Reported CO_2 emissions, kt
1990	34.2	17.6	13.8	86	15.1	2.5	1.9
1995	24.2	12.4	9.7	86	10.7	1.7	1.4
2000	17.3	8.9	7.0	86	7.7	1.3	1.0
2005	14.7	7.6	5.9	86	6.5	1.1	0.8
2010	19.2	9.9	7.8	86	8.5	1.4	1.1
2011	22.4	11.5	9.0	86	9.9	1.6	1.3
2012	29.2	15.0	11.8	86	12.9	2.1	1.7
2013	31.3	16.4	12.9	86	14.1	2.3	1.8
2014	29.4	15.4	12.1	86	13.3	2.2	1.7
2015	18.3	9.6	7.5	86	8.2	1.3	1.1
2016	23.9	12.5	9.8	86	10.8	1.8	1.4
2017	27.4	14.4	11.3	86	12.4	2.0	1.6
2018	24.7	12.9	10.2	86	11.1	1.8	1.4
2019	23.2	12.1	9.5	86	10.5	1.7	1.3
2020	33.3	17.4	13.7	86	15.0	2.4	1.9

Estimated CO_2 emissions from lime production are provided in Table below (total, including sugar industry).

Table 4-7. Estimated CO_2 emissions from lime production, kt/year

Year	Reported CO_2 emissions from lime production	Reported CO_2 emissions from sugar industry	Total CO_2 emissions
1990	208.3	1.9	210.3
1995	52.3	1.4	53.7
2000	21.9	1.0	22.9
2005	28.6	0.8	29.4
2010	17.9	1.1	19.0
2011	36.2	1.3	37.5
2012	33.6	1.7	35.3
2013	25.9	1.8	27.7
2014	27.2	1.7	38.9
2015	35.8	1.1	36.9
2016	33.7	1.4	35.1
2017	18.1	1.6	19.7
2018	0.1	1.4	1.5
2019	0.1	1.3	1.4
2020	NO	1.9	1.9

4.2.2.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Activity data uncertainty is assumed to be 5%. Data on lime production was taken from Statistics Lithuania publications;
- Emission factor uncertainty is assumed to be 5%;
- Combined uncertainty is 7%.

CO_2 emission was calculated using production data provided by Statistics Lithuania and limestone composition data provided by lime production company. Quantities of the lime produced in sugar production were obtained from the sugar producing companies. Data is consistent over the time series.

4.2.2.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.2.2.5 Category-specific recalculations

No recalculations have been done.

4.2.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.2.3 Glass Production (CRF 2.A.3)

4.2.3.1 Category Description

There were three glass production plants in Lithuania. One of them (producing cathode ray tubes) got bankrupt in 2006 and currently there are only two plants in operation.

One plant (first plant) produces both sheet glass and container glass. Its production has fallen down substantially in early nineties following the declaration of independence, but increased again later even exceeding pre-independence level. However, sheet glass production was stopped in 2002 causing again substantial reduction in production to approximately 40 thousand tonnes per year. A new glass melting furnace was under construction in 2017, therefore for a period of 2.5 months the glass melting process was stopped.

The oldest glass production plant (second plant) in Lithuania produces container glass. In the period 1990 to 2011, its production was comparatively stable averaging about 20 thousand tonnes annually. Due to modernization of container glass production line in 2012 (the company installed a new more powerful and more economical glass melting furnace and purchased equipment to produce thin-walled bottles) the production of glass increased by more than 60% in 2012.

Glass production in CRT manufacturer (third plant) decreased slightly in the very beginning of the period, but then was increasing continuously from 1993 to 2004. However, changing market conditions and sharp reduction of demand for CRTs caused sudden bankruptcy of the company and production was stopped completely in 2006.

Glass production in 1990-2020 is shown in the figure below.

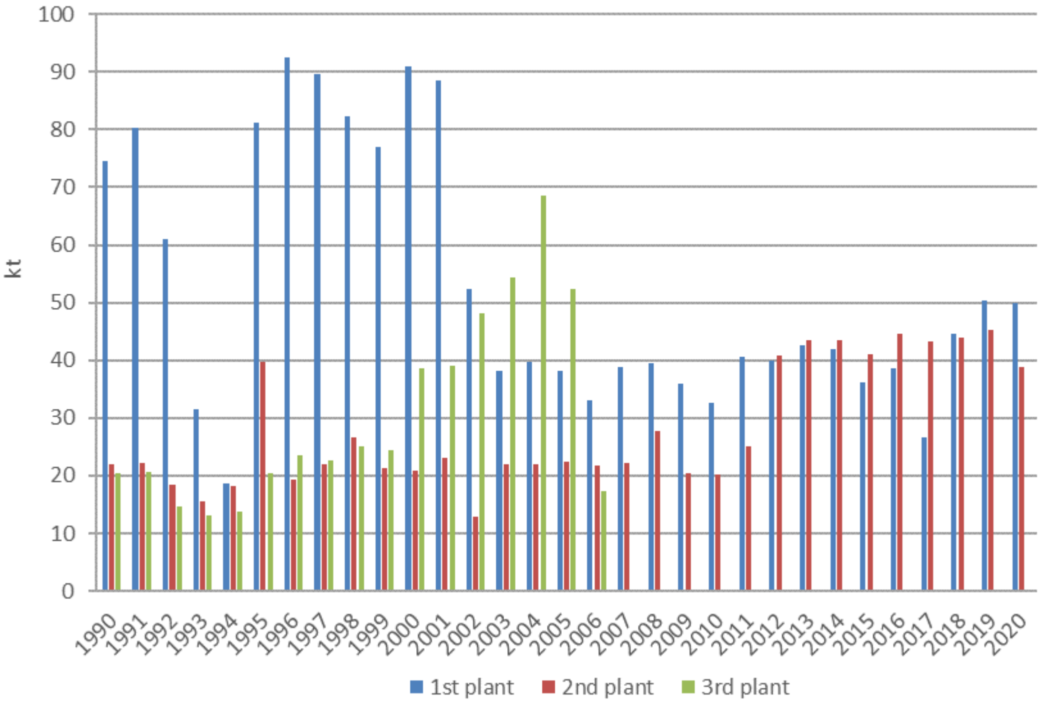


Figure 4-8. Glass production

4.2.3.2 Methodological issues

CO_2 emissions were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, Part 1, p. 2.28):

$$CO_2\ Emissions = \sum(M_i \times EF_i \times F_i) + M_c \times EF_c,$$

where:

CO_2 emissions	- emissions of CO_2 from glass production, tonnes;
EF_i	- emissions factor for the particular carbonate i, tonnes CO_2/tonne carbonate;
M_i	- mass of the carbonate i consumed, tonnes;
F_i	- fraction calcination achieved for the carbonate i, fraction. It was assumed that the fraction calcination is equal to 1.00 for all carbonate types;
EF_c	- emissions factor for carbon oxydised in glass furnace, tonnes CO_2/tonne carbon;
M_c	- mass of the carbon oxydised in glass furnace, tonnes.

Default emission factors for the particular carbonate (tonnes CO_2/tonne carbonate) were used, as provided in *2006 IPCC Guidelines* (Volume 3, Part 1, Table 2.1, page 2.7). According to EU ETS report of second plant, small quantity of carbon is oxidised directly in glass furnace. The factory uses natural gas as a fuel.

CO_2 emissions were calculated for each production plant based on plant specific data on use of particular carbonates. Summary for each production plant is provided below.

First plant

CO_2 emissions were calculated using plant specific data provided by the production company:

- Glass production data is available for 1990-2020 (tonnes of glass produced).
- Data on cullet use is available for the period 1999-2020.
- Data on consumption of particular carbonates: dolomite ($MgCO_3$, $CaCO_3$), soda ash (Na_2CO_3) and chalk ($MgCO_3$, $CaCO_3$) are available for 1999-2009. In 1999-2002 company has also used small quantities of potash (K_2CO_3) and carbon.
- Data on composition of dolomite and chalk is available for the period 2005-2020.
- Since 2005 the company is reporting under EU ETS, thus data on consumption of $MgCO_3$, $CaCO_3$ and Na_2CO_3 are available for the period 2005-2020.

Plant specific emission factor (t CO_2/t glass produced, excluding cullet) was calculated based on available data outlined above. The emission factor was used for extrapolation of emissions in 1990-1998. The period of time considered for averaging the EF was 1999-2004.

Second plant

CO_2 emissions were calculated using plant specific data provided by the production company:

- Glass production data is available for 1990-2020 (tonnes of glass produced).
- Data on cullet use is available for the period 2004-2020.
- Data on consumption of particular carbonates: dolomite (MgCO3, CaCO3) and soda ash (Na2CO3) is available for 2004-2006.
- Data on composition of dolomite is available for 2004-2020.
- Since 2007 the company is reporting under EU ETS, thus data on consumption of MgCO3, CaCO3, Na2CO3 and Carbon oxidised directly in glass furnace are available for the period 2007-2020.

Plant specific emission factor (t CO_2/t glass produced, excluding cullet) was calculated based on available data outlined above. The emission factor was used for extrapolation of emissions in 1990-2003. The period of time considered for averaging the EF was 2004-2009.

Third plant

The production plant produced cathode ray tubes, but got bankrupt in 2006. Production data (number of cathode ray tubes produced) is available for 1990-2006. EU ETS reports provide data on consumption of particular carbonates: Na_2CO_3, K_2CO_3, $BaCO_3$, $CaCO_3$, $SrCO_3$ and dolomite in 2005 and 2006. Average plant specific emission factor (t CO_2/t glass produced, excluding cullet) was calculated based on available 2005-2006 data. The emission factor was used for extrapolation of emissions in 1990-2004.

Estimated CO_2 emissions (excluding cullet) from glass production are provided in the table below.

Table 4-8. Estimated CO_2 emissions from glass production

Year	CO_2 emission, kt
1990	11.7
1995	14.4
2000	15.4
2005	10.2
2010	4.2
2011	6.5
2012	7.3
2013	8.1
2014	7.4

2015	6.4
2016	7.0
2017	5.7
2018	7.3
2019	8.0
2020	7.5

4.2.3.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- CO_2 emissions in glass production were calculated from the data on use of raw materials containing carbonates. Data were obtained from the production companies, but only for the second half of the period under consideration (1999-2020). In addition, only very limited data were obtained from cathode ray tubes producer which got bankrupt in 2006. In view of these considerations, it was assumed that activity data uncertainty for glass production is 7%;
- Emission factor uncertainty is assumed to be 5%;
- Combined uncertainty is 8.6%.

Activity data is not fully consistent over the time-series. Starting from 2005 data is fully consistent and reliable.

4.2.3.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.2.3.5 Category-specific recalculations

No recalculations have been done.

4.2.3.6 Category-specific planned improvements

Category-specific improvements are not planned.

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

Category of other process uses of carbonates (CRF 2.A.4) are divided into four sub-categories: ceramics (CRF 2.A.4.a), other uses of soda ash (CRF 2.A.4.b), non-metallurgical magnesia production (CRF 2.A.4.c) (NO) and other (mineral wool; flue gas desulphurisation) (CRF 2.A.4.d).

4.2.4.1 Category Description

Ceramics (CRF 2.A.4.a)

This category includes CO_2 emissions from bricks and tiles production. Data on ceramic bricks, tiles and vitrified clay pipes production were taken from Statistics Lithuania publications[10]. Production of bricks, tiles and clay pipes has fallen down dramatically from 1990. Tiles are not produced since 2004 and vitrified clay pipes are not produced since 2007. In the period of 2000-2002 ceramic bricks production decreased due to the economic crisis in Russia. From 2010 country economy started to recover which led to increase production of ceramic bricks.

[10] Database of Statistics Lithuania

Ceramic bricks production data from Statistics Lithuania publications for various periods are provided in different units. The data for 1990-2001 are provided in millions of bricks, while the data for the following years are in thousands cubic meters. Recalculation of data to mass units was made by applying average conversion factors based on information provided by the largest ceramic bricks and pipes producer in Lithuania. It was assumed that average brick mass is 2.7 kg and average volume weight of bricks is 1.6 t/m^3.

Vitrified clay pipes production data from Statistics Lithuania publications are provided in thousands of kilometers for the period 1990-2001 and in tonnes for the remaining period. Production of vitrified clay pipes were converted to mass units using conversion factor 3.0 tonnes per km.

Ceramic tiles production data were provided in square meters from 1990 to 2001 and in tile units from 2002. These data were converted to weight units assuming that average tile area is 350×200 mm and average weight is 2.8 kg (information by ceramic bricks producer).

As there was number of ceramics manufacturing companies, activity data (ceramic bricks/tiles production) for period 1990-2018 were taken from Statistics Lithuania and emissions were estimated from material balance based on average CaO and MgO contents in the product provided by the main ceramic bricks producers. During 2018-2019 many ceramic manufacturing companies went bankrupt and remained only one company, which is included in the ETS, therefore from 2019 emissions were assessed according to data of this company reported in it's ETS report.

Ceramics production in Lithuania in 1990-2020 is provided in the figure below.

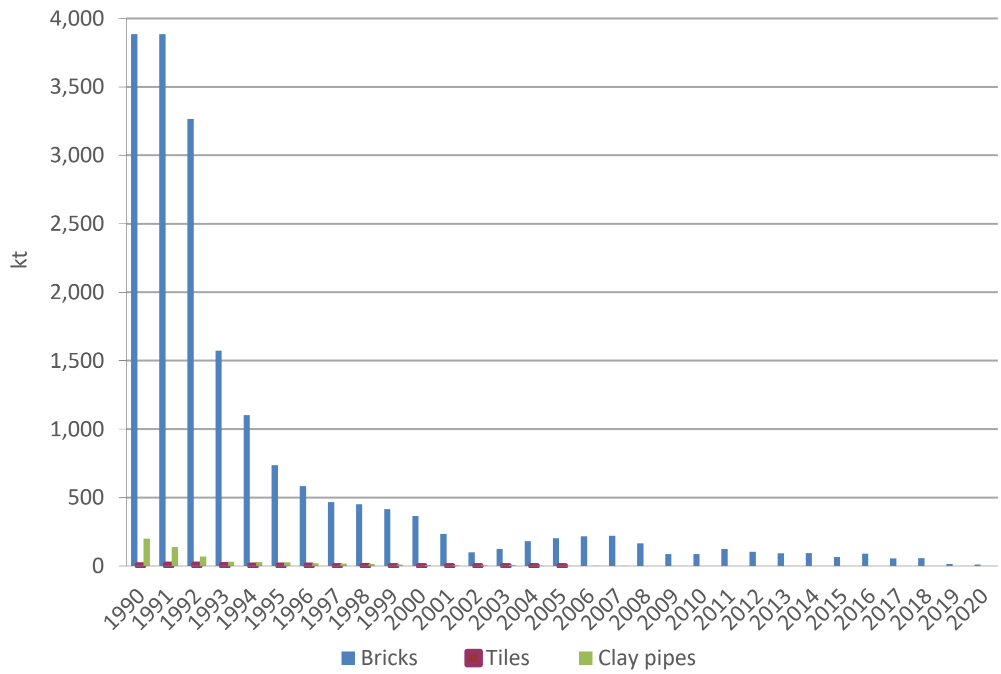


Figure 4-9. Production of ceramic products

Other Uses of Soda Ash (CRF 2.A.4.b)

CO_2 emissions from soda ash consumed in glass production is covered under CRF 2.A.3. This chapter covers other uses of soda ash. The data on overall use of soda ash were obtained from the publications of Statistics Lithuania[11]. In 2010 the Statistics Lithuania has stopped collection of statistical data on the overall use of soda ash. Therefore for the years 2010-2020 overall soda ash use is determined via balancing (import minus export). The relevant import and export quantities are taken from the foreign-trade statistics of the Statistics Lithuania. For the consistency reasons the analysis between data on total soda ash consumption, soda ash use in glass industry and foreign trade data has been conducted (Figure 4-10).

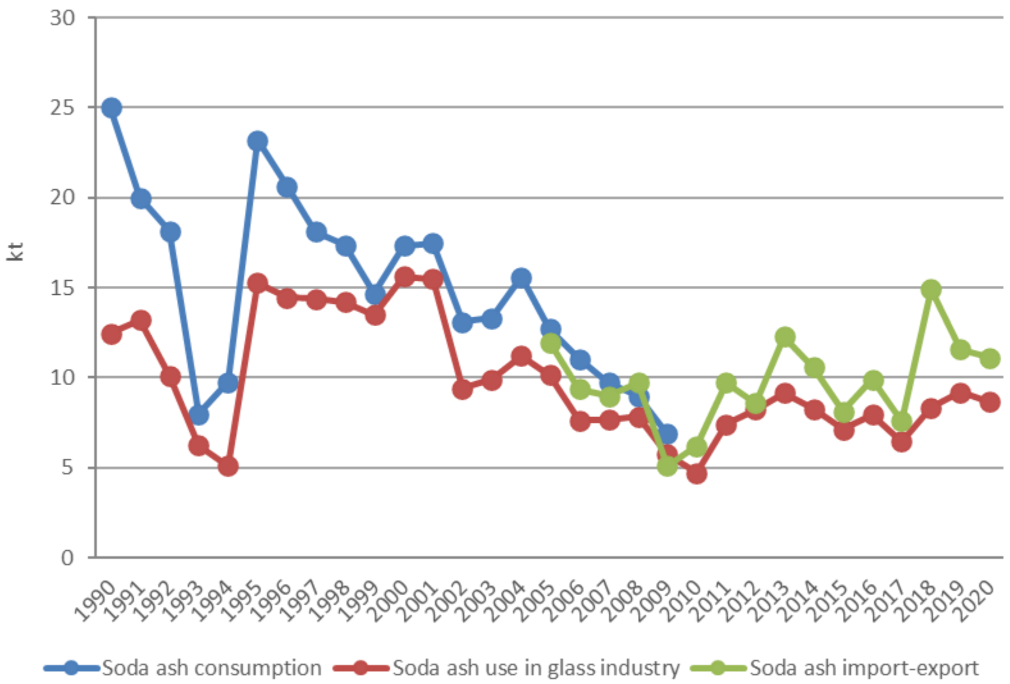


Figure 4-10. Consumption of soda ash

The foreign trade data is available from 2005 onwards. 2005-2009 foreign trade data overlaps with data on soda ash consumption, therefore correlation has been done for this time period. The analysis showed strong correlation (r=0.92) (Figure 4-11 a). The correlation between soda ash use in glass industry and foreign trade data has been done for period 2005-2014 and also showed strong correlation (r=0.91) (Figure 4-11 b), therefore it was concluded that import/export data is consistent for further emission calculation.

[11] Statistic Lithuania publication "Raw Materials"

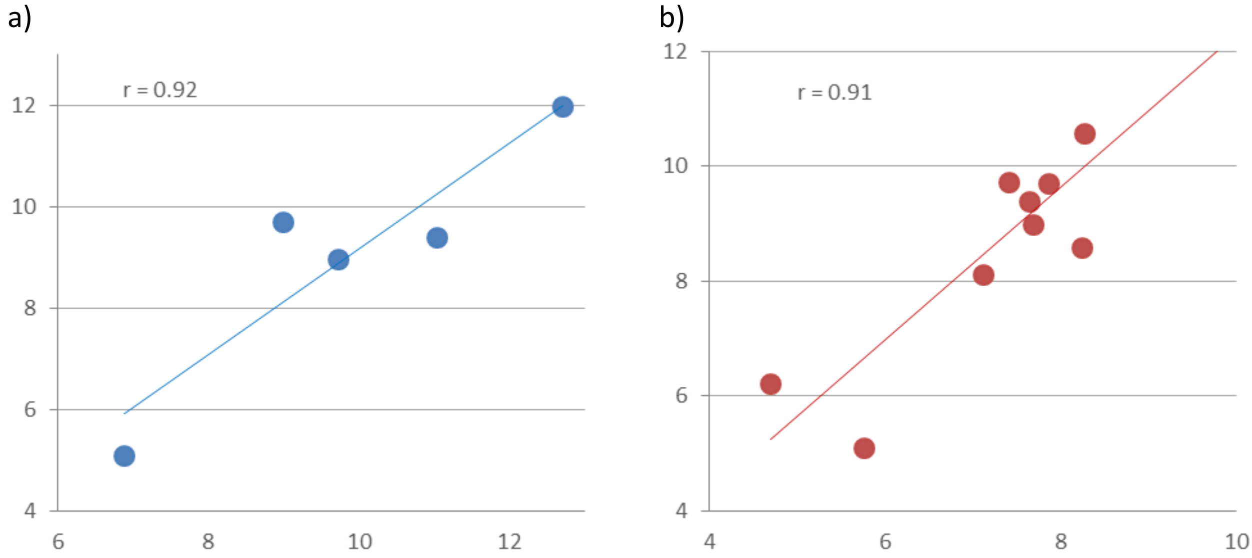


Figure 4-11. Correlation between foreign trade data and total soda ash consumption (a), soda ash us in glass industry (b)

Soda ash consumed in the glass production industry was subtracted from the overall use of soda ash.

Soda ash consumption in the glass companies was calculated based on the data on consumption of carbonates provided by the production companies:

- First plant 1999-2020. For the period 1990-1998 average soda ash consumption (1990-1998) per tonne of glass was used. Cullet was excluded from the calculation.
- Second plant 2004-2020. For the period 1990-2003 average soda ash consumption (1990-2002) per tonne of glass was used. Cullet was excluded from the calculation.
- Third plant 2005-2006. The plant got bankrupt in 2006. For the period 1990-2004 average soda ash consumption (1990-2003) per tonne of glass was used. Cullet was excluded from the calculation.

Variations of soda ash use are shown in Figure 4-12.

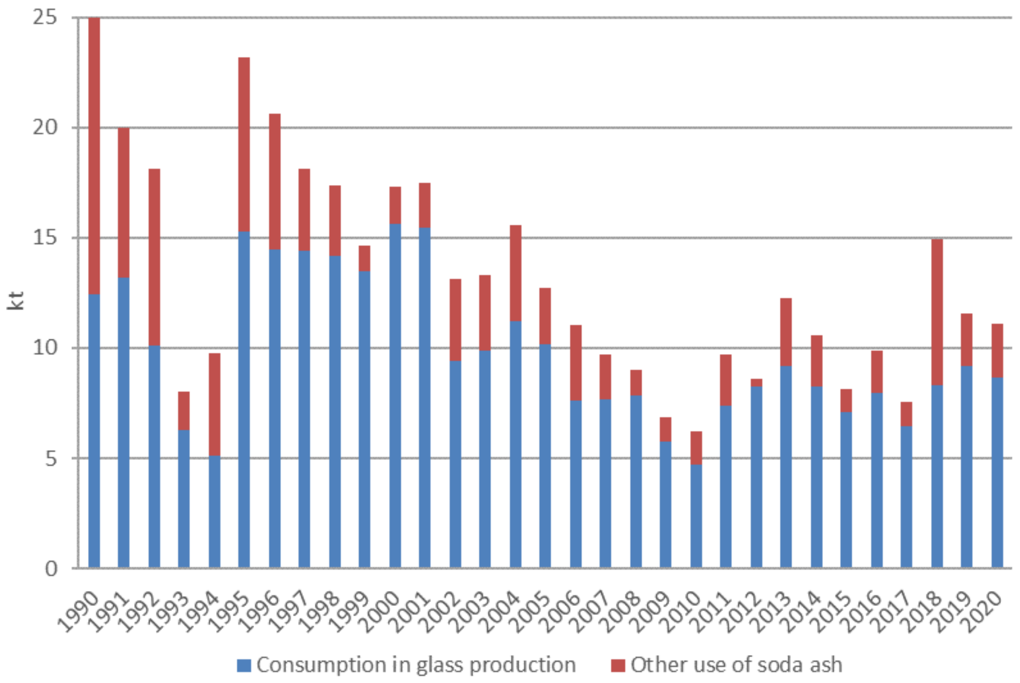


Figure 4-12. Evaluated use of soda ash

Non Metallurgical Magnesia Production (CRF 2.A.4.c)

Emissions from non-metallurgical magnesia production are not occurring in Lithuania so for the category "CRF 2.A.4.c Non Metallurgical Magnesia Production" notation key "NO" is used.

Other (CRF 2.A.4.d)

CO_2 emissions from the 2.A.4.d Other category include emissions from mineral wool production and consumption of carbonates use in flue gas desulphurisation. The CRF reporter does not allow separation of these two sub-categories by adding new nodes under 2.A.4.d Other category. Consequently, mineral wool and consumption of carbonates use in flue gas desulphurisation sub-categories are reported collectively.

Mineral wool (CRF 2.A.4.d)

Two mineral wool plants were in operation in Lithuania in 1990. One plant was closed soon after independence. Another plant continued operation, but production was constantly decreasing. Finally it was bought by the Finnish company which performed major upgrading of the plant in 1996 when production fell down actually to zero.

It was not possible to find actual data on mineral wool production from 1990 to 1997. Evaluation of production figures for that period based on remaining data was performed by prof. A. Kaminskas who was the director of the Institute of Thermal Insulation in Vilnius in eighties and nineties. Production data for the period 1998-2020 were provided by the production company.

Mineral wool production in 1990-2020 is shown in the figure below.

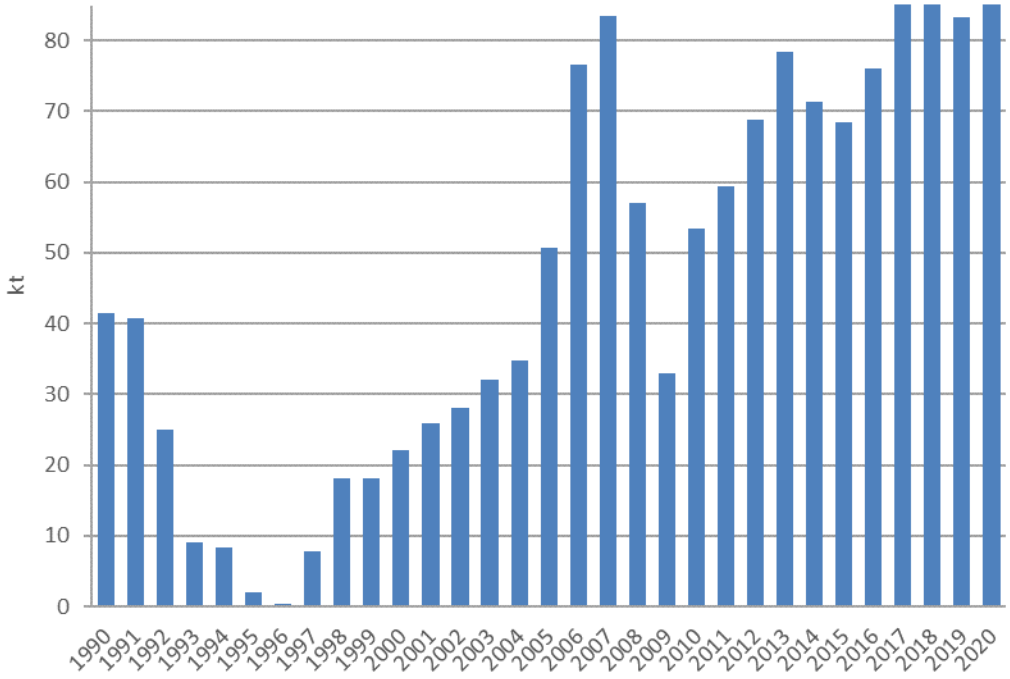


Figure 4-13. Mineral wool production

In mineral wool production CO_2 is formed by decomposition of dolomite. Data on consumption of dolomite for production of the mineral wool was provided by the company (1997-2020).

Consumption of carbonates use in flue gas desulphurisation (CRF 2.A.4.d)

In previous submission CO_2 emissions from consumption of carbonates use in flue gas desulphurisation were under 2.H.3 Other subcategory. Following the recommendation by the Expert Review Team, all emissions from limestone used in flue gas desulphurisation are under 2.A.4.d. Other (Other process uses of carbonates) in this submission. Information on CO_2 emissions from limestone used for flue gas desulphurisation is included in Energy sector (CRF 1.A.1.a) in Chapter 3.3.1.5 (CO_2 emission from carbonates use in flue gas desulphurisation) of the NIR.

4.2.4.2 Methodological issues

Ceramics (CRF 2.A.4.a)

CO_2 emissions from ceramics production were calculated from material balance based on CaO and MgO contents in the product provided by the ceramic bricks producer. According to the company, CaO content in bricks is fluctuating from 3.5% to 4.7% and MgO content is varying from 1.65% to 2.65%. Average values of 4.1% CaO and 2.15% MgO were taken as emission factors for calculation of emissions.

CO_2 emissions were calculated using the following equation:

$$Emission = CP \times (C_{CaO} \times (MCO_2/M_{CaO}) + C_{MgO} \times (MCO_2/M_{MgO})$$

where:

CP	- ceramics production, kt;
C_{CaO} and C_{MgO}	- CaO and MgO fractions in ceramics products;

MCO_2, M_{CaO}, M_{MgO} - molecular weights of CO_2, CaO and MgO.

During 2018-2019 many ceramic manufacturing companies went bankrupt and remained only one company, which is included in the ETS, therefore from 2019 CO_2 emissions data have been accessed via the verified EU ETS reports of the production plant. Emissions were calculated using plant specific data on consumption of raw material and plant specific emission factors.

Estimated CO_2 emissions from ceramics production are provided in the table below.

Table 4-9. Estimated CO_2 emissions from bricks and tiles production

Year	CO_2 emission, kt
1990	227.9
1995	42.8
2000	20.9
2005	11.4
2010	4.8
2011	7.0
2012	5.8
2013	5.2
2014	5.2
2015	3.7
2016	5.0
2017	3.1
2018	3.3
2019	2.2
2020	0.7

Other uses of soda ash (CRF 2.A.4.b)

CO_2 emissions were calculated from mass balance assuming that all carbon contained in soda ash was released to the atmosphere after use as CO_2. The following equation was used:

$$Emission = M \times EF$$

where:

M - mass of soda ash, tonnes;

EF - emission factor for soda ash, tonnesCO_2/tonne carbonate.

Estimated CO_2 emissions from other use of soda ash are provided in the table below.

Table 4-10. Estimated CO_2 emissions from soda ash use

Year	CO_2 emission, kt
1990	5.2
1995	3.3
2000	0.7
2005	1.1
2010	0.6
2011	1.0
2012	0.1
2013	1.3
2014	1.0
2015	0.4
2016	0.8
2017	0.5
2018	2.7

2019	1.0
2020	1.0

Mineral wool (CRF 2.A.4.d)

For the period 1990-1996 CO_2 emissions from mineral wool production were calculated using average emission factor which was calculated as 0.15 tonnes CO_2 per tonne mineral wool produced (the period of time considered for averaging the emission factor was 1998-2010).

CO_2 emissions in 1997-2007 were calculated using data on consumption of dolomite and emission factor provided by the production company (for the period 1997-2007 average emission factors was used 0.45 t CO_2/t dolomite ((the period of time considered for averaging the emission factor was 2008-2010).

For the period 2008-2020 CO_2 emissions data have been accessed via the verified EU ETS reports of the production plant. Emissions were calculated using plant specific data on consumption of dolomite and plant specific emission factors (t CO_2/t dolomite).

Estimated CO_2 emissions from mineral wool production are provided in the table below.

Table 4-11. Estimated CO_2 emissions from mineral wool production

Year	CO_2 emission, kt
1990	6.4
1995	0.3
2000	3.4
2005	8.2
2010	8.3
2011	9.1
2012	10.0
2013	11.9
2014	11.3
2015	10.5
2016	12.0
2017	12.8
2018	13.4
2019	11.6
2020	11.6

4.2.4.3 Uncertainties and time-series consistency

Ceramics (CRF 2.A.4.a)

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Activity data uncertainty is assumed to be 5%;
- Emission factor uncertainty is assumed to be 5%;
- Combined uncertainty is 7.1%.

Data on ceramic bricks, tiles and vitrified clay pipes production were taken from Statistics Lithuania publications[12]. Ceramic bricks production data in Statistics Lithuania publications for various periods are provided in different units. Data for 1990-2001 are provided in millions of bricks, while the data for the following years are in thousands cubic meters. Recalculation of data

[12] https://osp.stat.gov.lt/statistikos-leidiniu-katalogas

to mass units was made. Vitrified clay pipes production data in Statistics Lithuania publications are provided in thousands of kilometers for the period 1990-2001 and in tonnes for the remaining period. Production of vitrified clay pipes were converted to mass units. Ceramic tiles production data were provided in square meters from 1990 to 2001 and in tile units from 2002. These data were converted to weight units.

Other uses of soda ash (CRF 2.A.4.b)

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Soda ash use was evaluated as difference of data provided by Statistics Lithuania and evaluated other uses (namely glass production). As each of these components contains certain uncertainty, the total uncertainty in soda ash use activity data was assumed to be 15%;
- Emission factor uncertainty is assumed to be 5%;
- Combined uncertainty is 15.8%.

Data on overall use of soda ash were taken from the publications of Statistics Lithuania. Data on overall use of soda ash was not available for 2010-2020 therefore the data on soda ash import and export was taken from Statistics Lithuania. Issues related to time-series consistency of the soda ash use by glass production is covered in section Glass Production (CRF 2.A.3).

Mineral wool (CRF 2.A.4.d)

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- The data on mineral wool production and raw materials consumption obtained from the production company are reliable and precise, however, they cover only the period after reconstruction of the plant (from 1997). Historic data for 1990-1996 are expert evaluation and is less reliable. It was assumed that overall uncertainty of mineral wool production activity data is 7%;
- Emission factor uncertainty is assumed to be 5%;
- Combined uncertainty is 8.6%.

Production data for the period 1997-2020 were provided by the producer company. Activity data is not available for the period 1990-1996 and was extrapolated.

4.2.4.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

Mineral wool category-specific quality control procedures have been carried out in this submission. Activity data and plant-specific emission factors provided by the producer for years 2008-2020 have been verified with EU ETS data and the correspondence between these data is 100%.

4.2.4.5 Category-specific recalculations

No recalculations have been done.

4.2.4.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.3 Chemical Industry (CRF 2.B)

In Lithuanian GHG inventory this category includes non-fuel emissions of CO_2 from ammonia production and methanol production, N_2O from nitric acid production and CH_4 emissions from methanol production (Table 4-14).

Table 4-12. Reported emissions under the category chemical industry

CRF	Source	Emissions reported	Methods	Emission factor
2.B.1	Ammonia production	CO_2	Tier 3	CS
2.B.2	Nitric acid production	N_2O	Tier 3	PS
2.B.8.a	Methanol	CO_2, CH_4	Tier 1	D

Ammonia and nitric acid production are key categories of this source category in Lithuanian inventory. Adipic acid, caprolactam, glyoxal and glyoxylic acid, carbides, titanium dioxide, pertrochemical and carbon black, fluorochemical production dichloroethylene and styrene are not produced in Lithuania.

Emissions of chemical industry in 2020 were 1,937.9 kt CO_2 eq., and it was 63% of industry sector emissions.

Nitric acid and ammonia is nowadays produced in Lithuania in a single company. Emissions of CO_2 from ammonia production were 1,783.1 kt in 2020. Emissions of N_2O from nitric acid production were 0.52 kt in 2020. Ammonia and nitric acid production show recovery after the financial crisis and reached the levels of 2007-2008. Significant decline in N_2O emissions in 2009-2012 are due to installing of secondary catalyst in August 2008.

Emissions of CO_2 and CH_4 from methanol production comprise a small fraction in the emissions of greenhouse gases from chemical industry (emissions of CH_4 did not exceed 0.2% and emissions of CO_2 did not exceed 2.7% during the whole time series 1990-2008). No methanol was produced in 1999 and since 2008 due to economic reasons the production of methanol was stopped.

4.3.1 Ammonia Production (CRF 2.B.1)

4.3.1.1 Category Description

There is a single ammonia production company in Lithuania. In the production plant ammonia is produced at 22.0-24.0 MPa pressure from hydrogen and nitrogen, which are generated at 800-1100°C temperatures by conversion of natural gas. The converted gas is cleaned from impurities (CO, CO_2, H_2O vapour, etc.).

Capacities of ammonia production:

- AM-70 unit – project (design or primary) capacity was 1,360 t/day; after reconstruction (in 1995) it reached 1,560 t/day or 569,400 t/year.
- AM-80 unit – project capacity is 1,560 t/day or 569,400 t/year.
- Total ammonia production capacity is 1,138.800 t/year.

Ammonia production and natural gas consumption data (Figure 4-14) were provided by company. Other fuels are not used in the ammonia production process.

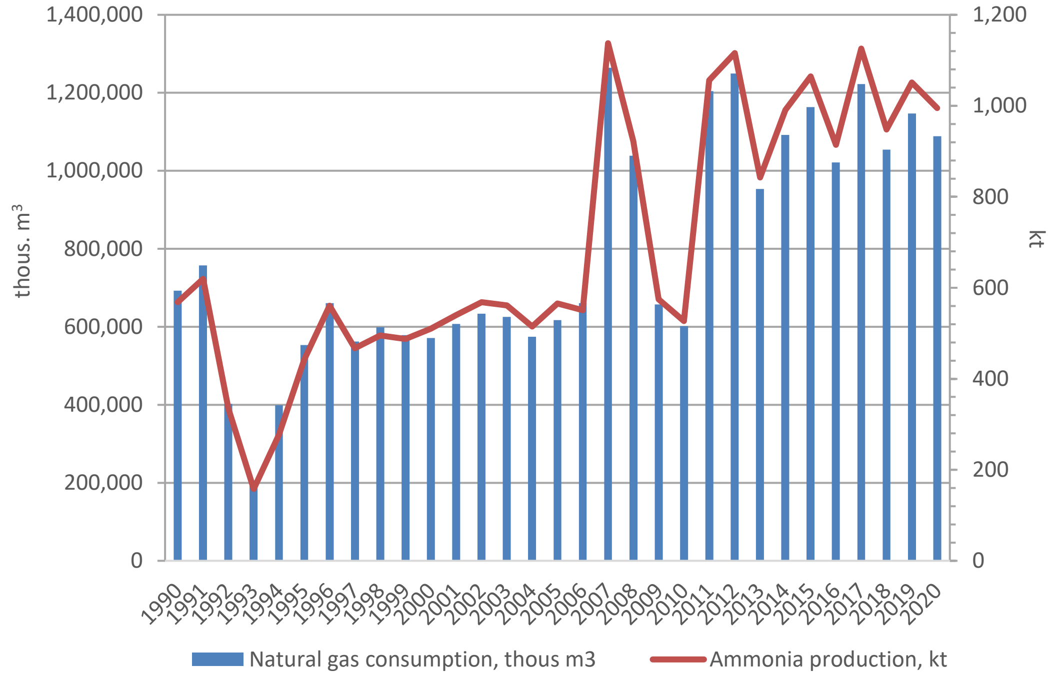


Figure 4-14. Ammonia production and natural gas consumption

Variations in ammonia production closely follow the variations in natural gas consumption. The increase of fuel consumption in 2007 was caused by launch of the second ammonia production unit at the end of 2006. A sharp downwards trend in ammonia production in 2008-2010 was caused by the financial crisis. In 2018 ammonia production were 948 kt, compared to 2017 ammonia production has decreased by 16%. In 2019 ammonia production were 1051 kt and has increased by 10 % compared to 2018. In 2020 ammonia production were 995.0 kt and has decreased by 5 % compared to 2019.

4.3.1.2 Methodological issues

The CO_2 emissions were calculated using Tier 3 method (*2006 IPCC Guidelines*, Volume 3, Part 1, p. 3.13) and based on the following data:

- data provided by producer:
  - annual production of ammonia;
  - data on natural gas consumption;
  - data on CO_2 recovered for urea production;
  - data on amount of exported urea;
  - lower calorific values (annual average) of natural gas.
- data on CO_2 emitted from urea application on soils;
- data on CO2 emitted from the use of urea based catalyst;
- country specific emission factor.

CO_2 emissions were calculated using the following equation:

$$CO_2\ emitted = (TFR \times Cv \times 4.186 \times 10^{-9} \times EF) - RCO_2$$

where:

TFR_{NG} - total fuel requirements for ammonia production (= total consumption of natural gas, thousand m^3);

Cv - lower calorific value of the natural gas (kcal/m³);

4.186×10^{-9} - conversion factor TJ/kcal;

EF - country specific CO_2 emission factor for natural gas (t CO_2/TJ) is based on the results of the study "Update of country specific GHG emission factors for Energy sector" performed in 2016 by Lithuanian Energy Institute. In the study it was recommended to use an average value (55.14 t/TJ) for a period 1990-2003. EF for natural gaswas determined considering the chemical composition of natural gas during 2004-2014 that was provided by Central Calibration and Test Laboratory of JSC "Lietuvos dujos"[13] In the study it was recommended since year 2015 to estimate EF for natural gas annually based on composition of natural gas and taking into consideration the share of the gas imported via LNG terminal and via pipeline (LNG terminal started to operate in 2015). Ammonia production company confirmed that in 2015 the gas used in ammonia production was imported only via pipeline, thus country specific EF for 2015 used in energy sector (55.53 t/TJ) will not reflect the composition of natural gas used by company. Therefore in consultation with energy sector expert it was decided for year 2015 to use EF for natural gas from the study performed in 2012 (55.23 t/TJ). The same EF is used in company's EU ETS report 2015. CO_2 EF for natural gas for 2016-2020 was determined considering the import structure (share of gas imported via LNG terminal and via pipeline) and chemical composition of natural gas (55.73 t/TJ, 55.57 t/TJ, 55.54 t/TJ, 55.59t/TJ and 55.34 t/TJ respectively) and it corresponds to EF used in energy sector;

R_{CO2} - CO_2 recovered for urea production, kg. According to *2006 IPCC Guidelines* Volume3-1, p. 3.16, Box 3.2, CO_2 recovered for downstream use in urea production must be subtracted from the total quantity of CO_2 generated from ammonia production. Moreover, the emissions of CO_2 from urea use should be accounted for in the corresponding sectors. Since the emissions of CO_2 from urea used in agriculture and urea used in urea-based catalyst are reported in the corresponding sector, these emissions were excluded from the total emissions from ammonia production. In addition, the exported urea was excluded from the total emissions as the emissions will not occur in Lithuania. According to company data about 30% of urea production was exported in 2018-2020. According to company data the import of urea occurred only in 2009. The use of urea-based catalyst in transport sector were simulated considering the number of cars, which use urea based catalyst and by mileage data provided by COPERT model. Emissions from the use of urea-based catalyst are reported under Non-energy products from fuels and solvent use (CRF 2.D.3). Emissions of CO_2 from urea used in agriculture are reported under CO_2 emissions from urea application (CRF 3.H).

Data on average annual lower calorific value of natural gas is provided by the producer for the whole time series. Data is calculated on the basis of reports from the natural gas supplier.

[13] Summary of study on "Update of country specific GHG emission factors for Energy sector" is presented in Annex VI

Calorific value of supplied natural gas is measured twice per month at Lithuania's natural gas supplier laboratory.

According to *2006 IPCC Guidelines* (Volume 3, chapter 3, p. 3-16, box 3.2) "In order to avoid double counting, the total quantities of oil or gas used (fuel plus feedstock) in ammonia production must be subtracted from the quantity reported under energy use in the Energy Sector". As ammonia producer provides detailed data on fuel consumption for each installation in EU ETS report, the separation of fuel used for heat production and feedstock is available, therefore no double counting occur. As the fuel used for heat production is associated with fuel combustion, it was decided to allocate these emissions under 1.A.2.c Chemicals category (Chapter 3.4.1.3). Moreover, the ammonia producer operates cogeneration plant for heat and electricity production, consequently part of emissions from fuel combustion are allocated under 1.A.1.a.ii Combined Heat and Power Generation category (Chapter 3.3.1.3).

Taking into account ERT recommendation (ARR 2019, issue I.23, p. 30) with regard to reporting separately CO_2 emissions from natural gas consumption for non-energy use (feedstock for ammonia production) under category 2.B.1 and CO_2 emissions from natural gas consumption used for heat production during ammonia production under category 1.A.2.c in the energy sector and impact of such reporting on IEF comparability, the table below contains comparison of CO_2 emissions from ammonia production (process emissions) vs total CO_2 emissions from ammonia production (process and combustion emissions) and difference in associated IEFs.

Table 4-13. Comparison of CO_2 emissions from ammonia production (process emissions vs process and combustion emissions) and associated IEFs

	2013	2014	2015	2016	2017	2018	2019	2020
CO_2 emissions from ammonia production – process (2.B.1 category), t CO_2 e	1 776,738	2 039,015	2 182,578	1 956,241	2 320,863	1 992,758	2 183,036	2 061,621
CO_2 recovery, t CO_2 e	91,202	169,680	136,812	128,176	177,819	164,794	193,770	278,575
CO_2 emissions from ammonia production – process including recovery (2.B.1 category), t CO_2 e	1 685,536	1 869,335	2 045,766	1 828,065	2 143,044	1 827,964	1 989,266	1 783,046
CO_2 emissions from ammonia production – combustion (1.A.2.c category), t CO_2 e	4,905	4,149	4,212	14,243	2,616	6,810	3,377	4,394
CO_2 emissions from	1 781,643	2 043,164	2 186,790	1 970,484	2 323,479	1 999,568	2 186,413	2 066,015

ammonia production – process and combustion, t CO_2 e								
Ammonia production, t	842,278	990,758	1 064,312	914,515	1 125,998	948,207	1 051,062	994,885
Ammonia production IEF – process	2.11	2.06	2.05	2.14	2.06	2.10	2.08	2.07
Ammonia production IEF – process and combustion	2.12	2.06	2.05	2.15	2.06	2.11	2.08	2.08

Total CO_2 emission from ammonia production (as reported in the CRF), amount of CO_2 in exported urea, CO_2 emitted from urea used in agriculture and urea-based catalyst are provided in the table below.

Table 4-14. Estimated CO_2 emissions from ammonia production, kt/year

Year	Total CO_2 emission	Exported CO_2	CO_2 emitted from urea application on soils	CO_2 emitted from the use of urea-based catalyst	Reported CO_2 emission
1990	1,289.4	NO	35.7	NO	1,253.7
1995	1,015.6	NO	6.7	NO	1,008.9
2000	1,053.7	NO	16.5	NO	1,037.2
2005	1,138.9	69.5	31.5	NO	1,037.9
2010	1,111.6	62.3	15.8	NO	1,033.5
2011	2,226.9	97.5	14.2	NO	2,115.2
2012	2,316.2	174.8	14.2	0.01	2,127.3
2013	1,776.7	75.4	15.8	0.02	1,685.5
2014	2,039.0	128.6	41.0	0.09	1,869.3
2015	2,182.6	118.7	18.0	0.15	2,045.8
2016	1,956.2	109.4	18.5	0.34	1,828.1
2017	2,320.9	163.2	14.0	0.56	2,143.0
2018	1,992.8	148.0	15.9	0.90	1,828.0
2019	2,183.0	177.0	15.8	1.05	1,989.3
2020	2,061.6	261.6	15.9	1.06	1,783.0

4.3.1.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Activity data uncertainty is assumed to be 2%;
- Emission factor uncertainty is assumed to be 2%;
- Combined uncertainty is 2.8%.

The data is consistent over the time-series. Natural gas consumption data, CO_2 recovered for urea production and annual average lower calorific values of the natural gas were provided by the production company.

4.3.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission. The consistency check of reported emissions in the greenhouse gas inventory with data of EU ETS is performed every year as it is required in Regulation No 525/2013 of the European Parliament. Emissions differences in GHG inventory and ETS reports are mainly due to CO_2 from ammonia production recovered for downstream use is excluded from the reporting in category 2.B.1 in GHG inventory, but not in ETS report due to different methodological requirements.

4.3.1.5 Category-specific recalculations

Following recalculations in this category have been done:

- recalculation of CO_2 emissions from urea application (year 2019) in agriculture sector (see Chapter 5.10);

Table 4-15. Reported in previous submission and recalculated CO_2 emissions from ammonia production

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2019	1,988.8	1,989.3	0.42	0.02

4.3.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.3.2 Nitric Acid Production (CRF 2.B.2)

4.3.2.1 Category Description

Nitric acid is produced by the single nitric acid producer in Lithuania. According to information provided by company, the nitric acid is produced in UKL-7 units and GP, GP-2 units by absorbing NO_2 with water. NO_2 is produced by air oxidation of NO with oxygen. Nitric oxide (NO) produced by air oxidation of ammonia with oxygen on Pt mesh catalyst. UKL-7 units are working by single pressure (high pressure) scheme. Gaseous emissions after absorption are cleaned from NO_x in a reactor. Grande Paroisse (GP) unit uses a dual-pressure scheme (medium/high). Gaseous emissions from GP are cleaned from NO_x in the reactor using a $DeNO_x$ technology. Grande Paroisse 2 (GP-2) nitric acid plant started in late autumn of 2015. This unit reduces energy costs and increases productions quantities.

Capacities:

At present company operates 9 UKL-7 units. The biggest capacity of one UKL-7 unit is 120 thous t/year (calculated to 100% HNO_3). Capacity of all UKL-7 units is 1,080 thous t/year. Capacity of GP unit is 360 thous t/year and capacity of GP-2 unit is 239 thous t/year. Total nitric acid production capacity is 1,679 thous t/year. Information on nitric acid production units operated during 1990-2019 period is provided in the table below.

Table 4-16. Nitric acid production units

Nitric acid production unit	1990-2002	2003	2004	2005-2008	2009-2014	2015-2020
UKL-1	operational	operational	operational	operational	operational	operational
UKL-2	operational	operational	operational	operational	operational	operational

UKL-3	operational	operational	operational	operational	operational	operational
UKL-4	operational	operational	operational	operational	operational	operational
UKL-5	operational	operational	operational	operational	operational	operational
UKL-6	operational	operational	operational	operational	operational	operational
UKL-7		operational	operational	operational	operational	operational
UKL-8				operational	operational	operational
UKL-9					operational	operational
GP			operational	operational	operational	operational
GP-2						operational

The Joint Implementation project was carried out by installing secondary catalyst in August 2008. The baseline campaign was launched from September 2007 to July 2008 during which emissions were monitored to determine the baseline emissions of the plant. After installing of the secondary catalyst, the first project campaign was launched and the Project emissions monitored until the end of the campaign – 26 September 2009.

BASF technology was applied by introducing a new catalyst bed which was installed in a new basket, directly under the Platinum gauze in the nitric acid reactors. The secondary catalyst (on Al_2O_3 basis with active metal oxides CuO and ZnO) was installed underneath the platinum gauze. In order to be able to install a secondary catalyst the reconstruction of a burner basket was performed.

Nitric acid production data were provided by the company (Figure below).

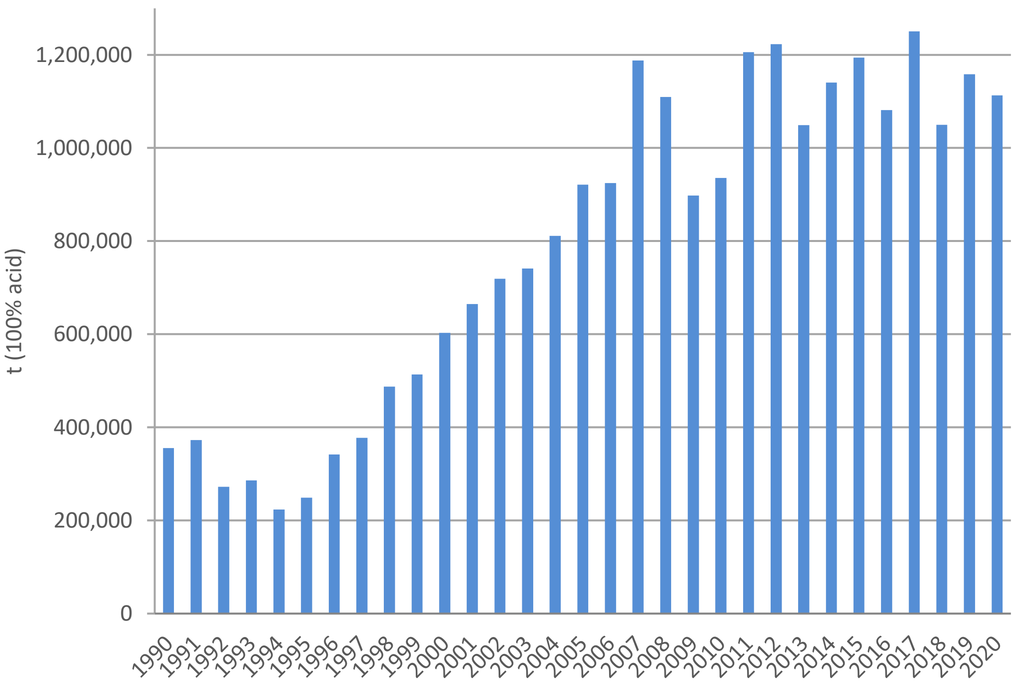


Figure 4-15. Nitric acid production

4.3.2.2 Methodological issues

N_2O emissions from the nitric acid production were estimated based on the following data:

- Annual production of nitric acid:
  - Data on the level of production plant (1990-2008).

  - Data on the level of production units (2009-2020).
- Production unit specific N_2O emission factors (Table 4-16):
  - Prior to installation of catalyst (2007-2008 monitoring campaign data).
  - After installation of catalyst (2009-2020).

For the years 2009-2020 production unit specific N_2O emission factors were obtained from the producer (Table 4-17). The emission factors are based on the data from the automated monitoring system (AMS) by the plant. Until October of 2016 the measurements were made in all 9 UKL-7 units. In order to achieve accuracy and control over the monitoring system the measurement points were transferred to two chimneys (ST-1 and ST-2) (Figure 4-16), in which emissions from nitric acid of nine UKL-7 units are discharged.

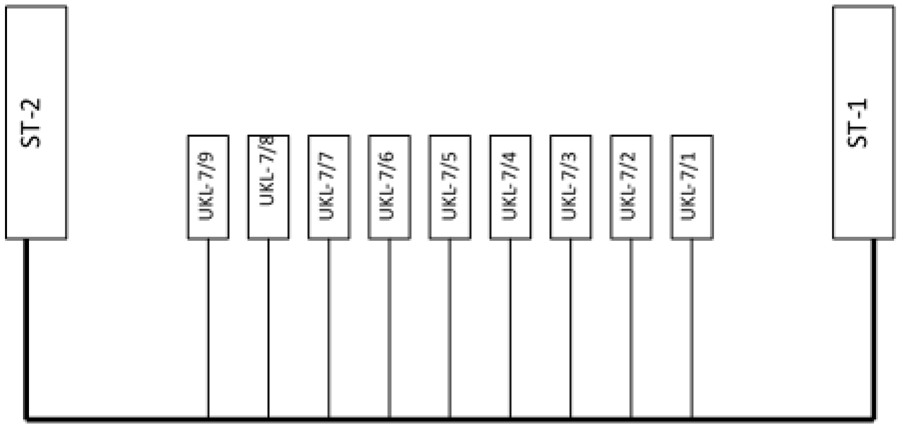


Figure 4-16. UKL-7 units monitoring system from October of 2016

Table 4-17. N_2O emission factors calculated using measured and registered data in automated monitoring system, kg N_2O/t HNO_3 (100%)

Production unit code	2007-2008*	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
UKL-1	9.63	1.72	1.86	1.87	1.62	1.77	1.79	1.44	0.88	NO	NO	NO	NO
UKL-2	9.51	1.43	1.42	1.65	1.71	1.31	1.08	0.84	0.80	NO	NO	NO	NO
UKL-3	5.45	2.22	2.92	2.16	1.32	1.18	1.87	1.06	1.00	NO	NO	NO	NO
UKL-4	7.73	1.88	2.40	1.68	0.77	0.72	0.97	1.16	0.69	NO	NO	NO	NO
UKL-5	6.61	2.07	1.87	1.69	1.43	1.39	1.19	1.01	0.89	NO	NO	NO	NO
UKL-6	10.34	3.73	3.51	2.65	2.48	0.88	1.01	0.79	0.87	NO	NO	NO	NO
UKL-7	9.09	2.70	1.54	1.16	1.64	0.95	0.66	0.81	0.66	NO	NO	NO	NO
UKL-8	6.96	2.35	1.58	1.50	1.18	0.42	0.71	0.55	0.41	NO	NO	NO	NO
UKL-9	NO	4.81	4.84	6.65	1.66	0.54	0.42	0.48	0.43	NO	NO	NO	NO
GP	8.83	1.17	0.96	2.32	1.63	1.26	0.76	0.33	0.39	0.59	0.43	0.25	0.16
GP-2	NO	NO	NO	NO	NO	NO	NO	0.70	0.89	0.33	0.45	0.43	0.29
ST-1	NO	NO	NO	NO	NO	NO	NO	NO	0.90	0.74	0.63	0.79	0.85
ST-2	NO	NO	NO	NO	NO	NO	NO	NO	0.74	0.67	0.66	0.58	0.57

* Data source: Report of the plant for the calculation of EU allowances for the third EU ETS period 2013-2020.

Annual emissions of N_2O from nitric acid production were estimated:

- 1990-2008: based on extrapolated unit specific activity data and the mean value of EFs of the actually operating units.
- 2009-2020: based on the results of continuous emissions monitoring.

For 1990-2008 emissions calculation production of nitric acid for each operational unit was extrapolated from the data on total annual production of nitric acid in a particular year based on information on unit-specific output (share of each production unit as % of the total production based on 2009-2010 data). Mean value of EFs of the actually operating production units is based on 2007-2008 measurements in automated monitoring system prior to installation of the catalyst.

For 2009-2020 N_2O emissions are based on the measurements carried out in automated monitoring system by the plant. The unit specific emission factors and unit specific production data provided by the producer. The installation of secondary catalyst let to the N_2O emission reduction.

Estimated emissions of N_2O from nitric acid production are provided in the table below.

Table 4-18. Estimated emissions of N_2O from nitric acid production

Year	N_2O emission, kt
1990	3.0
1995	2.1
2000	5.1
2005	7.8
2010	1.9
2011	2.9
2012	1.9
2013	1.1
2014	1.1
2015	0.9
2016	0.7
2017	0.8
2018	0.6
2019	0.6
2020	0.5

4.3.2.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgement:

- Activity data is provided by a single producer. Uncertainty is assumed to be 2%;
- Emission factor uncertainty is assumed to be 10%;
- Combined uncertainty is 10.2%.

4.3.2.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

Plant specific EFs are based on measurements carried out in automated monitoring system by the plant, therefore it is considered that those plant-specific EFs represent the best possible knowledge and are accurate.

4.3.2.5 Category-specific recalculations

No recalculations have been done.

4.3.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.3.3 Adipic Acid Production (CRF 2.B.3)

Emissions from adipic acid production are not occurring in Lithuania so for the category "CRF 2.B.3 Adipic Acid Production" notation key "NO" is used.

4.3.4 Caprolactum, Glyoxal and Glyoxylic Acid Production (CRF 2.B.4)

Emissions from caprolactum, glyoxal and glyoxylic acid production are not occurring in Lithuania so for the category "CRF 2.B.4 Caprolactum, Glyoxal and Glyoxylic Acid Production" notation key "NO" is used.

4.3.5 Carbide Production (CRF 2.B.5)

Emissions from carbide production are not occurring in Lithuania so for the category "CRF 2.B.5 Carbide Production" notation key "NO" is used.

4.3.6 Titanium Dioxide Production (CRF 2.B.6)

Emissions from titanium dioxide production are not occurring in Lithuania so for the category "CRF 2.B.6 Titanium Dioxide Production" notation key "NO" is used.

4.3.7 Soda Ash Production (CRF 2.B.7)

Emissions from soda ash production are not occurring in Lithuania so for the category "CRF 2.B.7 Soda Ash Production" notation key "NO" is used.

4.3.8 Petrochemical and Carbon Black Production (CRF 2.B.8)

This category is divided into six sub-categories: methanol production (CRF 2.B.8.a), ethylene production (CRF 2.B.8.b), ethylene dichloride and vinyl chloride monomer (CRF 2.B.8.c), ethylene oxide (CRF 2.B.8.d), acrylonitrile (CRF 2.B.8.e) and carbon black (CRF 2.B.8.f).

Methanol Production (CRF 2.B.8.a)

4.3.8.1 Category Description

There is a single methanol production company in Lithuania. According to information provided by the company, methanol was produced from the CO, CO_2 and H_2. The medium temperature technological scheme was used in which methanol synthesis reactions are carried out in 8.0 MPa and 180-280°C. Gases required for methanol synthesis are generated by converting natural gas. Project capacity of methanol unit is 74,000 t/year.

Methanol production data (Figure 4-17) 1990-2008 were obtained from Statistics Lithuania publications[14]. According to company data methanol was not produced in 1999. The company is not producing methanol since 2008 due to economic reasons (high natural gas prices, competitiveness issues) and there are no plans to renew methanol production in the future.

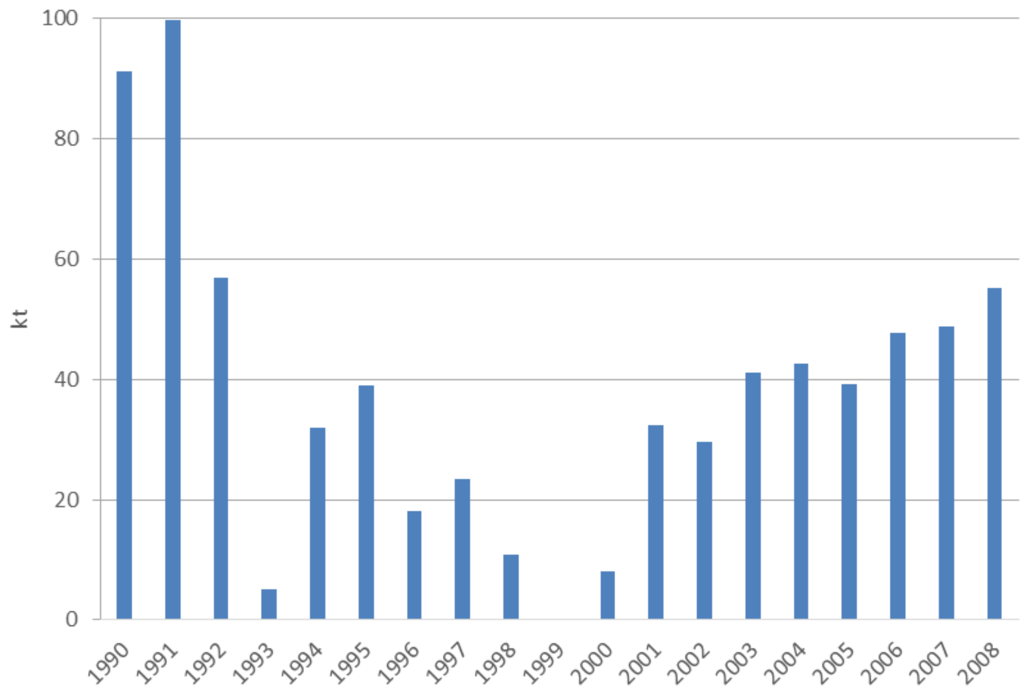


Figure 4-17. Methanol production

Ethylene (CRF 2.B.8.b)

Emissions from ethylene production are not occurring in Lithuania so for the category "CRF 2.B.8.b Ethylene" notation key "NO" is used.

Ethylene Dichloride and Vinyl Chloride Monomer (CRF 2.B.8.c)

Emissions from ethylene dichloride and vinyl chloride monomer production are not occurring in Lithuania so for the category "CRF 2.B.8.b Ethylene Dichloride and Vinyl Chloride Monomer" notation key "NO" is used.

Ethylene Oxide (CRF 2.B.8.d)

Emissions from ethylene oxide production are not occurring in Lithuania so for the category "CRF 2.B.8.d Ethylene Oxide" notation key "NO" is used.

Acrylonitrile (CRF 2.B.8.e)

Emissions from acrylonitrile production is not occurring in Lithuania so for the category "CRF 2.B.8.e Acrylonitrile" notation key "NO" is used.

Carbon Black (CRF 2.B.8.f)

[14] Database of Statistics Lithuania

Emissions from carbon black production is not occurring in Lithuania so for the category "CRF 2.B.8.d Carbon Black" notation key "NO" is used.

4.3.8.2 Methodological issues

Methanol production (CRF 2.B.8.a)

CH_4 emissions were calculated from methanol production data using emission factor 2.3 kg CH_4 per tonne of produced methanol taken from the *2006 IPCC Guidelines* (Volume 3, Part 1, p. 3.74). Estimated emissions of CH_4 (kt/year) from methanol production are provided in the table below.

CO_2 emissions were calculated from methanol production data using default emission factor 0.267 tonne CO_2 per tonne of produced methanol taken from the *2006 IPCC Guidelines* (Volume 3, Part 1, Table 3.12, p. 3.73). Estimated emissions of CO_2 (kt/year) from methanol production are provided in the table below.

Table 4-19. Estimated emissions of CH_4 and CO_2 from methanol production

Year	CH_4, kt	CO_2, kt
1990	0.210	24.35
1995	0.090	10.41
2000	0.019	2.15
2005	0.090	10.47
2009-2020	NO	NO

4.3.8.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Activity data was obtained from Statistics Lithuania publications. Uncertainty is assumed to be 5%;
- Emission factor uncertainty is assumed to be 30%;
- Combined uncertainty is 30.4%.

Data is consistent over the time-series. Methanol production activity data 1990-2008 was obtained from Statistics Lithuania publications. According to the production company no methanol was produced in 1999, 2009-2020.

4.3.8.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.3.8.5 Category-specific recalculations

No recalculations have been done.

4.3.8.6 Category-specific planned improvements

Category-specific improvements are not planned. NO

4.3.9 Fluorochemical Production (CRF 2.B.9)

Fluorochemical production category is divided into two sub-categories: by-product emissions (CRF 2.B.9.a) and fugitive emissions (CRF 2.B.9.b). Emissions from by-product emissions (CRF

2.B.9.a) and fugitive emissions (CRF 2.B.9.b) sub-categories are not occurring in Lithuania so for these sub-categories notation key "NO" is used.

4.3.10 Other (CRF 2.B.10)

Emissions from other production are not occurring in Lithuania so for the category "CRF 2.B.10 Other" notation key "NO" is used.

4.4 Metal industry (CRF 2.C)

In Lithuanian GHG inventory this category includes non-fuel emissions of CO_2 from cast iron production (Table 4-20).

Table 4-20. Reported emissions under the category metal industry

CRF	Source	Emissions reported	Methods	Emission factor
2.C.1.f	Iron and steel production	CO_2	Tier 2	D

Steel, sinter, coke, ferroalloys, aluminium, magnesium, lead and zinc are not produced in Lithuania. Emissions from cast iron production in 2020 were 0.04 kt CO_2 eq., and it was only 0.001% of industry sector's emissions.

4.4.1 Iron and Steel Production (CRF 2.C.1)

4.4.1.1 Category Description

There were three companies producing cast iron until 2009. Only pig iron scrap was used as raw material. The largest company was producing cast iron in induction furnace, but it went bankrupt in 2010. The other two companies are still operating and one is producing cast iron in blast furnace and the other was producing cast iron in blast furnace until 2011, after 2011 it has been using induction furnace. In the blast furnance cast iron is made by remelting scrap pig iron along with coke and limestone. In the induction furnace only limestone is added.

Estimated CO_2 emissions from the cast iron production are shown in the figure below.

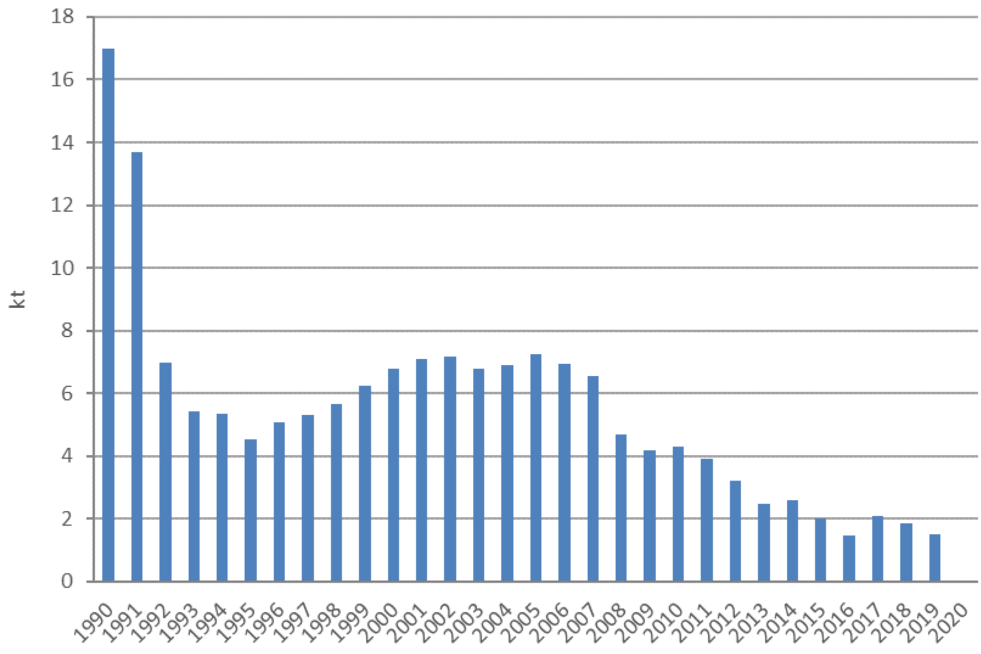


Figure 4-18. CO_2 emissions from the cast iron production

The reason of declining trend after 2011 is that one of the cast iron producing companies have decreased the amount of production due to economic reasons.

4.4.1.2 Methodological issues

The CO_2 emissions from the cast iron production were estimated based on the following data:

- Annual production of cast iron (Statistics Lithuania[15] data (1990-2009) and the producing companies data since 2010).
- Coke consumption (the companie`s data for period 1990-2020).
- Limestone consumption in blast furnace:
  - data on consumed amount of limestone for period 2003-2020 (the company data);
  - amount of limestone consumed for 1 tonne cast iron produced (85 kg/t cast iron, the company data).
- Limestone consumption in induction furnace:
  - data on consumed amount of limestone for 2006-2020 (the company data);
  - amount of limestone consumption for 1 tonne cast iron produced (10 kg/t cast iron, the company data).
- Carbon content of consumed pig iron scrap and produced cast iron (the company data).

CO_2 emissions from the cast iron production were calculated by Tier 2 method using following modified *2006 Guidelines IPCC* equation (*2006 IPCC Guidelines*, Volume 3, Part 1, p. 4.22):

$$E_{CO2,non-energy} = [PI \times C_{PI} + PC \times C_{PC} + L \times C_L - CI \times C_{CI}] \times \frac{44}{12}$$

where:

PI - quantity of pig iron consumed in cast iron production, tonnes. (The amount of used pig iron is based on the literature[16]. It was assumed that reduction of the quantity of produced cast iron is 2%);

C_{PI} - carbon content for pig iron scrap consumed (0.04 tonnes C/tonne, the company data);

PC - quantity of coke consumed in cast iron production, tonnes;

C_{PC} - carbon content for coke consumed (default – 0.83 tonnes C/tonne);

L - quantity of limestone consumed in cast iron production, tonnes;

C_L - carbon content for limestone consumed (default – 0.12 tonnes C/tonne);

CI - quantity of produced cast iron, tonnes;

C_{CI} - carbon content for produced cast iron (0.03 tonnes C/tonne, the company data).

4.4.1.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

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[15] Database of Statistic Lithuania

[16] H S Bawa Manufacturing Processes – I

- Data on the total cast iron production for period 1990-2009 were taken from Statistics Lithuania and the data were provided by the production companies since 2010. Uncertainty of the activity data is assumed to be 10%;
- Emission factor uncertainty is assumed to be 10%;
- Combined uncertainty is 14.1%.

Data is consistent over the time-series.

4.4.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.4.1.5 Category-specific recalculations

No recalculations have been done.

4.4.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.4.2 Ferroalloys Production (CRF 2.C.2)

Emissions from ferroalloys production are not occurring in Lithuania so for the category "CRF 2.C.2 Ferroalloys Production" notation key "NO" is used.

4.4.3 Aluminium Production (CRF 2.C.3)

Emissions from aluminium production are not occurring in Lithuania so for the category "CRF 2.C.3 Aluminium Production" notation key "NO" is used.

4.4.4 Magnesium Production (CRF 2.C.4)

Emissions from magnesium production are not occurring in Lithuania so for the category "CRF 2.C.4 Magnesium Production" notation key "NO" is used.

4.4.5 Lead Production (CRF 2.C.5)

Emissions from lead production are not occurring in Lithuania so for the category "CRF 2.C.5 Lead Production" notation key "NO" is used.

4.4.6 Zinc Production (CRF 2.C.6)

Emissions from zinc production are not occurring in Lithuania so for the category "CRF 2.C.6 Zinc Production" notation key "NO" is used.

4.4.7 Other (CRF 2.C.7)

Emissions from other production are not occurring in Lithuania so for the category "CRF 2.C.7 Other" notation key "NO" is used.

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

This category includes emissions from lubricant use, paraffin wax use, urea-based catalyst, solvent use, asphalt roofing and road paving with asphalt (Table 4-21).

Table 4-21. Reported emissions under the category non-energy products from fuels and solvent use

CRF	Source	Emissions reported	Methods	Emission factor
2.D.1	Lubricant use	CO_2	Tier 1	D
2.D.2	Paraffin wax use	CO_2	Tier 1	D
2.D.3	Urea-based catalysts	CO_2	Tier 3	D
2.D.3	Solvent use	CO_2	Tier 1	CR
2.D.3	Asphalt roofing	CO_2	Tier 1	CR
2.D.3	Road paving with asphalt	CO_2	Tier 1	CR

4.5.1 Lubricant use (CRF 2.D.1)

4.5.1.1 Category Description

The Statistics Lithuania provides data on non-energy use of lubricants in Energy Balance (see Annex III). There is no subdivision of lubricants into oils and greases in Energy Balance. Data on consumption of lubricants is available for 1990-2020 and is shown in the figure below.

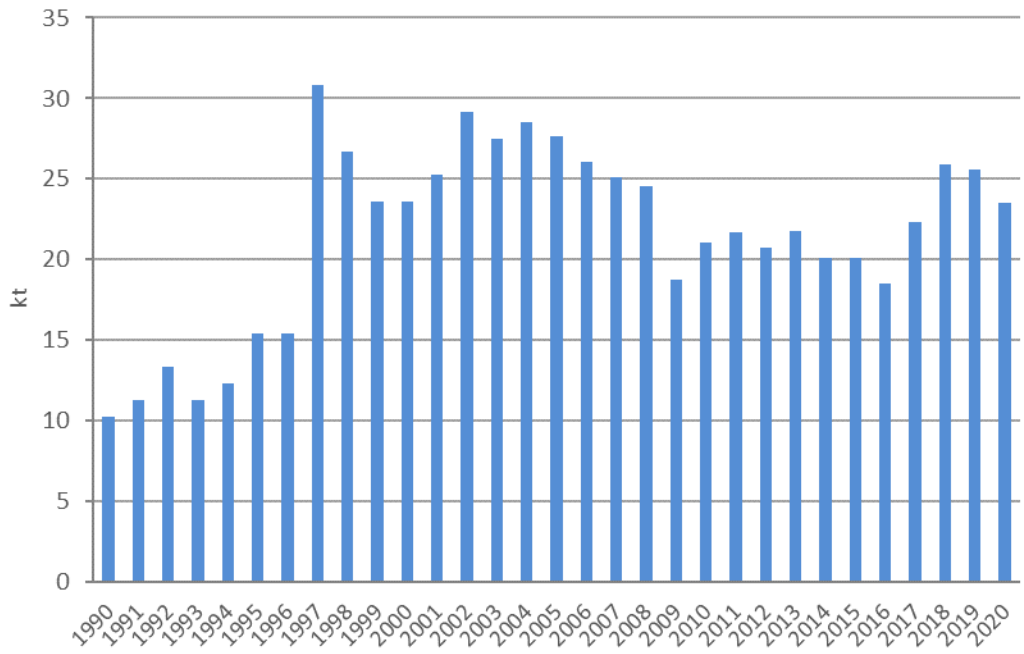

Figure 4-19. Consumption of lubricants for non-energy purposes

4.5.1.2 Methodological issues

CO_2 emission calculations are based on total consumption of lubricants, the default carbon content and ODU factors. Emissions are calculated according to following equation (*2006 IPCC Guidelines*, Volume 3, Part 2, p. 5.7):

$$CO_2 Emissions = LC \times CC_{Lubricant} \times ODU_{Lubricant} \times 44/12$$

where

LC - total lubricant consumption, TJ;

$CC_{Lubricant}$ - carbon content of lubricants (default – 20 C/TJ);

$ODU_{Lubricants}$ - amount of lubricants oxidised during use factor (default – 0.2);

44/12 - mass ratio of CO_2/C.

Estimated CO_2 emissions from use of lubricants are provided in the table below.

Table 4-22. Estimated CO_2 emissions from use of lubricants

Year	CO_2 emission, kt
1990	6.1
1995	9.1
2000	13.9
2005	16.3
2010	12.4
2011	12.8
2012	12.2
2013	12.8
2014	11.8
2015	11.9
2016	10.9
2017	13.1
2018	15.3
2019	15.1
2020	13.9

4.5.1.3 Uncertainties and time-series consistency

Activity data was obtained from Statistics Lithuania publications. Uncertainty is assumed to be 5%. Emission factor uncertainty is assumed to be 50.1% and combined uncertainty is 50.3%.

Data is consistent over the time-series. Data on consumption of lubricants for all period was obtained from Statistics Lithuania.

4.5.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.5.1.5 Category-specific recalculations

Following recalculations in this category have been done:

- recalculation of CO_2 emissions from lubricants use (year 2019) due to updated statictical activity data on consumption of lubricant oil for non energy purposes.

Table 4-23. Reported in previous submission and recalculated CO_2 emissions from use of lubricants

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2019	15.59	15.09	-0.50	-3.20

4.5.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

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

4.5.2.1 Category Description

The Statistics Lithuania provides data on non-energy use of paraffin wax in Energy Balance (see Annex III). Data on consumption of paraffin wax was provided by Statistics Lithuania for the period 2001-2020, although the activity was observed in the period 1990-2000, the data was not available. Therefore, for the period 1990-2000 it is assumed that consumption of paraffin wax use was the same as in 2001-2002. Paraffin wax is used in the production of candles, wood and furniture, therefore the consumption of paraffin wax in the 2002-2020 varies with manufacture demand (Figure 4-20).

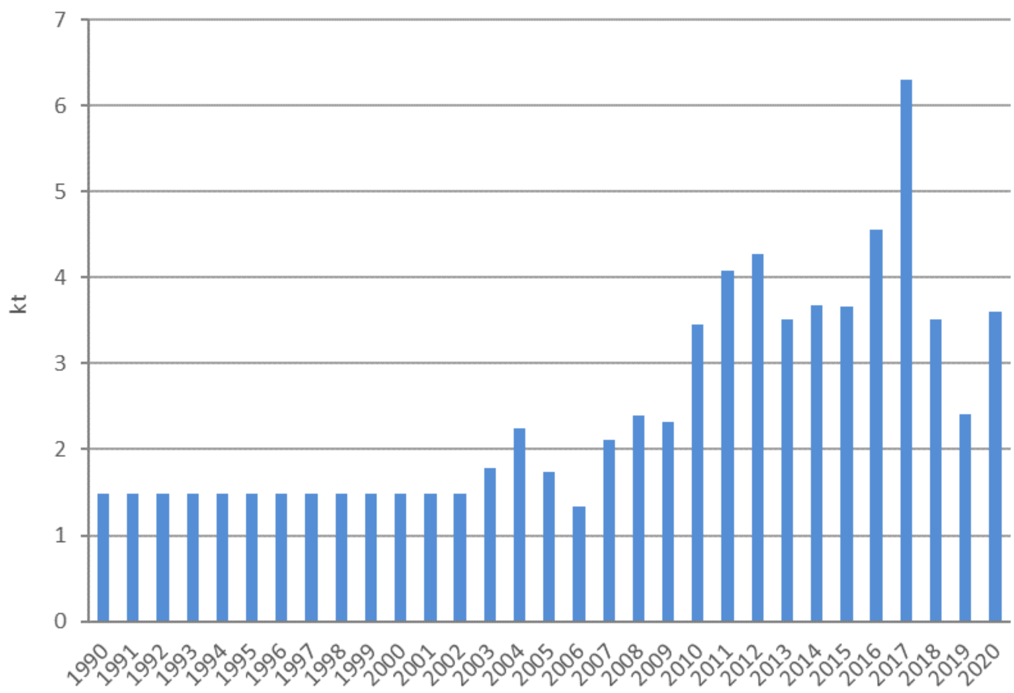

Figure 4-20. Consumption of paraffin wax for non-energy purposes

4.5.2.2 Methodological issues

CO_2 emission calculations are based on total consumption of paraffin wax, the default carbon content and ODU factors. Emissions are calculated according to following equation (*2006 IPCC Guidelines*, Volume 3, Part 2, p. 5.11):

$$CO_2 Emissions = PW \times CC_{Wax} \times ODU_{Wax} \times 44/12,$$

where

PW - total wax consumption, TJ;

CC_{Wax} - carbon content of paraffin wax (default – 20 C/TJ);

ODU_{Wax} - amount of paraffin wax oxidised during use factor (default – 0.2);

44/12 - mass ratio of CO_2/C.

Estimated CO_2 emissions from use of paraffin wax are provided in the table below.

Table 4-24. Estimated CO_2 emissions from use of paraffin wax

Year	CO_2 emission,kt
1990	0.9
1995	0.9
2000	0.9
2005	1.0
2010	2.0
2011	2.4

2012	2.5
2013	2.1
2014	2.2
2015	2.2
2016	2.7
2017	3.7
2018	2.1
2019	1.4
2020	2.3

4.5.2.3 Uncertainties and time-series consistency

Activity data was obtained from Statistics Lithuania publications. Uncertainty is assumed to be 5%. Emission factor uncertainty is assumed to be 100% and combined uncertainty is 100.2%.

Data is consistent over the time-series. Data on consumption of paraffin wax was obtained from Statistics Lithuania.

4.5.2.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.5.2.5 Category-specific recalculations

No recalculations have been done.

4.5.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.5.3 Other (CRF 2.D.3)

4.5.3.1 Category Description

This chapter describes emissions from Urea-based catalysts, Solvent use, Asphalt roofing and Road paving with asphalt sub-sector under Other (CRF 2.D.3).

CO_2 emissions from urea-based catalysts

Information on CO_2 emissions from urea-based catalysts in transport is reported in the Energy sector in Chapter 3.5.3 (CO_2 emissions from urea-based catalysts) of the NIR under category CRF 1.A.3 Transport.

Solvent use

Solvent use contributes a small amount to the total GHG emissions in Lithuania. Share to the total emission was only 0.2% in 2020 (excl. LULUCF). Indirect CO_2 emission from NMVOC for the following subcategories was estimated:

- Domestic solvent use;
- Dry cleaning;
- Degreasing;
- Chemical products;
- Coating applications: paint application;
- Printing;

– Other solvent use and product use (tabacco consumption, use of shoes and wool production).

Asphalt roofing

There is a single company in Lithuania producing asphalt roofing materials. The company started operation in 2001 after reorganization of Soviet construction materials production company. Company produces bitumen tiles as well as roll roofing materials. Data on production of roofing materials was provided by the producer and is available for the period 2001-2020 (Table 4-25). The production of roll roofing materials was stopped from 2014 due to the import of the cheaper production from other countries.

Table 4-25. Production of asphalt roofing materials (thous m^2)

Year	Bitumen tiles	Roll roofing materials
2001	253	2,087
2005	3,157	4,488
2010	3,681	477
2011	3,265	573
2012	3,737	29
2013	3,743	0.001
2014	3,883	NO
2015	3,491	NO
2016	3,107	NO
2017	3,314	NO
2018	3,130	NO
2019	3,463	NO
2020	4,694	NO

According to the producer, asphalt roofing materials were also produced in 1990-2000 prior to reorganization of the company in 2001, but data for this period is not available.

Production of the asphalt roofing materials in 1990-2000 was estimated based on annual average use of bitumen. The period of time considered for averaging the use of bitumen was 2001-2010. Asphalt roofing production is provided in the figure below.

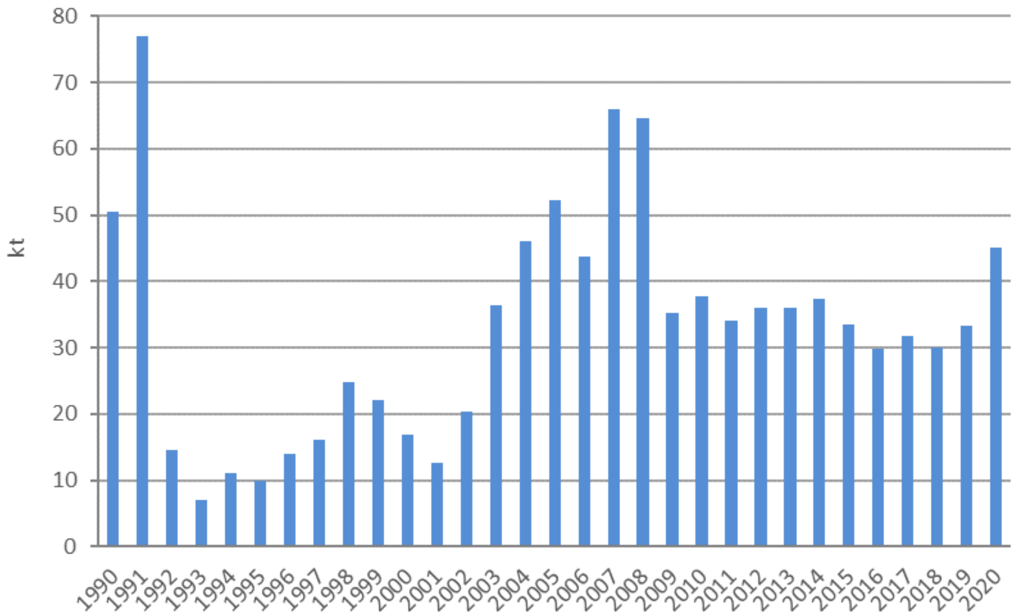

Figure 4-21. Production of asphalt roofing

Road paving with asphalt

Statistics Lithuania collects data on production of bitumen (data available for 2002-2020), but not on consumption of bitumen, therefore data available from Statistics Lithuania, was used to extrapolate consumption of bitumen for the period 2002-2006. To extrapolate data on the consumption of bitumen in 1990-2001 the data on installed, rebuilt and modified asphalt roads (1989-2000) were used. This data was taken from 2002-2015 program on the maintenance and development of the Lithuanian state roads.

The CO_2 emissions from this category are considered as insignificant (emissions are below 0.05% of the total inventory (without LULUCF) and they would not exceed 500 kt CO_2 eq. according to decision 24/CP.19, para. 37(b)), it was assumed that the consumption of bitumen for road paving with asphalt is constant at 100 kt per year. Consumption of bitumen in road industry is provided in the figure below.

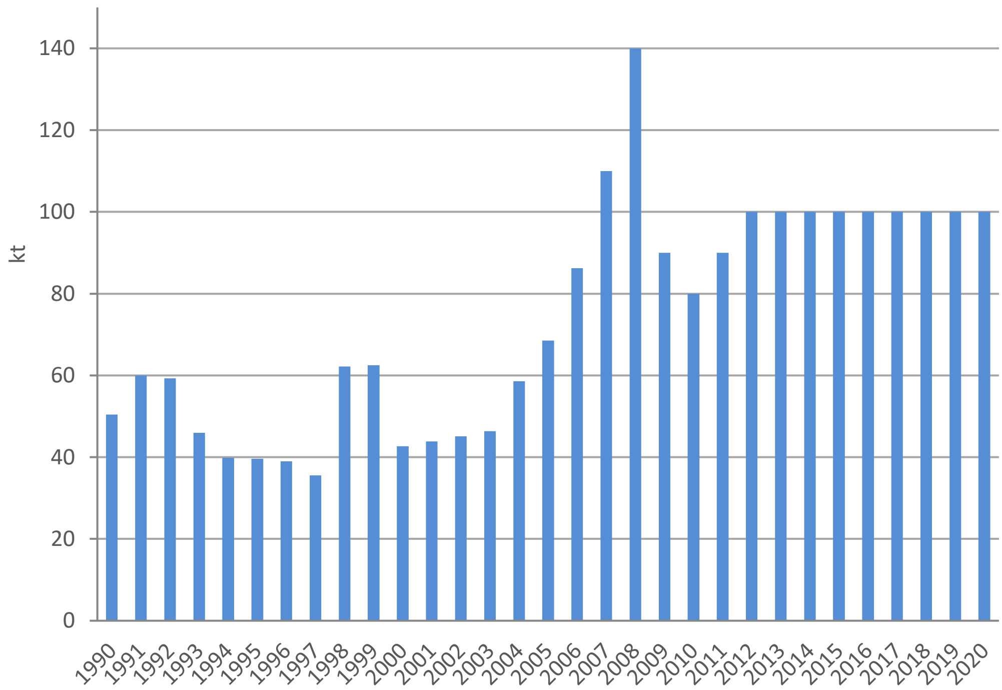

Figure 4-22. Consumption of bitumen

4.5.3.2 Methodological issues

Solvent use

CO_2 emission from Solvent use category have been calculated based on annual average population data, import, export and production data provided by the Statistics Lithuania and default emission factor proposed in EMEP/EEA air pollutant emission inventory guidebook.

NMVOC emission from *2D3a Domestic solvent use*, *2D3f dry cleaning*, *2D3e Degreasing* and *2D3g Chemical products* subcategories for the period 1990-2019 were estimated based on annual average population data provided by the Statistics Lithuania and default emission factor proposed in EMEP/EEA guidebook (respectively 1.2 kg/cap, 0.3 kg/cap, 0.7 kg/cap and 0.65 kg/cap).

Emission of NMVOC from *2D3d Coating application* subcategory for the years 1990-2004 was extrapolated (based on 2005-2019 data), as no data on production/import/export is available for this period. Since 2005 NMVOC emissions calculations have been based on production, import and export data (Lithuanian Statistics) and emission factor proposed in EMEP/ guidebook (250 g/kg).

Emission of NMVOC from *2D3h Printing* subcategory for the years 1990-2004 was extrapolated (based on 2008-2019 data), as no data on production/import/export is available for this period. Since 2005 NMVOC emissions calculations have been based on production, import and export data (Lithuanian Statistics) and emission factor proposed in EMEP/ guidebook (500 g/kg).

The calculations of emission of NMVOC from *2D3i Other solvent use and product use* subcategory on tabacco consumption (2000-2019) were based on average population data and cigarettes per inhabitant/year data provided by the Statistics Lithuania and emission factor proposed in EMEP/EEA guidebook (4.84 kg/t). The calculations of emission of NMVOC for years 1990-1999 was extrapolated according data of 2000-2019. The calculations of emission of NMVOC from use of shoes were based on average population data provided by the Statistics Lithuania and emission factor proposed in EMEP/EEA guidebook (60 g/pair). The calculations of emission of NMVOC from wool production are based on data provided by companies to EPA database.

CO_2 emissions from solvent use were calculated using the equation below.

$$\textit{Emission } CO_2 = \textit{Emission NMVOC} \times 0.6 \times 44/12$$

The default fossil carbon content fraction of NMVOC (2006 IPCC Guidelines, Volume 3, part 2, p. 5.17) was used for all subcategories under sector of solvent use.

CO_2 and NMVOC emissions from solvent use are pr esented in the table below.

Table 4-26. CO_2 and NMVOC emissions (kt) from solvent use

Year	CO_2 emission	NMVOC emission
1990	34.33	15.60
1995	35.01	15.91
2000	35.34	16.06
2005	38.09	17.31
2010	32.36	14.71
2011	31.74	14.43
2012	29.71	13.50
2013	27.41	12.46
2014	31.95	14.52
2015	34.97	15.90
2016	35.60	16.18
2017	36.07	16.40
2018	37.93	17.24
2019	41.68	18.94
2020	37.75	17.16

Asphalt roofing

Weight of the asphalt roofing material was calculated using area to weight ratio provided by the production company: 9.6 kg/m^2 for bitumen tiles and 4.9 kg/m^2 for roll roofing material. Amount of bitumen used for production of asphalt roofing is 2 kg/m^2 for bitumen tiles and 2.6 kg/m^2 for roll roofing.

Production of the asphalt roofing materials in 1990-2000 was estimated based on annual average use of bitumen. During the period between 2001 and 2010 production of asphalt roofing materials annually consumed on average 13% of the bitumen used for non-energy uses. Data on bitumen use for non-energy uses was obtained from energy balance by Statistics Lithuania. It was also assumed that only roll roofing was produced in 1990-2000.

Emissions of non-methane volatile organic compounds (NMVOC) from asphalt roofing were calculated from the national data on the total mass of production. Default emission factor of 0.13 kg NMVOC per tonne product was used (*EMEP/EEA*, 2.D.3.c Asphalt roofing, Table 3.1, p.7).

Estimated NMVOC emissions form asphalt roofing production were converted to CO_2 equivalent assuming that NMVOC contain 80% carbon by weight (*2006 IPCC Guidelines*, Volume 3, part 2, page 5.16). Estimated NMVOC and CO_2 eq. emissions from asphalt roofing production are shown in the table below.

Table 4-27. Estimated NMVOC and CO_2 eq. emissions from asphalt roofing production

Year	NMVOC, kt	CO_2 eq., kt
1990	0.0066	0.0192
1995	0.0013	0.0038
2000	0.0022	0.0065
2005	0.0068	0.0199
2010	0.0049	0.0144
2011	0.0044	0.0130
2012	0.0047	0.0137
2013	0.0047	0.0137
2014	0.0048	0.0142
2015	0.0044	0.0128
2016	0.0039	0.0114
2017	0.0041	0.0121
2018	0.0039	0.0115
2019	0.0043	0.0127
2020	0.0059	0.0172

Road paving with asphalt

NMVOC emissions from road paving with asphalt are calculated based on annual consumption of bitumen. NMVOC emission was calculated using default emission factor 0.016 kg/tonne of asphalt (*EMEP/EEA*, 2.D.3.b Road paving with asphalt, Table 3.1, p.8).

Estimated NMVOC emissions from road paving with asphalt were converted to CO_2 eq. assuming that NMVOC contain 45% carbon by mass (*2006 IPCC Guidelines*, Volume 3, part 2, p. 5.16). Estimated NMVOC and CO_2 eq. emissions from road paving with asphalt are shown in the table below.

Table 4-28. Estimated NMVOC and CO_2 eq. emissions from road paving with asphalt

Year	NMVOC, kt	CO_2 eq., kt
1990	0.001	0.001
1995	0.001	0.001
2000	0.001	0.001

2005	0.001	0.002
2010	0.001	0.002
2011	0.001	0.002
2012	0.002	0.003
2013	0.002	0.003
2014	0.002	0.003
2015	0.002	0.003
2016	0.002	0.003
2017	0.002	0.003
2018	0.002	0.003
2019	0.002	0.003
2020	0.002	0.003

4.5.3.3 Uncertainties and time-series consistency

Solvent use

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Uncertainty of activity data is assumed to be 30%;
- Emission factor uncertainty is assumed to be 20%;

Combined uncertainty is 36%.

Asphalt roofing

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- The data on production of asphalt roofing materials and raw materials consumption obtained from the production company are reliable and precise. However, they cover only the period after reconstruction of the plant (from 2001). Historic data for 1990-2000 are expert evaluation and may be less reliable. It was assumed that overall uncertainty of asphalt roofing activity data is 5%;
- Emission factor uncertainty is assumed to be 25%;
- Combined uncertainty is 25.4%.

Data on production of roofing materials was provided by the producer and is available for the period 2001-2020. Production of the asphalt roofing materials in 1990-2000 was estimated based on annual average use of bitumen.

Road paving with asphalt

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- The data on consumption of bitumen obtained from the European Asphalt Pavement Association are reliable. However, it covers only the period 2007-2015. Historic data for 1990-2006 are expert evaluation and may be less reliable. It was assumed that overall uncertainty of road paving with asphalt activity data is 20%;
- Emission factor uncertainty is assumed to be 50%;
- Combined uncertainty is 53.8%.

4.5.3.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.5.3.5 Category-specific recalculations

No recalculations have been done.

4.5.3.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.6 Electronics industry (CRF 2.E)

This section covers emissions of sulphur hexafluoride (SF_6) from semiconductor and nitrogen trifluoride (NF_3) from photovoltaics production (Table 4-29).

Table 4-29. Reported emissions under the category Electronics industry

CRF	Source	Emissions reported	Methods	Emission factor
2.E.1	Integrated Circuit or Semiconductor	SF_6	Tier 3	PS
2.E.3	Photovoltaics	NF_3	Tier 2	PS

There is one company in Lithuania, which produces semiconductors and there is one company, which is manufacturer of high efficiency solar cells. In 2020 the emissions from electronic industry were estimated at 9.54 kt CO_2 eq.

4.6.1 Integrated Circuit or Semiconductor (CRF 2.E.1)

4.6.1.1 Category Description

There is one company in Lithuania which produces semicondutors. The company's authorities informed that in 2008 company started to use SF_6 gas, so the emission data are only available for the period 2008-2020. 50% of emissions are released into environment. Emissions from semiconductors fluctuation are highly related to economic situation and production demand. The company has confirmed that PFCs and NF_3 were not used during the production of semiconductors in Lithuania.

4.6.1.2 Methodological issues

Emissions of SF_6 from semiconductor manufacturing were calculated using the following modified equation (*2006 IPCC Guidelines* Volume 3, p. 3.104):

$$E_{SF_6,t} = F_{SF_6,t} \times C_i$$

where:

F_{SF6}, t - quantity of HFCs used by the company in year t, t;

C_i - emission factor during production.

Estimates of SF_6 emissions from semiconductor manufacture are demonstrated in the figure and table below.

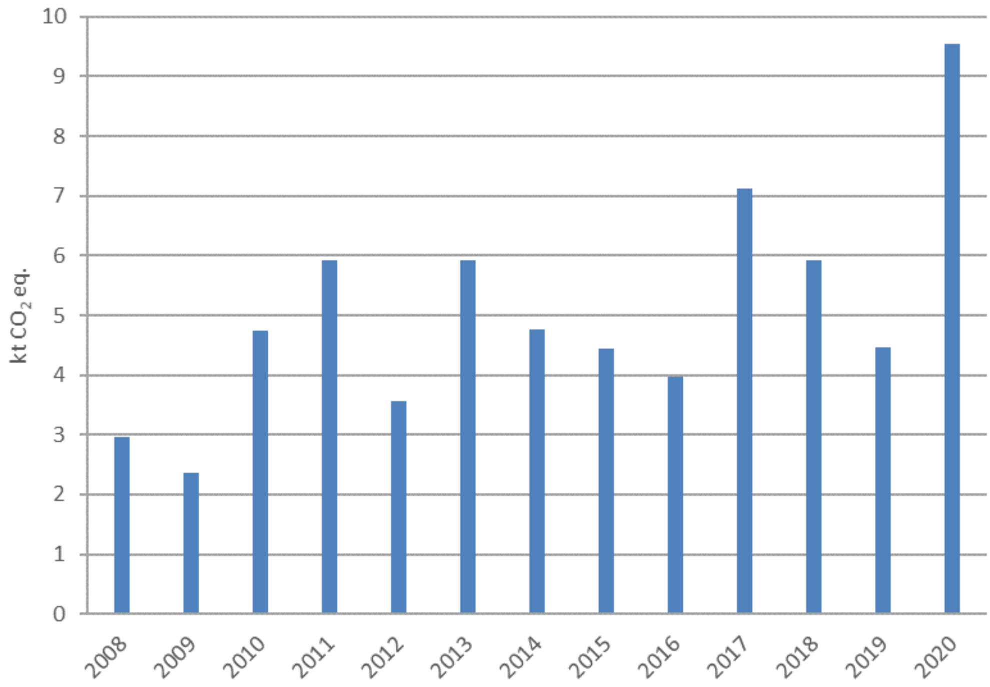

Figure 4-23. SF_6 emissions from semiconductor manufacture

Table 4-30. SF_6 emissions from semiconductor manufacture

Year	Emissions, kt CO_2 eq.
2008	2.96
2010	4.74
2011	5.93
2012	3.56
2013	5.93
2014	4.75
2015	4.45
2016	3.97
2017	7.11
2018	5.93
2019	4.46
2020	9.54

In 2017 production volumes were 1.6 times higher than in 2016, so the emissions in 2017 were higher than in 2016. In 2020 the production volume increased due to increased demand of the production.

4.6.1.3 Uncertainties and time-series consistency

Emission uncertainty was estimated using Approach 1 of the *2006 IPCC Guidelines* Volume 1 (p. 3.27):

- Input data uncertainty is assumed to be 5%;
- EF during operation uncertainty is assumed to be 5%;
- Total emission uncertainty is assumed to be 7%.

4.6.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.6.1.5 Category-specific recalculations

No recalculations have been done.

4.6.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.6.2 TFT Flat Panel Display (CRF 2.E.2)

Fluorinated compounds (FC) emissions from TFT flat panel display production are not occurring in Lithuania so for the category "CRF 2.E.2 TFT Flat Panel Display" notation key "NO" is used.

4.6.3 Photovoltaics (CRF 2.E.3)

4.6.3.1 Category Description

The single company in Lithuania is producing high efficiency solar cells. The company owns the latest manufacturing equipment and advanced industrial facilities with an annual capacity of 80 MW from PV cells and 50 MW from Glass/Glass modules. 100% of raw materials used in companies PV cell manufacturing are provided by European suppliers. The company holds the complete production chain of PV cells of finished Glass/Glass modules. In its production activities only NF_3 gases are used. CF_4 and C_2F_6 emissions are not occurring in this category.

4.6.3.2 Methodological issues

During year 2019 NF_3 gases has not been consumed. One of the solar cell production processes is deposition of antireflective SiNx layer by Plasma Enhanced Chemical Vapour Deposition (PECVD) method. NF_3 is used as cleaning agent for process chambers of PECVD equipment. This equipment is connected to the burner scrubber on the outlet of the vacuum pump. All waste gases generated after chemical vapor deposition process and cleaning step (including NF_3) are diluted in nitrogen and cleaned via burning, wet scrubbing and aerosol retention.

Burning

The gases requiring disposals are called waste gases and they are exposed to a natural gas/compressed air flame. At a temperature of over 1000^0 C the reaction products and process gases remaining in the waste gas are either burned or thermally decomposed and converted into products that can be wet scrubbed.

Wet Scrubbing

After leaving the burner unit the waste gases are led to a scrubber column. Components that are soluble or react with the washing liquid are wet scrubbed and neutralized at waste water treatment (WWT) plant. The drain of the scrubber is connected to the waste water treatment plant. Dust particles are retained from the waste gas and are removed with the washing liquid. After burning and wet scrubbing procedure the gas, which is fed into exhaust system is designated clean gas.

Company's authorities informed that the efficiency of the cleaning device is 99%, which means that only 1% of NF_3 is released to the environment. Moreover, company informed that during production it is possible that small amounts of CF_4 may be formed or small amounts of unreacted NF_3 may remain, but after the end of the production process remaining emissions are immediately incinerated and subsequently neutralized with alkali. According to the company's authorities NF_3 has been used only since 2013.

Estimates of NF_3 emissions from photovoltaics are demonstrated in the figure and table below.

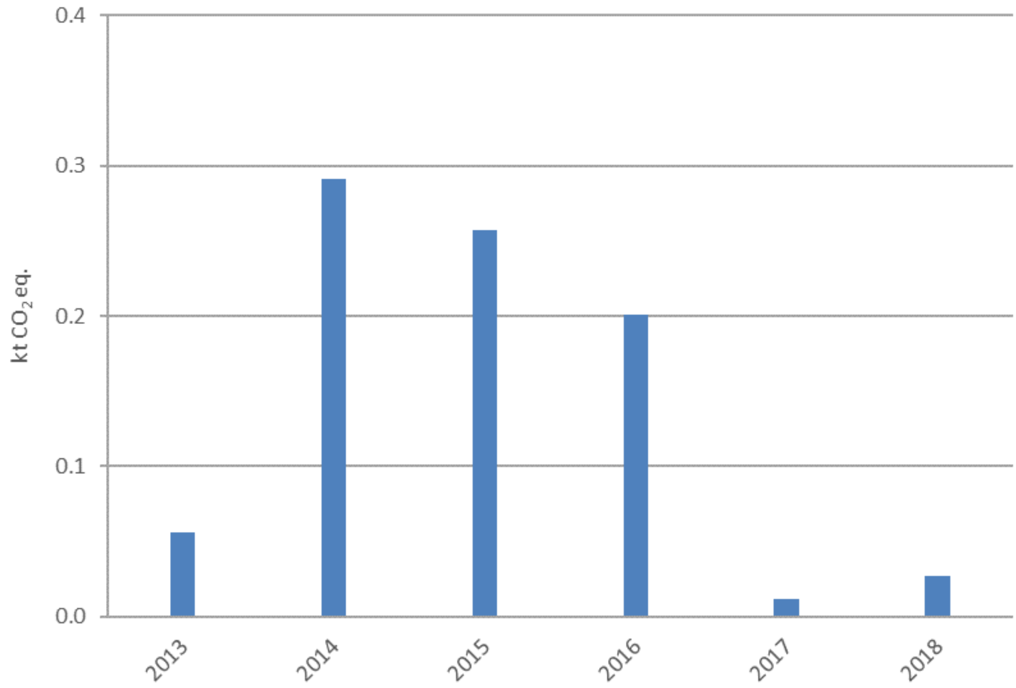

Figure 4-24. NF_3 emissions from photovoltaics production

Table 4-31. NF_3 emissions from photovoltaics production

Year	Emissions, kt CO_2 eq.
2013	0.06
2014	0.29
2015	0.26
2016	0.20
2017	0.01
2018	0.03
2019-2020	NO

The company did not carry out any production activities in 2017, and NF_3 gases were used only in scientific experimental activities. In 2018 the company continued scientific experimental activities and partially carried out production. The company did not carry out any production activities in 2019-2020.

4.6.3.3 Uncertainties and time-series consistency

Emission uncertainty was estimated using *2006 IPCC Guidelines*, Volume 3, p. 6.25:

- Input data uncertainty is assumed to be 5%;
- EF during operation uncertainty is assumed to be 20%;

– Total emission uncertainty is assumed to be 21%.

4.6.3.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.6.3.5 Category-specific recalculations

No recalculations have been done.

4.6.3.6 Category-specific planned improvements

Category-specific improvements are not planned.

FC emissions from heat transfer fluid production are not occurring in Lithuania so for the category "CRF 2.E.4 Heat Transfer Fluid" notation key "NO" is used.

4.6.1 Other (CRF 2.E.5)

FC emissions from other production are not occurring in Lithuania so for the category "CRF 2.E.5 Other" notation key "NO" is used.

4.7 Product Uses as Substitutes for Ozone Depleting Substances (CRF 2.F)

This section covers emissions of hydrofluorocarbons (HFCs) from Commercial Refrigeration (2.F.1.a), Domestic Refrigeration (2.F.1.b), Industrial Refrigeration (2.F.1.c), Transport Refrigeration (2.F.1.d), Mobile Air-Conditioning (2.F.1.e), Stationary Air-Conditioning (2.F.1.f), Closed Cells (2.F.2.a), Fire Protection (2.F.3) and Metered Dose Inhalers (2.F.4.a)(Table 4-32).

Table 4-32. Reported emissions under the category Product Uses as Substitutes for Ozone Depleting Substances

CRF	Source	Emissions reported	Methods	Emission factor
2.F.1.a	Commercial Refrigeration	HFCs	Tier 2	D
2.F.1.b	Domestic Refrigeration	HFCs	Tier 2	D, PS
2.F.1.c	Industrial Refrigeration	HFCs	Tier 2	D
2.F.1.d	Transport Refrigeration	HFCs	Tier 2	D, PS
2.F.1.e	Mobile Air-Conditioning	HFCs	Tier 2	CS, D
2.F.1.f	Stationary Air-Conditioning	HFCs	Tier 2	D
2.F.2.a	Closed Cells	HFCs	Tier 2	D
2.F.3	Fire Protection	HFCs	Tier 1b	D
2.F.4.a	Metered Dose Inhalers	HFCs	Tier 1a	D

Hydrofluorocarbons (HFCs) are used as alternatives to chlorofluorocarbons (CFCs), ozone depleting substances being phased out under the Montreal Protocol. Emissions of HFCs occur as leakage from the charge of equipment, its use and from the destruction of such equipment at the end of life.

The main data source for fluorinated gases emissions calculations is Environmental Protection Agency (EPA) F-gases database. According to the Order of the Minister of Environment No. D1-12/2006 (as amended in 2015 by MoE Order No. D1-394) operators are obliged to report on fluorinated gases and mixtures, they had used, imported/exported and put on the market last year. The operators also has to notify EPA about the equipment fluorinated gases or blends of fluorinated gases.

As there are still data drawbacks in some sub-sectors, this is the reason why studies were carried out for specific sub-sectors and used as a supplementary data source for calculations. A study "Analysis of the use of fluorinated greenhouse gases in Lithuania in 1990-2011" was carried out in 2012. The project was financed from the national sources. The results of the study were partly used for the preparation of the present report.

Emissions from the consumption of HFCs were constantly increasing during 1993-2016 period, but started to decrease in 2017. In 2020 the emissions were estimated at 508.1 kt CO_2 eq. (or 16.4% from the total emissions from Industrial processes and product use).

The major sources of GHG emissions in the Product Uses as Substitutes for ODS category are Commercial Refrigeration (CRF 2.F.1.a) and Mobile air-conditioning (CRF 2.F.1.e) accounting for 32% and 30% of the 2020 emissions, respectively.

Estimated emissions from consumption of HFCs in 1993-2020 are shown in the figure below.

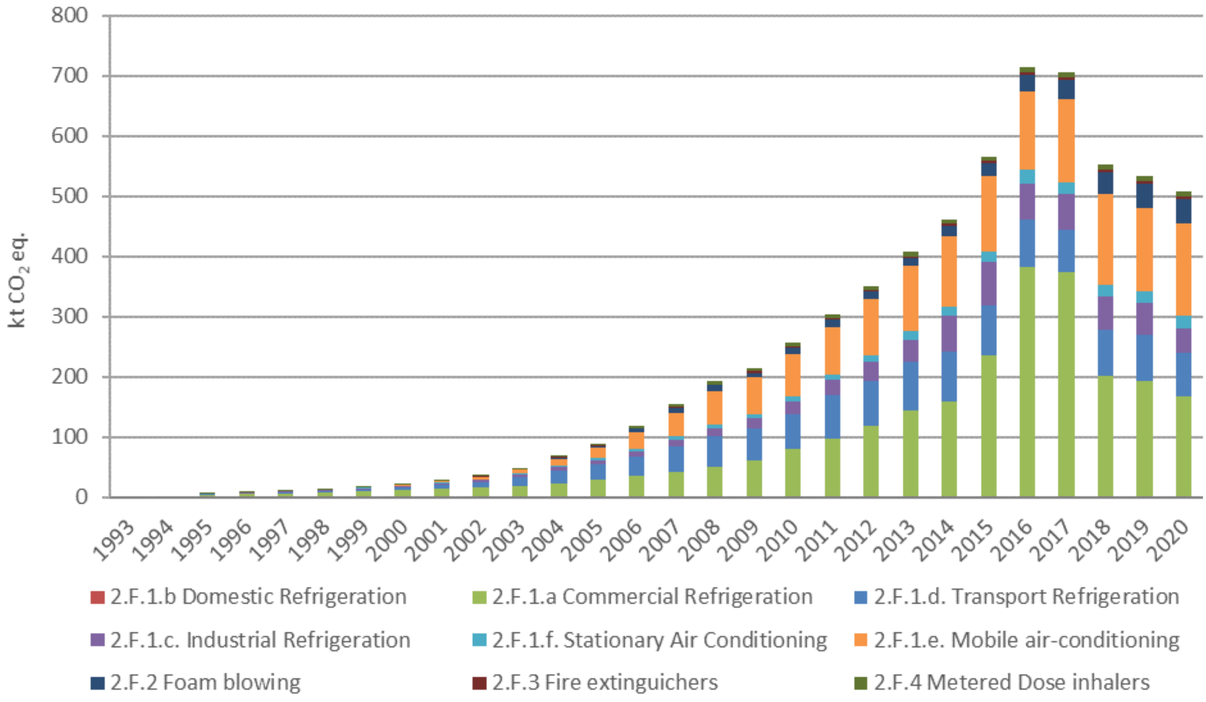

Figure 4-25. Estimated emissions from consumption of HFCs

With the adoption of Regulation (EU) No 517/2014 of the European Parliament and of the Council on Fluorinated Greenhouse Gases (F-gases regulation) the European Union has set out restrictions to reduce HFC emissions, and as a result of implementation of this regulation, HFCs emissions from these subcategories started to decrease in 2017 (1% compared with 2016). Comparing with 2019 HFCs emissions decreased by 5 % in 2020.

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

This section covers emissions of HFCs from: Commercial Refrigeration (CRF 2.F.1.a), Domestic Refrigeration (CRF 2.F.1.b), Industrial Refrigeration (CRF 2.F.1.c), Transport Refrigeration (CRF 2.F.1.d), Mobile Air-Conditioning (CRF 2.F.1.e) and Stationary Air-Conditioning (CRF 2.F.1.f).

4.7.1.1 Category Description

Commercial Refrigeration (CRF 2.F.1.a) and Industrial Refrigeration (CRF 2.F.1.c)

The main HFCs in this category are HFC-125 and HFC-143a, also small amounts of HFC-32 and HFC-134a are occurring. Based on study „Analysis of the use of fluorinated GHG in Lithuania in 1990-2011“ (2012) results, it was considered that the lifetime of the commercial and industrial refrigeration equipment is 15 years, which is in the range of lifetime values provided in *2006 IPCC Guidelines*. The end-of-life emissions were estimated for 2010-2020 years taking into account that HFCs have been used in commercial and industrial refrigeration in Lithuania since 1995.

The main data source for Commercial Refrigeration (CRF 2.F.1.a) and Industrial Refrigeration (CRF 2.F.1.c) categories is Environmental Protection Agency (EPA) database.

Furthermore, F-gases recovery in Lithuania is taking place in one company, which has the single refrigerator recycling unit in Baltic countries since 2007. The company has certificated refrigerator recycling line, where ozone depleting substances (ODS) and F-gases are collected from pipes and walls of refrigerators. According to the company specialists, more than 90% of F-gases are collected during the process. All collected ODS and F-gases are exported for further recycling/destruction to Germany. Amount of intentional destruction is considered to be zero, as F-gases destruction is not taking place in Lithuania.

Domestic Refrigeration (CRF 2.F.1.b)

The predominant refrigerant in domestic refrigeration equipment is HFC-134a, a small number of the appliances are also filled with the refrigerant HFC-125. Over the past decade, the use of these refrigerants has been limited, so more and more of new equipment is charged with isobutane R600a which does not contain fluorinated gases.

There is only one company manufacturing domestic refrigerators in Lithuania. According to the company data, all domestic refrigerators manufactured by the company are being filled with the refrigerant R600a since 2011. The company started using isobutane (R600a) in 2000. Over the period 2000-2010, part of refrigerators manufactured by company were charged with the refrigerant HFC-134a, which resulted in HFCs emissions during their assembly/manufacturing process when refrigerators were being filled with the refrigerant. The company provided annual data on sales/production of domestic refrigerators for 2000-2011, specifying number refrigerators filled with HFC-134a. The use of the refrigerant HFC-134a for the charging of new equipment during the said period was continuously going down and was completely discontinued from 2011.

According to the study "Analysis of the use of fluorinated greenhouse gases in Lithuania in 1990-2011" conducted in 2012, the HFCs were not collected in Lithuania until 2007. Since 2007 one company started ODS and fluorinated gases recovery activity. Refrigerators collected by this company account for up to 50% of the total amount of refrigerators discarded in Lithuania. The remaining refrigerators are collected by other companies, however, part of the collected refrigeration equipment is transferred to recycling center. According to EPA's waste database electrical and electronic equipment from other countries are imported to the recycling center. Recycling center's representative informed that only domestic refrigerators are imported. These units are included in the estimation of emissions from domestic refrigerators disposal (Table 4-33).

Table 4-33. Emissions from recycling center

Year	Emissions, kt CO_2 eq.
2010	0.48
2011	0.68
2012	0.81

2013	0.70
2014	0.67
2015	0.75
2016	0.90
2017	1.01
2018	1.15
2019	1.47
2020	1.54

Following the aforementioned study "Analysis of the use of fluorinated greenhouse gases in Lithuania" (2012) and expert judgement, over the period 1986-2002 the refrigerant R12 in domestic refrigeration compressors was gradually replaced by HFC-134a. The use of HFC-134a at the beginning of the said period was insignificant, meanwhile over the period 1994-1995 the use of HFC-134a increased considerably in domestic refrigeration equipment, as witnessed by the experience of other European countries in the production of these domestic appliances. According to the situation described, HFCs emissions from domestic refrigeration equipment have been estimated since 1995.

Since 2015 it is forbidden to supply new domestic refrigeration equipment with HFCs which has greater GWP than 150 (Regulation (EU) No 517/2014). The peak of emissions for this category was reached in 2010 and gradually started to decrease (Figure 4-29). HFCs emissions have increased since 2010 as a result of inclusion of emissions at the time of disposal of equipment in 2010.

Transport Refrigeration (CRF 2.F.1.d)

Emission sources in transport refrigeration category are refrigerated road vehicles and refrigerated rail vehicles. It is considered that refrigerated road vehicles are: refrigerated trucks, refrigerated vans and refrigerated semi-trailers. HFCs in refrigeration units of vehicles have been used since 1993. The refrigerant R-404a is a blend, consisting of HFC-125 (44%), HFC-143a (52%) and HFC-134a (4%).

The following companies were surveyed for the 2012 study on the use of HFCs in Lithuania:

- State enterprise Regitra – in order to obtain missing data on vehicles with refrigeration units registered in Lithuania by class and year of manufacture;
- companies servicing vehicles with refrigeration units in order to obtain more specific data on the variety of refrigerants used in refrigeration equipment, average charge of refrigerated vehicles by vehicle class, and factors of emission during equipment operation;
- national railway company – in order to collect data on refrigerated freight wagons and to assess HFCs emissions from refrigeration on the basis of this information;
- companies which operate shipping containers and reefers – in order to obtain data for the assessment of HFCs emissions.

The EPA database could not be used for the assessment of HFCs emissions from refrigerated vehicles for the following reasons:

- there is no such category of gas use in the EPA 2009-2010 database (it covers both stationary and mobile equipment classified by refrigerant weight); also, not all companies servicing refrigeration units in vehicles submitted reports to the EPA (there are only a few declarations of the gas use in the equipment of this category);
- the data collection period (2009-2020) and assessment of the missing period by way of extrapolation does not show the actual/factual annual consumption and emissions of

fluorinated gases (the accuracy would be higher if suppliers and servicing companies provided relevant information);

- information provided by individual companies servicing refrigeration equipment in vehicles does not allow formulating country-specific assumptions and emission factors.

Based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results the assumptions on the distribution of refrigerants in transport refrigeration were updated: F-gases used in transport refrigeration (2015-2020) – HFC-134a, R404A and R452A (blend of HFC-125 (59%); HFC-32 (11%) and HFC-1234YF (30 %)). The operation emission factor has been updated as well. Furthermore, emissions from vehicles manufacturing are included.

Mobile Air-Conditioning (CRF 2.F.1.e)

Road vehicles with air conditioning are: passenger vehicles, buses and freight vehicles. According to the information provided in the study on the use of HFCs in Lithuania (2012) the refrigerant R-134a has been used in mobile air-conditioning systems since 1993. EU MAC Directive17 prohibits the use of F-gases with GWP of more than 150 in new types of cars and vans introduced from 2011, and in all new cars and vans produced from 2017 and refrigerant R-1234yf is used as a replacement for R134a in mobile air conditioning systems. It is assumed, that air conditioning systems of vehicles produced from 2017 are filled with refrigerant R-1234yf and given that state enterprise Regitra provides data by year of manufacture, these vehicles are not included in the total number of cars. The total emissions of R-1234yf from mobile air conditioning are 0.02 kt CO2 eq. Taking into account that these emissions are insignificant and are not subject to reporting obligations, they are not reported in the CRF tables or included in the national total emissions.

The refrigerant R-134a in passenger train carriages equipped with air conditioning has been used since 2006. According to the data provided by national railway company, at present this company has 21 passenger carriages equipped with air conditioning, with each carriage having a UKV-type air conditioner. The company performs regular maintenance of air conditioners and in 2006-2019 five passenger carriages were disposed.

Based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results the assumptions on the share of vehicles equipped with mobile air conditioning systems by category and year of production since 2018 were updated. Futhermore, the state enterprise Regitra statictical data (2017-2020) on deregistered vehicle (end-of-life (reported destruction)' and 'end-of-life without certificate of destruction') were used in assesing emissions from disposal.

Stationary Air-Conditioning (CRF 2.F.1.f)

Stationary air-conditioning category is divided to air-conditioning and ventilation equipment sub-category and heat pumps sub-category. The main HFCs in this category are: HCF-32, HFC-125 and HFC-134a. Small amounts of HFC-143a also are occurring in stationary air-conditioning.

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17 Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC

Data of other countries demonstrate that stationary air-conditioning has been used since approximately 1995, therefore, in the absence of other information source, it is reasonable to assume that Lithuania also started using such systems charged with HFCs not earlier than in 1995.

4.7.1.2 Methodological issues

Commercial Refrigeration (CRF 2.F.1.a) and Industrial Refrigeration (CRF 2.F.1.c)

Activity data for 2013-2020 emission calculation are used from annual reports by F-gases operators at EPA's database. According to the Order No. D1-12 of the Minister of Environment of 7 January 2010 on the approval of the procedure for the provision, collection and handling of data on fluorinated greenhouse gases and ozone depleting substances and accounting of equipment and systems containing such gases or substances, as amended in 2015, every company shall report annually to the Lithuanian Environmental Protection Agency (EPA) on the amount of F-gases charged into the new equipment that year; and the amount of F-gases refilled into equipment in operation that year, as well as imported, exported, recycled, regenerated, disposed amounts. All used blends are broken into constituent substances by the companies. Furthermore, company has to indicate the sub-category of equipment for which substance was used (industrial, commercial, air conditioning etc.).

The following factors and assumptions were used to estimate the emissions from commercial and industrial refrigeration:

- refrigerants charged in the equipment are HFC-125, HFC-143a, HFC-134a and HFC-32;
- the average lifetime of equipment is 15 years;
- emission factor during the initial charging is 3% (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.52);
- the emission factor during the operation of the equipment is 22.5% for commercial and 16% for industrial refrigeration (it is an average of default factors provided in *2006 IPCC Guidelines*, Volume 3, part 2, p. 7.52);
- initial charge remaining – 90%, recovery efficiency – 70% (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.52);
- the amount of HFCs refilled into the systems was assumed to be equal to emitted amount that year;
- since the data on amount of HFCs in operating equipment is not known, for transparency reasons the data was estimated according to statistical HFCs refill data from EPA database. The amount of gases contained in equipment in year x = annual recharge *100/EF during operation (22.5% for commercial and 16% for industrial refrigeration).
- 2013-2016 data were used as a basis for estimation of emissions for 1995-2012 period. The gradual increase of emissions since year 1995 has been used considering the trends in other EU countries.

Estimates of HFCs emissions from commercial refrigeration are demonstrated in the figure below.

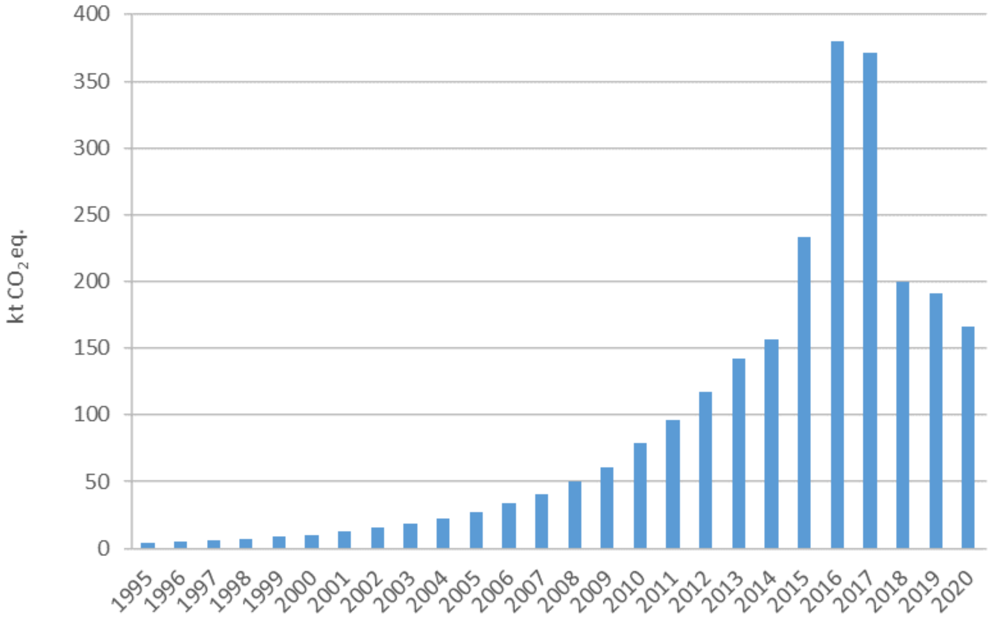

Figure 4-26. HFCs emissions from commercial refrigeration

In 2013 one of the largest Lithuanian commercial company had opened and reconstructed more stores and had bought and installed a lot of new refrigerators compared with 2014. This lead to decrease in the amount of HFC-143a for "filled into new manufactured products" between 2013 and 2014 for sub-category Commercial Refrigeration.

The change of the commercial refrigeration equipment containing HFCs and consequently reduction in HFCs emissions in 2018 has occurred mostly due to rising HFCs prices and Article 13(3) of F-gases regulation restrictions: "From 1 January 2020, the use of fluorinated greenhouse gases, with a global warming potential of 2 500 or more, to service or maintain refrigeration equipment with a charge size of 40 tonnes of CO_2 equivalent or more, shall be prohibited". Preparing to implement this requirement the companies started to replace or modify the commercial refrigeration systems. The largest company servicing commercial refrigeration equipment in Lithuania has informed that commercial equipment filled with refrigerant R-404A in most Lithuanian supermarkets has been replaced by new CO_2 systems. Remaining supermarkets have modified and adapted old systems to systems using CO_2 or continue using old installations. The refrigerant R-404A was recovered and stored in the containers and will be used to refill old equipment. In case of leak of the CO_2 systems the direct impact on environment is very low compared to systems filled with F-gases. In addition, these systems are easier to maintain and the same system operates efficiently with less amount of CO_2 (30-40%) than systems with R-404A. Also a small part of old equipment with F-gases were exported.

Estimates of HFCs emissions from industrial refrigeration are demonstrated in the figure below.

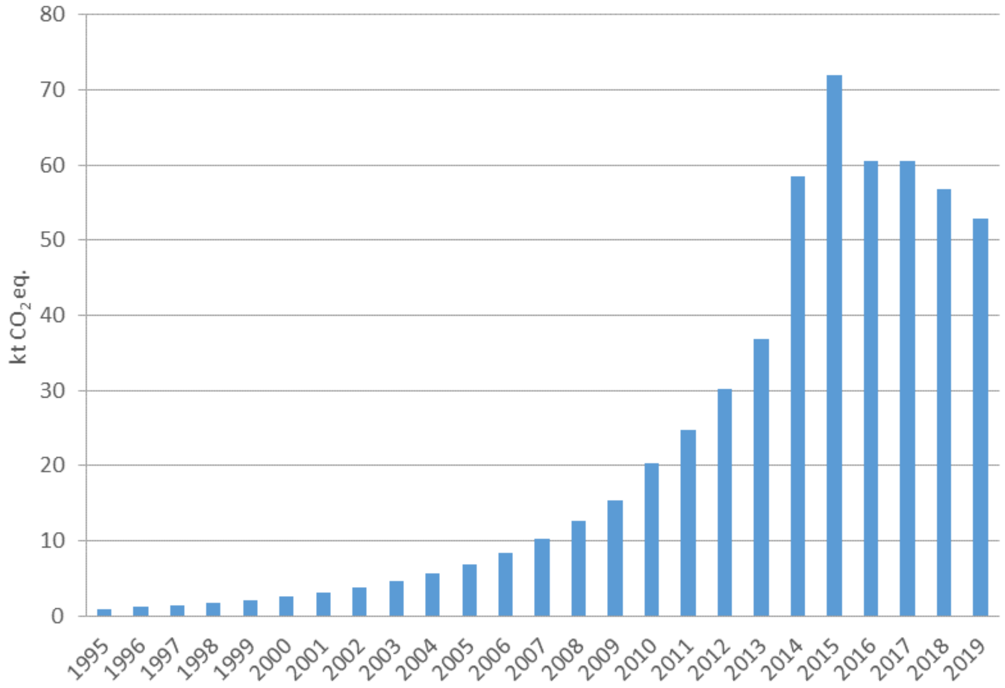

Figure 4-27. HFCs emissions from industrial refrigeration

Since 2013 emissions are estimated based on the EPA's database (data collected from the companies) while prior to 2013 data was extrapolated, therefore the trend of emissions for the period 1995-2012 is smooth, whereas the trend for the years 2013-2018 is fluctuating. The companies report data on amount of HFC-134a, HFC-143a, HFC-32 and HFC-125 refilled to the systems and it was assumed that the amount of HFC-134a, HFC-143a, HFC-32 and HFC-125 refilled into the systems was to be equal to emitted amount that year, therefore emission are directly depended on the reported data by the companies.

The emissions of HFCs from commercial and industrial refrigeration are provided in the table below.

Table 4-34. Total emissions of HFCs from commercial and industrial refrigeration

Year	Emissions from commercial refrigeration, kt CO_2 eq.	Emissions from industrial refrigeration, kt CO_2 eq.
1995	3.77	0.95
2000	10.17	2.57
2005	27.42	6.94
2010	78.44	20.31
2011	95.66	24.77
2012	116.66	30.21
2013	142.27	36.84
2014	156.51	58.40
2015	232.95	71.88
2016	379.53	60.49
2017	371.39	60.48
2018	199.78	56.79
2019	190.53	52.82
2020	166.27	40.11

Domestic Refrigeration (CRF 2.F.1.b)

Emissions of HFCs from the charging process of new equipment were estimated using following factors and assumptions provided by company:

- the average charge of the equipment with refrigerant is 120 g;
- the emission factor during the initial charging of new equipment k – 0.5%.

Emissions of HFCs due to the charging process of new equipment were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50):

$$E_{charge,t} = M_t \times k$$

where:

$E_{charge,\,t}$	- emission during system manufacture/assembly in year t, t;
M_t	- amount of HFCs charged into new equipment in year t, t;
k	- emission factor of assembly losses of the HFCs charged into new equipment, %.

Estimates demonstrated in the figure below.

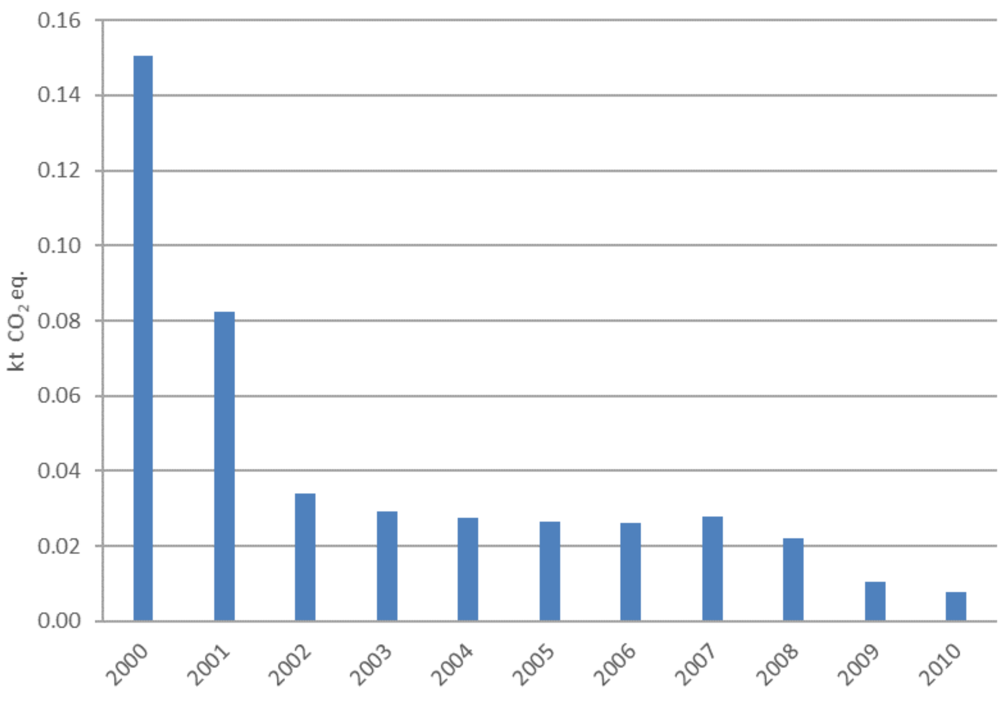

Figure 4-28. HFCs emissions during the initial charging of refrigerant into domestic refrigerators manufactured by company

The largest amounts of HFCs (0.15 kt CO_2 eq.) were emitted in 2000 as a result of rather extensive use of the refrigerant HFC-134a for the initial charging of domestic refrigerators at the company (about 80% of the total amount used). The use of this refrigerant in the subsequent years gradually went down. The use of the refrigerant HFC-134a for the charging of new equipment was completely discontinued from 2011.

The following data from Statistics Lithuania was used for the estimation of emissions from the stock of HFCs in existing domestic refrigerators:

- the number of inhabitants in Lithuania;
- the average size of households in Lithuania;
- the percentage of households using domestic refrigerators.

This information is used to obtain the amount of F-gases in operation.

Due to absence of sufficient data for estimating the amount of HFCs charged in domestic refrigerators and the percentage of domestic refrigerators containing HFCs, the following assumptions based on expert judgment and 2021 study results were made:

- the average amount of refrigerant charged in a refrigerator is 120 g (1995-2014) and 125 g (2015-2020) (data source: Lithuanian producer of domestic refrigerators);
- the average amount of refrigerant charged in a freezer is 150 g (according to the data of Recycling center, the charge is about 30% higher than in refrigerators);
- 13% of refrigerators (of the total number) used to be filled with HFC-134a until 1995. The same assumption is applied to freezers (based on laboratory analysis of gases collected from recycled domestic refrigerators, data source: Recycling center);
- 5% of refrigerators (of the total number) used to be filled with HFC-125 until 1995. The same assumption is applied to freezers (based on laboratory analysis of gases collected from recycled domestic refrigerators, data source: Recycling center);
- average annual refrigerant loss/leakage is 0.7% of the quantity in stock (emission factor during the operation of the equipment) (revised according to 2021 study results);
- 30% of new refrigerators in 1995-2009 were filled with HFC-134a and since 2010 it started to decrease. The same assumption is applied to freezers;
- 7% of new refrigerators in 1995-2009 were filled with HFC-125 and since 2010 it started to decrease. The same assumption is applied to freezers.

Annual leakage from the stock in the domestic refrigerators was calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50):

$$E_{liftime,t} = B_t \times x$$

where:

$E_{lifetime,\,t}$ - amount of HFCs banked in existing systems in year t, t;

B_t - amount of HFCs banked in existing systems in year t, t;

x - emission factor of HFCs of each sub-application bank during operation, accounting for average annual leakage and average annual emission during servicing, %.

Emissions at system disposal were calculated from 2010 using the following factors and assumptions:

- the average lifetime of the refrigerator and freezers is 20 years (data source: Recycling center);
- the recovery efficiency at disposal for refrigerators and freezers is 60% (data source: Recycling center);
- the residual gas amount at system disposal (refrigerators and freezers) is 90% of the initial charge filled into the system during the production process.

Emissions at disposal of domestic refrigeration equipment were calculated using the following formula (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.51):

$$E_{end-of-life,t} = M_{t-d} \times p \times (1 - \eta_{rec,d}),$$

where:

$E_{end\text{-}of\text{-}life,\ t}$ - amount of HFCs emitted at system disposal in year t, t;

M_{t-d} - amount of HFCs initially charged into new systems installed in year (t-d), t;

p - residual charge of HFCs in equipment being disposed of expressed in percentage of full charge, %;

$\eta_{rec,d}$ - recovery efficiency at disposal, which is the ratio of recovered HFCs referred to the HFCs contained in the system, %.

Total emissions:

$$E_{total,t} = E_{charge,t} + E_{lifetime,t} + E_{end-of-life,t},$$

Estimated total emissions of HFCs from domestic refrigeration and freezers are provided in the table below.

Table 4-35. Total HFCs emissions from domestic refrigeration

Year	Emissions from refrigerators				Emissions from freezers			Total, kt CO_2 eq.
	Manufacturing kt CO_2 eq.	Operation kt CO_2 eq.	Disposal kt CO_2 eq.	Total form refrigerators	Operation kt CO_2 eq.	Disposal kt CO_2 eq.	Total from freezers	
1995	NO	0.39	NO	0.39	0.03	NO	0.03	0.43
2000	0.15	0.47	NO	0.62	0.10	NO	0.10	0.72
2005	0.03	0.62	NO	0.65	0.17	NO	0.17	0.82
2010	0.01	0.70	0.48	1.19	0.20	0.00	0.20	1.39
2011	NO	0.69	0.68	1.37	0.20	0.00	0.20	1.57
2012	NO	0.67	0.81	1.49	0.20	0.00	0.20	1.69
2013	NO	0.64	0.69	1.33	0.18	0.01	0.18	1.51
2014	NO	0.60	0.66	1.25	0.15	0.01	0.16	1.41
2015	NO	0.58	0.73	1.31	0.12	0.02	0.14	1.45
2016	NO	0.54	0.88	1.42	0.11	0.02	0.13	1.55
2017	NO	0.49	0.98	1.46	0.09	0.03	0.12	1.58
2018	NO	0.44	1.10	1.54	0.05	0.05	0.10	1.64
2019	NO	0.38	1.41	1.79	0.04	0.06	0.10	1.89
2020	NO	0.29	1.47	1.76	0.02	0.06	0.08	1.84

HFCs emissions have increased since 2010 as a result of inclusion of emissions at the time of disposal of equipment in 2010 and since then. Domestic refrigerators are imported and recycled by Recycling center in Lithuania. These units are included in the estimation of emissions from domestic refrigerators disposal, therefore the emission trend is fluctuating and depends on the amount recycled.

Estimates of HFCs emissions from domestic refrigerators in Lithuania for 1995-2020 are demonstrated in the figure below.

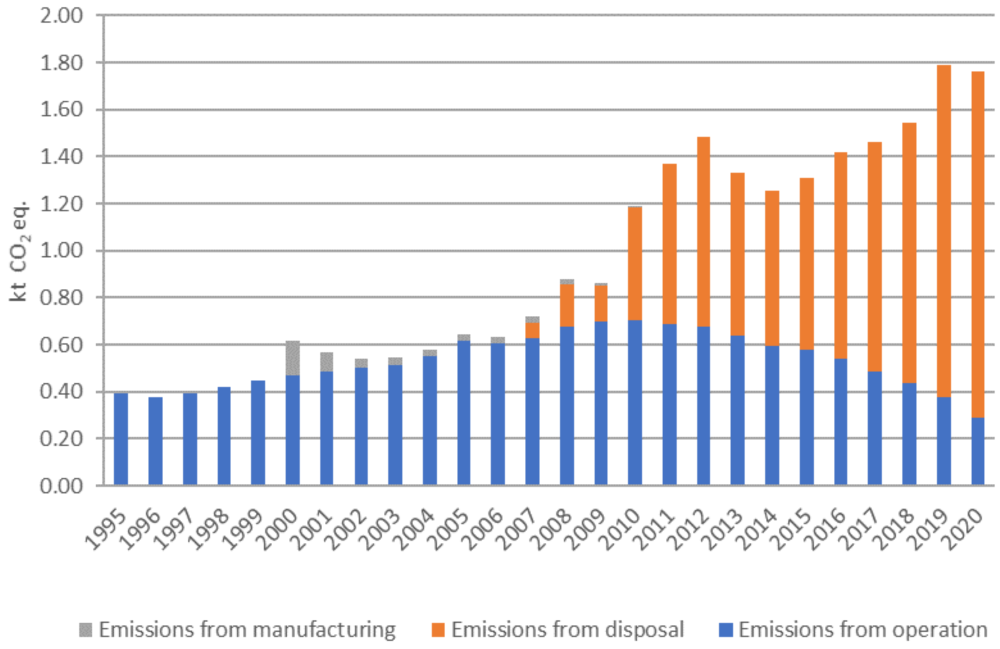

Figure 4-29. HFCs emissions from domestic refrigerators

Estimates of HFCs emissions from domestic freezers are demonstrated in the figure below.

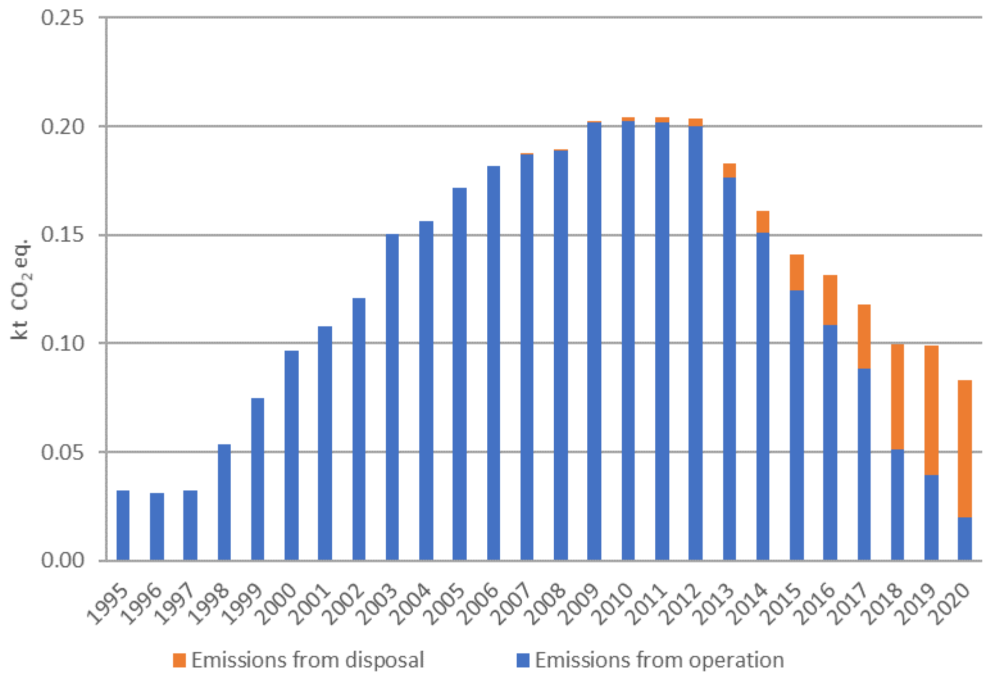

Figure 4-30. HFCs emissions from domestic freezers

Transport Refrigeration (CRF 2.F.1.d)

Transport refrigeration category is divided to refrigerated road vehicles and refrigerated rail vehicles sub-categories.

Refrigerated road vehicles

HFCs emissions from refrigerated road vehicles equipment are assessed following the *2006 IPCC Guidelines*. Assessments are based on the number of refrigerated vehicles registered on the territory of the Republic of Lithuania. The data on vehicles with refrigeration units registered in Lithuania in 1992-2020 by vehicle class and year of manufacture was obtained from the state enterprise Regitra.

The following classes of freight vehicles and semi-trailers were considered:

- refrigerated trucks;
- refrigerated vans;
- refrigerated semi-trailers.

The said refrigerated vehicles were manufactured in 1993-2020. In addition, Regitra provided the average lifetime of the vehicles by class.

Four companies servicing refrigerated vehicles were contacted in order to specify the refrigerants used, the average refrigerant charge in refrigerated vehicles, and factors of emission at the time of operation; however, a partial reply was received only from one company. According to the data of the said company, the refrigerants used in refrigeration equipment are R-134a and R-404a:

- R-134a and R-404a are used in freight vehicles up to 3.5 t (trucks, vans, semi-trailers);
- mainly R-404a is used in freight vehicles above 3.5 t (trucks, vans, semi-trailers).

Following the German experience, it was assumed that if two refrigerants are used in one vehicle category, the use of each refrigerant is considered to be 50%.

According to 2021 study refrigerants R-134a, R-404a and R452a are used in freight vehicles since 2015. Assumptions on the distribution of refrigerants in transport refrigeration equipment are presented in the table below.

Table 4-36. Proportions of refrigerants used in transport refrigeration

Category of transport	Refrigerant	Year						
		Up to 2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Truck, vans up to 3,5 t	HFC-134a	50%	30%	30%	30%	30%	25%	20%
	R404A	50%	70%	70%	70%	60%	55%	50%
	R452A	0%	0%	0%	0%	10%	20%	30%
Truck, vans over 3,5 t	R404A	100%	90%	80%	70%	60%	50%	40%
	R452A	0%	10%	20%	30%	40%	50%	60%
Semi-trailer up to 3,5 t	HFC-134a	50%	40%	10%	20%	20%	20%	20%
	R404A	50%	50%	50%	50%	50%	50%	50%
	R452A	0%	10%	20%	30%	30%	30%	30%
Semi-trailer up to 3,5 t	R404A	100%	90%	80%	70%	60%	50%	40%
	R452A	0%	10%	20%	30%	40%	50%	60%

The 2021 study has showed that there is one freight vehicle manufacturer in Lithuania, which started operations in 2019. Emissions of HFCs from the charging process of new equipment were estimated using following factors and assumptions:

- amount of HFCs charged into new equipment in 2019-2020, t (EPA F-gases database);
- the emission factor during the initial charging of new equipment k – 0.6% (average value of *2006 IPCC Guidelines*, Volume 3, chapter 7, p. 7.52).

Emissions of HFCs due to the charging process of new equipment were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50):

$$E_{charge,t} = M_t \times k$$

where:

$E_{charge,\ t}$ - emission during system manufacture/assembly in year t, t;

M_t - amount of HFCs charged into new equipment in year t, t;

k - emission factor of assembly losses of the HFCs charged into new equipment, %.

Estimates demonstrated in the table below.

Table 4-37. Refrigerant charge emissions of new equipment in transport refrigeration

Year	Emissions, kt CO_2 eq.
2019	0.02
2020	0.03

The assessment of emissions during the operation of the equipment was based on the following factors and assumptions provided below.

The average amount of refrigerant charged in the equipment in the below listed vehicle classes is as follows (according to the data on freight vehicles by their weight provided by company servicing refrigerated vehicles):

- 2 kg in refrigerated trucks and refrigerated vans up to 3.5 t;
- 7 kg in refrigerated trucks and refrigerated vans over 3.5 t;
- 2 kg in refrigerated semi-trailers up to 3.5 t;
- 7 kg in refrigerated semi-trailers over 3.5 t

The emission factor during the operation of the equipment is 30% (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.52); Based on 2021 study results EF of 25 % is applied since 2020.

There is no data available for the assessment of the emission factor during equipment servicing, therefore this factor was assumed to be included in the emission factor during operation.

Emissions during lifetime were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50):

$$E_{liftime,t} = B_t \times x$$

where:

B_t - amount of HFCs banked in existing systems in year t, t;

x - emission factor of HFCs for each sub-application bank during operation, %.

The assessment of emissions of HFCs at system disposal was based on the following assumptions:

- the initial charge remaining is 50% (2006 IPCC Guidelines, Volume 3, part 2, p. 7.52);
- there is no data available on recycling processes of refrigerated vehicles, therefore recovery efficiency was not assessed.

Emissions at end-of-life were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.51):

$$E_{end-of-life,t} = M_{t-d} \times p \times (1 - \eta_{rec,d})$$

where:

M_{t-d} - amount of HFCs initially charged into new systems installed in year (t-d), t;

P - residual charge of HFCs in equipment being disposed of expressed in percentage of full charge, %;

$\eta_{rec,d}$ - recovery efficiency at disposal, which is the ratio of recovered HFCs referred to HFCs contained in the system, %.

HFCs have been used in refrigerated vehicles since 1993, which is demonstrated by the German experience in the production of refrigerated vehicles. Most of refrigerated vehicles which are operated in Lithuania were manufactured in Western Europe (including Germany), therefore HFCs emissions during equipment operation have also been assessed since 1993.

Estimations of HFCs emissions from refrigerated road vehicles are demonstrated in the figure below.

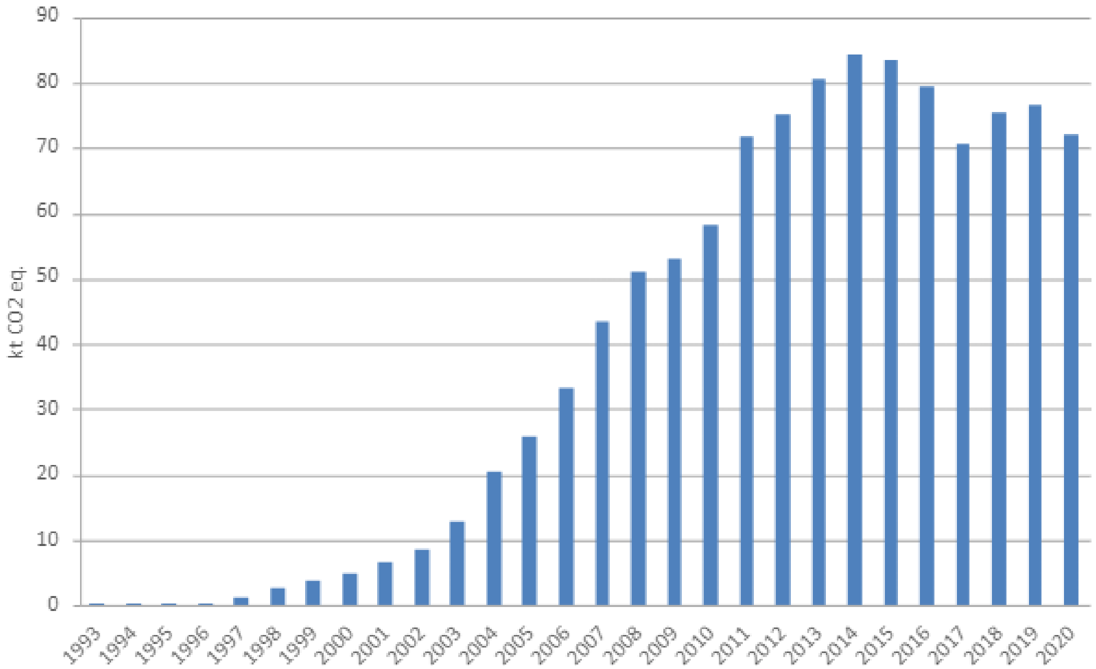

Figure 4-31. HFCs emissions from refrigerated road vehicles

Emissions from 2.F.1.d are calculated based on data on actual number of registered refrigerated road vehicles provided by state enterprise Regitra, which keeps the Register of vehicles of the Republic of Lithuania and emissions (also annual stocks in t) are directly dependent on the registered number of refrigerated road vehicles. In 2017, the number of registered refrigerated road vehicles decreased, resulting in lower emissions and the number of refrigerated road vehicles registered in 2018 and in 2019 was higher than in 2017, resulting in higher emissions.

Train – freight wagons

The refrigerant R-134a has been used in refrigerated freight wagons since 2006. The number of freight wagons was continuously going down during the period 2006-2012. National railway company was contacted to obtain necessary data.

The company provided the number of refrigerated freight wagons operated in 2006-2020 pointing out that every wagon has two refrigeration equipments. The refrigerant used in wagons is R-134a.

There is no data available on the original factory charge therefore the emission factor during the initial charging and the emissions were not assessed.

Freight wagons carry goods to Eastern countries riding in Lithuania only a short segment of the whole trip. Upon consultation of the head of the company, it was assumed that only 10% of HFCs emissions during the operation of the refrigeration equipment shall attributed to Lithuania.

The assessment of the emissions during equipment operation was based on the following factors and assumptions provided below.

Pursuant to the data of national railway company:

- the average amount of refrigerant charged in the equipment is 5 kg;
- the emission factor during the operation of the equipment is 10% (2006-2014);
- amount of HFCs filled into equipment in operation (2015-2020).

Other assumptions:

- 80% of all freight wagons are charged with the refrigerant R-134a for the period 2006-2011;
- there is no data available for the assessment of the emission factor during equipment servicing, therefore this factor was assumed to be included in the total emission factor.

Emissions during the lifetime were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50):

$$E_{liftime,t} = B_t \times x$$

where:

B_t - amount of HFCs banked in existing systems in year t, t;

X - emission factor of HFCs for each sub-application bank during operation, %.

Despite the fact, that the refrigeration equipment in freight wagons is fairly new – operated since 2006 and its lifetime is about 28 years and according to data provided by national railway company some wagons were modernized by removing refrigeration equipment during the period 2009-2016.

The assessment of emissions of HFCs at system disposal was based on the following assumptions:

- the residual charge in the system being disposed is 50% (is calculated according to data provided by national railway company);
- recovery efficiency at disposal is 25% (is calculated according to data provided by national railway company).

Emissions at system disposal were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.51):

$$E_{end-of-life,t} = M_{t-d} \times p \times (1 - \eta_{rec,d})$$

where:

M_{t-d} - amount of HFCs initially charged into new systems installed in year (t-d), t;

p - residual charge of HFC in equipment being disposed of expressed in percentage of full charge, %;

$\eta_{rec,\ d}$ - recovery efficiency at disposal, which is the ratio of recovered HFCs referred to HFCs contained in the system, %.

Estimates of HFCs emissions from freight wagons are demonstrated in the figure below.

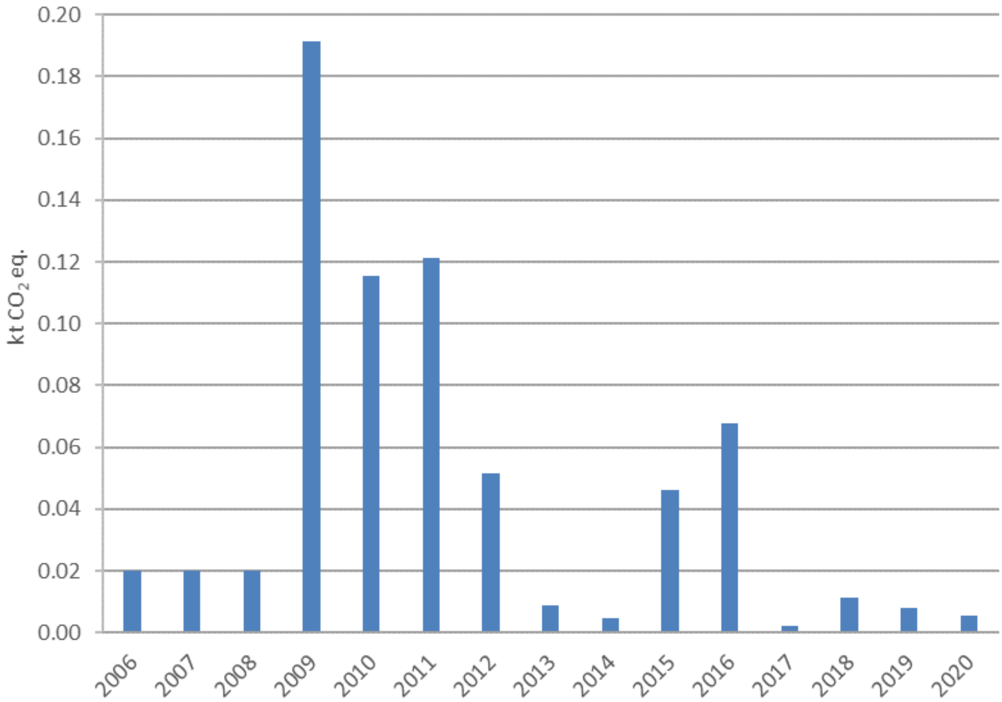

Figure 4-32. HFCs emissions from freight wagons

As seen in Figure 4-32 emissions over the period of 2009-2012 and 2016 were higher than in the remaining years of the period 2006-2019. The main reason of higher emissions is that HFCs emissions at system disposal were estimated over the period of 2009-2012 and 2016.

Total HFCs emissions from transport refrigeration were calculated using the following formula:

$$E_{total,t} = E_{lifetime,t} + E_{end-of-life,t},$$

Estimates of the total HFCs emissions from transport refrigeration are provided in the table below.

Table 4-38. Total HFCs emissions from transport refrigeration

Year	Emissions from refrigerated road vehicles, kt CO_2 eq.	Emissions from refrigerated rail vehicles, kt CO_2 eq.	Total emissions, kt CO_2 eq.

1995	0.14	NO	0.14
2000	4.75	NO	4.75
2005	25.95	NO	25.95
2010	58.01	0.12	58.13
2011	71.77	0.12	71.89
2012	75.11	0.05	75.16
2013	80.41	0.01	80.42
2014	84.17	0.00	84.18
2015	83.36	0.05	83.41
2016	79.27	0.07	79.34
2017	70.66	0.00	70.66
2018	75.44	0.01	75.45
2019	76.61	0.01	76.62
2020	71.92	0.01	71.93

Shipping containers

A few companies were interviewed in order to identify Lithuanian companies which operate shipping containers. During the interview, one company pointed out that most of their cold storage facilities are stationary and their shipping containers are shipped all over the world and serviced abroad as well, meanwhile other company does not have any refrigerated containers at all.

HFCs emissions from shipping containers were not assessed for the following reasons:

- the number of shipping containers in Lithuania is not available and difficult to determine;
- most refrigerated containers ship cargo all over the world and practically do not call Lithuanian ports and are serviced in foreign countries.

Reefers

According to the data provided by the Lithuanian Maritime Safety Administration (currently reorganized to Lithuanian Transport Safety Administration), seven reefers (six transport vessels and one fishing vessel) were registered at the Register of Seagoing Ships of the Republic of Lithuania as on 31 July 2012. Refrigeration equipment for the needs of the crew and passengers is installed on 36 cargo and fishing vessels. The average lifetime of marine vessels is 30-50 years.

The data of reefer vessels registered in Lithuania in 2000-2020 is provided by Statistics Lithuania and presented in the figure below.

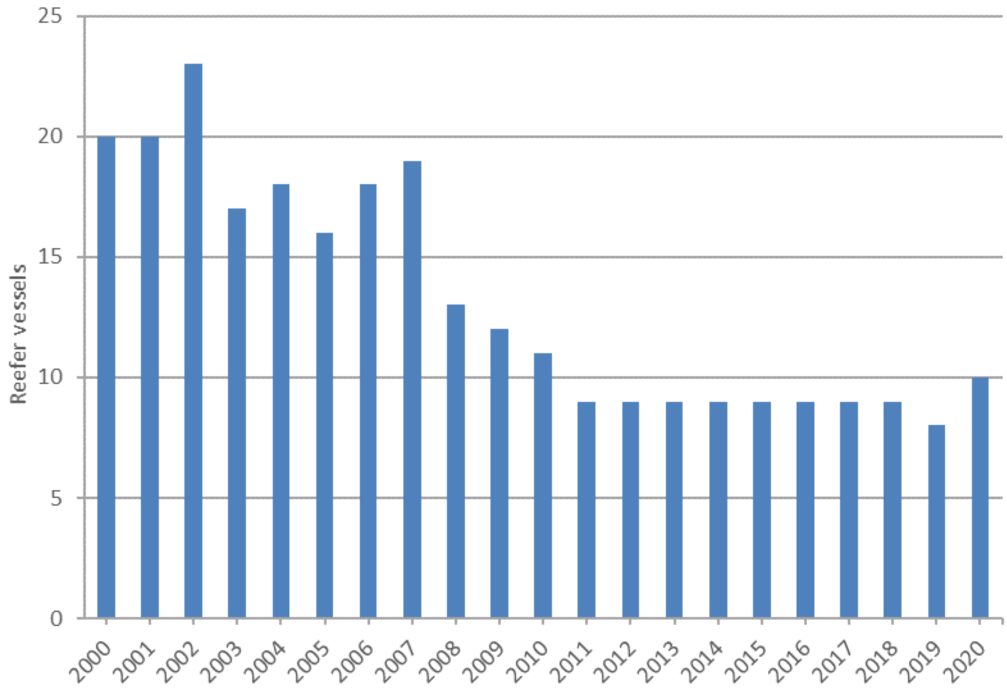

Figure 4-33. Reefer vessels registered in Lithuania

HFCs emissions from reefer vessels were not assessed for the following reasons:

- according to specialists, the annual number of reefer vessels with the Lithuanian flag calling Klaipėda Seaport is very small;
- the part of the voyage spent by reefer vessels at the shores of the Republic of Lithuania is not known;
- there is no data available from companies servicing refrigeration equipment, therefore it is difficult to establish average refrigerant charges and the emission factor during the operation of the equipment;
- reefer vessels migrate/ship freight all over the world.

Mobile Air-Conditioning (CRF 2.F.1.e)

Road vehicles with air-conditioning

HFCs emissions from this equipment were estimated following the *2006 IPCC Guidelines* and on the basis of the statistical data on vehicles registered in the Republic of Lithuania.

The data on vehicles registered in 1991-2020 by vehicle category and year of manufacture was obtained from state enterprise Regitra:

- M1 – passenger cars;
- M2 – buses ≤ 5 t;
- M3 – buses > 5 t;
- N1 – freight vehicles up to 3.5 t;
- N2 – freight vehicles from 3.5 to 12 t;
- N3 – freight vehicles above 12 t.

The vehicles considered in this report were manufactured in 1993-2020. The company Regitra also provided the average lifetime by vehicle category. The percentage of vehicles equipped with air conditioning in the vehicle fleet of Lithuania by vehicle category and year of manufacture was estimated on the basis of vehicle suppliers (Table 4-39).

Table 4-39. Estimated percentage of vehicles equipped with air conditioning in the stock

Year of manufacture	M1	M2	M3	N1	N2	N3
1990	0%	0%	0%	0%	0%	0%
1995	15%	0%	0%	0%	0%	12%
2000	50%	30%	30%	25%	25%	28%
2005	70%	40%	40%	40%	40%	54%
2010	84%	60%	60%	50%	50%	82%
2011	85%	60%	60%	50%	50%	86%
2012	88%	60%	60%	50%	50%	88%
2013	90%	60%	60%	50%	50%	90%
2014	92%	60%	60%	50%	50%	92%
2015	92%	60%	60%	50%	50%	92%
2016	95%	60%	60%	50%	50%	95%
2017	95%	60%	60%	50%	50%	95%
2018	95%	70%	70%	70%	70%	95%
2019	95%	80%	80%	80%	80%	95%
2020	95%	95%	100%	90%	90%	95%

There is no data available on the original factory charge therefore the emission factor during the initial charging and the emissions were not estimated.

The assessment of the emissions during the operation of the equipment was based on the following factors and assumptions provided below.

Data of a vehicle maintenance company on the average annual amount of refrigerant in the equipment:

- M2 – buses ≤ 5 t – 8 kg (1993-2014); 5 kg (since 2020);
- M3 – buses > 5 t – 13 kg;

According to *2006 IPCC Guidelines*, Volume 3, part 2, (p. 7.52) the average annual amount of refrigerant in the equipment:

- M1 - passenger car – 0.7 kg
- N1 - freight vehicles up to 3.5 t – 0.7 kg;
- N2 - freight vehicles from 3.5 to 12 t – 1.2 kg;
- N3 - freight vehicles above 12 t – 1.2 kg;

The emission factor during the operation of the equipment (for all vehicle categories) is 15%.

Other assumptions:

- there is no data available for the assessment of the emission factor during equipment maintenance, therefore this factor was assumed to be included in the emission factor during operation.

Emissions of HFCs during the lifetime of the equipment were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50, Tier 2a):

$$E_{liftime,t} = B_t \times x$$

where:

B_t - amount of HFCs banked in existing systems in year t, t;

X - emission factor of HFCs for each sub-application bank during operation, accounting for average annual leakage and average annual emission during servicing, %.

The assessment of emissions at system disposal was based on the following factors and assumptions:

Data of state enterprise Regitra on the lifetime of vehicles (2010-2016):

- M1 – passenger car – 17 years;
- M2 – buses ≤ 5 t – 16 years;
- M3 – buses > 5 t – 21 years;
- N1 – freight vehicles up to 3.5 t – 22 years;
- N2 – freight vehicles from 3.5 to 12 t – 23 years;
- N3 – freight vehicles above 12 t – 20 years.

Other assumptions:

- the residual gas amount in the system being disposed is 50% (*2006 IPCC Guidelines* Volume 3, part 2, p.7.52, Table 7.9);
- there is no data available on recycling of vehicle air-conditioning systems, therefore the factor of recovery efficiency was not estimated.
- Air conditioning systems of vehicles produced from 2017 are filled with refrigerant R-1234yf and given that state enterprise Regitra provides data by year of manufacture, these vehicles are not included in the total number of cars.
- state enterprise Regitra statictical data (2017-2020) on deregistered vehicle (end-of-life (reported destruction)' and 'end-of-life without certificate of destruction') are used in assesing emissions from disposal.

Emissions at system end-of-life were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.51):

$$E_{end-of-life,t} = M_{t-d} \times p$$

where:

M_{t-d} - amount of HFCs initially charged into new systems installed in year (t-d), t;

p - residual charge of HFCs in equipment being disposed of expressed in percentage of full charge, %.

It is likely that HFCs contained in vehicle air-conditioning systems are not collected or recovered in Lithuania and are simply emitted into the atmosphere.

Estimations of HFCs emissions from vehicles with air conditioning are demonstrated in the figure below.

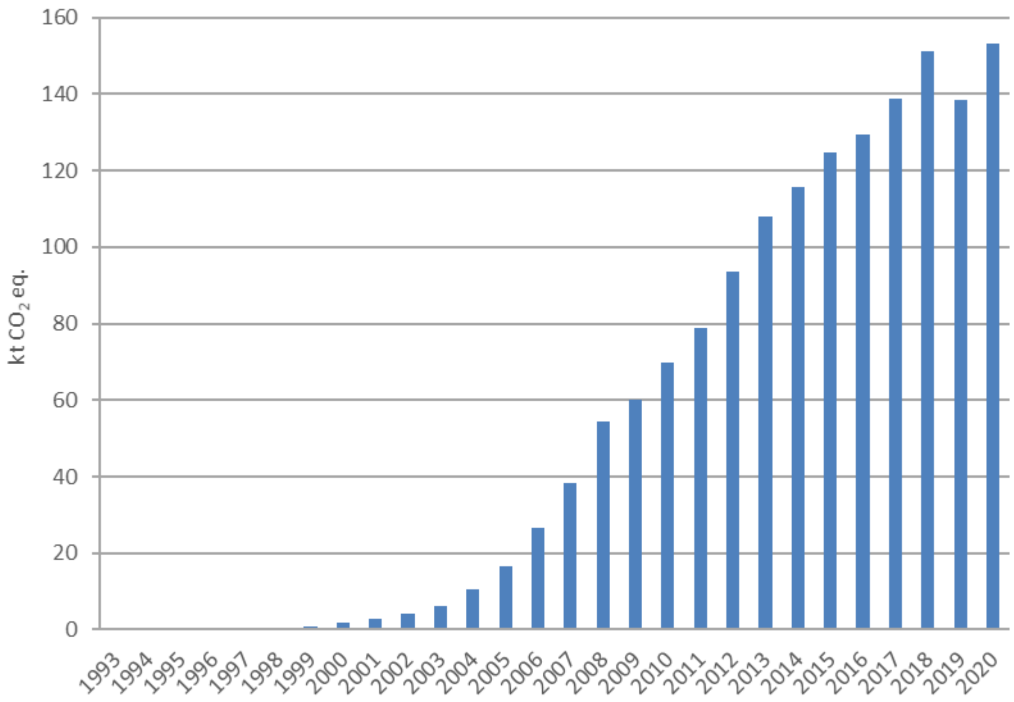

Figure 4-34. HFCs emissions from vehicles with air conditioning

Emissions from 2.F.1.e are calculated based on data on actual number of registered vehicles provided by state enterprise Regitra, which keeps the Register of vehicles of the Republic of Lithuania and emissions (also annual stocks in t) are directly dependent on the registered number of vehicles. The number of vehicles registered in 2020 was higher than in 2019, resulting in higher emissions. However the number of vehicles registered in 2019 was lower than in 2018, resulting in lower emissions.

Trains – passenger carriages with air conditioning

There is no data available on the original factory charge, therefore the emission factor during the initial charging and the emissions were not assessed.

The assessment of the emissions during the operation of the equipment was based on the following factors and assumptions provided below.

Data of the Passenger Transportation Directorate of the national railway company:

- the average annual amount of refrigerant in UKV-type air conditioner is 10 kg;
- the emission factor during the operation of the equipment is 2%.

Other assumptions:

- there is no data available for the assessment of the emission factor during equipment maintenance, therefore this factor was assumed to be included in the emission factor during operation.

Emissions of HFCs during the lifetime of the equipment were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50):

$$E_{liftime,t} = B_t \times x$$

where:

B_t - amount of HFCs banked in existing systems in year t, t;

X - emission factor of HFCs for each sub-application bank during operation, accounting for average annual leakage and average annual emission during servicing, %.

The air-conditioning equipment installed in passenger carriages which belongs to the national railway company and it has been used since 2006. Despite the fact, that the passenger carriages is fairly new and its lifetime is about 28 years and according to data provided by national railway company some carriages were disposed during the year 2012, 2016-2017 and 2020.

The assessment of emissions of HFCs at system disposal was based on the following assumptions:

- the initial charge remaining is 50% (2006 IPCC Guidelines, Volume 3, part 2, p. 7.52);
- there is no data available on recycling processes of passenger carriages, therefore recovery efficiency was not assessed.

Emissions at end-of-life were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.51):

$$E_{end-of-life,t} = M_{t-d} \times p \times (1 - \eta_{rec,d})$$

where:

M_{t-d} - amount of HFCs initially charged into new systems installed in year (t-d), t;

P - residual charge of HFCs in equipment being disposed of expressed in percentage of full charge, %;

$\eta_{rec,d}$ - recovery efficiency at disposal, which is the ratio of recovered HFCs referred to HFCs contained in the system, %.

Estimates of HFCs emissions from passenger carriages are demonstrated in the figure below.

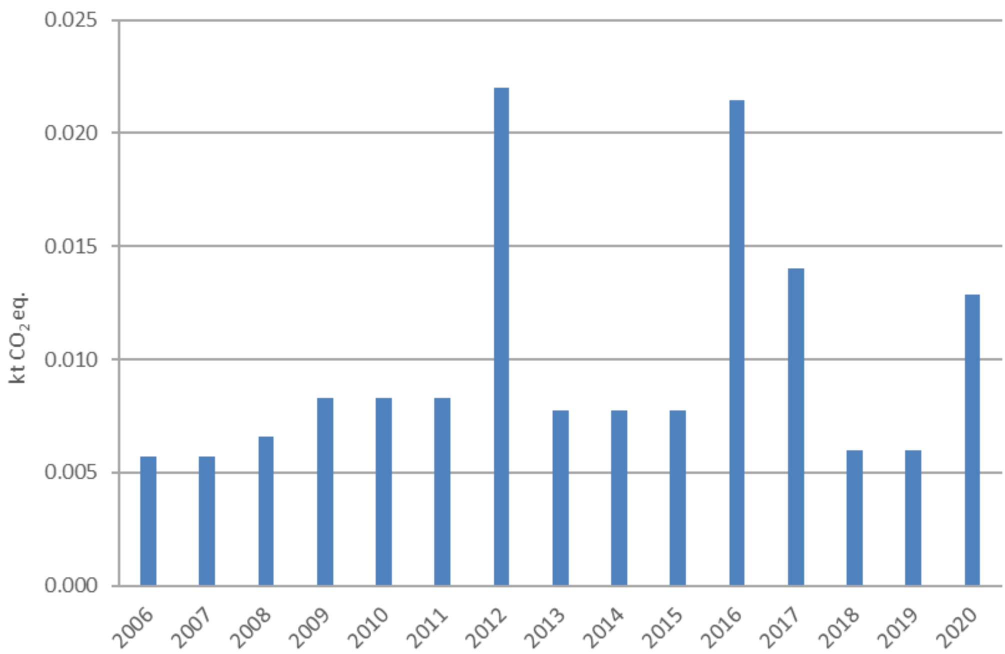

Figure 4-35. HFCs emissions from passenger carriages

As seen in Figure 4-35 emissions over the period of 2012 and 2016-2017 were higher than in the remaining years of the period 2006-2019. The main reason of higher emissions is that HFCs emissions at system disposal were estimated over the year of 2012, 2016-2017 and 2020.

Total emissions:

$$E_{total,t} = E_{lifetime,t} + E_{end-of-life,t}$$

Estimates of HFCs emissions from mobile air-conditioning systems are presented in the table below.

Table 4-40. Total HFCs emissions from mobile air-conditioning

Year	Emissions from vehicles with air conditioning, kt CO_2 eq.	Emissions from rail vehicles with air conditioning, kt CO_2 eq.	Total emissions, kt CO_2 eq.
1995	0.12	NO	0.12
2000	1.67	NO	1.67
2005	16.52	NO	16.52
2010	69.68	0.008	69.69
2011	78.76	0.008	78.77
2012	93.57	0.022	93.59
2013	108.12	0.008	108.12
2014	115.61	0.008	115.62
2015	124.83	0.008	124.84
2016	129.36	0.021	129.38
2017	138.92	0.014	138.93
2018	151.04	0.006	151.05
2019	138.57	0.006	138.57
2020	153.33	0.013	153.34

Stationary Air-Conditioning (CRF 2.F.1.f)

Air-conditioning and ventilation equipment

Taking into account the EPA's database analysis results obtained during the study on the use of HFCs in Lithuania (2012), emissions from stationary air-conditioning systems were estimated observing the following recommendations:

1) the amounts of HFC-125, HFC-134a, HFC-143a, HFC-32 declared in the EPA's database of year x are deemed to be annual recharge amounts in air-conditioning systems;
2) the amount of gases contained in air-conditioning systems in year x = annual recharge *10 (assumption that the annual amount of gases in the systems is ten times larger than the amount of recharge);
3) pursuant to the information that refrigerants have been used in stationary air-conditioning systems since 1995 (information provided in national reports of other countries), it was assumed that the initial amount of refrigerants in the systems was 1% as compared to the year 2012. The amounts of refrigerants for 1996-1999 were estimated by way of direct interpolation;
4) the emission factor during the operation of the equipment is 10% (upper range limit of the factor given in the *2006 IPCC Guidelines*).

Emissions of HFCs during the lifetime of the equipment were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50, Tier 2a):

$$E_{liftime,t} = B_t \times x$$

where:

B_t - amount of HFCs banked in the existing systems in year t, t;

x - emission factor of HFCs for each sub-application bank during operation, accounting for average annual leakage and average annual emission during servicing, %.

Emissions from the stationary A/C equipment initial charging and decommissioning were calculated taking into account the following assumptions:

- Based on study „Analysis of the use of fluorinated GHG in Lithuania in 1990-2011" results, it was considered that the lifetime of the stationary A/C equipment is 15 years, which is in the range of lifetime values provided in *2006 IPCC Guidelines* (10-20 years). Taking into account that HFCs have been used in stationary A/C equipment in Lithuania since 1995, end-of-life emissions were estimated for 2010-2020 years.
- Emissions during the initial charging of stationary A/C were estimated for all-time series, using emission factor 0.6%, which is based on study on F-gases (2012) experts recommendations (average range limit of the factor given in the *2006 IPCC Guidelines*, Volume 3, part 2, Table 7.9, p. 7.52).
- initial charge remaining factor – 80% (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.52).
- Recovery efficiency at disposal – 80% is based on expert judgement. After consultations with several refrigeration and A/C equipment servicing companies it was concluded that as a common practice in Lithuania refrigerants from A/C equipment are usually extracted before decommissioning and reused in other systems.

Emissions from end-of-life stationary A/C equipment were estimated using equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.51):

$$E_{end-of-life,t} = M_{t-d} \times p \times (1 - \eta_{rec,d})$$

where:

M_{t-d} - amount of HFCs initially charged into new systems installed in year (t-d), t;

P - residual charge of HFC in equipment being disposed of expressed in percentage of full charge, %;

$\eta_{rec,\ d}$ - recovery efficiency at disposal, which is the ratio of recovered HFCs referred to HFCs contained in the system, %.

Estimates of HFCs emissions from stationary air-conditioning systems are demonstrated in the figure below.

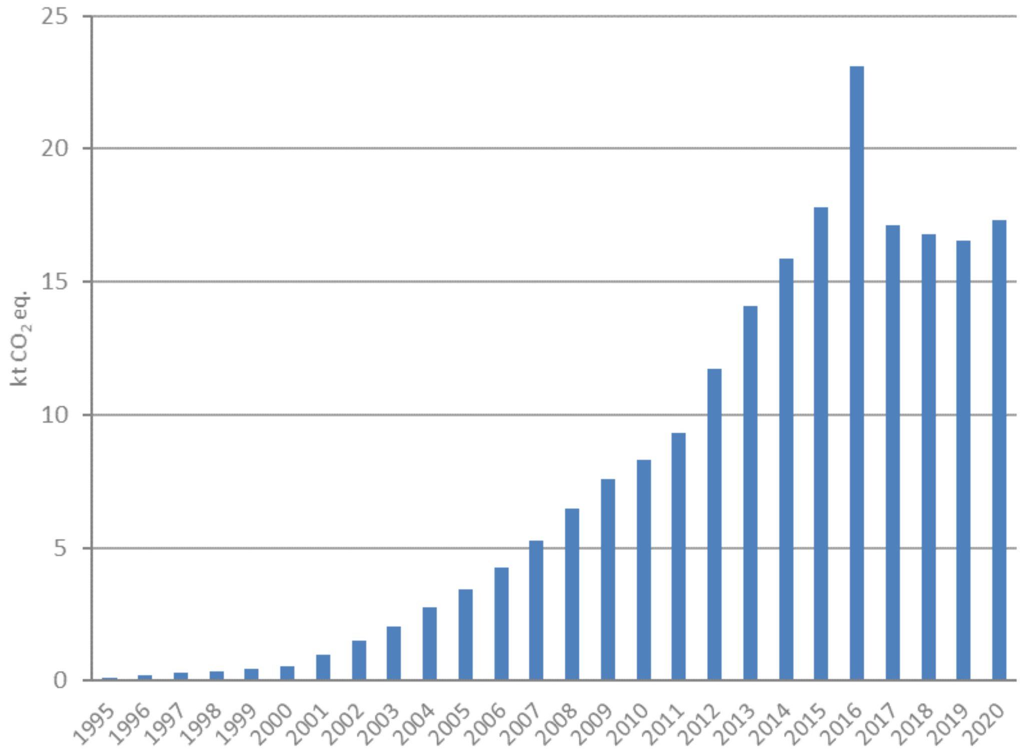

Figure 4-36. HFCs emissions from stationary air conditioning

As a result of implementation of F-gases regulation, HFCs emissions from stationary air-conditioning systems have started to decrease since 2017. However in 2020 emissions increased slightly (4 % compared with 2019) due to increased installation of new systems with HFC-32.

Heat pumps

Lithuanian Geothermal Association and companies which are engaged in installation and service heat pumps were contacted with a request to provide necessary data.

The Lithuanian Geothermal Association provided the following information:

- in Lithuania heat pumps have been installed since 2005, the largest number was installed in 2007, (about 700 units), approximately 400 units were installed in 2008;
- the average amount of refrigerant charged in the equipment is about 3 kg, though 6 kg is also possible;
- the main refrigerants used are R-407C and R-410A;
- the lifetime of the equipment is around 15 years;
- there are no leakages of emission during the operation of the equipment.

Companies installing heat pumps consider information on the number of installed heat pumps as confidential information, therefore the only source of information is summary data provided by EurObserv'ER (https://www.eurobserv-er.org/category/all-heat-pumps-barometers/ (2009-2019) and by Lithuanian Geothermal Association (2005-2008). Following the data provided by private liability companies and by the Lithuanian Geothermal Association, the following assumptions were formulated:

- the proportion of new geothermal/aerothermal pumps installed until 2010 was 75% : 25%, from 2010 – 50% : 50% (the company data) and from 2013 – 70%: 30% (based on EurObserv'ER data);
- the average amount of refrigerant charged in the equipment is 3 kg;
- R-407C accounts for about 80% and R-410A – for approximately 20% of the total amount of refrigerants in geothermal pumps, meanwhile 100% of aerothermal pumps are filled with R-410A;

In Lithuania heat pumps have been installed since 2005, their lifetime is 15 years, therefore emissions at system disposal were not estimated yet.

The calculations of emissions during the charging and operation of the equipment were made using the factors in the lower range limit given in the *2006 IPCC Guidelines*:

- the emission factor during the initial charging is 0.2%;
- the emission factor during the operation of the equipment is 1%.

Emissions of HFCs during the initial charging of new equipment were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.50, Tier 2a):

$$E_{charge,t} = M_t \times k$$

where:

$E_{Charge,\,t}$ - emissions during system manufacture/assembly in year t, t;

M_t - amount of HFCs charged into new equipment in year t, t;

k - emission factor of assembly losses of HFCs charged into new equipment, %.

Emissions during lifetime:

$$E_{liftime,t} = B_t \times x$$

where:

B_t - amount of HFCs banked in existing systems in year t, t;

x - emission factor of HFCs for each sub-application bank during operation, accounting for average annual leakage and average annual emission during servicing, %.

Total emissions:

$$E_{total,t} = E_{charge,t} + E_{lifetime,t}$$

Emissions in this sector were calculated for 2005-2020 on the basis of specific information on the beginning of the installation of these systems in Lithuania (2005). Estimates of HFCs emissions from heat pumps are demonstrated in the figure below.

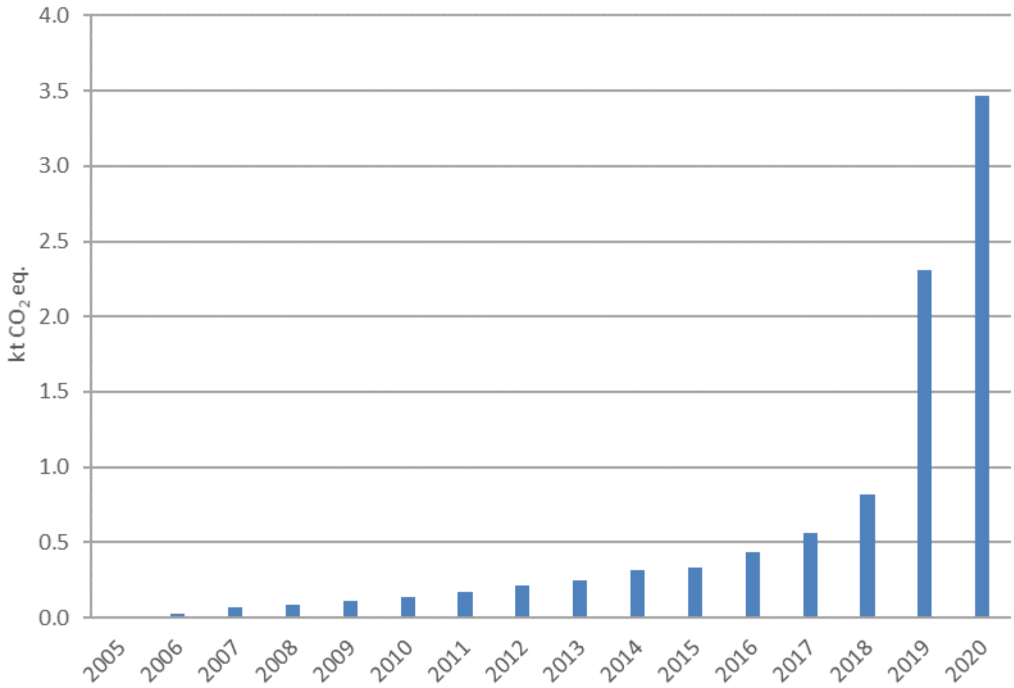

Figure 4-37. HFCs emissions from heat pumps

Estimates of total HFCs emissions from stationary air conditioning and heat pumps are provided in Table below. There was increase in number of installed heat pumps (in 2019-2021) according Study carried out by EurObser'ER in 2021, due to the installation of the new equipment.

Table 4-41. Total HFCs emissions from stationary air conditioning and heat pumps

Year	Emissions from stationary air conditioning, kt CO_2 eq.	Emissions from heat pumps, kt CO_2 eq.	Total emissions, kt CO_2 eq.
1995	0.10	NO	0.10
2000	0.57	NO	0.57
2005	3.46	0.00	3.46
2010	8.31	0.13	8.45
2011	9.34	0.17	9.51
2012	11.73	0.21	11.94
2013	14.08	0.25	14.33
2014	15.86	0.31	16.17
2015	17.78	0.34	18.12
2016	23.12	0.43	23.55
2017	17.10	0.56	17.66
2018	16.80	0.82	17.61
2019	16.55	2.31	18.86
2020	17.30	3.47	20.77

4.7.1.3 Uncertainties and time-series consistency

Uncertainties of acivity data were estimated using Approach 1 of the *2006 IPCC Guidelines* Volume 1 (p. 3.27):

- Uncertainty of activity data is 20%;
- Emission factors uncertainty is 50%.

4.7.1.4 Category-specific QA/QC and verification

All quality control procedures have been performed according to the procedures presented in Chapter 1.2.3. These procedures involve the check of the input data, assumptions and data criteria, references provided, emission calculations, units and conversion, consistency between source categories, aggregation and transcription. All findings have been documented using quality control protocols and checklists. All estimations of the emissions done in the EPA are checked for the logical mistakes by checking the time series of the activity data, emission factors and emissions consistency to display all significant and illogic changes in the activity data and emissions.

4.7.1.5 Category-specific recalculations

Following recalculations in this categories have been done:

- Recalculations of HFCs emissions in Domestic refrigeration have been done based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results for 1995-2019 (Table 4-42). Based on 2021 study results operation EF (0.7% is used instead of 0.4%) and the initial charge remaining at system disposal (refrigerators and freezers) were updated (90% is used instead of 80%).
- Recalculations of HFCs emissions in Transport refrigeration for 2014-2019 have been done based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results. The assumptions on the distribution of refrigerants in transport refrigeration were updated: F-gases used in transport refrigeration for 1993-2014– HFC-134a and R404A, and since 2015 refrigerant R452A was included. Futhermore the operation emission factor has been updated (EF-25% since 2020) and emissions from vehicles manufacturing were included (2018-2019) (Table 4-43).
- Recalculations of HFCs emissions in Mobile Air Conditioning for 2012-2019 have been done due to mistake in calculations and updated activity data on passenger carriages disposal. Based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results the assumptions on the share of vehicles equipped with mobile air conditioning systems by category and year of production since 2018 were updated (Table 4-44).
- Recalculations of HFCs emissions in Stationary Air-Conditioning have been done due to updated activity data for 2019 provided by EurObserv`ER Heat Pumps Barometer (Table4-45).

Table 4-42. Reported in previous submission and recalculated HFCs emissions from Domestic refrigeration, kt CO2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
1995	0.24	0.43	0.18	75.0
1996	0.25	0.41	0.16	67.0
1997	0.27	0.43	0.16	60.3
1998	0.30	0.47	0.18	59.1
1999	0.33	0.52	0.19	58.8
2000	0.51	0.56	0.05	10.7
2001	0.47	0.59	0.12	26.4
2002	0.45	0.63	0.18	39.7
2003	0.47	0.67	0.19	41.0
2004	0.50	0.71	0.21	40.9
2005	0.55	0.79	0.24	44.4
2006	0.56	0.79	0.23	41.5

2007	0.59	0.88	0.29	49.8
2008	0.62	1.05	0.43	69.7
2009	0.63	1.05	0.42	66.3
2010	1.86	1.39	-0.47	-25.5
2011	1.63	1.57	-0.05	-3.2
2012	1.68	1.69	0.01	0.5
2013	1.57	1.51	-0.06	-3.5
2014	1.65	1.41	-0.23	-14.2
2015	1.71	1.45	-0.26	-15.3
2016	1.67	1.55	-0.12	-7.3
2017	1.60	1.58	-0.02	-1.0
2018	1.56	1.64	0.08	4.9
2019	1.57	1.89	0.32	20.4

Table 4-43. Reported in previous submission and recalculated HFCs emissions from Transport refrigeration, kt CO2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2014	84.18	84.18	0.00	0.0
2015	86.81	83.41	-3.40	-3.9
2016	89.38	79.34	-10.04	-11.2
2017	86.30	70.66	-15.64	-18.1
2018	100.44	75.45	-24.99	-24.9
2019	110.81	76.62	-34.19	-30.9

Table 4-44. Reported in previous submission and recalculated HFCs emissions from Mobile Air-Conditioning, kt CO2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2012	93.59	93.59	0.01	0.01
2013	108.09	108.12	0.03	0.03
2014	115.56	115.62	0.06	0.05
2015	124.75	124.84	0.09	0.08
2016	129.35	129.39	0.04	0.03
2017	137.86	138.93	1.08	0.78
2018	146.31	151.05	4.74	3.24
2019	142.904	138.573	-4.33	-3.03

Table 4-45. Reported in previous submission and recalculated HFCs emissions from Stationary Air-Conditioning, kt CO2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2019	17.37	18.86	-1.49	-8.57

4.7.1.6 Category-specific planned improvements

Gradual improvement of the assumptions used to estimate the emissions of F-gases is ongoing. According to Regulation (EU) No 517/2014 emissions from Domestic refrigeration equipment are expected to decline due to EU wide measures and technical changes resulting in decreased leakage. One can assume that due to the ban on HFCs in domestic refrigerators and freezers the use of (and thus emissions from) HFCs in domestic refrigeration will be phased out gradually and that mainly emissions from disposal will occur. It is expected that emissions from Commercial and Industrial refrigeration sectors will decline in 2020–2035. The projected decline in 2020 is expected due to the entering into force of the new prohibition on the use of HFCs with GWP of 2500 and more to service or maintain refrigeration equipment. Due to HFC-125 and HFC-143a gases GWP is higher than 2500, the use of these gases to service and maintain refrigeration equipment will be prohibited from 2020. Furthermore, refrigerators and freezers for commercial use that contain HFCs with GWP of 150 or more will be prohibited to place on the market from 2022 (HFC-32, HFC-134a). Implementation of F-gases quota system (EU Regulation No 517/2014) will reduce amount of HFCs placed on the market by 79% between 2015 and 2030.

4.7.2 Foam Blowing Agents (CRF 2.F.2)

The study on the use of F-gases in Lithuania (2012) verified the information provided in the previous National inventory reports that HFCs are not used for foam manufacture in Lithuania. A number of producers of foams for construction or packaging are using BASF technology in which foams are blown by the steam. Lithuanian producer of domestic refrigerators uses cyclopentane for production of insulation foams.

4.7.2.1 Category Description

Foam blowing agent category is divided into two sub-categories: closed cells (CRF 2.F.2a) and open cells (CRF 2.F.2.b) (NO).

Closed Cells (CRF 2.F.2.a)

In this sector HFCs are emitted only from the use of imported foam products containing fluorinated gases. Eleven biggest companies importing foam products were interviewed in 2013. Two companies using closed cell polyurethane (PU) foams (insulation spray) have confirmed the use of products containing HFCs and provided data on the total amount of material used and composition of the HFCs (HFC-365mfc, HFC-134a, HFC-245fa, HFC-227ea). According to the data provided by one of the company, actual amounts of HFCs used for the foam blowing constitute 7.5% of the foam material by weight.

Open Cells (CRF 2.F.2.b)

The study on the use of F-gases (2012) in Lithuania verified that HFCs are not used for foam manufacture in Lithuania, so for the category "CRF 2.F.2.b Open Cells" notation key "NO" is used.

4.7.2.2 Methodological issues

Closed Cells (CRF 2.F.2.a)

The following assumptions and calculations were made on the basis of summary information provided by companies and in national reports and literature of other countries:

- The amounts (import and export) used in Lithuania were estimated following the statistical data on PU foam import and export for 2004-2019 provided by Statistics Lithuania (according to the results of the study "Analysis of the use of fluorinated greenhouse gases in Lithuania in 1990-2011" (2012) prior to 2004 in closed cell polyurethane (PU) foams HCFC-141b has been used, therefore emissions are estimated only for the period 2004-2019);
- 50% of this amount accounts for systems with HFCs (data source: UAB Termosnaigė);
- Blends used in systems with HFCs:
  - Variant I: 93% HFC-365mfc, 7% HFC-227ea;
  - Variant II: 95% HFC-365mfc, 5% HFC-245fa;
  - Variant III: 100% HFC-134a.

Frequency of the use of these blends: Variant I – 60%, Variant II – 20%, Variant III – 20% (based on the 2012 National Inventory Report of Lithuania, Estonia and Germany and other literature);

- Estimations included the initial amount of HFCs for PU foam production in the system;

- Following the *2006 IPCC Guidelines* Volume 3, part 2 (p. 7.35):
  - the first year loss emission factor is 10%;
  - the annual loss emission factor is 4.5%;
  - the lifetime of the system is 20 years, therefore emissions at system disposal were not estimated.

Emissions of HFCs from closed cell foam were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.33, Tier 2a):

$$Emissions_t = M_t \times EF_{FYL} + Bank_t \times EF_{AL}$$

where:

M_t - total HFCs used in manufacturing new closed-cell foam in year t, t;

EF_{FYL} - first year loss emission factor, fraction;

$Bank_t$ - HFC charge blown into closed-cell foam manufacturing between year t and year t-n, t;

EF_{AL} - annual loss emission factor, fraction.

According to the information received from companies, HCFC 141b was used until 2004 (which is verified by data from other countries and literary sources). When the use of this gas was prohibited, other blowing agents were started to be used (HFC-365mfc, HFC-227ea, HFC-245 fa, HFC-134a), therefore emissions in Lithuania were estimated for the period 2004-2020.

Estimations of HFCs emissions from closed cell foam are demonstrated in the figure below.

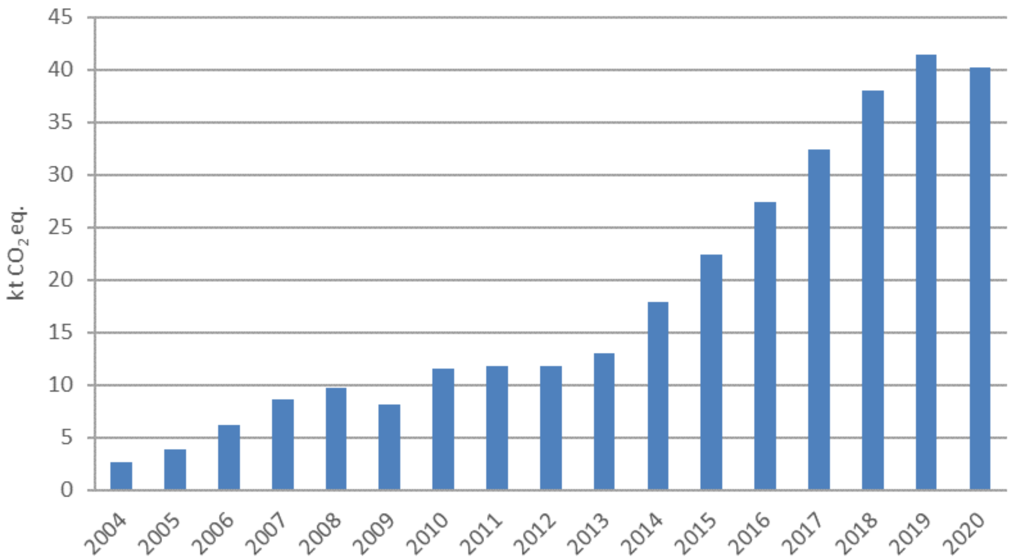

Figure 4-38. Emissions from closed cell foam

One company, which has been operating in Lithuania since 1997, one of the largest polyurethane producers in the world, informed that it has never used fluorinated gases in its production and has been using chlorides instead.

Estimates of HFCs emissions from foam blowing are presented in he table below.

Table 4-46. Total HFCs emissions from foam blowing

Year	Emissions, kt CO_2 eq.
2005	3.91

2010	11.60
2011	11.79
2012	11.84
2013	12.97
2014	17.91
2015	22.41
2016	27.42
2017	32.45
2018	38.00
2019	41.39
2020	40.22

4.7.2.3 Uncertainties and time-series consistency

Emission uncertainty was estimated using Approach 1 of the *2006 IPCC Guidelines* (Volume 1, p. 3.27):

- Input data uncertainty is assumed to be 30%;
- EF during operation uncertainty is assumed to be 30%;
- Total emission uncertainty is assumed to be 42%.

4.7.2.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.7.2.5 Category-specific recalculations

No recalculations have been done.

4.7.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.7.3 **Fire Protection (CRF 2.F.3)**

4.7.3.1 Category Description

The following information on fluorinated gas use in fire protection systems was provided as a result of the Study on F-gases (2012) and EPA database:

- the main source of fluorinated gases in fire extinguishers is automatic gas systems;
- the main gas is FM 200 (HFC-227ea), which has been used since 1996;
- small amounts of HFC-23 have also been used;
- the average amount of gas contained in one system totals 100 kg, however, the range is 50-500 kg (or even 1.000 kg), therefore it is not appropriate to estimate gas amounts on the basis of the number of installed systems;
- as from the year 2008 basically only FM 200 is used, meanwhile FS49C2 (R866) is no longer in use;
- fluorinated gases are not used in newly installed fire extinguishing systems;
- systems were triggered by fire or accidentally, when all gasses are emitted into the atmosphere, only once or twice a year, therefore the emission factor used for emission calculations was the one recommended in the *2006 IPCC Guidelines* (1.5%);
- there are no recovery systems yet.

The Ministry of National Defence provided data on the amounts of HFC-236fa contained in fire protection systems installed in vehicles. So far these systems have not been triggered. Emissions were estimated using the emission factor recommended in the *2006 IPCC Guidelines* (1.5%).

4.7.3.2 Methodological issues

Emissions were calculated using the methodology described below. The amounts of FS49C2 and emissions were estimated on the basis of the EPA data because no other data was available. The annual amounts for 2000-2020 were estimated on the basis of the following assumptions:

- the gas has been used since 2000;
- the amount of the gas in 2000 comprised 20% of the amount in 2011;
- the amount of the gas in 2012-2019 is estimated on the basis of the EPA data;
- the gas has not been used in systems since 2007;
- the emission factor is 1.5% (*2006 IPCC Guidelines*).

The study "Analysis of the use of fluorinated greenhouse gases in Lithuania in 1990-2011" (2012) identified possible negligible use of HFC-23 in the fire protection systems, however no data on amount of HFC-23 was gathered during the study, therefore in order to determine the possible emissions of HFC-23, estimate using per capita emission data from neighboring countries (Latvia and Estonia) was done. The data of HFC-23 in t was taken from Latvian and Estonian national inventories and the arithmetic mean per capita was calculated. HFC emissions per capita in Latvia varies from 4.7 to 6.6 kg CO_2 eq, in Estonia from 167 to 768.3 kg CO_2 eq. HFC-23 emissions in Lithuania were calculated based on the average HFC emission per capita in Latvia and Estonia and the population in Lithuania. Estimated data revealed that emissions from this sub-category are insignificant as per decision 24/CP.19, para. 37(b)) and it was assumed that emissions of HFC-23 since 2017 is constant at 1.01 kt CO2 eq. per year.

Estimates of HFC-23 emissions are presented in the table below.

Table 4-47. HFC-23 emissions in the fire protection systems

Year	Emissions, kt CO_2 eq.
2005	0.28
2010	0.90
2011	0.89
2012	0.97
2013	0.97
2014	1.04
2015	1.03
2016-2020	1.01

The annual amounts of HFC-227ea were estimated on the basis of:

- information provided by companies;
- assumption that installation of the systems depends on construction trends (data of Statistics Lithuania on the useful floor area of completed buildings for 2000-2010);
- the amount of the gas in 2011-2020 is estimated on the basis of the EPA data;
- the emissions factor is 1.5% (*2006 IPCC Guidelines*).

Data on the amount of HFC-227ea in 2.F.3 Fire protection have been collected in EPA's database only since 2011 and for the period 2011-2020, emission estimates are based on this data. Prior to 2010, there was no data. Therefore, 2011 EPA data and Statistics Lithuania data on the useful floor area of completed buildings were used to gap fill for missing data. This estimation method was developed and performed during the study "Analysis of the use of fluorinated greenhouse gases in Lithuania in 1990-2011" (2012).

The lifetime of the equipment is 20 years (the lifetime of military equipment is longer, 25-30 years) therefore emissions at system disposal were not estimated.

Emissions of HFCs from fire protection systems were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.61):

$$Emissions_t = Bank_t \times EF$$

where:

$Bank_t$ - bank of agent in fire protection equipment in year t, t;

EF - fraction of agent in equipment emitted each year.

Estimates of HFCs emissions from fire protection systems are demonstrated in the figure below.

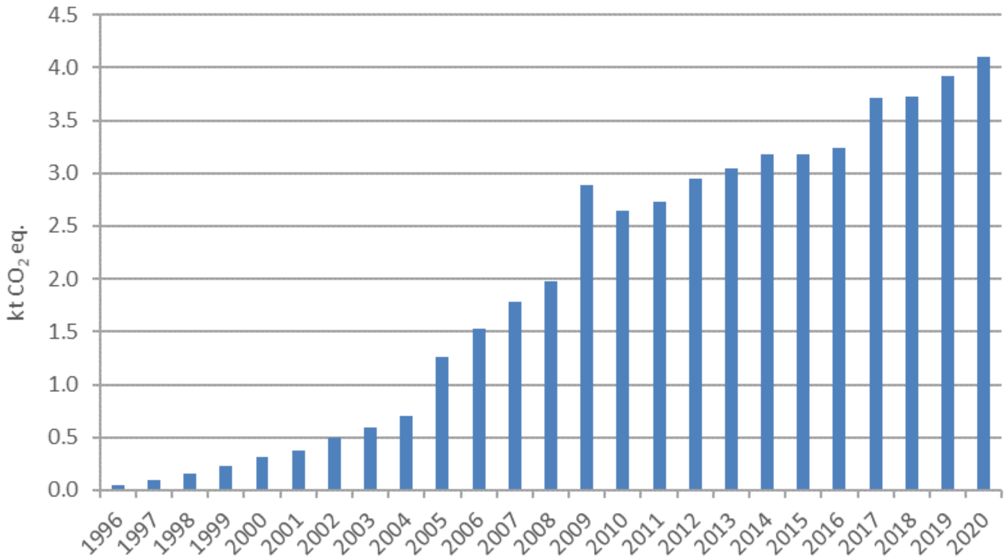

Figure 4-39. HFCs emissions from fire protection systems

Estimates of HFCs emissions from fire protection systems are presented in the table below.

Table 4-48. Total HFCs emissions from fire protection systems

Year	Emissions, kt CO_2 eq.
2000	0.31
2005	1.26
2010	2.64
2011	2.72
2012	2.95
2013	3.04
2014	3.18
2015	3.18
2016	3.24
2017	3.71
2018	3.72
2019	3.92
2020	4.10

4.7.3.3 Uncertainties and time-series consistency

Emission uncertainty was estimated using Approach 1 of the *2006 IPCC Guidelines* (Volume 3, p. 3.27):

- Input data uncertainty is assumed to be 20%;
- EF during operation uncertainty is assumed to be 20%;
- Total emission uncertainty is assumed to be 28%.

4.7.3.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.7.3.5 Category-specific recalculations

No recalculations have been done.

4.7.3.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.7.4 **Aerosols (CRF 2.F.4)**

Based on the results of the study "Analysis of the use of fluorinated greenhouse gases in Lithuania in 1990-2011", there are no production of aerosols containing F-gases in Lithuania, all aerosols are imported and aerosols containing F-gases have not been identified. Therefore, only emissions from metered dose inhalers are reported under this sector. The new study (2021) has not identified other sources of aerosols in Lithuania (except for medical aerosols already accounted).

4.7.4.1 Category Description

Aerosols category are divided into two sub-categories metered dose inhalers (CRF 2.F.4.a) and other (CRF 2.F.4.b) (NO).

Metered Dose Inhalers (CRF 2.F.4.a)

Data on total annual sales of metered dose inhalers containing HFCs and a specific amount of HFC-134a and HFC-227ea initially charged in product was obtained from the State Medicines Control Agency under the Ministry of Health of the Republic of Lithuania. The State Medicines Control Agency has detailed data on total annual sales of metered dose inhalers and amount of HFCs (types of HFCs used as propellants) initially charged in product. The data is very reliable and detailed as all medicines sold in Lithuania have to be registered in the Register of Medicinal Products of the Republic of Lithuania. Information only on sales of MDIs charged with HFC-134a and HFC-227ea was reported by the State Medicines Control Agency.

The data was available for the period 2004-2020. Emissions for the period 1995-2003 were extrapolated, taking into account that metered dose inhalers containing HFCs started to be registered in Lithuania's Register of Medicinal Products from 1994 year and making an assumption that emissions in 1995 constituted 50% of emissions in 2004.

Other (CRF 2.F.4.b)

HFC emissions from other aerosols production is not occurring in Lithuania so for the category "CRF 2.F.4.b Other" notation key "NO" is used.

4.7.4.2 Methodological issues

Metered Dose Inhalers (CRF 2.F.4.a)

Emissions of HFCs from metered dose inhalers were calculated using the following equation (*2006 IPCC Guidelines*, Volume 3, part 2, p. 7.28):

$$E_t = S_t \times EF + S_{t-1} \times (1 - EF)$$

where:

S_t - quantity of HFCs contained in aerosol products sold in year t, t;

S_{t-1} - quantity of HFCs contained in aerosol products sold in year t-1, t;

EF - emission factor (fraction of chemical emitted during the first year).

Estimates of HFCs emissions from metered dose inhalers are demonstrated in the figure below.

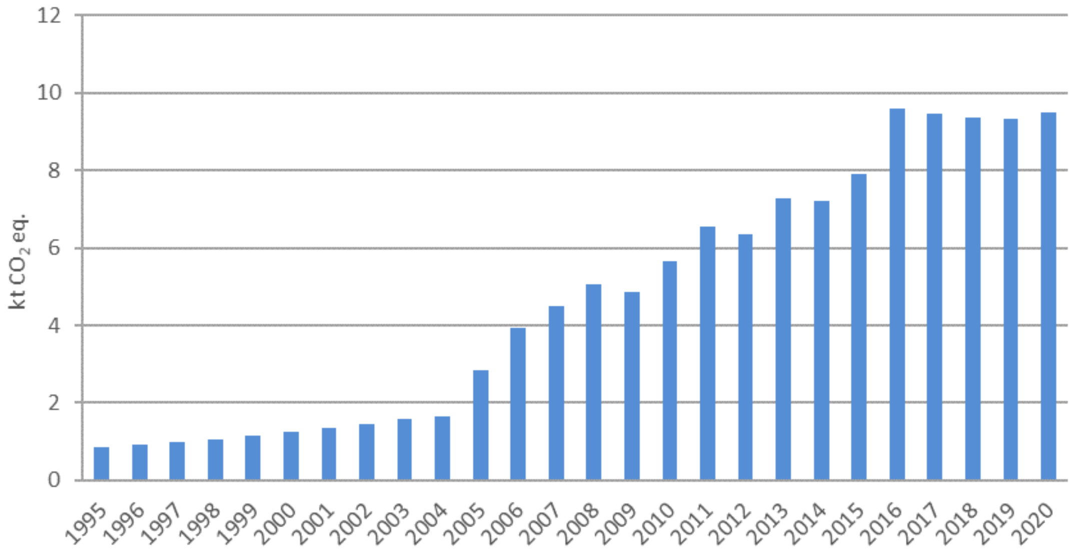

Figure 4-40. HFCs emissions from metered dose inhalers

Estimates of HFC emissions from metered dose inhalers are presented in the table below.

Table 4-49. Total HFCs emissions from metered dose inhalers

Year	Emissions, kt CO_2 eq.
1995	0.85
2000	1.25
2005	2.84
2010	5.65
2011	6.55
2012	6.35
2013	7.26
2014	7.21
2015	7.89
2016	9.59
2017	9.45

2018	9.36
2019	9.33
2020	9.51

4.7.4.3 Uncertainties and time-series consistency

Emission uncertainty was estimated using Approach 1 of the *2006 IPCC Guidelines* (Volume 1, p. 3.27):

- Input data uncertainty is assumed to be 5%;
- EF during operation uncertainty is assumed to be 5%;
- Total emission uncertainty is assumed to be 7%.

4.7.4.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.7.4.5 Category-specific recalculations

Recalculations in this category have been done based on 2021 study on F-gases use results. Activity data on metered dose inhalers with HFC-227ea use were additionally included in the NIR (2014-2019).

Table 4-50. Reported in previous submission and recalculated CO_2 emissions from metered dose inhalers

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2014	6.20	7.21	1.01	0.16
2015	5.94	7.89	1.96	0.33
2016	7.67	9.59	1.92	0.25
2017	7.56	9.45	1.89	0.25
2018	7.49	9.36	1.87	0.25
2019	7.38	9.33	1.96	0.27

4.7.4.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.7.5 **Solvents (CRF 2.F.5)**

Three studies of the use of fluorinated gases in Lithuania (2008, 2012 and 2021) have not identified any potential area for application for the solvents containing fluorinated gases. Taking into account the experience from other countries it is very unlikely that solvents containing fluorinated gases are used in significant quantities in Lithuania. Therefore notation keys „NA“ (1990-1994) and „NO“ (1995-2019) are used.

4.7.6 **Other Applications (CRF 2.F.6)**

Fluorinated gases emissions from other applications are not occurring in Lithuania, so for the category “CRF 2.F.6.a Emissive” and “CRF 2.F.6.b Contained” notation key “NO” is used.

4.8 Other product manufacture and use (CRF 2.G)

This section covers emissions of sulphur hexafluoride (SF_6) and nitrious oxide (N_2O) from Electrical Equipment (2.G.1), Accelerators (2.G.2.b), Medical Applications (2.G.3.a) and Other (2.G.3.b) (Table 4-50). SF_6 is used for electrical insulation and current interruption in equipment used in the transmission and distribution of electricity and in hospitals providing oncological treatment. In 2020 SF_6 emissions were estimated at 0.21 kt CO_2 eq. N_2O is used for anesthesia and aerosol cans. In 2020 N_2O emissions were estimated at 3.4 kt CO_2 eq. Emissions of the category were 0.1 % of the emissions of the industrial processes and product use sector.

Table 4-51. Reported emissions under the category Other product manufacture and use

CRF	Source	Emissions reported	Methods	Emission factor
2.G.1	Electrical Equipment	SF_6	Tier 3	CS
2.G.2.b	Accelerators	SF_6	Tier 3	CS
2.G.3.a	Medical Applications	N_2O	Tier 1	D
2.G.3.b	Other	N_2O	Tier 1	OTH

4.8.1 Electrical Equipment (CRF 2.G.1)

4.8.1.1 Category Description

Sulphur hexafluoride (SF_6) is used for electrical insulation and current interruption in equipment used in the transmission and distribution of electricity. Most of the SF_6 used in electrical equipment is used in gas insulated switchgear and substations and in gas circuit breakers.

The Lithuanian energy management system is on continual reorganization. The study on the use of F-gases (2012) in Lithuania identified all electrical equipment which was transferred from the balance of some companies to others, drawing up a single register. The data was provided by the following 3 companies:

- operator of the electricity transmission system;
- operator of the electricity distribution network;
- operator of electrical equipment.

As for 2020, high voltage equipment, which suffers operational losses and requires annual recharge is managed by the companys. Medium voltage equipment is leak proof and will be returned to the manufacturer after the expiry of its lifetime.
These 3 companies provided exact data on annual operating losses meanwhile other companies pointed out that there have been no emissions from their equipment. Operating losses from electric equipment are relevant exclusively to high voltage grid. SF_6 containing units used in medium voltage grid are hermetic. Leak proof is guaranteed and serviced by the producer. At the end of the service period the units will be returned to the producer. Until now the companies operating medium voltage grid were not asked to provide any measurements or tests to proof emissions from sealed units.

All companies ensured that the lifetime of their equipment has not expired yet therefore there have been no emissions at system disposal (but even in such case the equipment would be forwarded to the manufacturer).

Operating companies also declared the use of the SF_6 gas in their equipment:

- the SF6 gas has been contained in high voltage power equipment since 2000, no operating losses have been registered so far;
- the SF6 gas has been contained in many facilities operated by electrical company for about 20 years, the equipment is hermetic, no maintenance has been required so far (in such case the equipment would be forwarded to the manufacturer).

4.8.1.2 **Methodological issues**

Following the *2006 IPCC Guidelines*, emissions were estimated using Tier 3 method (on the basis of the data directly obtained from each company) for the period 1995-2020 (first operating losses were registered in 1995).

Estimates of SF_6 emissions in the sub-category of electrical equipment are demonstrated in the figure below.

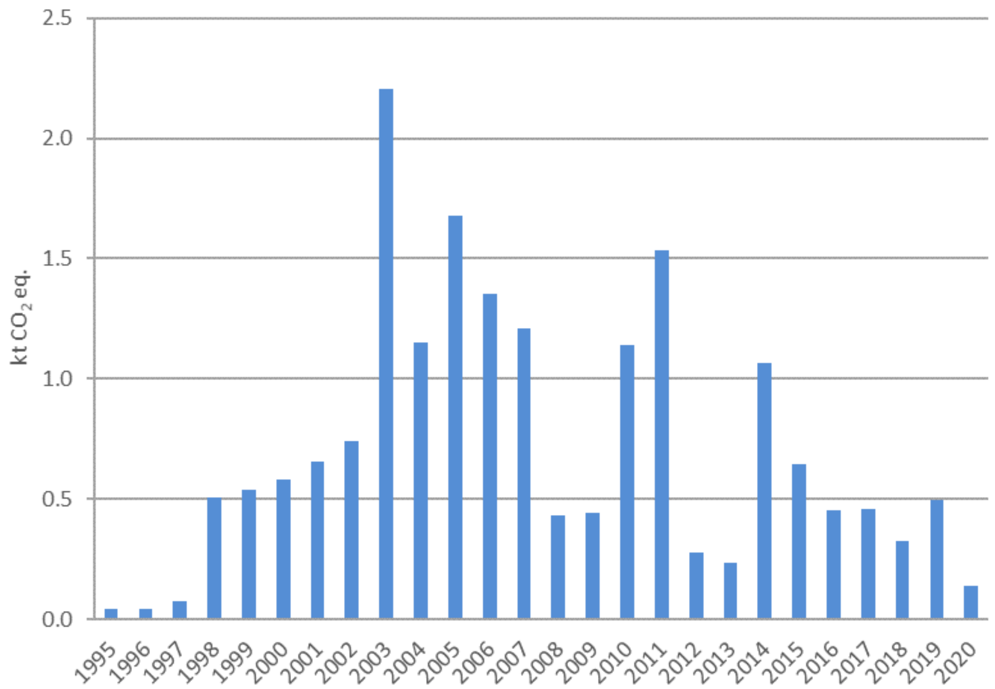

Figure 4-41. SF_6 emissions from electrical equipment

Operating companies were asked to comment on the emission variations. It was explained that the emissions cover both allowable operating losses and leakages due to various technical faults and in due to system reorganization.

Estimates of fluorinated gas emissions from electrical equipment are presented in the table below.

Table 4-52. Total SF_6 emissions from electrical equipment

Year	Emissions, kt CO_2 eq.
1995	0.05
2000	0.58
2005	1.68
2010	1.14
2011	1.53
2012	0.28
2013	0.24
2014	1.06

2015	0.64
2016	0.46
2017	0.46
2018	0.32
2019	0.49
2020	0.14

4.8.1.3 Uncertainties and time-series consistency

Emission uncertainty was estimated using Approach 1 of the *2006 IPCC Guidelines* (Volume 3, p. 3.27):

- Input data uncertainty is assumed to be 5%;
- EF during operation uncertainty is assumed to be 5%;
- Total emission uncertainty is assumed to be 7%.

4.8.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.8.1.5 Category-specific recalculations

No recalculations have been done.

4.8.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.8.2 **SF_6 and PFCs from other Product Use (CRF 2.G.2)**

4.8.2.1 Category Description

The entities surveyed during the study on the use of F-gases (2012) in Lithuania also included:

- largest manufacturers of double-glazed windows;
- hospitals providing oncological treatment.

The manufacturers of sound-proof double-glazed windows confirmed that the SF_6 gas for double-glazed windows is not used in Lithuania. The gas used instead is inert argon (in rare cases – crypton). Moreover, all windows that contain F-gases are prohibited to place on EU market since 2008 (windows for domestic use are prohibited already since 2007) (Annex III of Regulation (EU) No 517/2014).

The surveyed hospitals which apply radiation therapy for cancer treatment confirmed the use of accelerators containing the SF_6 gas (4 hospitals, 12 units).

SF_6 gas emissions were estimated based on the data provided directly by the hospitals for 1999-2011 (the first devices were put into operation in 1999). The activity data on accelerators containing F-gases use were updated in 2021 study.

Emissions increased in 2000, 2003, 2006, 2009, and 2011 due to the use of the equipment Mevatron MD2 in the one of the hospitals when the total amount of the SF_6 gas was emitted during the replacement of the magnetron. According explanation received from the hospital, during the change of magnetron due the specifics of the operation all amount of SF_6 gas is emitted directly to atmosphere. There is no information on the specific years when the magnetron was replaced; however, it is known that it was replaced four times from the start of its operation, so it was assumed that the replacements took place at regular intervals. This equipment was dismantled in 2011.

Estimates of SF_6 emissions from accelerators (in radiation therapy facilities) are demonstrated in the figure below.

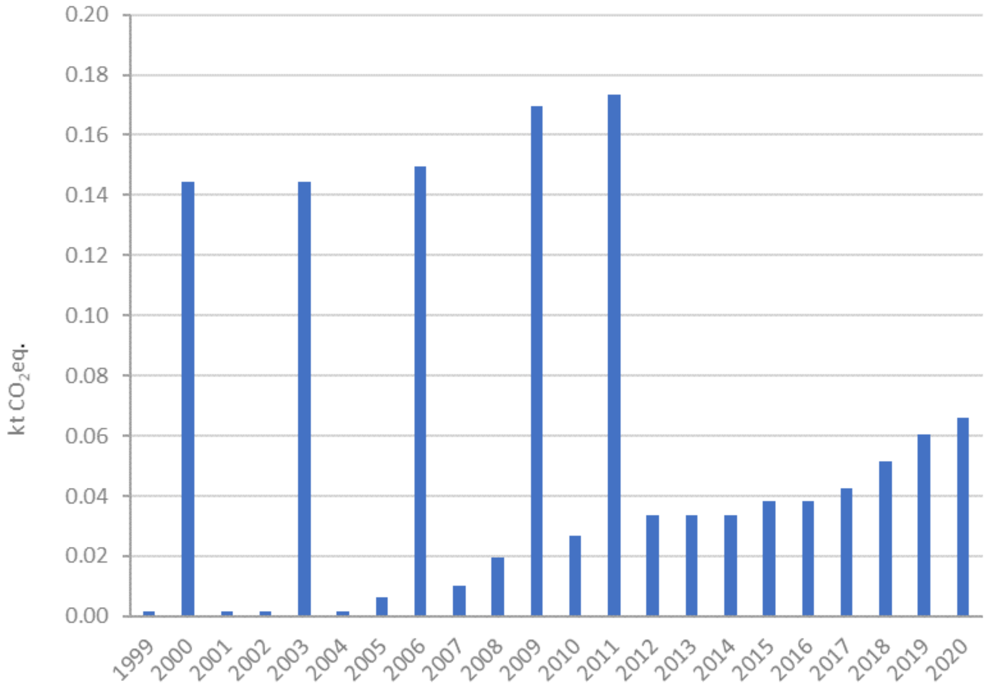

Figure 4-42. SF_6 emissions from accelerators (in radiation therapy facilities)

Estimates of SF_6 emissions from accelerators (in radiation therapy facilities) are presented in the table below.

Table 4-53. Total SF_6 emissions from accelerators (in radiation therapy facilities)

Year	Emissions, kt CO_2 eq.
2000	0.14
2005	0.01
2010	0.03
2011	0.17
2012	0.03
2013	0.03
2014	0.03
2015	0.04
2016	0.04
2017	0.04
2018	0.05
2019	0.06
2020	0.07

4.8.2.2 Uncertainties and time-series consistency

Emission uncertainty was estimated using Approach 1 of the *2006 IPCC Guidelines* (Volume 3, p. 3.27):

- Input data uncertainty is assumed to be 5%;
- EF during operation uncertainty is assumed to be 5%;
- Total emission uncertainty is assumed to be 7%.

4.8.2.3 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.8.2.4 Category-specific recalculations

Recalculations in this category have been done based on 2021 study on F-gases use results. Activity data on accelerators containing F-gases use were updated (2005-2019).

Table 4-54. Reported in previous submission and recalculated CO_2 emissions from SF_6 and PFCs from other Product Use

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
2005	0.02	0.01	-0.01	-0.69
2006	0.18	0.15	-0.03	-0.18
2007	0.04	0.01	-0.03	-0.74
2008	0.08	0.02	-0.06	-0.75
2009	0.24	0.17	-0.07	-0.29
2010	0.11	0.03	-0.09	-0.76
2011	0.28	0.17	-0.11	-0.38
2012	0.16	0.03	-0.12	-0.79
2013	0.16	0.03	-0.12	-0.79
2014	0.16	0.03	-0.12	-0.79
2015	0.16	0.04	-0.12	-0.76
2016	0.16	0.04	-0.12	-0.76
2017	0.16	0.04	-0.11	-0.73
2018	0.16	0.05	-0.11	-0.67
2019	0.16	0.06	-0.10	-0.61

4.8.2.5 Category-specific planned improvements

Category-specific improvements are not planned.

4.8.3 N_2O from Product Uses (CRF 2.G.3)

4.8.3.1 Category Description

This category includes emissions from the use of N_2O for anesthesia and N_2O emissions from aerosol cans.

The data from anesthesia on the N_2O sales was available since 2005. Activity data was provided by the State Medicines Control Agency, which collects data from the wholesale companies. Emissions for 1990-2004 were extrapolated with the increasing trend accordingly. Decrease in N_2O emissions since 2008 is related to decreasing number of inhalational anesthesia (N_2O is used only during inhalational anesthesia) comparing with injection anaesthesia, which is more widely used in recent years in Lithuania.

Currently there is no possibility to collect data from N_2O emissions from aerosol cans in Lithuania. However, N_2O emissions from aerosol cans in Lithuania was estimated based on Belgium data (Belgium greenhouse inventory report, 2016).

4.8.3.2 Methodological issues

N_2O emissions from N_2O used in anesthesia were estimated taking into account amount of N_2O sold in Lithuania. Following the *2006 IPCC Guidelines*, it was assumed that 100% of N_2O sold for anesthesia was emitted to the air, therefore activity data is equal to estimated emissions.

According to Belgium inventory report the N_2O emission from aerosol cans was estimated on the basis of the average European consumption (number of food aerosol can/inhab) obtained from DETIC (Belgian-Luxembourg Association of producers and distributors of soaps, cosmetics, detergents, cleaning products, hygiene and toiletries, glues, and related products) for the year 2012. Because of a lack of activity data before 2012, this average consumption is assumed to be constant over time. The activity data (number of aerosol cans) is then calculated for the complete time series on the basis of the number of inhabitant. The emission factor for N_2O is 7.6 g/can (as estimated in the Netherlands on the basis of data provided by one producer) and is assumed to be constant over time. When compared to several countries estimated emissions show comparable value (Figure 4-43).

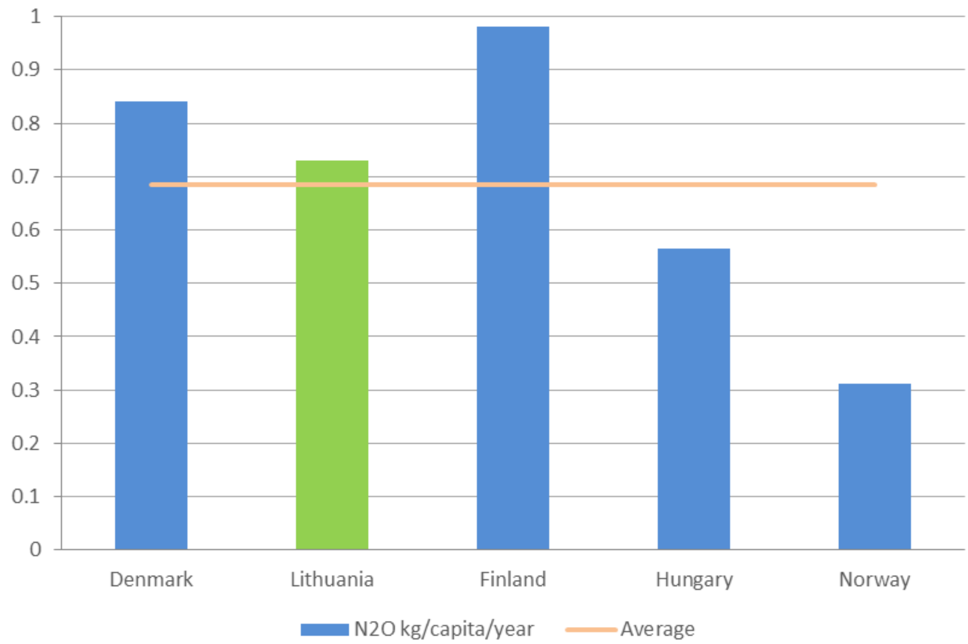

Figure 4-43. Comparison of estimated N_2O kg/capita/year from aerosol cans data with other countries

N_2O emissions from medical applications and from aerosol cans are shown in the table below.

Table 4-55. Estimated N_2O emissions from medical applications and aerosol cans, kt/year

Year	N_2O emissions from anesthesia, kt CO_2 eq.	N_2O emissions from aerosol cans, kt CO_2 eq.
1990	93.35	2.70
1995	84.41	2.65
2000	75.47	2.55
2005	66.53	2.43
2010	3.24	2.26

2011	3.52	2.21
2012	2.50	2.18
2013	2.60	2.16
2014	3.05	2.14
2015	2.77	2.12
2016	2.58	2.09
2017	3.01	2.06
2018	3.06	2.05
2019	2.56	2.04
2020	1.34	2.04

4.8.3.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Uncertainty of activity data is assumed to be 5% for N_2O emissions from N_2O used in anesthesia and 20% for N_2O emissions from aerosol cans;
- Emission factor uncertainty is assumed to be 5% for N_2O emissions from N_2O used in anesthesia and 100% for N_2O emissions from aerosol cans;
- Combined uncertainty is 41%.

4.8.3.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.8.3.5 Category-specific recalculations

No recalculations have been done.

4.8.3.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.8.4 Other (CRF 2.G.4)

HFC emissions from other sources are not occurring in Lithuania so for the category "CRF 2.G.4 Other" notation key "NO" is used.

4.9 Other (CRF 2.H)

This category includes emissions from pulp and paper, food and beverages industry (NO) and other (NO) (Table 4-51).

Table 4-56. Reported emissions under the category other

CRF	Source	Emissions reported	Methods	Emission factor
2.H.1	Pulp and paper	CO_2	Tier 1	D

4.9.1 Pulp and paper industry (CRF 2.H.1)

4.9.1.1 Category Description

In Lithuanian inventory this category includes non-fuel emissions of NOx, NMVOC and SO_2 from paper and pulp production. Pulp was produced in 1990-1993 in a single paper mill. Data on the pulp production was provided by company. Variations of pulp production are shown in Figure 4-44. Pulp is not produced in Lithuania since 1993. From 1994 to 2012 paper and corrugated board used for manufacturing of sanitarian and domestic products are made in the process of recycling the secondary raw material – waste-paper. Paper is produced in two companies in Lithuania.

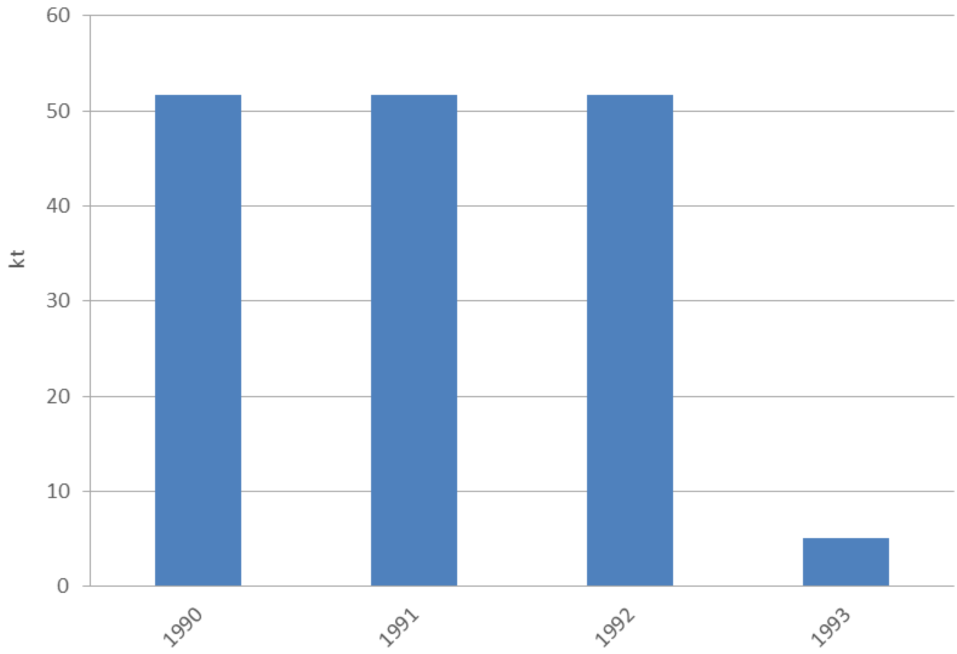

Figure 4-44. Pulp production

4.9.1.2 Methodological issues

Emissions of NO_x, NMVOC and SO_2 from pulp and paper manufacturing were calculated using *EMEP/EEA* emission inventory guidebook 2019. The company used acid sulphite pulping process for production of pulp. NO_x, NMVOC and SO_2 emissions were calculated from pulp production data using default emission factors shown in the table below (*EMEP/EEA*, 2H1. Pulp and paper industry, Table 3.1, p. 14).

Table 4-57. Emission factors for pulp production

Pollutant	EF, kg/tonne dried pulp
NO_x	2
NMVOC	0.2
SO_2	4

Estimated NMVOC emissions from pulp and paper production were converted to CO_2 using method provided in *2006 IPCC Guidelines* (Volume 1, Chapter 7, box 7.2, p. 7.6). Estimated NOx, NMVOC, CO_2 and SO_2 emissions from pulp production are shown in the table below.

Table 4-58. Estimated emissions from pulp and paper production, kt/year

Year	NO_x	NMVOC	CO_2 eq.	SO_2
1990	0.103	0.010	0.023	0.207
1991	0.103	0.010	0.023	0.207
1992	0.103	0.010	0.023	0.207
1993	0.010	0.001	0.002	0.020
1994-2020	NO	NO	NO	NO

4.9.1.3 Uncertainties and time-series consistency

All uncertainty estimates of activity data and emission factors have so far been based on expert judgment:

- Uncertainty of activity data is assumed to be 10%;
- Emission factor uncertainty is assumed to be 5%;
- Combined uncertainty is 11.2%.

Historical data on production of pulp was obtained from production company and covers period 1990-1993. Production of pulp was stopped in 1993.

4.9.1.4 Category-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

4.9.1.5 Category-specific recalculations

No recalculations have been done.

4.9.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

4.9.2 **Food and beverages industry (CRF 2.H.2)**

NMVOC emissions from food and beverages industry are from biogenic carbon so for the category "CRF 2.H.2 Food and beverages industry" notation key "NO" is used. Following the recommendation by the Expert Review Team, precipitated amount of lime from 2.A.2 category reported in 2.H.2 food and beverage. Information on CO_2 removals from consumption of carbonates in the sugar production industry is included in IPPU sector (CRF 2.A.2) in Chapter 4.2.2.2. Lime production of the NIR.

4.9.3 **Other (CRF 2.H.3)**

4.9.3.1 Category Description

Emissions from other production are not occurring in Lithuania so for the category "CRF 2.H.3 Other" notation key "NO" is used.

5 AGRICULTURE (CRF 3)

5.1 Overview of sector

Greenhouse gas (GHG) emissions from agriculture sector in Lithuania include: methane (CH_4) emissions from enteric fermentation of domestic livestock; CH_4 and nitrous oxide (N_2O) (direct and indirect) emissions from manure management; direct and indirect N_2O emissions from managed soils; carbon dioxide (CO_2) emissions from soil liming and application of urea. Direct N_2O emissions from agricultural soils include emissions that occur from application of synthetic nitrogen (N) containing fertilizers, application of organic fertilizers (manure, sewage sludge and compost), N deposited on pasture, range and paddock soils by grazing animals, N that is returned to soil with crop residues, including N-fixing crops and forages, N mineralized from loss in soil organic C, and cultivation of histosols. Indirect N_2O emission sources include emissions from atmospheric deposition and from nitrogen leaching and run-off. Source of CO_2 emissions is liming of soils (lime and dolomite) and application of urea. Rice is not cultivated and savannahs do not exist in Lithuania, therefore reported as "NO" in CRF tables. Field burning of agricultural residues is prohibited by the legislation and reported as "NO".

Emissions from energy use in agriculture (e.g. fuel combustion in agriculture machinery, heating of agriculture buildings, ect.) are reported in the Energy sector (NIR Chapter 3, CRF Table 1.A.4.c Agriculture/Forestry/Fishery) and are not included in the emissions reported in the Agriculture sector.

Significant reforms in Agriculture sector were introduced in early 1990s, particularly after the restoration of independence. The reform included the re-establishment of private ownership and management in the agriculture sector. Legislation defined dismemberment of the collective farms, but they did not definitively ensure their replacement by at least equally productive private farms or corporations. Agricultural production decreased by more than 50% from 1989 to 1994. The farms were broken into small holdings, averaging 8.8 ha in size, often not large enough to be economically viable. The agriculture sector contributed 24% of the national GDP in 1992 and employed 19% of the labour force. Lithuania's agriculture, efficient according to the past soviet standards, produced a huge surplus that could not be consumed domestically. Lithuania was producing crops, developing livestock farming and food processing industry. Crops accounted for 1/3 and livestock for 2/3 of the total value of agricultural output. Lithuanian agricultural production was high enough to allow the export of about 50% of the total output. In recent years Lithuanian economy has experienced a lot of structural changes –contribution of industrial and services sectors have increased rapidly, however, agriculture remains one of the most important sectors in export, and also it provides income to the tenth of Lithuanian population.

Table 5-1. GHG emissions from agriculture sector by sources during the period 1990-2020, kt CO_2 eq.

Year	Enteric fermentation	Manure management			Agricultural soils		Liming	Urea application	Total
			Direct	Indirect	Direct	Indirect			
	CH_4	CH_4	N_2O	N_2O	N_2O	N_2O	CO_2	CO_2	CO_2 eq.
1990	4,290.9	665.9	333.3	247.6	2,575.2	617.4	20.59	35.71	8,756.0
1995	2,170.5	370.9	154.8	119.2	1,281.0	219.9	4.03	6.74	4,327.1
2000	1,715.4	290.9	108.5	89.5	1,437.5	270.1	7.67	16.51	3,936.1
2005	1,697.0	316.9	111.4	99.3	1,504.0	303.4	6.92	31.54	4,070.5
2010	1,649.9	293.5	100.3	99.3	1,656.9	334.7	6.29	15.77	4,156.7

2011	1,631.6	290.4	98.6	98.1	1,708.0	346.9	8.75	14.19	4,196.7
2012	1,616.8	287.5	98.5	97.4	1,782.4	363.6	11.17	14.19	4,271.6
2013	1,585.8	287.5	99.7	96.8	1,778.6	365.1	16.77	15.77	4,246.1
2014	1,626.1	285.1	105.0	98.1	1,888.4	398.8	24.79	41.00	4,467.3
2015	1,634.3	285.9	108.0	99.2	1,956.5	416.6	19.25	17.98	4,537.7
2016	1,584.5	262.5	105.6	94.4	1,939.5	413.1	13.80	18.45	4,431.9
2017	1,537.3	249.0	103.4	91.7	1,963.1	419.4	12.23	14.04	4,390.1
2018	1,513.2	237.8	100.8	89.2	1,882.2	397.5	11.45	15.93	4,248.1
2019	1,483.1	229.4	97.2	85.0	1,927.8	405.9	12.42	15.77	4,256.6
2020	1,445.4	231.6	95.7	84.1	2,121.5	449.6	7.02	15.94	4,450.9

From 1990 to 2020 emissions in agriculture sector have decreased by 49.2% (Table 5-1). In 2020, overall GHG emissions from agriculture sector have increased by 4.6% comparing with 2019.

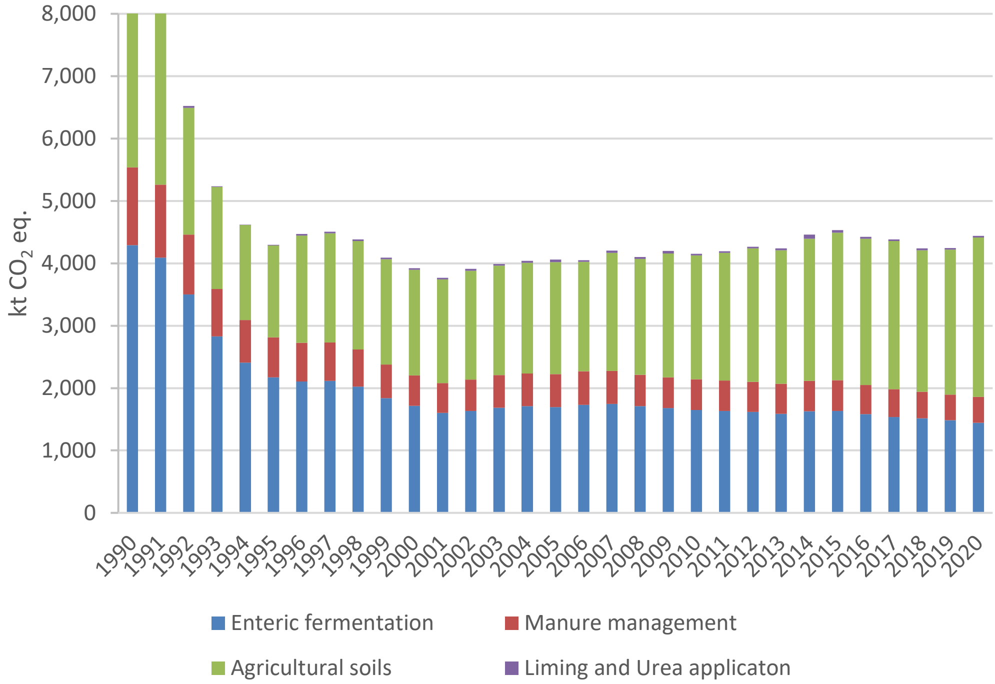

Figure 5-1. Emissions by category during the period 1990-2020

The most important GHG gases in agriculture sector are N_2O and CH_4, in 2020 it contributed to the agriculture emissions respectively 61.8% and 37.7%. The major part of N_2O emissions comprises from agriculture soils – 57.8%. Application of inorganic N fertilizer and cultivation of histosols leads to substantial emissions of N_2O from agricultural soils. Digestive processes are responsible for the major part of CH_4 emissions from agriculture sector – 32.5%. Liming and Urea application are the two sectors that are responsible for CO_2 emissions from agriculture sector, accounting for 0.6% share of total agriculture emissions in 2020.

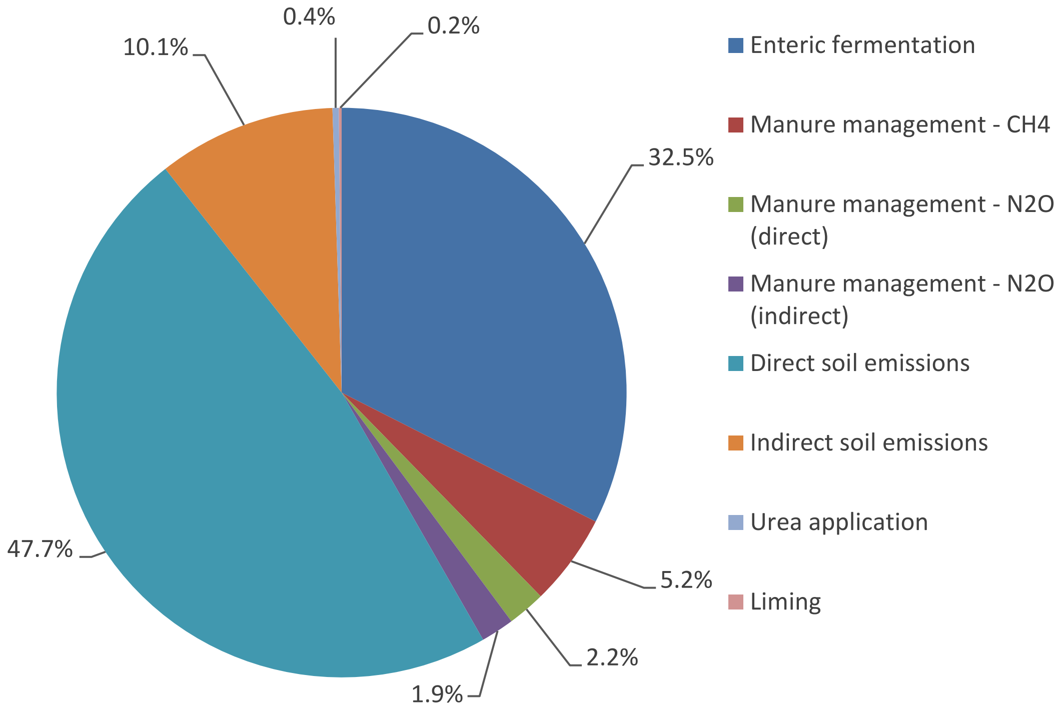

Figure 5-2. The share of emissions by categories from key sources within the sector in 2020, %

Characterization of livestock data

Livestock population data

Livestock population data were obtained from the database and publications of Statistics Lithuania (as of 1st of January)[18]. The data given in the database and publications of Statistics Lithuania is collected by applying continuous accountability for agriculture companies and applying sampling methods for farmers and households.

In order to estimate GHG emissions resulting from livestock species (enteric fermentation, CH_4 and N_2O from manure management, and, the direct and indirect N_2O emissions from agricultural soils associated with livestock) livestock population data based on Statistics Lithuania as of 1st of January of each year were recalculated into annual average livestock population according to *2006 IPCC Guidelines* recommendations. For adult animals, population data were based on the average between two years of data on the 1st of January. Annual average population data of growing (grown up to one year and marketed or slaughtered for human consumption) animals were calculated using the equation[19]:

$$AAP = Days\_alive \times \left(\frac{NAPA}{365}\right)$$

where:

AAP - annual average population;

NAPA - number of animals produced annually.

[18] Data on livestock population Statistics Lithuania reports as of 1st of January for the previous year, e.g. data reported 1st of January 2020 would represent data of 2019. *Note: this reporting format might, in some cases, be the cause of disparities between national and international databases.*

[19] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, eq. 10.1, p. 10.8

CRF 3.A.4 Other category consists of fur-bearing animals, rabbits and other (nutria) livestock categories. The reason why nutria is called "Other" is that there is no possibility in CRF to rename it to nutria. Therefore, for the clarity purpose, it was decided near Other category in bracket write nutria.

In Lithuanian's inventory, livestock category of cattle consists of dairy cattle and non-dairy cattle. Non-dairy cattle category, according to database of Statistics Lithuania, consists of 11 subcategories (table below). For the period of 1990-1996 not all information on relevant 11 sub-categories were available in the database of Statistics Lithuania. At that period non-dairy cattle category was divided in to the following sub-categories: bulls, dairy cattle, from 1 to 2 years old heifers, and 2 years old and older heifers, therefore the data for this period was calculated proportionally, based on the data of the subsequent years.

Table 5-2. The annual average number of non-dairy cattle by sub-categories in Lithuania, thous. heads

Year	Cattle sub-categories												
	Suckling cows	Less than 1 year old			From 1 to 2 years old			2 years old and older					Other cows
		Calves for slaughter	For breeding		Bulls	Heifers		Bulls			Heifers		
			Bulls	Heifers		For slaughter	For breeding	Dairy sires	Non-dairy sires	Other bulls	For slaughter	For breeding	
1990	-	360.0	50.4	310.6	236.0	65.3	276.8	0.1	0.0	58.4	24.6	123.1	35.7
1995	-	155.5	16.8	103.4	78.5	21.7	92.1	0.2	0.0	19.3	8.2	41.0	8.6
2000	3.0	126.5	14.2	74.6	52.5	18.7	57.7	0.2	0.1	10.2	4.9	22.0	4.2
2005	3.4	111.4	15.9	91.4	43.1	13.4	74.8	0.1	0.1	8.2	3.9	26.2	2.9
2010	14.5	84.9	20.0	96.4	44.6	8.1	94.8	0.1	0.6	5.5	2.4	32.3	2.1
2015	36.4	72.7	24.3	103.3	48.6	4.7	97.4	0.0	1.5	5.6	2.2	34.1	3.2
2016	41.8	77.5	24.0	95.7	46.5	4.4	96.3	0.0	1.7	5.1	2.3	31.9	3.1
2017	45.6	77.4	25.3	90.0	45.0	3.7	90.1	0.0	1.8	4.5	2.3	30.7	3.0
2018	50.3	79.8	26.2	83.9	44.8	3.1	86.1	0.0	2.0	3.8	2.0	29.2	2.7
2019	55.2	77.1	25.1	81.0	44.0	2.6	85.7	0.0	2.2	3.7	1.8	28.6	1.9
2020	58.3	74.4	24.9	81.1	42.3	2.2	85.6	0.0	2.3	4.2	1.7	29.1	1.6

The population of dairy cattle in 2020 has decreased by 72.0% comparing with 1990. In the same period, non-dairy cattle population has decreased by 73.5%, population of horses decreased by 83.4%, swine population – by 78.1%. The population of sheep increased by 123.2%, goats – by 228.5%. Generally, significant decline of the livestock population in the beginning of reporting period was caused by the changes in economy due to collapse of the Soviet Union. However, the population of sheep in the past few years increased due to promotion of farming in poorer lands.

Table 5-3. The average annual number of livestock population per year, thous. heads

Year	Dairy cattle	Non-dairy cattle	Sheep	Goats	Horses	Swine	Rabbits	Other (Nutria)	Fur-bearing animals	Poultry
1990	844.9	1,541.0	72.2	4.6	78.9	2,577.3	71.8	39.5	614.4	17,800.6
1995	600.5	545.4	43.0	13.5	77.9	1,266.3	86.1	21.5	348.6	8,640.1
2000	466.3	388.8	15.1	23.9	71.6	895.9	83.9	5.0	153.9	5,553.4
2005	425.2	395.0	30.6	24.5	63.1	1,094.0	98.2	3.5	530.2	8,349.0
2010	367.2	406.4	66.0	15.4	46.8	928.8	105.5	3.1	485.9	10,577.1
2015	307.3	433.9	154.5	13.3	17.8	701.0	122.8	1.0	1,477.8	9,687.1
2016	293.1	430.4	172.9	13.5	16.8	675.9	127.1	8.5	1,460.5	10,560.1
2017	279.3	419.6	178.9	13.9	15.6	637.9	125.1	8.4	1,456.7	11,196.0
2018	264.5	414.1	178.5	14.3	13.9	592.0	118.3	0.3	1201.7	11,626.9
2019	248.5	409.0	172.8	14.7	12.9	561.4	95.0	0.3	966.9	10,740.0
2020	236.9	407.8	161.1	14.9	12.8	565.6	68.3	1.2	1066.8	10,435.4

Total swine population and swine population by sub-categories were obtained from Statistics Lithuania. The annual average population of swine and population by sub-categories were estimated based on Equation 10.1 of *2006 IPCC Guidelines* (vol. 4, ch. 10.2.2 p.10.8). This data are presented in Table 5-3 (total population of swine) and Table 5-4.

Table 5-4. The annual average population of swine by sub-categories in Lithuania, thous. heads

Year	Sows				Piglets‹ 2 months (‹20 kg)	Growing pigs			Pigs >110 kg (8 months and >)	Boars		Gilts for breed
	Breeding*		Replacement									
	Mated	Nursing young	Mated	Nursing young		20-50 kg	50-80 kg	80-110 kg		Mature	Young for breed	
1990	70.9	25.5	61.1	29.3	474.9	610.7	638.8	397.3	198.0	5.0	3.6	62.2
1995	43.6	14.5	46.8	20.7	223.3	287.1	300.3	186.8	97.0	2.3	1.9	42.0
2000	34.0	10.3	25.8	10.4	159.8	212.4	221.7	142.4	75.5	1.2	2.2	0.0
2005	51.0	14.0	11.9	4.3	210.5	267.8	232.2	212.2	72.1	1.4	0.6	16.1
2010	46.0	11.3	8.0	2.6	200.4	225.0	208.0	155.6	55.7	0.9	0.5	14.8
2015	31.2	7.0	5.4	1.6	122.3	187.9	169.9	111.9	53.4	0.4	0.4	9.6
2016	29.2	6.5	5.0	1.5	122.3	178.5	173.8	102.9	46.7	0.4	0.3	8.9
2017	26.9	6.0	5.1	1.5	120.8	170.3	157.9	97.1	42.2	0.3	0.3	9.4
2018	25.1	5.6	5.1	1.5	115.3	159.2	134.8	100.9	34.1	0.3	0.2	9.9
2019	23.6	5.3	5.0	1.5	108.5	152.3	120.1	105.5	30.8	0.3	0.1	8.5
2020	23.5	5.3	5.3	1.6	107.7	155.3	123.1	106.4	28.8	0.3	0.1	8.3

*Selected for second and subsequent farrowing

The annual average population of sheep for the period 1990-2020 is reported in Table 5-5. Since the population of sheep by sub-categories in 1990-2013 was not available, it is calculated according to the average data of herd structure in 2014-2016.

Table 5-5. The annual average population of sheep by sub-categories, thous. heads

Year	Sheep sub-category					
	Mature ewe	Ewe over 1 years	Ewe to 1 years	Lambs to 1 years	Mature Rams	Rams over 1 year
1990	27.0	12.6	14.4	11.5	1.1	5.6
1995	16.1	7.5	8.6	6.9	0.6	3.3
2000	5.6	2.6	3.0	2.4	0.2	1.2
2005	11.4	5.3	6.1	4.9	0.5	2.4
2010	24.7	11.5	13.2	10.5	1.0	5.1
2015	56.3	29.0	30.1	24.1	2.3	12.7
2016	63.5	31.2	33.9	27.2	2.5	14.5
2017	68.4	26.4	36.5	29.2	2.7	15.6
2018	69.3	24.2	37.0	29.6	2.8	15.6
2019	66.4	25.1	35.5	28.4	2.7	14.7
2020	62.2	22.9	33.2	26.6	2.5	13.7

Livestock databases comparison

According to ERT recommendation provided in the review of 2016, livestock populations taken from Statistics Lithuania as of 1st of January were recalculated into annual average populations, therefore populations data provided in the NIR differs from Lithuania Statistics and FAO databases, differences are shown in the table below. Moreover, there are inconsistency between Statistics Lithuania and FAO databases. Statistics Lithuania database provides data on populations as of 1st of January; this means that data in the column 2020 (of 1st January) represents the data for 2019.

Table 5-6. Comparison of Cattle population (thous. heads) Lithuanian Statistics vs. FAO

Data base	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Lithuania Statistics	747.98	722.60	694.75	676.89	653.51	634.58	629.51
FAO	759.40	736.61	722.60	694.75	653.50	634.60	629.50

Livestock weight data

According to *2006 IPCC guidelines* to estimate feed intake it is required to collect livestock weight data. The average weight of dairy cattle for the year 1990 was based on expert judgment. The average weight of dairy cattle during the period 1991-2015 was interpolated (Table 5-7). Recently, with the aim to increase cow productivity, genetic potential of external breeds, especially Holstein breed bulls has been used more widely. In 2016-2020 the average weight of most common Lithuanian breeds has been updated and was calculated based on the number of various cow breeds[20] and degree of Holstein cow blood[21]. The average weight of other dairy cattle breeds has been calculated using available references[22].

Table 5-7. The average weight of livestock during the period 1990-2020, kg

	Dairy cattle	Non-dairy cattle	Swine	Sheep	Horses
1990	575	327	64.8	45.6	520
1995	584	308	70.1	45.4	510
2000	594	293	63.9	45.5	500
2005	603	293	63.4	46.8	491
2010	613	312	63.4	46.3	481
2015	622	333	61.7	46.6	471
2016	625	335	61.3	46.4	469

[20] Annual Report on milk Recording, No. 79(2).
[21] https://zum.lrv.lt/uploads/zum/documents/files/LT_versija/Veiklos_sritys/Mokslas_mokymas_ir_konsultavimas/Moksliniu_tyrimu_ir_taikomosios_veiklos_darbu_galutines_ataskaitos/2darbas2014.pdf
[22] Gyvulininkystės žinynas. Baisogala (en. Livestock manual. Institute of Animal Science of LVA), 2007, p. 38-45

2017	626	338	61.5	46.3	467
2018	627	340	61.9	46.0	465
2019	629	344	61.7	45.9	466
2020	630	348	61.6	45.9	468

Average weight of non-dairy cattle was calculated in accordance with the average weight of each non-dairy cattle sub-category proportionally to its population:

$$m_{average} = \frac{(\sum m_i \cdot population_i)}{population_{total}}$$

where:

$m_{average}$ - average weight of non-dairy cattle, kg;

m_i - average weight of each non-dairy cattle sub-category, kg;

$population_i$ - population of each non-dairy cattle sub-category, thous. heads;

$population_{total}$ - total population of non-dairy cattle sub-category, thous. heads.

The average weight of suckling cows has been calculated using available data on number of bred breeds of animals and their typical weight, indicated in the reference sources[23,24]. Weight and weight gain of non-dairy cattle in each sub-category were estimated based on data provided by the expert. Data on average weight of non-dairy cattle is presented in table above (Table 5-7).

Based on expert judgement the average weight gain was estimated for each non-dairy cattle subcategory which remains constant for the whole time period. Basing on this data average weight gain of non-dairy cattle was estimated:

$$w_{average} = \frac{(\sum w_i \cdot population_i)}{population_{total}}$$

where:

$w_{average}$ - average weight gain of non-dairy cattle, kg/day;

w_i - average weight gain of each non-dairy cattle sub-category, kg/day;

$population_i$ - population of each non-dairy cattle sub-category, thous. heads;

$population_{total}$ - total population of non-dairy cattle sub-category, thous. heads.

Table below presents data on cattle subcategories on mature body weight and weight gain.

Table 5-8. Mature body weight and rate of weight gain of non-dairy cattle, kg[25]

Cattle subcategories	Weight, kg	Weight gain, kg
Suckling cows	600	0
Less than 1 year old Calves for slaughter	166.8	0.82
Less than 1 year old Bulls for breeding	204.3	0.9
Less than 1 year old Heifers for breeding	176.9	0.75
From 1 to 2 year old Bulls	420	0.85

[23] Gyvulininkystės žinynas. Baisogala (en. Livestock manual. Institute of Animal Science of LVA), 2007, p. 67-71
[24] Jukna Č., Jukna V. Mėsinių galvijų auginimas (en. Beef cattle rearing), 2004, Kaunas
[25] Gyvulininkystės žinynas. Baisogala (en. Livestock manual. Institute of Animal Science of LVA), 2007

From 1 to 2 year old Heifers for slaughter	400	0.775
From 1 to 2 year old Heifers for breeding	400	0.525
2 years old and older Dairy cattle sire Bulls	900	0
2 years old and older Non-dairy cattle sire Bulls	900	0
2 years old and older Other Bulls	600	0
2 years old and older Heifers for slaughter	535	0.2
2 years old and older Heifers for breeding	535	0.8
Other cow	575-630	0

Mostly, Western breeds of swine are grown in Lithuania, also significant part of swine is grown in the swine farms of Danish financial capital. Therefore, swine weigh that is applied in Western Europe was used to calculate the average weight of swine. For marked swine 50 kg and for breeding - 198 kg weight was used[26]. Estimated average weight of swine are provided in the Table 5-7, weights on market and breeding swine categories are provided in the Annex VIII Table A 5-4.

Average weight of sheep during the 1990-2020 period differ slightly, sheep weight has increase by 0.6%. Data on sheep weight is provided in the Table 5-7.

During the 1990-2020 period, the average weight of horses resulted in a relatively faster decrease of working horses' population and increasing of pony horses' population. Average weight of horses has been estimated using available data on population of bred breeds of horses and their typical weight, indicated in the reference sources (Table 5-7). The distribution of horses' breeds in 2020 are provided in Annex VIII Figure A.5-2.

Expert judgement was made to evaluate the weight of goats, it was assumed that its weight is 33.8 kg and is constant over the whole period. As it is difficult to evaluate average weight of small animals (fur-bearing, nutria and rabbits) categories notation key NA were used. Expert judgement was also made to evaluate average weight of poultry categories, table below present's data on different poultry categories average weight.

Table 5-9. The average weight of poultry categories in 1990-2020

Poultry category	Weight, kg
Layer hens	1.56
Broilers	0.866 - 1.26
Turkeys	7.76
Ducks	1.58
Geese	6.03
Other poultry	1.36

Livestock housing and grazing period

The pasture-cowshed time estimations are based on the national zoo technical activity data[27,28] and on the data of farmers and specialists of agricultural enterprises. According to scientific literature, housing period for dairy cattle lasts around 220 days, grazing – 145 days in the 1990.

The number of small farms in recent decades is decreasing, therefore the number of cattle that are kept in the stall-housing systems are increasing, and as a result, the grazing period is relatively shorter. At the new larger farms mostly liquid manure management system are used. In order to estimate emissions more accurately breeders of cattle were contacted and the shares of pastures

[26] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 4, Ch. 10, Table 10A-7-10A-8, p.p. 10.80-10.81.
[27] Gyvulininkystės žinynas (en. *Livestock manual*). Mokslas, Vilnius, 2007.
[28] Tarvydas V. *et al.* Šėrimo normos, pašarų struktūra ir sukaupimas galvijams (en. *Feeding rate, feed composition and accumulation for cattle*). Vilnius, 1995, p. 4.

and cowshed periods were assessed. After discussions with the breeders the share of manure that fall under pasture and liquid manure management systems were redistributed. For recent years, the share of manure for pasture system was reduced approximately by 10%, and as a result liquid manure management system increased by 10%.

In the 2019, these periods last 255 and 110 days respectively according to the data of the farmers and specialists of agricultural enterprises. The duration of pasture-cowshed time during the period 1991-2020 was interpolated.

For sheep and goats housing period lasts around 200 days, grazing – 165 days. Expert judgement was used to evaluate housing-grazing period for geese, ducks and other poultry categories. The housing period lasts around half year, grazing – also around half year.

Assumption on manure fraction that remains on pasture was based on dairy and non-dairy cattle grazing time period. Bulls, partly calves and cows for slaughter, normally are kept in stalls throughout the year. Calves, heifers for breeding and beef cattle are grazed in pastures for approximately 145 days per year[10,11].

Manure management systems

There are 7 types of manure management systems in Lithuania: solid storage, liquid, anaerobic digesters, deep bedding, poultry with litter, poultry without litter and pasture. The most commonly used manure management systems are solid storage and liquid. Manure management system of dry lot is not used in the Lithuania.

Nitrogen in bedding per animal species

The content of N in bedding material per animal species are taken from national study "The study of Lithuanian GHG emissions from the agriculture soil"[29]. The results from the study are provided in the table below.

Table 5-10. N in bedding material per animal species

Animal category	N content in bedding per animal, kg/yr N
Dairy cattle	5.56
Non-dairy cattle	4.21
Sheep	1.03
Goats	1.04
Horses	13.89
Swine	0.89
Poultry	0.05
Fur-bearing animals	0.02

Livestock diet composition data

All data related to the diet composition and amounts of fats, proteins and carbohydrates for livestock (dairy and non-dairy cattle, swine and sheep) categories are provided in the Annex VIII Table A.5-5 – Table A.5-40. All data of nutrition standards were taken from Livestock manual[30].

Key categories for agriculture sector emissions

[29] Šiltnamio Efektą Sukeliančių Dujų Emisijų Šalies Augalininkystės Sektoriuje Inventorizavimas. Ataskaita (en. The study of Lithuanian GHG emissions from the agriculture soil). 2019. p. 22-35.

[30] Gyvulininkystės žinynas (en. Livestock manual). Mokslas, Vilnius,2007.

Key categories analysis was performed using Approach 1 and Approach 2. The results of both analyses are presented in Table 5-10. Analysis showed that twelve relevant categories from agriculture sector were indicated as the key categories.

Table 5-11. Key category from Agriculture sector in 2020

IPCC Category	*Greenhouse gas*	*Identification criteria*	*Comments**
3.A.1 Enteric Fermentation - Cattle	CH_4	L1, L2, T1, T2	
3.B.1.1 Manure Management - Cattle	CH_4	L1	
3.B.1.3 Manure Management - Swine	CH_4	T1	
3.B.2 Manure Management - Cattle	N_2O		L1sub, L2sub
3.B.2 Manure Management - Other	N_2O	T2	
3.B.2 Manure Management - Indirect N_2O Emissions	N_2O	L1, L2, T2	
3.D.1.1 Direct N_2O Emissions From Managed Soils - Inorganic N Fertilizers	N_2O	L1, L2, T1, T2	
3.D.1.2 Direct N_2O Emissions From Managed Soils - Organic N Fertilizers	N_2O	L1, L2, T2	
3.D.1.3 Direct N_2O Emissions From Managed Soils - Urine and dung deposited by grazing animals	N_2O	L1, L2, T1, T2	
3.D.1.4 Direct N_2O Emissions From Managed Soils - Crop Residues	N_2O	L1, L2, T1, T2	
3.D.1.6 Direct N_2O Emissions From Managed Soils -Cultivation of organic soils	N_2O	L1, L2, T1, T2	
3.D.2.1 Indirect N_2O Emissions From Managed Soils - Atmospheric deposition	N_2O	L1, L2	
3.D.2.2 Indirect N_2O Emissions From Managed Soils - Nitrogen leaching and run-off	N_2O	L1, L2, T1, T2	

**Lsub, Tsub denote the categories that were identified by level and trend assessment for a subset without LULUCF*

5.2 Enteric fermentation (CRF 3.A)

5.2.1 Category description

CH_4 emission from enteric fermentation of domestic livestock includes emissions from cattle (dairy cattle and non-dairy cattle), sheep, goats, horses, swine, rabbits, fur-bearing animals (minks, foxes and polar foxes) and other (nutria).

CH_4 emissions are primarily related to cattle, which in 2020 contributed almost 95.1% of the total emission from enteric fermentation. In 2020 dairy cattle produced 53.7% and non-dairy cattle – 41.4% of CH_4 emissions from enteric fermentation. Emission from swine comprised 1.3%, horses – 0.4%, sheep and goats – 3.0% of the total emission from enteric fermentation.

In 2020 overall CH_4 emission from enteric fermentation decreased by 2.5%, comparing with 2019. During the period 1990-2020 CH_4 emission from enteric fermentation decreased by 66.3% (Table 5-12).

Table 5-12. CH_4 emissions from enteric fermentation by livestock categories, kt

Year	**Cattle**		**Sheep**	**Goats**	**Horses**	**Swine**	**Fur-bearing**	**Rabbit**	**Other (Nutria)**
	Dairy	**Non-dairy**							
1990	84.11	81.74	0.74	0.02	1.42	3.50	0.06	0.04	0.0138
1995	54.94	28.14	0.44	0.07	1.40	1.74	0.03	0.05	0.0075

2000	46.27	19.49	0.15	0.12	1.29	1.23	0.02	0.05	0.0018
2005	45.20	19.54	0.31	0.12	1.14	1.46	0.05	0.06	0.0012
2010	41.88	21.20	0.67	0.08	0.84	1.21	0.05	0.06	0.0011
2015	38.15	24.10	1.58	0.07	0.32	0.93	0.15	0.07	0.0004
2016	35.94	24.18	1.77	0.07	0.30	0.90	0.15	0.08	0.0030
2017	34.46	23.80	1.82	0.07	0.28	0.84	0.15	0.07	0.0029
2018	33.68	23.75	1.81	0.07	0.25	0.77	0.12	0.07	0.0001
2019	32.57	23.81	1.75	0.07	0.23	0.74	0.10	0.06	0.0001
2020	31.05	23.94	1.63	0.07	0.23	0.74	0.11	0.04	0.0004

The overall reduction of CH_4 emission was caused by decrease in livestock population, having the greatest impact on emissions (excluding sheep, rabbits and minks). Although the number of sheep, rabbits, minks, partially goats has increased, this augmentation did not have a substantial effect to the reduction in CH_4 emissions. In case of dairy cattle the decrease of population was partly counterbalanced by an increase in productivity of livestock resulting in higher emission per animal.

5.2.2 Methodological issues

Cattle are the most important producer of CH_4 among all domestic animals due to their digestive system, relatively high weight and population comparing to other livestock population. Cattle are the key source due to the contribution to the total GHG emissions. Therefore Tier 2 method was applied in order to estimate CH_4 emission factors from enteric fermentation of dairy and non-dairy cattle. Tier 2 method was also used for CH_4 EF estimation from enteric fermentation of sheep and swine (Table 5-12). To estimate CH_4 EF from enteric fermentation of goats, horses, rabbits, nutria and fur-bearing animals (minks, foxes and polar foxes) the Tier 1 method was used.

Table 5-13. Information on methods and EF used for estimation of emissions from enteric fermentation

Animal category	**Sub-categories**			**Emission reported**	**Methods**	**Emission factor**
Dairy cattle				CH_4	Tier 2	CS
Non-dairy cattle	Suckling cows			CH_4	Tier 2	CS
	Less than 1 year old	Calves for slaughter		CH_4	Tier 2	CS
		For breeding	Bulls	CH_4	Tier 2	CS
			Heifers	CH_4	Tier 2	CS
	From 1 to 2 years old	Bulls		CH_4	Tier 2	CS
		Heifers	For slaughter	CH_4	Tier 2	CS
			For breeding	CH_4	Tier 2	CS
	2 years old and older	Bulls	Dairy cattle sire	CH_4	Tier 2	CS
			Non-dairy cattle sire	CH_4	Tier 2	CS
			Other Bulls	CH_4	Tier 2	CS
		Heifers	For slaughter	CH_4	Tier 2	CS
			For breeding	CH_4	Tier 2	CS
	Other cows			CH_4	Tier 2	CS
Sheep	Mature ewes			CH_4	Tier 2	CS
	Ewe over 1 years			CH_4	Tier 2	CS
	Ewe to 1 years			CH_4	Tier 2	CS
	Lambs to 1 years			CH_4	Tier 2	CS
	Mature Rams			CH_4	Tier 2	CS
	Rams over 1 years			CH_4	Tier 2	CS
Swine	Sows	Breeding	Mated	CH_4	Tier 2	CS
			Nursing young	CH_4	Tier 2	CS
		Replacement	Mated	CH_4	Tier 2	CS
			Nursing young	CH_4	Tier 2	CS
	Piglets < 2 months (< 20 kg)			CH_4	Tier 2	CS

	Growing pigs (20-50 kg)		CH_4	Tier 2	CS
	Growing pigs (50-80 kg)		CH_4	Tier 2	CS
	Growing pigs (80-110 kg)		CH_4	Tier 2	CS
	Pigs > 110 kg (8 months and >)		CH_4	Tier 2	CS
	Gilts for breed		CH_4	Tier 2	CS
	Boars	Mature	CH_4	Tier 2	CS
		Young for breed	CH_4	Tier 2	CS
Goats			CH_4	Tier 1	IPCC
Horse			CH_4	Tier 1	IPCC
Rabbits			CH_4	Tier 1	Russian EF
Other (Nutria)			CH_4	Tier 1	Russian EF
Fur-bearing animals			CH_4	Tier 1	Norwegian EF

To estimate total CH_4 emissions from enteric fermentation following equation[31] were applied:

$$CH_{4\ emissions} = \frac{EF_{(T)} \cdot N_{(T)}}{10^6}\ (kt\ CH_4\ yr^{-1})$$

where:

$EF_{(T)}$ - emission factor for each animal category, kg $head^{-1}\ yr^{-1}$;

$N_{(T)}$ - the number of head of livestock species/category in the country;

T - species/category of livestock.

National emission factors for dairy and non-dairy cattle, sheep and swine were calculated in accordance with Tier 2 method using the following equation[32]:

$$EF = \frac{(GE \cdot (\frac{Y_m}{100}) \cdot 365)}{55.65}$$

where:

EF - emission factor, kg CH_4 $head^{-1}\ yr^{-1}$;

GE - gross energy intake, MJ $head^{-1}\ day^{-1}$;

Y_m - methane conversion factor, percent of gross energy in feed converted to methane (for dairy cattle and non-dairy cattle were assumed to be 6.5%[33], for suckling cows were assumed to be 7.5%, for mature sheep and lambs to 1 year – 6.5% and 4.5%[34] respectively, for swine – 0.6%[35]). CH_4 conversion factor for calves up to ten[36], lambs up to five[37] and piglets up to five-seven[38] days were assumed to be zero as they are consuming only milk;

55.65 - energy content of methane, MJ/kg CH_4.

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[31] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, eq. 10.19, p. 10.28
[32] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, eq. 10.21, p.
[33] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10.12, p. 10.30
[34] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10.13, p. 10.31
[35] Revised 1996 IPCC GL, Reference Manual Vol. 3, Table A-4, p.4.35
[36] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual*. *Institute of Animal Science of LVA*), 2007, p. 104
[37] Zapasnikienė, B. Mitybos normos avims ir ožkoms (en. *Nutrition rates for sheep and goats*). 2 lentelė, p. 11
[38] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual*. *Institute of Animal Science of LVA*), 2007, p. 281

Estimated average values of methane conversion factor for dairy cattle, non-dairy cattle, swine and sheep for the 1990 – 2020 period are presented in Annex VIII, Table A. 5-1.

Gross energy estimations are based on the composition of feed intake and the energy content in proteins, fats and carbohydrates. GE for dairy cattle, non-dairy cattle, sheep and swine categories for entire period were calculated on the basis of nutrition standards[39].

GE of each feed was estimated by multiplying GE per kg of respective feed with amount of dry matter of that feed[40].

$$GE_{EachFeed} = \frac{GE \cdot (F_{quantity} \cdot DM)}{365}$$

where:

$GE_{EachFeed}$ - gross energy of the total amount of respective feed

GE - the amount of gross energy for 1 kg of respective feed, MJ/kg feed;

$F_{quantity}\ DM$ - the amount of forage during the year, kg (expressed in dry matter).

To receive total feed GE the amounts of GE of each feed consumed per day was summed. Gross energy for 1 kg of separate forage was calculated according to the equation[41]:

$$GE = 0.0239 \cdot CP + 0.0398 \cdot C_{Fat} + 0.0201 \cdot C_{Fiber} + 0.0175 \cdot NFE$$

where:

GE - gross energy, MJ / kg in DM;

CP - crude protein, g/kg in DM;

C_{Fat} - crude fat, g/kg in DM;

C_{Fibre} - crude fibre, g/kg in DM;

NFE - nitrogen-free extracts, g/kg in DM.

In order to estimate feed intake for dairy cattle milk production and fat content in milk must be known. According Statistics Lithuania, in 1996-1997 dairy cattle productivity in private farms was about 3,296-3,301 kg per cow and reached 3,444 kg in 1998, but in 1999 decreased to 3,223 kg and was lower than in agricultural companies and enterprises (3,266 kg). The purchase prices of milk decreased by 8% in 1999 comparing to 1998 and could have an impact on milk productivity indicators. Overall, during 1990-2020 dairy cattle productivity increased by 67.6% calculating whole milk or 69.2% calculating 4% fat corrected milk. Data on average milk yield per year per cow and fat content are presented in table below.

Table 5-14. Average milk yield and milk fat content during the period 1990-2020

Year	Milk yield (kg head^{-1} year^{-1})	Fat content (%)	Milk yield (4% fat) through lactation period (kg head^{-1} day^{-1})
1990	3,734	4.10	12.43

[39] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual. Institute of Animal Science of LVA*), 2007, p. 616

[40] Kulpys H., Šeškevičienė J., Jeroch H. Žemės ūkio gyvulių ir paukščių mitybos fiziologinės reikmės (en. *Agriculture livestock and poultry nutrition physiological needs*). Kaunas, 2004.

[41] Kulpys H., Šeškevičienė J., Jeroch H. Žemės ūkio gyvulių ir paukščių mitybos fiziologinės reikmės (en. *Agriculture livestock and poultry nutrition physiological needs*). Kaunas, 2004, p. 30

1995	3,010	4.10	10.02
2000	3,673	4.13	12.28
2005	4,312	4.11	14.37
2010	4,901	4.17	16.48
2015	5,636	4.21	19.06
2016	5,536	4.20	18.68
2017	5,601	4.19	18.88
2018	5,934	4.16	19.93
2019	6,225	4.19	20.98
2020	6,258	4.17	21.03

Nutrition standards for dairy cattle depends on productivity[42]. The diet nutrition parameters for dairy cattle that were used to estimate gross energy are presented in Annex VIII Table A. 5-5. The average diet nutrition indicators for the whole period is presented in the Annex VIII Table A.5-37. Impact of milk yield on GE and EFs are presented in Annex VIII, Figure A. 5-1.

Estimated average gross energy intake and emission factor for dairy cattle and dairy-cattle sub-categories is presented in tables below. During the 1990-2020 period gross energy for dairy cattle has increased by 31.7%.

Table 5-15. Calculated average gross energy intake and emission factors for dairy cattle

Year	GE (MJ/head/day)	EF (kg CH_4/head/year)
1990	233.51	99.55
1995	214.60	91.49
2000	232.73	99.22
2005	249.34	106.30
2010	267.52	114.05
2015	291.23	124.16
2016	287.58	122.60
2017	289.40	123.38
2018	298.70	127.34
2019	307.43	131.07
2020	307.43	131.07

Estimated EF for dairy cattle vary across time due to the changes in milk yield and feed consumption (Annex VIII Table A. 5-2). During the period 1990-2020 emission factor increased by 31.7%, however total emission decreased by 63.1% due to the decrease in dairy cattle population by 72.0%. The values of CH_4 EF's during the period 1990-1993 has decreased due to the reduced productivity of dairy cattle. During the period 1994-1998 EF has increased however in 1999 EF has decreased again as productivity of milk per head has decreased.

The average daily feed intake for each sub-category of non-dairy cattle was calculated on the basis of amount of feed which are fed to cattle[43] and according to the feed accumulation standards. These data is indicated in the national reference book of livestock production[44] according to national zootechnical activity data – weight and weight gain. The data on the composition of diet for non-dairy cattle are given in Annex VIII Table A. 5-6. – Table A. 5-18. Average diet nutrition for non-dairy cattle subcategories are given in Annex VIII Table A.5-38.

[42] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual*. *Institute of Animal Science of LVA*), 2007, p. 616

[43] Juška, R. *et al.* Studija „Lietuvos mėšlo tvarkymo sistemose susidarančių metano ir azoto suboksido kiekio tyrimai ir įvertinimas" (en. *Survey and evaluation of methane and nitrous oxide emission content in manure management systems of Lithuania. Study*), 2012

[44] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual*. *Institute of Animal Science of LVA*), 2007, p. 616

During the period 1990-2020 gross energy and emission factor for non-dairy cattle has increased accordingly by 6.7% and by 10.7%.

Table 5-16. Calculated average gross energy intake and emission factors for non-dairy cattle for 2020

Sub-category			**GE (MJ/head/day)**	**EF (kg CH_4/head/year)**
Suckling cows			221.25	108.84
Less than 1 year old	Calves for slaughter		82.75	34.31
	For breeding	Bulls	100.54	41.69
		Heifers	78.98	32.75
From 1 to 2 years old	Bulls		181.52	77.39
	Heifers	For slaughter	151.52	64.60
		For breeding	137.34	58.55
2 years old and older	Bulls	Dairy cattle sires	177.24	74.56
		Non-dairy cattle sires	222.29	94.77
		Other Bulls	203.06	86.57
	Heifers	For slaughter	171.38	73.06
		For breeding	171.10	72.94
Other cows			211.85	90.32
Total non-dairy cattle			133.84	58.70

Estimated EF and GE for non-dairy cattle vary across the time period due to the distribution of animals in subcategories. In estimation of EF for enteric fermentation of non-dairy cattle it was determined that weaning age of calves is up to ten days[45]. At this age they are nourished by milk only, therefore CH_4 conversion factor was assumed to be zero.

In response to the A.8 recommendation: data provided by Statistics Lithuania shows that suckling cows have been kept since 1997 and their number changes every year. Statistics Lithuania has updated data on suckling cows' population for the period of 1997-1999, a higher number of suckling cows were provided in the database, therefore this data was also updated in the 2019 NIR submission. GE parameter of suckling cows for the 1997-1999 has slightly increased regarding this livestock number update.

In estimation of CH_4 emission from swine, gross energy was estimated on the basis of feed accumulation standards presented in the national reference book for animal production[46]. Tables, showing composition of diets for swine are provided in Annex VIII Table A. 5-19 – Table A. 5-30. Average diet nutrition indicators used to estimate gross energy for sub-categories of swine are provided in Annex VIII Table A.5-39.

Estimated average gross energy intakes and EF for swine subcategories are provided in the table below. During the 1990-2020 period gross energy and emission factor has decreased by 3.2% and 3.3% respectively.

Table 5-17. Calculated average GE intake and EF for swine sub-categories for 2020

Sub-category			**GE (MJ/head/day)**	**EF (kg CH_4/head/year)**
Sows	Breeding	Mated	33.27	1.31
		Nursing young	86.95	3.42
	Replacement	Mated	34.97	1.38
		Nursing young	100.79	3.97
Piglets < 2 months (< 20 kg)			12.33	0.44

[45] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual*. *Institute of Animal Science of LVA*), 2007, p. 104

[46] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual*. *Institute of Animal Science of LVA*), 2007, p. 263-298.

Growing pigs (20-50 kg)		28.39	1.12
Growing pigs (50-80 kg)		42.10	1.66
Growing pigs (80-110 kg)		46.00	1.81
Pigs > 110 kg (8 months and >)		44.71	1.76
Gilts for breed		35.20	1.39
Boars	Mature	39.45	1.55
	Young for breed	39.59	1.56
Total Swine		33.58	1.31

Estimated EF and GE for swine slightly vary across the reporting period due to distribution of animals in sub-categories.

Data on the composition of diet for sheep sub-categories are provided in Annex VIII, Table A. 5-31 – Table A. 5-36. Average diet nutrition indicators for sheep are provided in Annex VIII Table A.5-40. Estimated average gross energy intake and EF for sheep are provided in below. In estimation of EF for enteric fermentation of sheep it was determined that lambs up to five days are consuming milk only[47]. At this age they are nourished by milk only and CH_4 conversion factor was assumed to be zero.

Table 5-18. Average gross energy intake and emission factors of sheep for 2020

Sub-category	**GE (MJ/head/day)**	**EF (kg CH_4/head/year)**
Mature ewes	33.03	14.08
Ewe over 1 years	28.06	11.96
Ewe to 1 years	16.88	4.91
Lambs to 1 years	14.42	3.49
Mature Rams	36.37	15.50
Rams over 1 years	32.48	13.85
Total sheep	25.93	10.14

Estimated GE and EF for sheep category varies slightly during the whole period. During the 1990-2020 period GE decreased by 0.2% and EF decreased by 0.5%.

Contribution of other livestock categories [horses, goats, fur-bearing, rabbits, other (nutria)] to the whole CH_4 emission from enteric fermentation is very small compared to cattle category. Therefore CH_4 emission from enteric fermentation of these livestock categories are estimated using Tier 1 method. Default EF for goats and horses were taken from *2006 IPCC Guidelines*. As no default *2006 IPCC* or national EF for fur-bearing animals, rabbits and Other (nutria) are available, the Norwegian EF for fur-bearing animals and Russian emission factors for rabbits and other (nutria) categories were used in calculations. Values of used EF and reference sources are provided in the table below.

Table 5-19. Default EF for other livestock categories used for CH_4 calculations from enteric fermentation

Livestock category	**EF (kg CH_4/head/year)**	**Reference**
Goats	5	*2006 IPCC*. Table 10.10, p. 10.28
Horses	18	*2006 IPCC*. Table 10.10, p. 10.28
Rabbits	0.59	Russian NIR 2014. Table 6.6, p. 199
Other (Nutria)	0.35	Russian NIR 2014. Table 6.6, p. 199
Fur-bearing animals (foxes, polar foxes, minks)	0.1	Norway's NIR 2014. Table 6.7, p. 259

[47] Zapasnikienė, B. Mitybos normos avims ir ožkoms (en. *Nutrition rates for sheep and goats*). 2 lentelė, p. 11

The population of fur-bearing animals reported by Statistics Lithuania as of 1st of January include only animals used for breeding purposes. The calculation of annual average fur-bearing population was based on the coefficients of group size. These coefficients are taken from the Order of Minister of Agriculture of 2016-10-14 No. 3D-592 "Requirements for technological design of fur-bearing animals and rabbits breeding farms" (Annex VIII, Table A. 5-41).

CH_4 emissions from other livestock (horses, goats, fur-bearing, rabbits and other (nutria)) categories during the 1990-2020 period has decreased by 71.0%. In 2020 emissions from these categories has decreased by 1.2% comparing with 2019.

5.2.3 Uncertainties and time-series consistency

Uncertainties of CH_4 emissions from enteric fermentation are estimated based on the uncertainty of livestock population and emission factors uncertainty.

Activity data uncertainty

Activity data on livestock population for the whole time period was collected from Statistics Lithuania. Data provided by Statistics Lithuania is collected by applying continuous accountability for agriculture companies and applying sampling methods for farmers and households. The subject of research is about 10 thousand farms what constitutes about 4% of registered farms in the statistical database. The simple random stratified sampling has been chosen from the elements of population list for the research. If the livestock population is smaller than 1,000 thousand heads, or if the population of cattle is smaller than 500 thousand heads, 5% accuracy requirements are applied according to the regulation of the European Parliament and of the Council No 1165/2008 concerning livestock and meat statistics requirements.

Complete data on swine and non-dairy cattle herd structure is available only since 1997-1998 from the statistical sources, therefore for the calculations of gross energy intake of swine and non-dairy cattle categories the constant values of 1997-1998 herd structure data were used in order to estimate and fill the gap of 1990-1996 period.

Overall uncertainty for activity data for enteric fermentation is assumed to be ±4.6%.

Emission factor uncertainty

Emission factors estimated using simple Tier 1 method may be uncertain to ±30-50%[48]. The uncertainty in CH4 emission factors for goats, horses, fur-bearing animals, rabbits and others is reported to be ±50%.

Emission factors estimated using the Tier 2 method is likely to be in the order of ±20%[49]. Country-specific uncertainty rates have been implemented for cattle, swine and sheep calculations.

The uncertainty of emissions factors for enteric fermentation was calculated according to the *2006 IPCC Guidelines* eq. 3.1. The calculated overall uncertainty of emission factors for enteric fermentation is ±26.2%.

Overall uncertainty

[48] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, p. 10.28
[49] *2000 IPCC Agriculture, p. 4.28*

Combined uncertainty was calculated using *2006 IPCC Guidelines* Equation 3.1[50]. This approach requires uncertainty values of the main activity data used and uncertainty of emission factor. Combined uncertainty was estimated to be ±27.7%.

5.2.4 Category-specific QA/QC and verification

Quality control procedures were conducted by performing checks in activity data for the whole time period, consistency check of data entered in CRF with calculation sheets, trends of emissions for each category, relevance of methodology applied. The results for the year 2020 as well as data quality and reliability were evaluated by comparing them to the 2019 data of neighbouring countries.

The gross energy intake for dairy-cattle's was verified using values reported by the neighbouring countries (Table 5-20). Comparing results obtained in 2019 it can be seen that CH_4 emission factor in Lithuania from enteric fermentation of dairy cattle category is lower than this indicator in Estonia and Latvia; however, higher than that in Belarus and Poland. Also, Estonia and Latvia showed higher productivity of cows and GE intake, while Belarus and Poland showed lower values.

Table 5-20. Comparison of EF and other parameters of CH_4 emissions calculation from enteric fermentation of dairy cattle

Country	Milk yield (kg/head/day)	GE intake (MJ/head/day)	EF (kg CH_4/head/year)
Belarus	13.71	271.81	115.88
Estonia	26.39	366.4	156.22
Latvia	22.59	342.77	146.13
Lithuania	17.15	307.43	131.07
Poland	16.38	278.67	118.80

The CH_4 emission factor from enteric fermentation of swine is higher than Estonia's EF's (table below). Latvia used *2006 IPCC* default emission factor.

Table 5-21. Comparison of EF and other parameters of CH_4 emissions calculation from enteric fermentation of swine

Country	Weight, kg	GE intake (MJ/head/day)	EF (kg CH_4/head/year)
Estonia	45.24	25.12	1.02
Latvia	64.74	32.09	1.5
Lithuania	61.60	33.58	1.31

5.2.5 Category-specific recalculations

No recalculations have been done.

5.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

5.3 Manure management – CH_4 emissions (CRF 3.B.1)

5.3.1 Category description

CH_4 is produced from the decomposition of organic matter remaining in the manure under anaerobic decomposition. The amount of CH_4 produced from manure depends on: manure

[50] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 3, eq. 3.1, p. 3.28

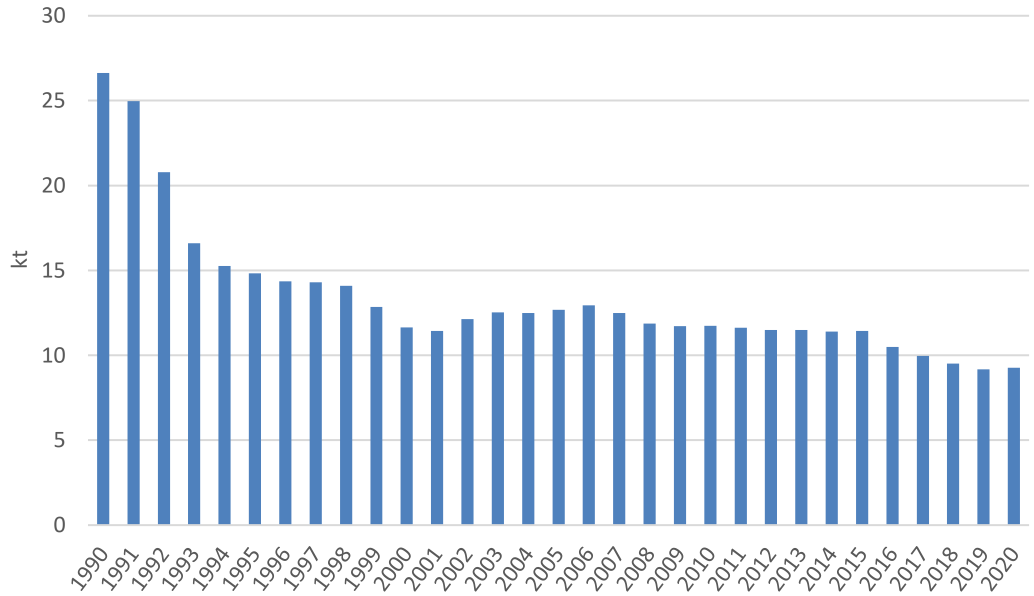
characteristics linked to animal type and diets, the amount of feed consumed, the digestibility of the feed, the type of waste management system and the climate conditions during the storage. The information on manure management systems was collected during the investigation[51], also taking into account expert judgement.

In 1990-2015 the highest CH_4 emission from manure management systems among different categories of domestic animals was determined in swine category. The use of anaerobic digester for biogas-treatment in 2004-2011 and 2014-2020 slightly reduced CH_4 emission.

Table 5-22. CH_4 emission from manure management by animal category, kt

Year	Dairy cattle	Non-dairy cattle	Sheep	Goats	Horses	Swine	Poultry	Fur-bearing animals	Rabbits	Other (nutria)
1990	5.04	5.02	0.030	0.001	0.12	13.17	2.80	0.42	0.01	0.0268
1995	3.70	1.88	0.018	0.002	0.12	6.71	2.16	0.24	0.01	0.0146
2000	3.45	1.46	0.006	0.003	0.11	4.82	1.67	0.10	0.01	0.0034
2005	3.70	1.54	0.013	0.003	0.10	5.65	1.30	0.36	0.01	0.0024
2010	3.73	1.91	0.027	0.002	0.07	4.73	0.92	0.33	0.01	0.0021
2015	3.68	2.58	0.063	0.002	0.03	3.62	0.45	1.00	0.01	0.0007
2016	3.52	2.69	0.071	0.002	0.03	2.80	0.39	0.99	0.01	0.0058
2017	3.42	2.73	0.073	0.002	0.02	2.49	0.31	0.99	0.01	0.0057
2018	3.40	2.82	0.073	0.002	0.02	2.21	0.28	0.82	0.01	0.0002
2019	3.33	2.91	0.071	0.002	0.02	2.03	0.26	0.66	0.01	0.0002
2020	3.23	2.98	0.066	0.002	0.02	1.98	0.26	0.73	0.01	0.0008

Comparing to 1990 CH_4 emissions from manure management decreased by 65.2% in 2020. In 2020, comparing with 2019, CH_4 emissions from manure management slightly increased (1.0%). Figure below presents changes in CH_4 emissions from manure management.



[51] Juška, R. *et al.* Studija „Lietuvos mėšlo tvarkymo sistemose susidarančių metano ir azoto suboksido kiekio tyrimai ir įvertinimas" (en. *Survey and evaluation of methane and nitrous oxide emission content in manure management systems of Lithuania. Study*), 2012

Figure 5-3. CH_4 emission from manure management during the period 1990-2020

The overall reduction of CH_4 emissions from manure in 1990-2020 is caused by decrease in total number of livestock population (excluding sheep, goats, rabbits and minks), however in case of dairy and non-dairy cattle the attrition of animals is partly counterbalanced by an increase in emissions per animal. Emission increase was caused by the growth of volatile solid excretion which is related to gross energy intake.

5.3.2 Methodological issues

CH_4 emissions from manure management systems of cattle, swine and sheep were calculated using Tier 2 method. Emissions from cattle and swine subcategories represent significant share of emissions.

Tier 2 method for estimation of CH_4 emission from manure management systems requires detailed information on animal characteristics and the manner in which manure is treated. Emission from goats, horses, rabbits, other (nutrias), fur-bearing animals (minks, foxes, polar foxes) and poultry have a minor impact to the total CH_4 emission from manure management, therefore Tier 1 method has been applied to estimate CH_4 emissions from these livestock categories. The summary of methods that were used for calculation of CH_4 emission from manure management is presented in table below.

Table 5-23. Methods and emission factors used to estimate CH_4 emission from manure management

Animal category	**Emission reported**	**Methods**	**Emission factor**
Dairy cattle	CH_4	Tier 2	CS
Non-dairy cattle	CH_4	Tier 2	CS
Sheep	CH_4	Tier 2	CS
Swine	CH_4	Tier 2	CS
Horses	CH_4	Tier 1	2006 IPCC
Goats	CH_4	Tier 1	2006 IPCC
Poultry (excl. Geese and Other poultry)	CH_4	Tier 1	2006 IPCC
Geese and Other poultry	CH_4	Tier 1	Revised 1996 IPCC
Rabbits	CH_4	Tier 1	2006 IPCC
Other (nutria)	CH_4	Tier 1	2006 IPCC
Fur bearing (minks, foxes, polar foxes)	CH_4	Tier 1	2006 IPCC

In 2020 during the stable period 36% of dairy cattle manure was treated in the solid manure management systems and 34% in the liquid manure management systems. About 30% of dairy cattle manure was deposited on pastures. Manure from non-dairy cattle categories distributed as follows: 33.9% in solid manure management systems, 21.6% in liquid manure management systems and 12.8% in deep bedding manure management systems. About 31.7% of manure was deposited on pastures. The most common manure management systems for swine manure treatment is liquid and anaerobic digesters manure management systems accounting for 55.5% and 34.2%. Around 8.6% of manure is managed in solid system and 1.7% - in deep bedding system. When the number of small farms who used solid manure management systems relatively decreased, the number of animals kept in the bigger herds, where the liquid manure management systems are used, relatively increased. Therefore it is assumed that the share of liquid manure management system increased in 2020, thus, based on this assumption, the data on manure management systems for cattle and swine categories have been extrapolated.

Since 1990 almost all fur-bearing animals, rabbits and other (nutrias) breeders used solid manure management systems. Liquid manure management systems was started to use only during the past few years in four fur-bearing animals' farms.

Methane conversion factors (MCF) for cattle, swine, sheep and goats in manure management systems were taken as default values from *2006 IPCC* (Table 5-28). For anaerobic digester *2006 IPCC* gives MCF value range from 0 to 100%. In calculation Lithuania uses 0% MCF value. Methane emissions from anaerobic digesters due to unintentional leakages during process disturbances or other unexpected events are included in the category of biological treatment of waste (Chapter 7.3.1).

MCF values by temperature for MMS for the whole period has been taken from column '10ºC' of table 10.17 from *2006 IPCC Guidelines*, these values where chosen because it is in line with countries national conditions (Figure 1-1) [52].

Table 5-24. MCF values for manure management systems, %

Manure management systems					
Pasture/Range/ Paddock	**Solid storage**	**Liquid/Slurry**		**Anaerobic digester**	**Cattle and Swine deep bedding > 1 month**
		With natural crust cover	**Without natural crust cover**		
1	2	10	17	0	17

Changes on manure management systems used in calculations for dairy, non-dairy cattle and swine are provided in Figures 5-4, 5-5 and 5-6 respectively.

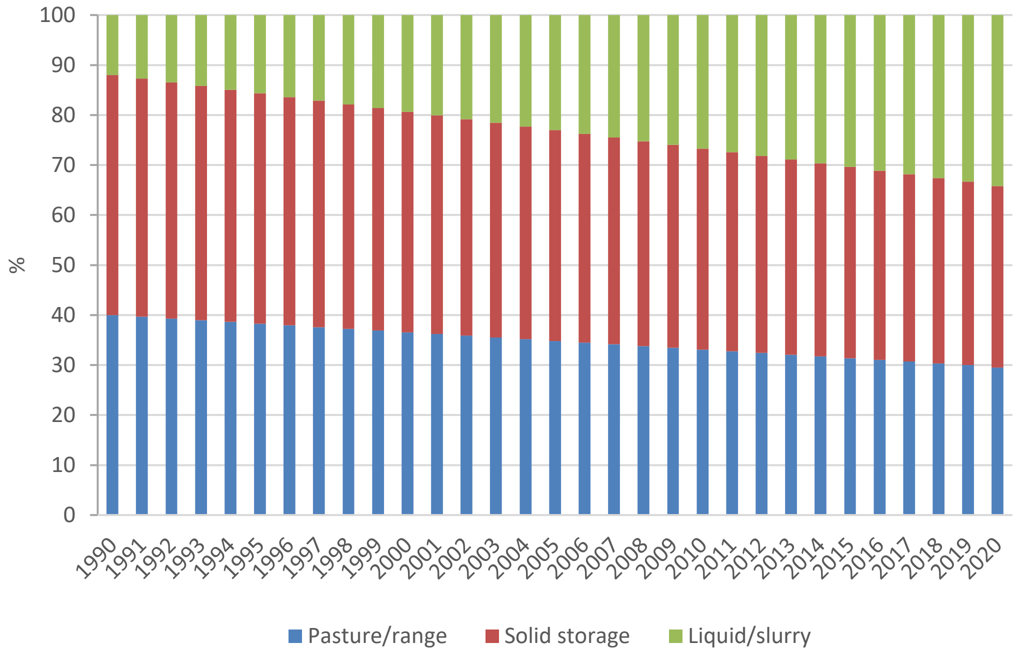


Figure 5-4. Data on manure management systems for dairy cattle

[52] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10.17, p. 10.44-10.47

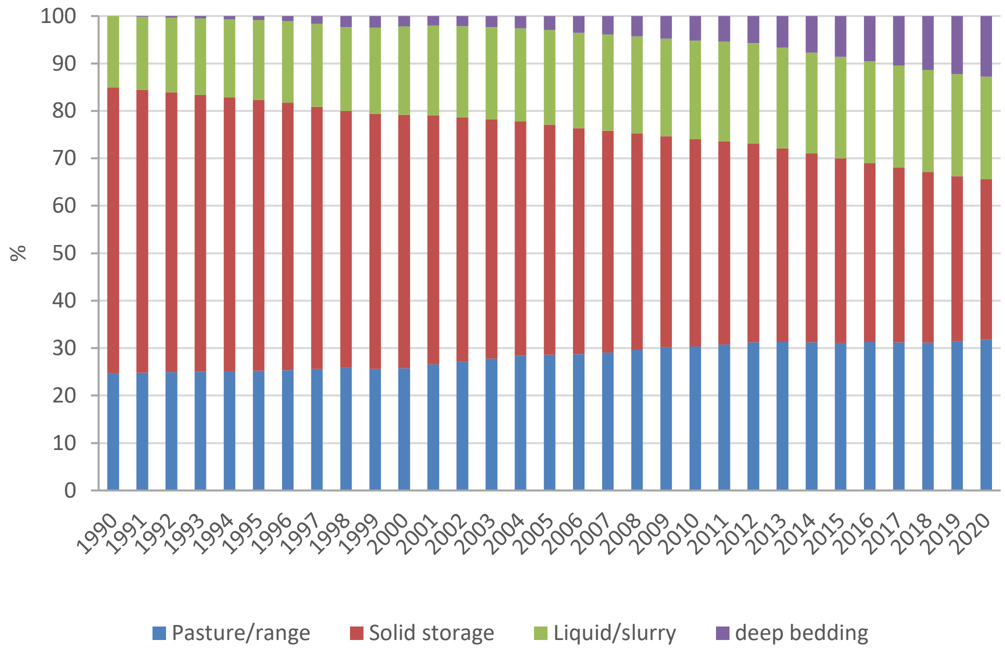


Figure 5-5. Data on manure management systems for non-dairy cattle

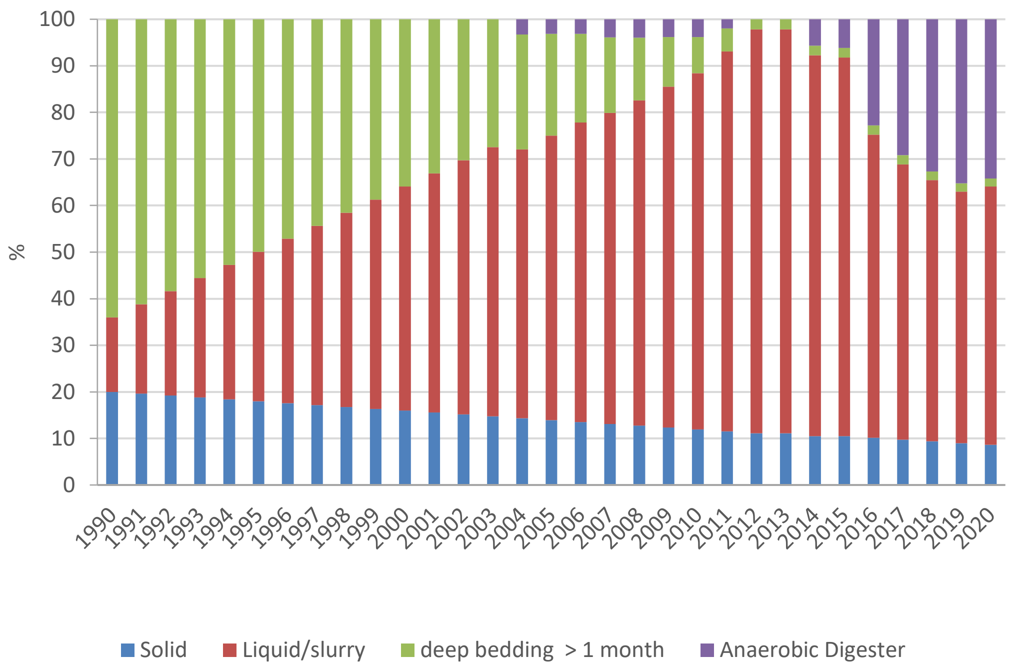


Figure 5-6. Data on manure management systems for swine

CH_4 emission from manure management was calculated using the following equation[53]:

$$CH_{4\,manure} = \sum_{(T)} \frac{\left(EF_{(T)} \cdot N_{(T)}\right)}{10^6}$$

where:

[53] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Eq. 10.22, p. 10.37

$CH_{4\,manure}$ - CH_4 emissions from manure management, for a defined population, kt CH_4 yr^{-1};

$EF_{(T)}$ - emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1};

$N_{(T)}$ - the number of head of livestock species/category T in the country;

T - species/category of livestock.

CH_4 emission factors for cattle, swine and sheep were determined using the fallowing equation[54]:

$$EF_{(T)} = \left(VS_{(T)} \cdot 365\right) \cdot \left[B_{0(T)} \cdot 0.67kg/m^3 \cdot \sum_{S,k} \frac{MCF_{S,k}}{100} \cdot MCF_{(T,S,k)}\right]$$

where:

$EF_{(T)}$ - annual CH_4 emission factor for livestock category *T*, kg CH_4 $animal^{-1}$ yr^{-1};

$VS_{(T)}$ - daily volatile solid excreted for livestock category *T*, kg dry matter $animal^{-1}$ day^{-1};

365 - basis for calculating annual VS production, days yr^{-1};

$B_{0(T)}$ - maximum methane producing capacity for manure produced by livestock category *T*, m^3 CH_4 $kg^{-1}$of VS excreted;

0.67 - conversion factor of m^3 CH_4 to kg CH_4;

$MCF_{(S,\,k)}$ - methane conversion factors for each manure management system *S* by climate region *k*, %;

$MS_{(T,\,S,\,k)}$ - fraction of livestock category *T's* manure handled using manure management system *S* in climate region *k*.

The VS excretion rate, calculated for dairy and non-dairy cattle, sheep and swine were estimated from feed intake levels[55]:

$$VS = \left[GE \cdot \left(1 - \frac{DE\%}{100}\right) + (UE \cdot GE)\right] \cdot \left[\left(\frac{1 - ASH}{18.45}\right)\right]$$

where:

VS - volatile solid excretion per day on a dry-organic matter basis, kg VS day^{-1};

GE - gross energy intake, MJ day^{-1};

DE% - digestibility of the feed in percent;

(UE • GE) - urinary energy expressed as fraction of GE;

ASH - the ash content of manure calculated as a fraction of the dry matter feed intake;

18.45 - conversion factor for dietary GE per kg of dry matter, MJ kg^{-1}.

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[54] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Eq. 10.23, p. 10.41

[55] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Eq. 10.24, p. 10.42

Gross energy consumption values for dairy cattle, non-dairy cattle, swine and sheep were estimated using same method as described in Chapter 5.2. Volatile solid excretion rate was calculated using digestible energy of the feed (65% for cattle, 75% for swine and 60% for sheep), ash content of manure (8% for cattle, 2% for swine and 8% for sheep)[56]. The urinary energy expressed as fraction of gross energy was 0.04 for cattle and sheep, 0.02 for swine[57]. Estimated daily VS excretions for cattle, swine and sheep are shown in table below.

Table 5-25. Daily VS excretions for dairy, non-dairy cattle, swine and sheep, kg-d.m./day

Year	Cattle		Swine	Sheep
	Dairy	Non-dairy		
1990	4.54	2.44	0.50	0.57
1995	4.17	2.38	0.50	0.57
2000	4.53	2.31	0.50	0.57
2005	4.85	2.28	0.49	0.57
2010	5.20	2.38	0.48	0.57
2015	5.66	2.50	0.49	0.57
2016	5.59	2.52	0.49	0.57
2017	5.63	2.54	0.48	0.57
2018	5.81	2.56	0.48	0.57
2019	5.98	2.59	0.48	0.57
2020	5.98	2.60	0.48	0.57

Estimated VS value for sheep shown in table above are higher than the default value in the *2006 IPCC Guidelines*, Vol. 4, Table 10A-9 (0.40 kg dm./head/day). The VS calculation formula includes GE value, which is based on sheep nutrition norms and feed nutrition tables provided in the national literature[58], therefore the difference between default and country-specific VS value is influenced by national nutritional standards. Also lambs are usually weaned at 3-4 months old in Lithuania, and on this basis more feed is needed for ewes, which leads to a higher GE value.

The CH_4 EF also depends on the maximum methane producing capacity of the manure (B_o). For dairy cattle, suckling cows and other cows the methane producing capacity (B_o) 0.21 m^3 CH_4/kg VS has been used[59]. The B_o was obtained using a standardized method and is based on the total excreted VS and typical cattle rations.

Regarding, increasing milk yield and changes in housing types of animals when solid manure management was replaced by slurry-based system, EF of dairy cattle has increased as it could be seen in the table below. Methane conversion factor for slurry manure is higher than solid manure MCF.

Table 5-26. Estimated EF for dairy cattle, swine and sheep, kg CH_4/head/year

Year	Dairy cattle	Swine	Sheep
1990	5.97	5.11	0.41
1995	6.15	5.30	0.41
2000	7.40	5.38	0.41
2005	8.70	5.17	0.41
2010	10.17	5.10	0.41
2015	11.97	5.16	0.41
2016	12.00	4.14	0.41

[56] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10A-9, p. 10.82; p. 10.42

[57] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, p. 10.42

[58] Gyvulininkystės žinynas. Baisogala (en. Livestock manual. Institute of Animal Science of LVA), 2007. P. 394-402.

[59] Matulaitis, R. *The effectiveness of implements on mitigation of greenhouse gas emission and pollution reduction from manure*. Summary of Doctoral Dissertation. Kaunas, 2014

2017	12.26	3.74	0.41
2018	12.84	3.53	0.41
2019	13.40	3.41	0.41
2020	13.64	3.50	0.41

Each year more high productivity cattle are brought from the Western Europe countries. Therefore, higher quality forage is needed to meet nutrition needs of the high productivity livestock. The forage is produced using innovative technologies which are used in Western countries. Therefore, Western countries methane producing capacity (B_0) for non-dairy cattle (0.18 m^3 CH_4/kg VS) was used instead of Eastern countries. Methane producing capacity was taken from *2006 IPCC Guidelines* Table 10A-5 p. 10.78.

Inter-annual changes of CH_4 EF for dairy and non-dairy cattle in the manure management category mainly are determined by the GE intake and at the same time volatile solid excretion, as well as the allocation of manure per animal in manure management system.

Estimated EF's for Cattle 2 years old and older of Bulls dairy sires and non-dairy sires during the whole reporting period were constant – 3.81 and 18.43 kg CH_4/head/year respectively due to proportional distribution of MMS.

Table 5-27. Calculated EF used for calculation of CH_4 emission from manure management of non-dairy cattle subcategories during the period 1990-2020, kg CH_4/head/year

Year	Cattle sub-categories												
	Suckling cows	Less than 1 year old			From 1 to 2 years old			2 years old and older					Other cows
		Calves for slaughter	For breeding		Bulls	Heifers		Bulls			Heifers		
			Bulls	Heifers		For slaughter	For breeding	Dairy sires	Non-dairy sires	Other bulls	For slaughter	For breeding	
1990	-	2.18	3.10	1.73	5.59	3.99	3.01	3.81	-	5.46	4.52	3.75	6.52
1995	-	2.40	3.36	1.87	6.06	4.39	3.26	3.81	-	5.92	4.86	4.11	7.02
2000	23.42	2.61	3.61	2.02	6.53	4.78	3.51	3.81	18.43	6.39	5.21	4.46	7.52
2005	23.42	2.82	3.87	2.16	7.00	5.17	3.76	3.81	18.43	6.85	5.56	4.82	8.02
2010	23.42	3.04	4.13	2.30	7.47	5.56	4.01	3.81	18.43	7.31	5.90	5.18	8.51
2015	23.42	3.25	4.38	2.45	7.95	5.95	4.25	3.81	18.43	7.77	6.25	5.53	9.01
2016	23.42	3.29	4.43	2.48	8.04	6.03	4.30	3.81	18.43	7.87	6.32	5.61	9.11
2017	23.42	3.34	4.49	2.50	8.13	6.11	4.35	3.81	18.43	7.96	6.39	5.68	9.21
2018	23.42	3.38	4.54	2.53	8.23	6.18	4.40	3.81	18.43	8.05	6.46	5.75	9.31
2019	23.42	3.42	4.59	2.56	8.32	6.26	4.45	3.81	18.43	8.14	6.53	5.82	9.41
2020	23.42	3.46	4.64	2.59	8.42	6.34	4.50	3.81	18.43	8.24	6.60	5.89	9.41

EF for non-dairy cattle and swine has increased as a result of increasing number of housing variety for livestock when solid manure management system are being replaced by liquid manure management system. Estimated EF of non-dairy cattle are provided in the table above, EF for swine are provided in the Table 5-26.

Inter-annual changes of CH_4 EF for swine in manure management category is mainly determined by the volatile solid excretion, which reflects the higher or smaller quantity of breeding or market swine (%) in the population, also by the allocation of manure per animal in manure management system. The allocation of manure per animal in manure management system reflects the average methane conversion factors (MCF) for country manure management.

The majority of swine in Lithuania are grown under industrial production conditions on large farms where liquid manure management technologies are applied. However, there are low number of small farms, where swine are grown on the litter, and solid manure technologies are applied. *2006 IPCC Guidelines* recommended methane producing capacity (B_o) is 0.45 m^3 CH_4/kg VS, however, on investigation of Matulaitis (2014) was found that swine liquid manure methane producing capacity in Lithuanian conditions is 0.29 m^3 CH_4/kg VS, what is significantly lower than that indicated by *2006 IPCC Guidelines*. Studies have been carried out using a standardized method and is based on the total excreted VS and typical swine rations. The *2006 IPCC Guidelines* methane producing capacity default value (0.45 $m^3 CH_4$/kg VS) for swine originated from the USA where large amounts of maize constitute the feed composition. However, Dämmgen et al., (2012) pointed out that swine feed composition in Central Europe differs significantly from the US feeds and suggest using (B_o) 0.30 $m^3 CH_4$/kg VS 60. Morken et al., (2013)[61] for Norway also recommends to use methane producing capacity of 0.30 $m^3 CH_4$/kg VS. As mention above, that the methane producing capacity is not dependent on manure management system, in Lithuanians inventory report the methane producing capacity of 0.30 $m^3 CH_4$/kg VS has been used.

Anaerobic digesters, which were operating in 2004-2011 and 2014-2020 affected the CH_4 emission factor from manure management systems (MMS) (Annex VIII, Table A.5-3). The magnitude of the emission factor was also influenced by the ratio of breeding and market swine in the population (Annex VIII, Table A.5-4).

Estimated EF for sheep during the 1990-2013 period was constant – 0.41 kg CH_4/head/year, due to proportional distribution of animals in subcategories, the values of EF are provided in the Table 5-25. In 2014-2020 period inter-annual changes of CH_4 EF for sheep are mainly determined by the GE intake and at the same time volatile solid excretion in subcategories. Methane producing capacity (B_0) for sheep (0.19 m^3 CH_4/kg VS) was taken from *2006 IPCC Guidelines*[62].

For estimation of CH_4 emissions from horses, goats, poultry, rabbits, other (nutria) and fur-bearing animals default *2006 IPCC Guidelines* EF were used[63][64]. CH_4 EF for geese is not available in either *2006 IPCC Guidelines* or in the Revised *1996 IPCC Guidelines*, therefore EF of "other

[60] Dämmgen U., Amon B., Hutchings N. J.,. Haenel H.-D, Rösemann C. Data sets to assess methane emissions from untreated cattle and pig slurry and solid manure storage systems in the German and Austrian emission inventories. Landbauforschung, Agriculture and Forestry Research. 2012: (62):1-20.

[61] Morken J., Ayoub S., Sapci Z. Revision of the Norwegian model for estimating methane emission from manure management. IMT-RappoRT nR. 54/2013. Available at: https://www.researchgate.net/publication/284247299_Revision_of_the_Norwegian_model_for_estimating_methane_emission_from_manure_management

[62] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Tables 10A-5, 10A-9.p. 10.78, 10.82

[63] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10.15, p. 10.40

[64] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10.16, p. 10.41

poultry", provided in the Revised *1996 IPCC Guidelines*[65] was used. This EF is also used for "other poultry" (Table 5-28).

Table 5-28. EF used for calculation of CH_4 emission from manure management, kg CH_4/head/year

Livestock category	Emission factor, kg CH_4/head/year
Goats	0.13
Horses	1.56
Layers (dry)	0.03
Layers (wet)	1.20
Broilers	0.02
Turkeys	0.09
Ducks	0.02
Geese	0.078
Other poultry	0.078
Rabbits	0.08
Other (Nutria)	0.68
Fur-bearing animals	0.68

5.3.3 Uncertainties and time-series consistency

CH_4 emission from manure management was calculated based on activity data and emission factors. Overall uncertainties result from uncertainty of livestock population (Chapter 5.2.3), uncertainty of emission factors and uncertainty values of other relevant parameters. However, the data on excretion and distribution of manure among the management systems are less reliable.

Activity data uncertainty

As elaborated in Chapter 5.2.3 uncertainty value for livestock population is ±5%. The uncertainty of the manure management system usage data can be ±10% or less[66]. Uncertainties in estimates of methane producing capacity (B_0) for cattle are ±15%[67]. In study on evaluation of country specific B_0 in Lithuania uncertainty of B_0 for dairy cattle for solid manure was estimated ±19%, for liquid manure – ±30%[68]. It was estimated that uncertainty value of B_0 for non-dairy cattle is ±18%. In study on evaluation of country specific B_0 uncertainty of B_0 for swine for liquid manure was estimated ±21%[69].

Emission factor uncertainty

2006 IPCC Guidelines indicates that for the Tier 1 method there is a larger uncertainty range for the default factors. For Tier 1 method uncertainty for CH_4 EF is estimated to be ±30%. Improvements achieved by Tier 2 methodologies are estimated to reduce uncertainty ranges in emission factors to ±20%.

The uncertainties in emissions factors of CH_4 emissions from manure management was calculated according to *2006 IPCC Guidelines* Equation 3.1. It is estimated that uncertainty of emission factor for dairy cattle category is likely to be in order of ±19.4%, for non-dairy cattle -

[65] Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual.Vol. 3, Table B-7, p.4.47.

[66] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, p. 10.48

[67] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10A-4, p. 10.77

[68] Matulaitis, R. *The effectiveness of implements on mitigation of greenhouse gas emission and pollution reduction from manure*. Summary of Doctoral Dissertation. Kaunas, 2014

[69] Matulaitis, R. *The effectiveness of implements on mitigation of greenhouse gas emission and pollution reduction from manure*. Summary of Doctoral Dissertation. Kaunas, 2014

±4.3%, for sheep - ±16.0%, for swine - ±15.6%. Overall estimated uncertainties in emissions factors of CH_4 emissions from manure management were estimated to be ±12.2%.

Overall uncertainty

Combined uncertainty was calculated using *2006 IPCC Guidelines* Equation 3.2[70]. This approach requires uncertainty values of the main activity data used and uncertainty of EF. Combined uncertainty was estimated to be ±18.2%.

5.3.4 Category-specific QA/QC and verification

Same general QC procedures as applied for category Enteric fermentation were applied for category Manure management – check of activity data for the whole time period, consistency check of data entered in CRF with calculation sheets, trends of emissions for each category, relevance of methodology applied, etc.

VS excretion, CH_4 producing potential and EF for the year 2019 as well as data quality and reliability were evaluated by comparing them to 2018 data with neighbouring countries.

National VS excretion (kg d.m./day) of dairy cattle category differs slightly (3.3-9.7%) from the one provided in Latvia's and Estonia's NIR (Table 5-29). However, CH_4 EF calculated for Estonia is considerably higher. National VS excretion (kg d.m./day) of swine category is similar with Belarus and significantly higher as pointed other countries. Lithuania's CH_4 EF is significantly lower as Estonia's however, the latter country used higher IPCC default CH_4 producing potential.

Table 5-29. Comparison of VS and other parameter for CH_4 emission calculation from manure management of dairy cattle

Country	VS excretions (kg-d.m./day)	CH_4 producing potential (m^3 CH_4/kg VS)	EF (kg CH_4/head/yr.)	Liquid manure system (%)
Dairy cattle				
Belarus	5.54	0.24	5.92	0
Estonia	6.76	0.24	33.70	81.76
Latvia	6.32	0.24	17.89	36.00
Lithuania	5.98	0.21	13.64	34.21
Poland	4.81	0.24	7.73	10.53
Swine				
Belarus	0.45	0.45	3.14	54.12
Estonia	0.28	0.45	5.09	95.28
Latvia	0.35	0.45	2.32	50.00
Lithuania	0.48	0.30	3.50	55.51
Poland	0.31	0.45	1.38	24.90

5.3.5 Category-specific recalculations

Methane emissions recalculation was performed only for the swine category for the period of 2017 – 2019 as more accurate information on usage of anaerobic digester manure management system was obtain.

Table 5-30. Reported in previous submission and recalculated CH_4 emissions from manure management, kt

Year	2021 submission	2022 submission	Absolute difference, kt	Relative difference, %
2017	10.07	9.96	-0.11	-1.09

[70] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 3, eq. 3.1, p. 3.28

2018	9.63	9.51	-0.12	-1.20
2019	9.30	9.18	-0.12	-1.29

5.3.6 Category-specific planned improvements

Study to develop country-specific data on feed digestibility currently is under implementation. On 16 December 2020 a contract was signed between the Ministry of Environment and the Institute of Animal Science (Lithuanian University of Health Sciences) to develop a "Study on determination of country-specific feed digestibility values by classic in vivo method". The final study results are expected to be ready on 1 April 2022, therefore developed digestibility values will be incorporated in the 2023 inventory submission.

5.4 Manure management – N_2O emissions (CRF 3.B.2)

5.4.1 Direct N_2O emission (CRF 3.B.2)

5.4.1.1 Category description

During manure storage and handling, manure emits nitrous oxide (N_2O) through nitrification or denitrification. The amount of emitted N_2O depends on nitrogen and carbon content in manure, type of manure storage system, duration of time manure is stored, climatic condition during the storage. N_2O is the most potent agricultural GHG with warming potential 298 times greater than that of CO_2.

The emission of N_2O is calculated based on the amount of nitrogen excretion per animal and manure management system. Emission estimates from manure deposited during grazing period are calculated and described in the section "Urine and dung deposited by grazing animals" (Chapter 5.6.1.2).

Direct N_2O emissions from manure management constituted 95.7 kt CO_2 eq. or 1.9% of the total Agriculture sector emissions in 2020. In 2020 comparing with 1990, direct N_2O emissions from manure management decreased by 71.3% (figure below). Estimated direct N_2O emissions from different manure management systems are provided in the Table 5-31.

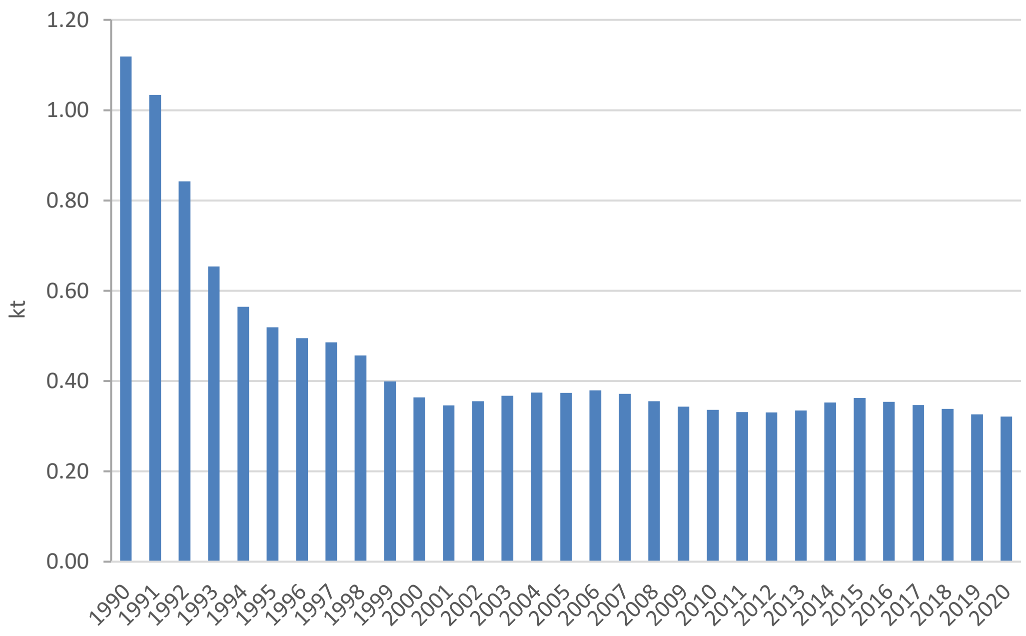

Figure 5-7. Direct N_2O emission from manure management

Table 5-31. Estimated direct N_2O emissions from different manure management systems, kt

Year	Manure management system		
	Liquid system	**Solid storage**	**Other systems**
1990	0.14	0.65	0.33
1995	0.08	0.30	0.14
2000	0.08	0.22	0.07
2005	0.09	0.22	0.06
2010	0.10	0.20	0.04
2015	0.11	0.22	0.04
2016	0.11	0.21	0.04
2017	0.11	0.20	0.04
2018	0.11	0.19	0.04
2019	0.10	0.18	0.05
2020	0.10	0.17	0.05

5.4.1.2 Methodological issues

To estimate N_2O emissions from manure management of cattle and sheep Tier 2 method was used. For calculation of N_2O emission from other livestock categories (swine, goats, horses, poultry, rabbits, other (nutria) and fur-bearing animals) Tier 1 method was used.

Table 5-32. Information on methods and EF used for estimation of emissions from manure management

Animal category	Emission reported	Methods	Emission factor
Dairy cattle	N_2O	Tier 2	2006 IPCC
Non-dairy cattle	N_2O	Tier 2	2006 IPCC
Sheep	N_2O	Tier 2	2006 IPCC
Swine	N_2O	Tier 1	2006 IPCC
Horses	N_2O	Tier 1	2006 IPCC
Goats	N_2O	Tier 1	2006 IPCC
Poultry	N_2O	Tier 1	2006 IPCC
Rabbits	N_2O	Tier 1	2006 IPCC
Other (nutria)	N_2O	Tier 1	2006 IPCC
Fur bearing (minks, foxes, polar foxes)	N_2O	Tier 1	2006 IPCC

Activity data

The data on populations of livestock were obtained from the database of Statistics Lithuania (1990-2019) and was recalculated into annual average population according to *2006 IPCC Guidelines*. More detailed information on annual average livestock population and distribution of livestock subcategories is provided in Chapter 5.1.

Fractions on the total annual excretion of livestock managed in specific manure management systems are provided in Figure 5-4, Figure 5-5 and Figure 5-6 in section above as well as in Table 5-33 and Figure 5-8.

Table 5-33. Manure production per animal waste management systems, %

Year	Solid storage	Liquid system	Pasture, range and paddock	Other systems
Sheep				
1990-2020	54.8	-	45.2	-
Goats				
1990-2020	54.8	-	45.2	-

Horses				
1990-2020	-	-	92	8
Rabbits				
1990-2020	100	-	-	-
Fur-bearing animals				
1990-2006	100	-	-	-
2007	92.7	7.3	-	-
2008	85.3	14.7	-	-
2009	78.0	22.0	-	-
2010	77.0	23.0	-	-
2015	72.0	28.0	-	-
2016	71.0	29.0	-	-
2017	70.0	30.0	-	-
2018-2020	69.0	31.0		
Other (Nutria)				
1990-2020	100	-	-	-

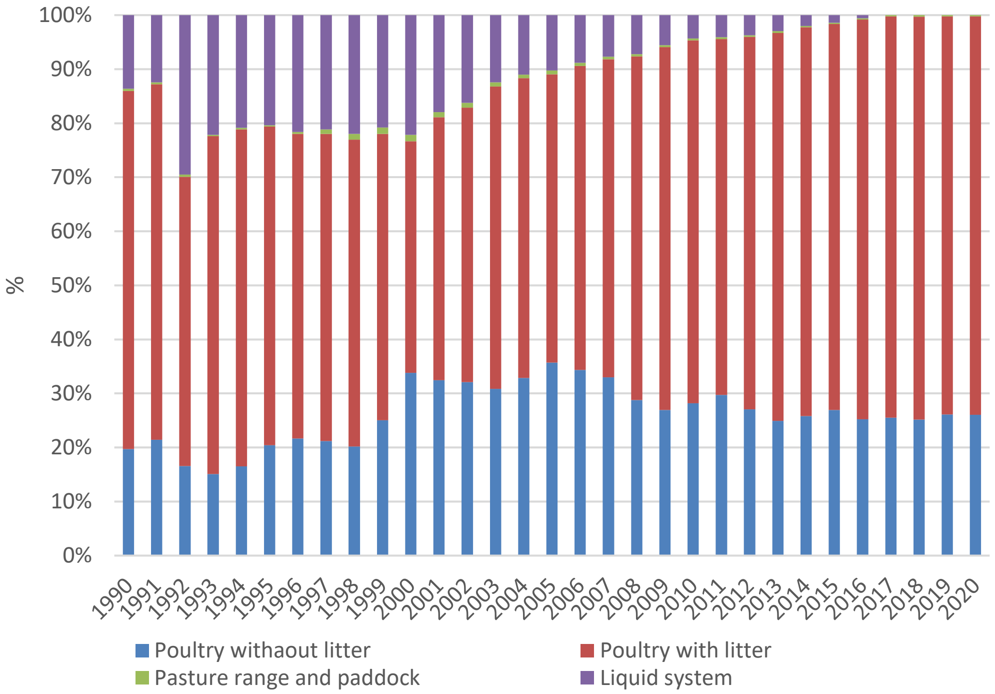

Figure 5-8. Poultry manure production per animal waste in manure management systems

Calculation of N_2O emissions

N_2O emissions from manure management are calculated by multiplying the total amount of N excretion (from all livestock categories) in each type of manure management system by an EF for that type of manure management system. Emissions are then summed over all manure management system[71]:

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

[71] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.25, p. 10.54

where:

$N_2O_{D(mm)}$ - direct N_2O emissions from manure management, kg N_2O yr^{-1};

$N_{(T)}$ - number of head of livestock species/category *T* in the country;

$Nex_{(T)}$ - annual average N excretion per head 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 manure management system *S* in the country, dimensionless;

$EF_{3(S)}$ - emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O-N/kg N in manure management system *S*;

S - manure management system;

T - species/category of livestock;

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

The annual amount of N excreted for dairy and non-dairy cattle as well as sheep categories were estimated using the following equation[72]:

$$N_{excretion} = N_{intake} - N_{retention}$$

where:

Nex - annual N excretion rates, kg N $animal^{-1}$ yr^{-1};

N_{intake} - the annual N intake per head of animal, kg N $animal^{-1}$ yr^{-1};

$N_{retention}$ - fraction of annual N intake that is retained by animal, kg N $animal^{-1}$ yr^{-1}.

Annual nitrogen intake for cattle, sheep and categories was calculated according to equation[73]:

$$N_{intake} = \frac{CP}{6.25} \cdot 365$$

where:

N_{intake} - the annual N intake per head of animal, kg N $animal^{-1}$ yr^{-1};

CP - amount of crude protein in diet of animal, kg/day $animal^{-1}$ day^{-1};

6.25 - conversion from kg of dietary protein to kg of dietary N, kg feed protein $(kg\ N)^{-1}$.

The nitrogen retained in dairy and non-dairy cattle was estimated using the following equation[74]:

$$N_{retention(T)} = \left[\frac{Milk \cdot \left(\frac{MilkPR\%}{100}\right)}{6.38}\right] + \left[\frac{WG \cdot \left[268 - \left(\frac{7.03 \cdot NE_g}{WG}\right)\right]}{\frac{1000}{6.25}}\right]$$

---

[72] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.31, p. 10.58

[73] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual. Institute of Animal Science of LVA*), 2007

[74] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.33, p. 10.60

where:

$N_{retention(T)}$ - daily N retained per animal of category *T*, kg N animal^{-1} day^{-1};

Milk - milk production, kg animal^{-1} day^{-1};

MilkPR% - percent of protein in milk, calculated as [1.9 + 0.4 * % Fat], where %Fat is an input, assumed to be 4%;

6.38 - conversion from milk protein to milk N, kg protein (kg N)$^{-1}$;

WG - weight gain, input for each livestock category, kg day^{-1};

268 and 7.03 - constants;

NE_g - net energy for growth, calculated in livestock characterisation, based on current weight, mature weight, rate of weight gain, and *2006 IPCC* constants, MJ day^{-1};

6.25 - conversion from kg dietary protein to kg dietary N, kg Protein (kg N)$^{-1}$.

Mature body weight and rate of weight gain of non-dairy cattle, used for estimation of net energy for growth are provided in Table 5-8.

Values of nitrogen retention for sheep were accepted as default values for the fraction of N intake that retained by the animal per year (0.10) multiplied by N intake per animal per year[75].

Net energy for growth (NE_g) for non-dairy cattle was calculated according equation[76]:

$$NE_g = 22.2 \cdot \left(\frac{BW}{C \cdot MW}\right)^{0.75} \cdot WG^{1.097}$$

where:

NE_g - net energy needed for growth, MJ day^{-1};

BW - the average live body weight of the animals in the population, kg;

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;

WG - the average daily weight gain of the animals in the population, kg day^{-1}.

The annual amount of N excreted for swine, horses, goats and poultry were calculated using equation[77]:

$$Nex_{(T)} = N_{rate(T)} \cdot \frac{TAM}{1000} \cdot 365$$

where:

$Nex_{(T)}$ - annual N excretion for livestock category T, kg N animal^{-1} yr^{-1};

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[75] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, Table 10.20, p. 10.60
[76] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.6, p. 10.17
[77] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.30, p. 10.57

$N_{rate(T)}$ - default N excretion rate[78], kg N (1,000 kg animal mass)$^{-1}$ day^{-1};

$TAM_{(T)}$ - typical animal mass for livestock category T, kg animal^{-1}.

The annual amount of N excretion per animal for dairy cattle, non-dairy cattle and sheep were estimated based on the total annual N intake and total annual N retention of the animal. Annual N intake per animal for cattle, sheep and swine were calculated in accordance with the Tables[79] of forage sustenance and ration. Estimated annual N excretion per cattle, horses, swine, goats and poultry per year are provided in the Tables 5-34 and 5-35.

Table 5-34. Estimated N excretion factors for cattle, horses and swine, kg N/head/yr

Year	Livestock category			
	Cattle		Horses	Swine
	Dairy	Non-dairy		
1990	79.63	41.00	56.94	12.36
1995	70.35	38.40	55.85	13.19
2000	79.35	35.87	54.75	12.22
2005	87.75	35.41	53.76	12.14
2010	96.36	38.58	52.67	12.14
2015	107.70	42.21	51.57	11.88
2016	105.91	42.74	51.36	11.81
2017	106.77	43.14	51.14	11.84
2018	110.93	43.60	50.92	11.91
2019	113.98	44.48	51.03	11.87
2020	113.88	45.08	51.25	11.86

Gross energy and crude protein for the period of 1990-2013 for sheep was calculated using the structure of sheep herd in 2013. New data on sheep herd structure was received in 2014, with the increased population of sheep up to 1 year subcategory and respectively decreased population of sheep over 1 year subcategories in 2014-2018. In 2020, comparing with 2019, population of sheep up to 1 year subcategory decreased in 6.4%, population of sheep over 1 year subcategories decreased in 8.7%. This resulted in higher or lower amount of proteins as well as higher or lower N excretion. Therefore, estimated N excretion for sheep in 1990-2013 and 2017 was 10.59 kg N/head/year, in 2014-2016 – 10.60-10.62, in 2018-2020 – 10.58 kg N/head/year.

N excretion rate for goats and poultry (layer hens, turkeys and duck) categories are constant through whole period. Values of estimated N excretion rate are provided in the table below. N excretion rate for broilers in the period 1990-2017 steadily increased and in the 2018-2020 has not changed.

Table 5-35. Estimated N excretion rate for goats and poultry (excl. geese and other poultry), kg N/head/yr

Year	Goats	Poultry			
		Layer hens	Broilers	Turkeys	Ducks
1990	15.81	0.47	0.36	2.09	0.48
2020			0.51		

[78] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, Table 10.19, p. 10.59

[79] Gyvulininkystės žinynas. Baisogala (en. *Livestock manual. Institute of Animal Science of LVA*), 2007, p. 584-601

The default N excretion for geese and other poultry were taken from *Revised 1996 IPCC Guidelines*[80]. Default N excretion for nutria, rabbits and fur-bearing animals were taken from *2006 IPCC Guidelines*[81].

Table 5-36. Default N excretion for livestock categories, kg N/head/yr

Livestock categories	**N excretion**
Rabbits	8.10
Minks, nutria	4.59
Foxes, polar foxes	12.09
Geese and other poultry	0.60

Default EF for direct N_2O emissions from manure management systems is reported in table below[82].

Table 5-37. Default EF for N_2O emission estimation from manure management, kg N_2O-N/kg N excreted

Manure management system		**EF**
Liquid / slurry	with natural crust cover	0.005
	without natural crust cover	0.000
Solid storage		0.005
Pasture/range/paddock	for cattle, poultry and swine	0.020
	for sheep and 'other animals'	0.010
Poultry manure	with litter	0.001
	without litter	0.001
Other system	deep bedding	0.010
	anaerobic digester	0.000
	solid storage	0.005

Inter-annual changes of N_2O EF fluctuation for the swine category is mainly determined by the nitrogen excretion and the share of manure which falls into solid or liquid manure management systems. Strong positive relationship between N_2O EF and amount of manure, which falls into solid manure management systems was estimated. Strong negative relationship between N_2O EF and the amount of manure, which falls into liquid manure management systems was estimated.

5.4.1.3 Uncertainties and time-series consistency

N_2O emission from manure management was calculated based on activity data and emission factors. Overall uncertainties result from uncertainty of livestock population (Chapter 5.2.3), uncertainty of emission factors and uncertainty values of other relevant parameters.

Activity data uncertainty

As elaborated in Chapter 5.2.3 uncertainty value for livestock population is ±5%. The uncertainty of the manure management system usage data can be ±10% or less (Chapter 5.3.3). The uncertainty ranges for the default N excretion rate calculating N excretion for goats, swine, horses, rabbits, nutria and fur-bearing animals as well as poultry (excluding subcategories geese and other poultry) is ±50%. N_2 excretion rate for cattle and sheep were estimated using Tier 2 method and based on expert judgment it was assumed that uncertainty is ±20%. Overall activity data uncertainty for indirect N_2O emissions from MMS activity data was estimated to be 6.4%

[80] *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook*. Vol. 1. Table 4-6. P. 4.10.
[81] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10.19, p. 10.59
[82] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10.21, p.p. 10.62-10.64.

Emission factor uncertainty

The uncertainty of EF for estimation of N_2O emissions in accordance with the data of *2006 IPCC* are in the range of -50 – +100%.

Overall uncertainty

Combined uncertainty was calculated using *2006 IPCC Guidelines* Equation 3.1[83]. This approach requires uncertainty values of the main activity data used and uncertainty of emission factor. Combined uncertainty was estimated to be ±112.2%.

5.4.1.4 Category specific QA/QC and verification

General QC procedures applied for this category – check of activity data for the whole time period, consistency check of data entered in CRF with calculation sheets, trends of emissions for each category, relevance of methodology applied, etc.

5.4.1.5 Category-specific recalculations

No recalculations have been done.

5.4.1.6 Category-specific planned improvements

Category-specific improvements are not planned.

5.4.2 Indirect N_2O emission (CRF 3.B.2.5)

5.4.2.1 Category description

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia (NH_3) and nitrogen oxides (NO_x). Nitrogen losses begin at the point of excretion in housings and other animal production areas[84].

Total N loss from manure management systems due to volatilization and leaching and run-off were 18.05 kt/year in 2020. Compared to 1990, average N loss from manure management decrease by 66.2% in 2020. Average N loss from manure management decreased by 15.6% during the period 2005-2020 (Figure 5-9).

[83] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 3, eq. 3.1, p. 3.28
[84] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, p. 10.52

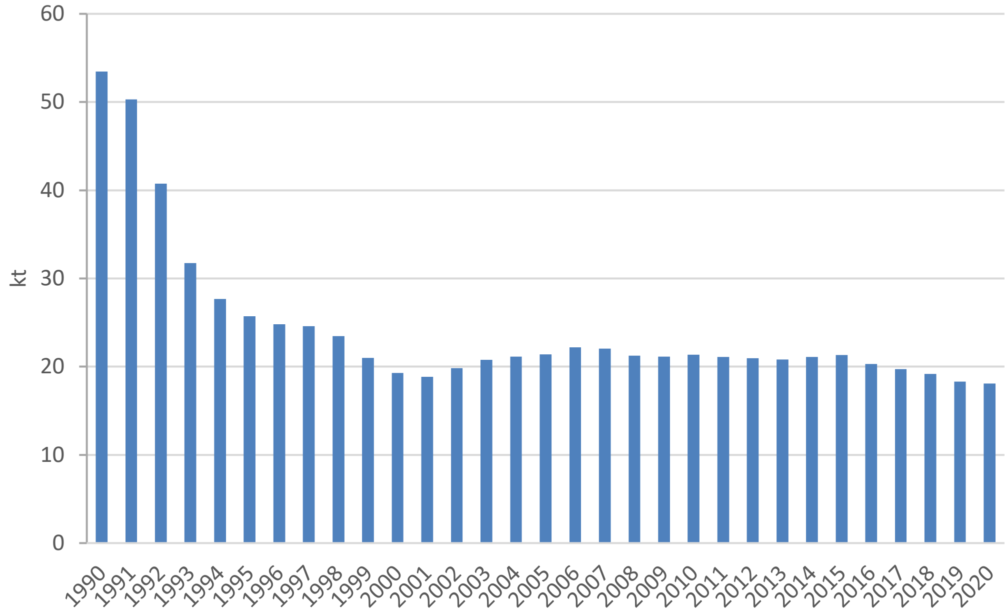


Figure 5-9. N losses due to volatilization of NH_3 and NO_x and leaching during the period 1990-2020

N loss due to volatilization in forms of NH_3 and NO_x and due to leaching from different manure management systems are presented in table below.

Table 5-38. Calculated N losses due to volatilization and leaching from different manure management systems, kt N/yr

Year	N losses due to volatilization			N losses due to leaching		
	AWMS					
	Liquid system	Solid storage	Other systems	Liquid system	Solid storage	Other systems
1990	9.94	30.36	10.80	0.0	1.65	0.72
1995	6.99	12.99	4.69	0.0	0.76	0.31
2000	6.70	9.26	2.61	0.0	0.55	0.15
2005	8.64	9.11	2.94	0.0	0.57	0.12
2010	9.58	8.33	2.86	0.0	0.51	0.06
2015	9.79	8.23	2.69	0.0	0.55	0.06
2016	8.89	7.85	2.97	0.0	0.53	0.07
2017	8.47	7.52	3.16	0.0	0.51	0.07
2018	8.10	7.19	3.32	0.0	0.48	0.08
2019	7.73	6.83	3.17	0.0	0.45	0.08
2020	7.79	6.60	3.14	0.00	0.43	0.09

Indirect N_2O emissions from manure management due to volatilization and leaching in 2020, comparing with 1990, decreased by 66.1%. From 2005 to 2020 indirect N_2O emissions from manure management decreased by 15.5% (Figure 5-10). Estimated indirect N_2O emissions due to volatilization and leaching of N from different manure management systems are presented in table above.

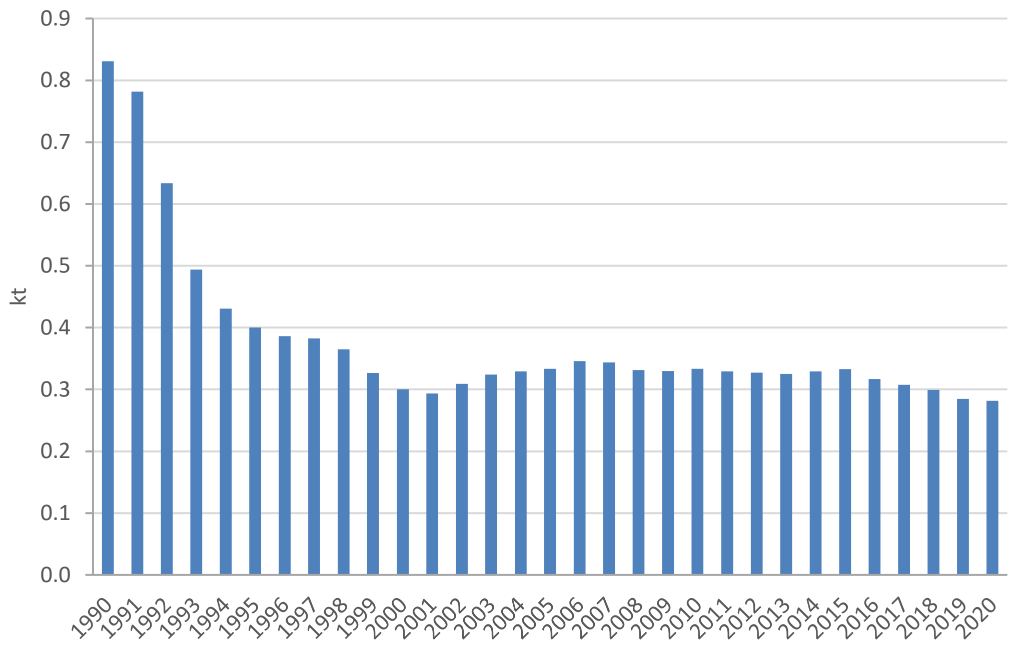


Figure 5-10. Indirect N_2O emission from manure management due to volatilization of N and leaching

Indirect N_2O emissions due to volatilization of N from different manure management are provided in the table below.

Table 5-39. Calculated indirect N_2O emissions from different manure management systems due to volatilization of N, kt N_2O

Year	AWMS		
	Liquid system	Solid storage	Other systems
1990	0.16	0.48	0.17
1995	0.11	0.20	0.07
2000	0.11	0.15	0.04
2005	0.14	0.14	0.05
2010	0.15	0.13	0.05
2015	0.15	0.13	0.04
2016	0.14	0.12	0.05
2017	0.13	0.12	0.05
2018	0.13	0.11	0.05
2019	0.12	0.11	0.05
2020	0.12	0.10	0.05

5.4.2.2 Methodological issues

To estimate indirect N_2O emissions from manure management the Tier 1 method was used.

N loss due to volatilization in forms of NH_3 and NO_x from manure management systems was calculated multiplying the amount of nitrogen excreted from all livestock categories and managed in each manure management system by a fraction of volatilized nitrogen[85].

[85] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.26, p. 10.54

$$N_{volatalization-MMs} = \sum_{S}\left[\sum_{T}\left[\left(N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)}\right) \cdot \left(\frac{Frac_{GasMS}}{100}\right)_{(T,S)}\right]\right]$$

where:

$N_{volatilization-MMS}$ - amount of manure nitrogen that is lost due to volatilization of NH_3 and NO_x, kg N yr^{-1};

$N_{(T)}$ - number of head of livestock species/category *T* in the country;

$Nex_{(T)}$ - annual average N excretion per head 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 manure management system *S* in the country, dimensionless;

$Frac_{GasMS}$ - percent of managed manure nitrogen for livestock category *T* that volatilizes as NH_3 and NO_x in the manure management system *S*, % (Table 5-39).

The Tier 1 method was applied for calculations indirect N_2O emissions due to volatilization of N in forms of NH_3 and NO_x from manure management[86].

$$N_2O_{G(mm)} = (N_{volatalization-MMS} \cdot EF_4) \cdot \frac{44}{28}$$

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[87] (kg NH_3-N + NO_x-N volatilized)$^{-1}$.

Table 5-40. Default values for N loss due to volatilization of NH_3 and NO_x from manure management, %

Livestock category	Manure management system	$Frac_{GasMS}$
Dairy cattle	Liquid	40
	Solid	30
Non-dairy cattle	Liquid	40
	Solid	45
	Other (Deep bedding)	30
Swine	Liquid	48
	Solid	45
	Other (Deep bedding)	40
Poultry (layer hens-wet)	Liquid	48
	Without litter	55
	With litter	40
Sheep, goats, rabbits, other (nutria), fur-bearing animals	Solid	12
Fur-bearing animals	Other	25
	Liquid	48

[86] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.27, p. 10.56
[87] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 11, Table 11.3, p. 11.24

Horses	Other	12

Nitrogen that leaches into soil and/or run-off during storage of manure at outdoor areas or in feedlots can be estimated using the following equation[88]:

$$N_{leaching-MMS} = \sum_{S}\left[\sum_{T}\left[\left(N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)}\right) \cdot \left(\frac{Frac_{leachMS}}{100}\right)\right]\right]$$

where:

$N_{leaching\text{-}MMS}$ - amount of manure nitrogen that leached from manure management systems, kg N yr^{-1};

$N_{(T)}$ - number of head of livestock species/category *T* in the country;

$N_{ex(T)}$ - annual average N excretion per head 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 manure management system *S* in the country, dimensionless;

$Frac_{leachMS}$ - percent of managed manure nitrogen losses for livestock category *T* due to runoff and leaching during storage of manure (Table 5-40).

As there are no national or *2006 IPCC Guidelines* default data of $Frac_{leachMS}$ values available, the values of $Frac_{leachMS}$ that is used to calculate indirect N_2O emission from Leaching and run-off were taken from 2019 IPCC Refinement to the *2006 IPCC Guidelines*. The table with $Frac_{leachMS}$ values used are provided in the table below.

The indirect N_2O emissions from leaching and run-off of nitrogen from manure management systems are estimated using the following equation[89]:

$$N_2O_{L(mm)} = \left(N_{leaching-MMS} \cdot EF_5\right) \cdot \frac{44}{28}$$

where:

$N_2O_{L(mm)}$ - indirect N_2O emissions due to leaching and runoff from manure management in the country, kg N_2O yr^{-1};

EF_5 - emission factor for N_2O emissions from nitrogen leaching and runoff, kg N_2O-N/kg N leached and run-off (default value 0.0075 kg N_2O-N[90] (kg N leaching/run-off)$^{-1}$.

Table 5-41. Default values of N losses due to leaching, %

Livestock category	Manure management system	$Frac_{leachMS}$
Dairy cattle	Liquid	0
	Solid	0.02
Non-dairy cattle	Liquid	0
	Solid	0.02
	Other (Deep bedding)	0.035

[88] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.28, p. 10.56
[89] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 10, eq. 10.29, p. 10.57
[90] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 11, Table 11.3, p. 11.24

Swine	Liquid	0
	Solid	0.02
	Other (Deep bedding)	0.035
Poultry (layer hens-wet)	Liquid	0
	Without litter	0
	With litter	0
Sheep, goats, rabbits, other (nutria), fur-bearing animals	Solid	0.02
Fur-bearing animals	Liquid	0
Horses	Other	0.02

5.4.2.3 Uncertainties and time-series consistency

Indirect N_2O emission from manure management was calculated based on activity data and emission factors. Overall uncertainties result from uncertainty of livestock population (Chapter 5.2.3), uncertainty of emission factors and uncertainty values of other relevant parameters.

Activity data uncertainty

As elaborated in Chapter 5.2.3 uncertainty value for livestock population is ±5%. The uncertainty of the manure management system usage data can be ±10% or less (Chapter 5.3.3). The uncertainty ranges for the default N excretion rate calculating N excretion for goats, swine, horses, rabbits, nutria and fur-bearing animals as well as poultry (excluding subcategories of geese and other poultry) is ±50%. N excretion rate for cattle and sheep were estimated using Tier 2 method and based on expert judgement it was assumed that uncertainty is ±20%. Overall activity data uncertainty for indirect N_2O emissions from MMS activity data was estimated to be 19.7%.

Emission factor uncertainty

The uncertainty of EF_4 and EF_5 for estimation of indirect N_2O emissions from volatilization and leaching were estimated to be ±192% and ±79% respectively.

Overall uncertainty

Combined uncertainty was calculated using *2006 IPCC Guidelines* Equation 3.1[91]. This approach requires uncertainty values of the main activity data used and uncertainty of emission factor. Overall uncertainty for indirect N_2O emission was estimated to be ±208%.

5.4.2.4 Category-specific QA/QC and verification

General QC procedures applied for this category – check of activity data for the whole time period, consistency check of data entered in CRF with calculation sheets, trends of emissions for each category, relevance of methodology applied, etc.

5.4.2.5 Category-specific recalculations

Recalculations of indirect N_2O emissions were made due to following reasons:

1. For swine category liquid manure management system was recalculated as more accurate information on usage of manure management system was obtain;

2. Typing error in the calculation of emissions for horses in 2018-2019 was corrected.

[91] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 3, eq. 3.1, p. 3.28

Recalculations results are provided in the table below.

Table 5-42. Reported in previous submission and recalculated indirect N_2O emissions from manure management due to volatilization of N and leaching from manure management, kt

Year	2021 submission	2022 submission	Absolute difference, kt	Relative difference, %
2017	0.3093	0.3077	-0.0016	-0.53
2018	0.3010	0.2990	-0.0020	-0.65
2019	0.2871	0.2849	-0.0023	-0.79

5.4.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

5.5 Rice cultivation (CRF 3.C)

Rice is not cultivated in Lithuania therefore reported as NO.

5.6 Agricultural soils (CRF 3.D)

Agricultural soils include direct and indirect nitrous oxide (N_2O) emissions (Table 5-43). Managed soils represent a large source of N_2O emissions. N_2O emission from managed soils contributed 58% of the total GHG emission from agriculture sector. N_2O emissions from agricultural soils were also identified as a key category (see Table 5-11).

Lithuania uses *2006 IPCC Guidelines* methodology for the calculation of N_2O emissions from agriculture soils. All assessed direct and indirect N_2O emissions from agriculture soils categories, method applied and emission factors are provided in the table below.

Table 5-43.Method and emissions factors used to estimated N_2O emission from agriculture soils category

CRF	Source	Emissions reported	Methods	Emission factor
3.D.1	Direct N_2O emissions from managed soils			
3.D.1.1	Inorganic N fertilizer	N_2O	Tier 1	D
3.D.1.2	Organic N fertilizer	N_2O	Tier 1	D
3.D.1.3	Urine and dung deposited by grazing animals	N_2O	Tier 1	D
3.D.1.4	Crop residue	N_2O	Tier 2	D
3.D.1.5	Mineralization/Immobilization associated with gain/loss of soil organic matter	N_2O	Tier 1	D
3.D.1.6	Cultivation of histosols	N_2O	Tier 1	D
3.D.2	Indirect N_2O emissions from managed soils			
3.D.2.1	Atmospheric deposition	N_2O	Tier 1	D
3.D.2.2	Nitrogen leaching and run-off	N_2O	Tier 1	D

5.6.1 Direct N_2O emissions from managed soils (CRF 3.D.1)

5.6.1.1 Category description

An increase in available N enhances nitrification and denitrification rates which then increase the production of N_2O. Increases in available N can occur through human-induced N additions or change of land-use and/or management practices that mineralize soil organic N. Estimated direct N_2O agriculture soil emissions consists of: inorganic N fertilizers, organic N fertilizer (animal manure applied to soils, compost and sewage sludge), urine and dung deposited by grazing animals, crop residue, N mineralization associated with loss/gain of soil organic matter and cultivation of histosols.

5.6.1.2 Methodological issues

Direct N_2O emissions from managed soils were estimated using 2006 *IPCC Guidelines* Tier 1 method. The following equation was used to estimate direct N_2O emissions from managed soils[92]:

$$N_2O_{Direct} - N = N_2O - N_{N\,inputs} + N_2O - N_{OS} + N_2O - N_{PRP}$$

Where:

$$N_2O - N_{N\,inputs} = [(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \cdot EF_1]$$

$$N_2O - N_{OS} = [(F_{OS,CG,Temp} \cdot EF_{2CG,Temp}) + (F_{OS,CG,Trop} \cdot EF_{2CG,Trop}) + (F_{OS,F,Temp,NR} \cdot EF_{2F,Temp,NR}) + (F_{OS,F,Temp,NP} \cdot EF_{2F,Temp,NP}) + (F_{OS,F,Trop} \cdot EF_{2F,Trop})$$

$$N_2O - N_{PRP} = [(F_{PRP,CPP} \cdot EF_{PRP,CPP}) + (F_{PRP,SO} \cdot EF_{PRP,SO})]$$

where:

$N_2O_{Direct-N}$ - annual direct N_2O–N emissions produced from managed soils, kg N_2O–N yr^{-1};

$N_2O–N_{N\,inputs}$ - annual direct N_2O–N emissions from N inputs to managed soils, kg N_2O–N yr^{-1};

$N_2O–N_{OS}$ - annual direct N_2O–N emissions from managed organic soils, kg N_2O–N yr^{-1};

$N_2O–N_{PRP}$ - annual direct N_2O–N emissions from urine and dung inputs to grazed soils, kg N_2O–N yr^{-1};

F_{SN} - annual amount of inorganic fertilizer N applied to soils, kg N yr^{-1};

F_{ON} - annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr^{-1};

F_{CR} - annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr^{-1};

F_{SOM} - annual amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1};

F_{OS} - annual area of managed/drained organic soils, ha (subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively);

F_{PRP} - annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1} (the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively);

EF_1 - emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$ (default);

[92] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, eq. 11.1, p. 11.7

EF_{1FR}	- emission factor for N_2O emissions from N inputs to flooded rice, kg N_2O–N (kg N input)$^{-1}$ (default);
EF_2	- emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N ha^{-1} yr^{-1} (the subscripts CG, F, Temp, Trop, NR and NP refer to cropland and grassland, forest land, temperate, tropical, nutrient rich, and nutrient poor, respectively) (default);
EF_{3PRP}	- emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O–N (kg N input)$^{-1}$ (the subscripts CPP and SO refer to cattle, poultry and pigs, and sheep and other animals, respectively) (default).

Applied inorganic N fertilizers (F_{SN}) (CRF 3.D.1.1)

The main data required to estimate amount of nitrogen that is being deposited on soil is consumption of nitrogen containing inorganic fertilizers. Data on consumption of inorganic N fertilizer for the 1990-2019 period are taken from International Fertilizer Industry Association (IFA)[93]. Data on inorganic N fertilizer consumption for the 2020 will be available in October of 2022. Therefore, to obtain missing activity data for the year 2020 preliminary data of fertilizer consumption was used, which was obtained from company that provides fertilizer consumption data for IFA data base. However, to ensure data consistency for the whole reporting period, after data on consumption of inorganic N fertilizer will become available at IFA, the emissions for 2020 will be recalculated.

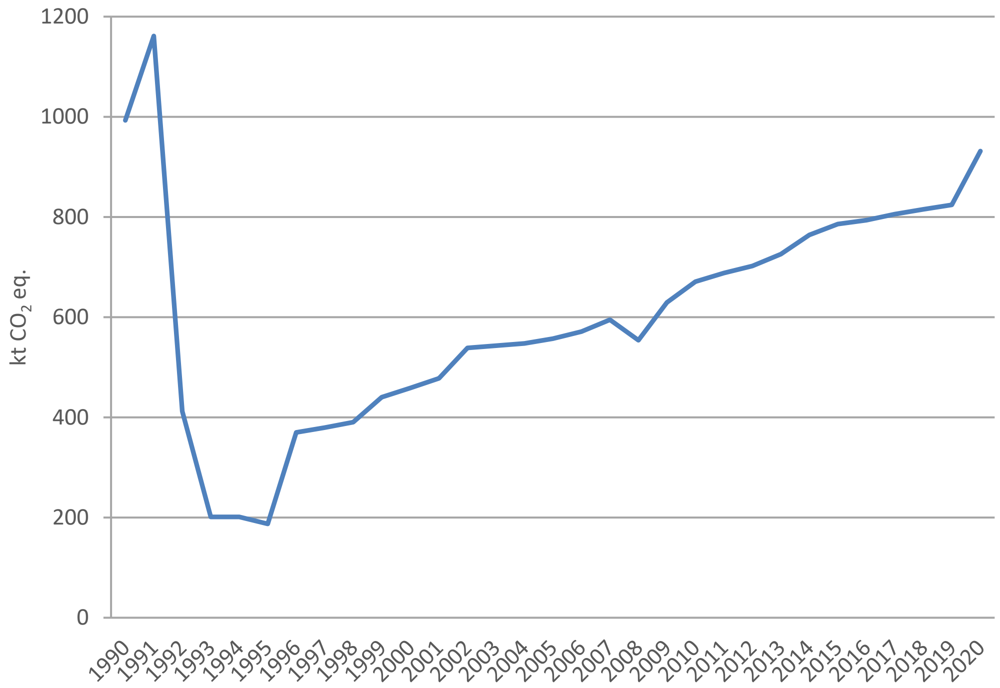


Figure 5-11. N_2O emissions from inorganic N fertilizers consumption

After the restoration of Lithuanian independence consumption of fertilizers drastically declined up to 40 kt per year in 1995. During the following years consumption rose as the economy was progressing together with the growth of agriculture, demand of crops and vegetables. The consumption dropped somewhat in 2008 due to economic crisis. Emissions from inorganic N

[93] Available from: *http://ifadata.fertilizer.org/ucSearch.aspx*

fertilizer consumption during the whole period are provided in the figure above. Comparing with 2019 emissions from consumption of inorganic N fertilizer has increased by 13% in 2020. This increase is related to the increase of crop harvest.

To calculate N_2O emissions from consumption of inorganic N fertilizers default emission factor (Table 5-43) was used.

Applied organic N fertilizers (F_{ON}) (CRF 3.D.1.2)

Amount of organic N inputs to soil in Lithuania refers to applied animal manure (other than by grazing animals), sewage sludge that is used as soil amendment and compost application as soil fertilizer. Overall organic N input to soil is calculated using Tier 1 method[94]:

$$F_{ON} = F_{AM} + F_{SEW} + F_{COMP}$$

where:

F_{ON} - total annual amount of organic N fertiliser applied to soils other than by grazing animals, kg N yr^{-1};

F_{AM} - annual amount of animal manure N applied to soils, kg N yr^{-1};

F_{SEW} - annual amount of total sewage N that is applied to soils, kg N yr^{-1};

F_{COMP} - annual amount of total compost N applied to soils, kg N yr^{-1}.

Animal manure applied to soils (F_{AM}) (CRF 3.D.1.2.a)

The main activity data used in calculations is presented in previous chapters: average annual livestock population (Chapter 5.1, Table 5-3), N excretion values were calculated in the sub-category Manure management – N_2O (Chapter 5.4.1.2), fraction of annual nitrogen excreted for each livestock category from each MMS type was indicated in the sub-category Manure management and is presented in Chapter 5.4.1.2. Amount of managed manure nitrogen for each livestock category that is lost in the MMS ($Frac_{LossMS}$) were taken from *2006 IPCC Guidelines*.[95] The amount of bedding for each livestock category were taken from the 2019 Study[96].

Animal manure in Lithuania is applied to soil as organic fertilizers. N inputs to soil were estimated using the following equation:

$$F_{AM} = N_{MMS\_Avb} \cdot [1 - (Frac_{FEED} + Frac_{FUEL} + Frac_{CNST})]$$

In Lithuania manure is not used as feed, fuel or material for construction therefore FAM = NMMS_Avb.

To estimate $N_{MMS,Avb}$ Equation 10.34 from *2006 IPCC Guidelines* was applied:

[94] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, eq. 11.3, p. 11.12
[95] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 10, Table 10.23, p. 10.67
[96] Šiltnamio Efektą Sukeliančių Dujų Emisijų Šalies Augalininkystės Sektoriuje Inventorizavimas. Ataskaita (en. The study of Lithuanian GHG emissions from the agriculture soil). 2019. p. 22-35.

$$N_{MMS_{Avb}} = \sum_{S} \left\{ \sum_{(T)} \left[\left[\left(N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)} \right) \cdot \left(1 - \frac{Frac_{LossMS}}{100} \right) \right] + \left[N_{(T)} \cdot MS_{(T,S)} \cdot N_{beddingMS} \right] \right] \right\}$$

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 manure management system *S* in the country, dimensionless;

$Frac_{LossMS}$ - amount of managed manure nitrogen for livestock category *T* that is lost in the manure management system *S*, %;

$N_{beddingMS}$ - amount of nitrogen from bedding (to be applied for solid storage and deep bedding MMS if known organic bedding usage), kg N $animal^{-1}$ yr^{-1};

S - manure management system;

T - species/category of livestock.

Sewage sludge applied to soils (F_{SEW}) (CRF 3.D.1.2.b)

Sewage sludge from wastewater treatment plants is used as soil amendment in Lithuania. According to the national database of waste – sewage sludge with recovery code R10 is being treated as useful amendment for agricultural soil[97]. Only municipal and industrial sewage sludge is applied to soils.

Data on the quantities of sewage sludge applied to soils for the periods 1991-1999 and 2004-2012 were obtained from Lithuanian Environmental Protection Agency (EPA) which collects information and manages waste database. The data on quantities of sewage sludge for the years 1990, 2000-2003 are not reliable. It is not clear how much sewage sludge has been used on agricultural soils during these years. As a result, it was decided to use interpolation in order to fill in the gap of data for the period 2000-2003. It was assumed that annual amount of sewage sludge in 1990 is similar to that of 1991 based on this assumption the same amount of sewage sludge was used both in 1990 and 1991.

To calculate the nitrogen input from application of sewage sludge the data of nitrogen concentration (%) was used (EPA's data). The data on nitrogen concentration is available for the period 2004-2019. Data on N concentration in sewage sludge for the period 1990-2003 was not available as at that time such data was not collected in Lithuania. To fill the gaps of missing

[97] Lietuvos Respublikos Aplinkos ministro 2011 m. gegužės 3 d. įsakymas Nr. D1-368 „Dėl Lietuvos Respublikos aplinkos ministro 1999 m. liepos 14 d. įsakymo Nr. 217 „Dėl atliekų tvarkymo taisyklių patvirtinimo" pakeitimo ir aplinkos ministro 2002 m. gruodžio 31 d. įsakymo Nr. 698 „Dėl alyvų atliekų tvarkymo taisyklių patvirtinimo" ir jį keitusių įsakymų pripažinimo netekusiais galios / Žin., 2011, Nr. 57-2721; 2011, Nr. 150-7100; 2012, Nr. 16-697

information on N concentration in sewage sludge for the period 1990-2003 arithmetic average value of the years 2004-2009 was used (3.8%).

The following equation was used for calculation of nitrogen input from sewage sludge application to agricultural soils:

$$F_{SEW} = S_{SLUDGE} \cdot \frac{S_N}{100}$$

where:

F_{SEW} - annual amount of total sewage N that is applied to soils, kg N yr^{-1};

S_{SLUDGE} - annual amount of sewage sludge applied to agricultural soils, kg d.m. yr^{-1};

S_N - nitrogen content in dry matter, %.

Compost applied to soils (F_{COMP})(CRF 3.D.1.2.c)

Using the financial resources of 2004-2006 EU ISPA/Cohesion funds Lithuania started improving municipal solid waste management system. The main task was to build 11 modern regional landfills and to close all the old landfills and dumps. This project also included construction of green waste composting sites (GWCS). The period 2004-2006 financed construction of 13 GWCS in different regional landfills. Second part of the project was implemented using finances from 2007-2013 EU Structural funds continuing projects started during 2004-2006. The period 2007-2013 financed construction of 39 GWCS in different regional landfills. Most of these GWCS have started accepting green waste in 2011 and producing compost in 2013. Regional waste management centres (RWMC) provided data on quantities of compost that was sold/used as organic fertilizers. As required these RWMC also provided data on dry matter (DM) content and compost composition that includes amount of N (kg/kg). Average DM content in compost in 2020 was 64% and average content of N in DM – 0.008 kg/kg.

To calculate amount of N that was deposited on soil using compost as organic fertilizer the following equation was used:

$$F_{COMP} = (S_{COMP} \cdot \frac{DM}{100}) \cdot C_N$$

where:

F_{COMP} - annual amount of total compost N that is applied to soils, kg N yr^{-1};

S_{COMP} - annual amount of compost applied to soils, kg yr^{-1};

DM - dry matter content in compost, %;

C_N - nitrogen content in compost, kg/kg.

Unfortunately until the GWCS were started operating no data on compost use in Lithuania was available. As the amount of compost used is negligible, N_2O emissions for the period 1990-2010 are reported as NO. No data on amount of compost used in private farms is available.

Urine and dung from grazing animals (F_{PRP}) (CRF 3.D.1.3)

Annual amount of N deposited on pasture, range and paddock soils by grazing animals (F_{PRP}) was estimated using parameters estimated in the category Manure management (Chapter 5.4.1.2). The main data used was: annual average livestock population by category, fraction of total annual N excretion of each livestock category that was deposited on pasture, range and paddock soils, and annual average N excretion per head of livestock category. To estimate N deposited on pasture, range and paddock soils the following equation was used:

$$F_{PRP} = \sum_{T} \left[\left(N_{(T)} \cdot Nex_{(T)} \right) \cdot MS_{(T,PRP)} \right]$$

where:

F_{PRP} - annual amount of urine and dung N deposited on pasture, range, paddock and by grazing animals, kg N yr^{-1};

$N_{(T)}$ - number of head of livestock species/category *T* in the country;

$Nex_{(T)}$ - annual average N excretion per head of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1};

$MS_{(T,PRP)}$ - fraction of total annual N excretion for each livestock species/category *T* that is deposited on pasture, range and paddock.

Crop residues (F_{CR}) (CRF 3.D.1.4)

N_2O emissions from crop residues are estimated using *2006 IPCC Guidelines* Tier 1 approach 11.6 equation[98]:

$$F_{CR} = \sum_{T} \left\{ Crop_{(T)} \cdot Frac_{Renew(T)} \cdot \left[\left(Area_{(T)} - Area\ burnt_{(T)} C_f \right) \cdot R_{AG(T)} \cdot N_{AG(T)} \cdot \left(1 - Frac_{Remove(T)} \right) + Area_{(T)} \cdot R_{BG(T)} \cdot N_{BG(T)} \right] \right\}$$

where:

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;

$R_{AG(T)}$ - ratio of above-ground residues dry matter ($AG_{DM(T)}$) to harvested yield for crop *T* ($Crop_{(T)}$), kg d.m. $(kg\ d.m.)^{-1}$;

[98] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, Eq. 11.6, p. 11.14

$N_{AG(T)}$ - 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.)$^{-1}$;

$N_{BG(T)}$ - N content of below-ground residues for crop *T*, kg N (kg d.m.)$^{-1}$;

T - crop or forage type.

As it is suggested in the Study[99] plants were divided into 5 categories: non-N-fixing grain crops, N fixing grains and pulses, root/tuber crops, N fixing forage crops, other industrial and forage crops (including annual and perennial pastures and meadows). Detail list of accounted plants is provided in the table below.

Table 5-44.The list of plants that is accounted under the crop residues category

Non-N-fixing grain crops	
Winter wheat	Winter rape
Spring wheat	Spring rape
Triticale	Flax
Rye	Buckwheat
Barley	Mixed cereals
Oats	Other cereal
Grain maize	
N fixing grains and pulses	
Peas	Lupines
Beans	Vetches
Soya beans	Mixed died pulses
Root/tuber crops	
Potatoes	Fodder beet
Sugar beet	Field vegetable
N fixing forage crops	
Alfalfa	Silage crops
Clover and their mixture	
Other industrial and forage crops including annual and perennial pastures and meadows	
Maize for silage	Perennial pastures
Annual grasses	Meadows and natural pastures
Perennial grasses (excl. alfalfa, clover and their mixture)	

Activity data on crop production (crop harvest and area harvested) were taken from Statistics Lithuania database.

Lithuanian Statistics provides data on harvest of total perennial grasses from 1993-2002. However, from 2003 Statistics disaggregate total perennial grasses into: 1. Alfalfa; 2. Clover and their mixture; 3. Perennial grasses (excl. alfalfa, clover and their mixture) categories. In order to avoid double counting, data on total perennial grasses (excl. alfalfa, clover and their mixture) for 2003-2020 period was excluded from the estimation.

[99] Azoto suboksido (N_2O) apskaitos iš žemės ūkio kultūrų pasėlių likučių subkategorijos nacionalinės metodikos parengimas. Ataskaita. (en. Study of estimations of nitrous oxide (N_2O) from the crop residues category). 2020. p. 38.

All parameters used for estimation of N_2O emission from crop residue such as dry matter, N content in above-ground and below-ground residues, $Frac_{RENEW}$ and etc. were taken from the national Study[100]. The summary of the Study is provided in the NIR Annex IX.

The fraction of above-ground residues of annually removed crop ($Frac_{REMOVE}$) for bedding was taken into account. Proportion of straw used as bedding material were subtracted here to avoid N_2O emissions double counting, as the N from straw in bedding material was taken into account in the category of 3.D.1.2.a Animal manure applied to soils. The value of $Frac_{REMOVE}$ was estimated for all reporting period from the N content of straw used for bedding divided by the sum of the N content of the above-ground residues of grain crops of which straw is used for bedding (wheat, barley, triticale, rye). For other crops the value of $Frac_{REMOVE}$ was assumed 0.

All activity data used for F_{CR} estimations are provided in the NIR Annex VIII, Table A.5 42 – Table A.5 -47.

The default emission factor of 0.01 kg N_2O-N/kg N multiplied by 44/28 was used for estimating the N_2O emissions from N inputs from crop residues.

In 2020 N_2O emissions from crop residue has increased by 27% compared to 2019. Total amount of N returned to soil and N_2O emission from crop residues are provided in table below.

Table 5-45. The amount of nitrogen returned to soil and N_2O emission from crop residue

Year	Total N returned to soil, kg N/yr	N_2O emission, kt CO_2 eq.
1990	57,269,032	268.18
1995	34,285,575	160.55
2000	37,697,162	176.53
2005	36,150,598	169.29
2010	40,919,525	191.62
2011	50,099,082	234.61
2012	62,878,197	294.45
2013	58,328,260	273.14
2014	69,806,581	326.89
2015	79,036,324	370.12
2016	75,267,815	352.47
2017	77,631,274	363.54
2018	58,750,594	275.12
2019	68,461,442	320.60
2020	86,782,236	406.39

Mineralization/Immobilization associated with loss/gain of soil organic matter (F_{SOM}) (CRF 3.D.1.5)

The amount of N mineralized from loss in soil organic C in mineral soils through land use change or management practices was estimated using the following equation[101] only for the period 1991 – 2001:

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,\ LU} \cdot \frac{1}{R} \right) \cdot 1000 \right]$$

[100] Azoto suboksido (N_2O) apskaitos iš žemės ūkio kultūrų pasėlių likučių subkategorijos nacionalinės metodikos parengimas. Ataskaita. (en. Study of estimations of nitrous oxide (N_2O) from the crop residues category). 2020. p. 37-52.

[101] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, eq. 11.8, p. 11.16

where:

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), tones C;

R - C:N ratio of the soil organic matter;

LU - land-use and/or management system type.

Average annual loss of soil carbon due to land use change or management systems was obtained from LULUCF sector Cropland remaining cropland subcategory. A default value of 10 for the C:N ratio (R) was taken from *2006 IPCC Guidelines*[102].

In order to improve inventory data quality, the consultations with specialists from the Ministry of Agriculture were held, therefore the data on carbon stock change were revised which resulted in updated information of organic cropland area and stock change factors, as a result no loss of organic C in mineral soil of cropland remaining cropland occurred for the 1990 and for the period 2002 – 2020, therefore N_2O emission from Mineralization/Immobilization associated with loss/gain of soil organic matter (FSOM) category was reported as NO. For more information please see LULUCF sector Chapter 6.3.2.1 Cropland remaining cropland Mineral soil and 6.3.4 Category-specific QA/QC and verification.

Cultivation of organic soils (F_{OS}) (CRF 3.D.1.6)

To estimate N_2O emission from cultivation of organic soils the data on organic soils area of Cropland and Grassland were taken from LULUCF sector. The definitions of Cropland and Grassland are provided in the NIR Chapters 6.3 and 6.4. The activity data on organic soils of Cropland and Grassland area is provided in the table below. This area is than multiplied by emission factor for each land use category: Cropland and Grassland – $EF_{2\ CG,Temp,Org}$ (8 kg N_2O-N/ha). Emission factor were obtained from *2006 IPCC Guidelines*[103].

Table 5-46. Area of Cropland and Grassland organic soils, ha

Year	Cropland area	Grassland area
1990	82,810	59,402
1995	71,849	67,749
2000	58,930	69,861
2005	46,833	71,147
2010	57,428	68,424
2011	57,442	67,105
2012	57,257	68,138
2013	57131	67,397
2014	58,602	67,661
2015	58,787	67,411
2016	58,549	67,473
2017	59,696	68,048
2018	59,713	70,156
2019	59,261	71,291
2020	59,564	72,625

[102] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, p. 11.16
[103] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, Table 11.1, p. 11.11

During the whole period Cropland organic soils area has decreased by 28%, while Grassland organic soils area has increased by 22%.

5.6.1.3 Uncertainty and time-series consistency

Activity data uncertainty

It is very difficult to estimate the actual uncertainty of activity data used to estimate direct N_2O emissions from managed soils. Most of uncertainty values were estimated based on expert assumptions. Uncertainty of activity data of sewage sludge N applied to soils was taken from Waste sector. Uncertainties of activity data of mineralization associated with loss of soil organic matter and cultivation of organic soils were taken from LULUCF sector. Activity data uncertainty values are provided in the table below for each sub-category of direct N_2O emissions from managed soils.

Table 5-47. Uncertainty values for each direct N_2O emissions from managed soils sub-category

Activity data	Uncertainty value
Consumption of Synthetic N fertilizers	±5%
Manure N applied to soils	±10%
Sewage sludge N applied to soils	±30%
Compost N applied to soils	±10%
N deposited on pasture, range and paddock by grazing animals	±15%
N returned to soil by crop residues, including N-fixing crops and forage/pasture renewal,	±36%
Mineralization associated with loss of soil organic matter	±9%
Cultivation of organic soils	±9%

Emission factor uncertainty

For the Tier 1 method there is a larger uncertainty range for the default factors. For Tier 1 method uncertainty of N_2O EF were estimated basing on EF uncertainty range: EF_1 – ±135%; $EF_{2\ CG,\ Temp}$ – ±137.5%; $EF_{2F,\ Temp,\ Org,\ R}$ – ±66.7%; $EF_{2F,\ Temp,\ Org,\ P}$ – ±140%; $EF_{3PRP,\ CPP}$ – ±132.5%; $EF_{3PRP,\ SO}$ – ±135%.

5.6.1.4 Category-specific QA/QC and verification

General quality control procedures where applied estimating direct N_2O emissions from managed soils: analysis of activity data trends, consistency check of calculated emissions and imported data to CRF reporter, consistency check of activity data sources, completeness check and etc. For 3.D.1 Direct N_2O emissions from agriculture soils category (inorganic N fertilizers, organic N fertilizer, urine and dung deposited by grazing animals, crop residue, mineralization/immobilization associated with loss/gain of soil organic matter and cultivation of organic histosols) calculation spreadsheets were assessed if used activity data, emissions factors and units are correct.

Comparison between activity data and other parameters used in estimation in 3.D.1. Direct N_2O emissions from managed soils (Animal manure applied to soils and Urine and dung deposited by grazing animals) and 3.B.2 N_2O and NMVOC emission from manure management categories were made to ensure data consistency. The same procedure was applied to the 3.D.1.5 Mineralization associated with gain/loss of soil organic matter and 3.D.1.6 Cultivation of organic soils categories to ensure activity data consistency with 4.B Cropland and 4.C Grassland categories.

In 2017 Statistics Lithuania started gathering data on inorganic N fertilizer consumption, therefore comparison of available data were made between IFA and Statistics Lithuania. Data comparison showed that difference between databases for 2016 on consumption of inorganic N fertilizer was 5%, for 2017 – 3%, for 2018 – 8% for 2019 – 7%. The difference between data occurs due to different methodologies used to estimate inorganic N fertilizer consumption. As it can be seen from the table below the comparison of activity data between databases shows that Statistics Lithuania provides lower amount of consumed inorganic N fertilizer.

Table 5-48. Comparison of inorganic N fertilizer consumption between databases of IFA vs. Lithuania Statistics, kt N/yr

Database	2016	2017	2018	2019	2020
IFA	169.5	172.0	174.1	199.0	-
Statistics Lithuania	160.2	167.1	159.4	178.6	185.8

It was decided to use inorganic N fertilizer consumption data provided by IFA database as it provides data on total consumption of inorganic N fertilizer for the whole accounting period, as well as data on different types of consumption of inorganic N fertilizer which are also used in the GHG emissions estimations. As the activity data from Statistics Lithuania diverge significantly from the IFA database in order to avoid emissions underestimation it was decided to use preliminary data of fertilizer consumption for 2020, which was obtained from company that provides fertilizer consumption data for IFA database. To ensure data consistency for the whole reporting period, after data on consumption of inorganic N fertilizer will become available at IFA, the emissions for 2020 will be recalculated.

Every year European Commission organizes a technical review of EU Member States' GHG inventories to ensure that the European Commission has accurate, reliable and verified data and information on annual GHG emissions to determine compliance with the EU Effort sharing decision and to strengthen Member States' capacity in managing GHG inventories. Number of valuable findings from EU experts are being received every year, which helps to improve GHG inventory report quality.

5.6.1.5 Category-specific recalculation

The following recalculation of direct N_2O emissions from agriculture soils were made:

1. IFA has provided data on inorganic N fertilizers consumption for 2019 only in October of 2021, therefore emissions from the category 3.D.1.1 Inorganic N fertilizer for 2019 was recalculated;
2. Recalculations for 3.D.1.2.a Animal manure applied to soils were made due to recalculations made in CRF 3.B.2 Manure management category and the emissions from anaerobic digester system of swine category was included, also typing error for non-dairy cattle and swine categories were corrected;
3. 3.D.1.6 Cultivation of organic soils were made due to recalculations made in the LULUCF sector for the whole period.

Table 5-49. Reported in previous submission and recalculated Direct N_2O emissions from agriculture soils, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
1990	2,521.54	2,575.16	53.62	2.13
1991	2,641.24	2,688.10	46.86	1.77
1992	1,690.59	1,726.86	36.27	2.15
1993	1,389.78	1,416.76	26.97	1.94
1994	1,297.94	1,322.83	24.89	1.92
1995	1,256.95	1,281.02	24.07	1.91
1996	1,449.93	1,471.91	21.98	1.52
1997	1,475.53	1,495.90	20.37	1.38

1998	1,462.71	1,481.82	19.11	1.31
1999	1,419.18	1,435.48	16.30	1.15
2000	1,423.99	1,437.53	13.54	0.95
2001	1,398.22	1,411.17	12.95	0.93
2002	1,458.92	1,472.15	13.23	0.91
2003	1,458.92	1,472.15	13.23	0.91
2004	1,476.97	1,490.69	13.73	0.93
2005	1,490.61	1,504.00	13.39	0.90
2006	1,458.30	1,470.92	12.62	0.87
2007	1,571.63	1,582.91	11.28	0.72
2008	1,549.34	1,559.10	9.76	0.63
2009	1,646.48	1,655.65	9.17	0.56
2010	1,648.45	1,656.92	8.47	0.51
2011	1,700.83	1,708.05	7.22	0.42
2012	1,777.92	1,782.37	4.45	0.25
2013	1,773.47	1,778.61	5.14	0.29
2014	1,879.96	1,888.35	8.40	0.45
2015	1,946.80	1,956.50	9.70	0.50
2016	1,923.45	1939.52	16.07	0.84
2017	1,945.33	1,963.05	17.72	0.91
2018	1,863.58	1,882.23	18.65	1.00
2019	1,913.10	1,927.80	14.70	0.77

5.6.1.6 Category-specific planned improvements

Category-specific improvement are not planned.

5.6.2 Indirect N_2O emissions from managed soils (CRF 3.D.2)

5.6.2.1 Category description

In order to estimate indirect N_2O emissions from managed soils the following sources where included: application of synthetic N and organic N fertilizers, urine and dung N deposited from grazing animals, N in crop residues and N mineralization associated with gain/loss of soil organic matter resulting from change of land use or management on mineral soils. N_2O emissions occurs from the volatilization of N as NH_3 and oxides of N (NOx), and the deposition of these gases and their products NH_4^+ and NO_3^- onto soils and the surface of lakes and other waters, and leaching and runoff from land of N from different N input sources mentioned above.

5.6.2.2 Methodological issues

Both volatilization and leaching and run-off N_2O emissions were estimated using Tier 1 method. Default emission factors and fraction values from *2006 IPCC Guidelines* were used (Table 5-50).

Table 5-50. Default EF and fraction values used to estimate indirect N_2O emissions from managed soils

Parameter	Value	Uncertainty range
EF_4 (N volatilization and re-deposition), kg N_2O–N (kg NH_3–N + NOx–N volatilized)$^{-1}$	0.010	0.002-0.05
EF_5 (leaching / runoff), kg N_2O–N (kg N leaching/runoff)$^{-1}$	0.0075	0.0005-0.025
$Frac_{GASM}$ (Volatilization from all organic N fertilizers applied , and dung and urine deposited by grazing animals), (kg NH_3–N + NOx–N) (kg N applied or deposited)$^{-1}$	0.20	0.05-0.5
$Frac_{LEACH-(H)}$ (N losses by leaching/runoff for regions where Σ(rain in rainy season) - Σ(PE in same period) > soil water holding capacity, OR where irrigation (except drip irrigation) is employed), kg N (kg N additions or deposition by grazing animals)$^{-1}$	0.30	0.1-0.8

Atmospheric deposition of N volatilized from managed soils (CRF 3.D.2.1)

N_2O emissions from atmospheric deposition of N volatilized from managed soil were estimated using the following equation[104]:

$$N_2O_{(ATD)} - N = \left[(F_{SN} \cdot Frac_{GASF}) + \left((F_{ON} + F_{PRP}) \cdot Frac_{GASM}\right)\right] \cdot EF_4$$

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 inorganic fertilizer N applied to soils, kg N yr^{-1};

$Frac_{GASF}$ - fraction of inorganic fertilizer N that volatilizes as NH_3 and NOx, kg N volatilized (kg of N applied)$^{-1}$ (Table 5-50);

F_{ON} - annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr^{-1};

F_{PRP} - annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1};

$Frac_{GASM}$ - fraction of applied organic N fertilizer materials (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilizes as NH_3 and NOx, kg N volatilized (kg of N applied or deposited)$^{-1}$ (Table 5-50);

EF_4 - emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, (kg N–N_2O (kg NH_3–N + NOx–N volatilized)$^{-1}$) (Table 5-50).

Fraction $Frac_{GASF}$ defines fraction of N that volatilised from inorganic N fertilizers. The value of $Frac_{GASF}$ depends on the inorganic fertilizer mixture used during the relevant year. To evaluate amount of NH_3 and NO that volatiles from inorganic N fertilizer emission factors were obtained from 2019 EMEP/EEA methodology (emissions factors are provided in the Tables 3.1 and 3.2)[105]. The emission factor of 0.04 kg NO/kg N for NO that volatiles from inorganic N fertilizers were used. The emission factors used to evaluate amount of NH_3 that volatiles from inorganic fertilizers is shown in table below.

Table 5-51. EFs for NH_3 emission from different fertilizers types[106]

Inorganic fertilizer by types	**Volatilised as NH_3, kg NH_3/kg N applied**
Ammonium sulphate	0.09
Urea	0.155
Ammonium nitrate	0.015
Calc. amm. nitrate	0.008
Nitrogen solutions	0.098
Ammonium phosphate (N)	0.05
Other NP (N)	0.05
N P K compound (N)	0.05

IFA provides data on inorganic N fertilizers by type only from 2008, therefore CS $Frac_{GASF}$ were estimated from 2008. Average $Frac_{GASF}$ value of the 2008-2014 period was used to estimate

104 *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, eq. 11.9, p. 11.21
105 EMEP/EEA air pollutant emission inventory guidebook 2019. 3.D Crop production and agriculture soils, Table 3.1, p. 12.
106 EMEP/EEA air pollutant emission inventory guidebook 2019. 3.D Crop production and agriculture soils, Table 3.2, p. 15.

emissions for the 1990-2007 period. The amount of nitrogen in inorganic N fertilizers and estimated $Frac_{GASF}$ values are shown in the table below. However, $Frac_{GASF}$ were estimated after all estimations was done due to completion of CRF 3.D Agriculture Soils category Additional Information Table Fraction of synthetic fertilizer N applied to soils that volatilises as NH_3 and NO_X.

Table 5-52. Amount of N in different types of inorganic fertilizers (tonnes) and $Frac_{GASF}$

Year	Ammonium sulphate	Urea	Ammonium nitrate	Calc.amm. nitrate	Nitrogen solutions	Ammonium phosphate	Other NP	N P K	$Frac_{GASF}$
1990-2007	IE	IE	IE	IE	IE	IE	IE	IE	0.056
2008	12,500	12,300	50,500	7,900	15,000	14,100	3,000	3,000	0.056
2009	16,800	23,000	54,500	4,900	5,400	3,900	9,700	16,200	0.061
2010	10,000	10,000	60,000	5,000	20,200	5,000	10,000	23,000	0.054
2011	9,000	9,000	62,000	5,000	20,000	10,000	10,000	22,000	0.053
2012	10,000	9,000	63,000	3,000	20,000	5,000	15,000	25,000	0.053
2013	8,000	10,000	61,000	5,000	20,000	5,000	15,000	31,000	0.053
2014	12,600	26,000	56,900	6,000	16,800	4,000	18,200	22,700	0.062
2015	35,800	11,400	56,100	5,800	30,900	3,400	5,400	19,000	0.063
2016	35,000	11,700	58,400	6,600	31,500	2,900	5,300	18,100	0.062
2017	45,100	8,900	51,300	6,200	33,500	3,100	3,100	20,800	0.064
2018	37,700	10,100	55,400	7,200	35,500	3,600	2,500	22,100	0.063
2019	35,000	10,000	56,000	7,000	38,000	3,000	2,000	25,000	0.063
2020	35,382	10,109	56,611	7,076	38,415	3,033	2,022	25,273	0.057

N leaching and run-off from managed soils (CRF 3.D.2.2)

N_2O emissions from N leaching and run-off from managed soil were estimated using the following equation[107]:

$$N_2O_{(L)} - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \cdot Frac_{LEAC-(H)} \cdot EF_5$$

where:

$N_2O_{(L)}–N$ - annual amount of N_2O–N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kg N_2O–N yr^{-1};

F_{SN} - annual amount of synthetic fertilizer N applied to soils, kg N yr^{-1};

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};

F_{CR} - amount of N in crop residues, including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs, kg N yr^{-1};

[107] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, eq. 11.10, p. 11.21

F_{SOM} - annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching/runoff occurs, kg N yr^{-1};

$Frac_{LEACH-(H)}$ - fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N $addition)^{-1}$ (Table 5-54);

EF_5 - emission factor for N_2O emissions from N leaching and runoff, kg N–N_2O (kg N leached and $runoff)^{-1}$ (Table 5-54).

According to country scientific literature average annual amount of precipitation in Lithuania in 1981-2010 was 695 mm (CN was 675 mm)[108], this lets imply that country belongs to humid region, therefore the default $Frac_{LEACH-H}$ 0.30 kg N was used.

5.6.2.3 Uncertainty and time-series consistency

Activity data uncertainty

Same data used in category direct N_2O emission are applied in category indirect N_2O emission from managed soils. Uncertainty for activity data of category Atmospheric deposition – ±37%; Nitrogen Leaching and Run-off – ±52%.

Emission factor uncertainty

For the Tier 1 method there is a larger uncertainty range for the default factors. For Tier 1 method uncertainty values of indirect N_2O EF were estimated basing on EF uncertainty range: EF_4 – ±240%; EF_5 – ±163%.

5.6.2.4 Category-specific QA/QC and verification

General quality control procedures where applied estimating indirect N_2O emissions from managed soils: analysis of activity data trends, consistency check of calculated emissions and imported data to CRF reporter, consistency check of activity data sources, completeness check and etc. For 3.D.2 Indirect N_2O emissions from agriculture soils category (atmospheric deposition from N that volatilized from managed soils and N leaching and run-off from managed soils) calculation spreadsheets were assessed if used activity data, emissions factors and units are correct.

5.6.2.5 Category-specific recalculation

The following recalculation of indirect N2O emissions from agriculture soils were made:

Recalculations in the 3.D.2.1 Atmospheric deposition and 3.D.2.2 Nitrogen Leaching and run-off categories related to the activity data update are described in the Chapter 5.6.2.5 Category-specific recalculation as the same activity data are used for the 3.D.1 Direct N_2O emissions from managed soils category estimations.

[108] Lithuanian Hydro meteorological Service under the Ministry of Environment, Climate Atlaso f Lithuania, 2013, ISBN 978-9955-9758-5-4

Additional recalculation was made for the 3.D.2.1 Atmospheric deposition in order to update $Frac_{GASF}$. According to the air pollutant inventory NO_x is reported as NO_2; therefore, the NO_2 emissions were multiplied by 14/46 to get the NO_X-N losses.

Table 5-53. Reported in previous submission and recalculated total indirect N_2O emissions from managed soils, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference, %
1990	571.81	586.79	14.98	2.62
1991	606.41	617.43	11.02	1.82
1992	337.60	348.95	11.35	3.36
1993	247.81	256.59	8.78	3.54
1994	224.05	231.94	7.90	3.53
1995	212.26	219.90	7.64	3.60
1996	266.84	272.42	5.57	2.09
1997	275.20	280.03	4.83	1.75
1998	273.62	277.85	4.23	1.55
1999	265.79	268.50	2.71	1.02
2000	268.68	270.10	1.42	0.53
2001	265.77	266.82	1.05	0.40
2002	286.59	287.34	0.75	0.26
2003	291.72	292.18	0.46	0.16
2004	297.48	298.43	0.95	0.32
2005	302.79	303.44	0.65	0.21
2006	295.45	295.87	0.42	0.14
2007	319.70	319.58	-0.13	-0.04
2008	309.62	309.16	-0.46	-0.15
2009	337.53	336.34	-1.19	-0.35
2010	336.39	334.75	-1.65	-0.49
2011	349.40	346.88	-2.52	-0.72
2012	366.89	363.63	-3.26	-0.89
2013	368.32	365.11	-3.20	-0.87
2014	400.98	398.82	-2.16	-0.54
2015	418.63	416.64	-1.99	-0.48
2016	412.35	413.12	0.77	0.19
2017	418.03	419.42	1.38	0.33
2018	395.77	397.46	1.69	0.43
2019	405.52	405.93	0.41	0.10

5.6.2.6 Category-specific planned improvements

Category-specific improvements are not planned.

5.7 Prescribed burning of savannas (CRF 3.E)

Savannas do not exist in Lithuania therefore emission from prescribed burning of savannas is reported as "NO".

5.8 Field burning of agricultural residues (CRF 3.F)

Field burning of agricultural residues is prohibited by the legislation (Order of the Minister of Environment No 269 concerning the environmental protection requirements for burning of dry grass, reeds, straw and garden waste as amended, In force from September 9, 1999)[109], therefore emission from field burning of agricultural residues is reported as "NO".

5.9 CO_2 emissions from liming (CRF 3.G)

5.9.1 Category description

Starting with 30s in Lithuania, like in most of the Europe, intensive analysis on liming standards and soils had started. Technique on liming dust spreading in Lithuania was established in 70s based on scientific research and systematic analysis of soil liming. Following this in 80s every year around 200 thousand ha of acid soils were limed. However in the first years of independence (early 90s) liming was almost suspended due to lack of energetic resources. Later liming was restricted due to lack of financial resources. In mid 90s only 1/10 of acid soils were limed[110].

There are a lot of studies and scientific research conducted analysing efficiency of different liming products, impact on soil pH, fertility and other parameters. Unfortunately there are no official data sources that collect data on limestone or dolomite consumption in Lithuania. For this reason data was collected from the major companies that sell liming products. These products include special fertilizers for soil liming, by-products of production or waste products that are generated during production process. Major providers of liming products are companies that operate quarries and extracts constructions material (crashed stones, granite, limestone etc.). Other providers of liming products are sugar producers. During production of sugar the lime mud is generated as waste which later is used as a liming product for acid soils.

The data provided by the companies varied in time period as it depends on the year when companies began to produce products for soil liming. The actual data for soil liming products used is available for the period 1993-2020 (data provided by the companies). However the period 1990-1992 is not fulfilled with data that's why assumptions were made based on the literature and expert judgement.

As mentioned above after the independence liming drastically reduced due to lack of financial and technical resources. Before the 90s liming had exceeded 200 thous. ha per year and was aiming to reach 270 – 300 thous. ha per year. The standard rate was also growing and reached 4.5 t/ha (straight $CaCO_3$) during 70s and early 80s[111]. The extant of area limed in early 90s was estimated to be around 10.4 thous. ha. Based on this information and standard rate of 4.5 t/ha estimates for the period 1990-1992 were calculated in order to fulfil the data gap.

The figure below shows trend of CO_2 emission from liming of agricultural soils. As emission depend on the quantity of liming products consumed it has a direct link to data availability. Data provided by the companies varies through the time period and is strongly related to the economic factors e.g. economic crisis, demand of construction material, production of sugar etc. One of the companies which provides data of sold liming products has changed production technology and no cement dust has been produced in 2015, which had an impact on emission decrease. According to scientific literature more than half agriculture soils are acidic[112], therefore high

[109] LR aplinkos ministro 1999 m. rugsėjo 1 d. įsakymas Nr. 269 „Dėl Aplinkos apsaugos reikalavimų deginant sausą žolę, nendres, šiaudus bei laukininkystės ir daržininkystės atliekas patvirtinimo"/ Valstybės Žinios, 1999, Nr. 75-2284,aktuali akto redakcija, galiojanti nuo 2010 07 04

[110] Ežerinskas, V. Kalkinės medžiagos ir kalkinimas (en. *Liming products and liming*). Lietuvos žemdirbystės institutas, 1999. ISBN 9986-527-60-0

[111] Knašys, V. Dirvožemių kalkinimas (en. *Soil liming*). Mokslas, 1985

[112] Repšienė, R., Karčauskienė, D., Ambrazaitienė D. 2014. *The use of lime materials enriched with humus in acidic soil*. Scientific article. Klaipėda. Available from: http://www.zak.lt/mokslo_darbai/2014_157_164.pdf

amounts of liming materials were consumed in the period of 2011-2014, in the latest year the consumption of liming materials has slowed down.

One of the companies which provides data of sold crushed limestone and limestone products went bankrupt, therefore CO_2 emissions in 2020 has decreased significantly by 43% compared to 2019.

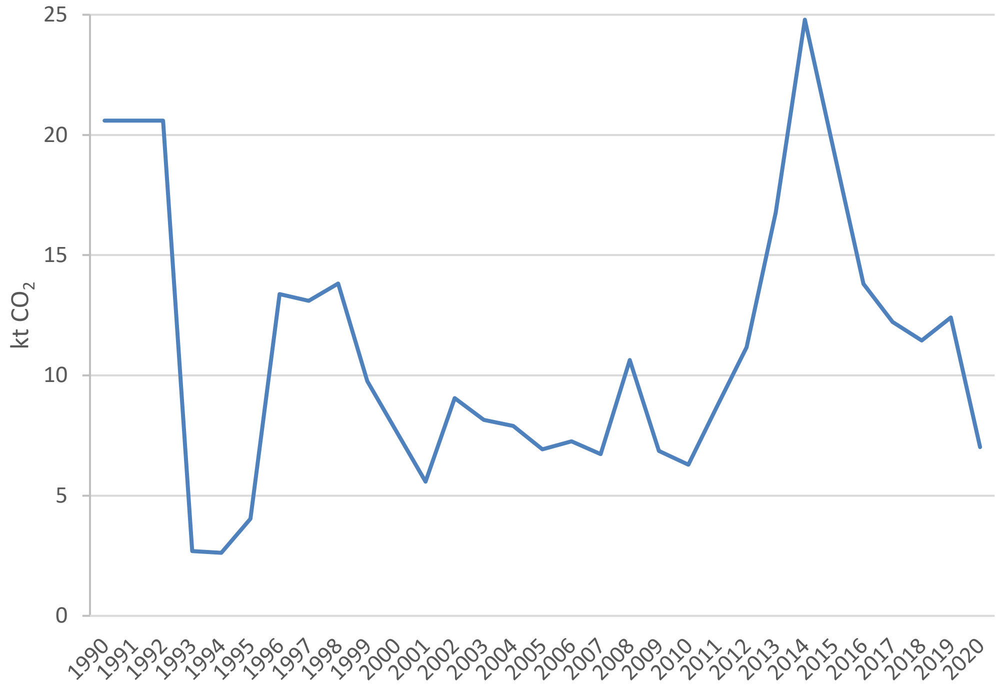


Figure 5-12. CO_2 emissions from application of liming products in agricultural lands

5.9.2 Methodological issues

Estimating CO_2 emission from agricultural soils liming was very important to know the actual percentage of $CaCO_3$ + $MgCO_3$ in product used for liming. Other important parameter is the dry matter of product as some products (e.g. lime mud) contains high percentage of humidity.

Depending on data availability and analysis done companies provided data on main parameters which were used in calculations. The following equation was used to estimate the annual amount of limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$):

$$M_{Limestone\ or\ dolomite} = M_{Product} \cdot \frac{C}{100} \cdot \frac{DM}{100}$$

where:

$M_{Limestone\ or\ dolomite}$	- amount of limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), tonnes d.m. yr^{-1};
$M_{Product}$	- amount of product used for soil liming, tonnes yr^{-1};
C	- amount of $CaCO_3$ + $MgCO_3$ in the product, %;
DM	- dry matter of product used for soil liming, %.

The main parameters of liming products that were used to estimate CO_2 emission for soil liming are provided in the table below.

Table 5-54. Parameters used for estimation of CO_2 emission from liming

Parameter	Dolomite	Cement dust	Limestone	Crushed limestone	Lime mud
	%				
$CaCO_3 + MgCO_3$	88.6 – 100	76.2 – 82.4	94 – 97	94.5 – 97	51.5 – 83.9
Average	94	79.3	95.5	95.8	67.7
Dry matter	86 – 96.3	98.5 – 100	99.6 – 99.8	87 – 88	40 – 68
Average	91.2	99.3	99.7	87.5	54

CO_2 emissions from additions of limestone or dolomite to agriculture soils are calculated using equation[113]:

$$CO_2 - C\ Emissions = (M_{Limestone} \cdot EF_{Limestone}) + (M_{Dolomite} \cdot EF_{Dolomite})$$

To convert CO_2-C emissions to CO_2 emissions the amount was multiplied by 44/12.

5.9.3 Uncertainty and time-series consistency

Activity data uncertainty

The main activity data used for calculations was lime and dolomite consumption for agricultural land liming. All data was collected from the main distributors of liming products with data indicated dry matter content and $CaCO_3$ + $MgCO_3$ content in the product based on laboratorial measurements. Knowing that not necessary all amount of sold liming products were used at the year they were sold and also knowing that there could be some other products in the market assumption was made that uncertainty of activity data is ±10%.

Emission factor uncertainty

Uncertainty of EF is ±50% as given in *2006 IPCC Guidelines*[114].

Overall uncertainty

Combined uncertainty was calculated using *2006 IPCC Guidelines* Equation 3.1[115]. This approach requires uncertainty values of the main activity data used and uncertainty of emission factor. Combined uncertainty for CO_2 emissions from liming was estimated to be ±51%.

5.9.4 Category-specific QA/QC and verification

General quality control procedures where applied estimating CO_2 emissions from liming of soils: analysis of activity data trends, consistency check of calculated emissions and imported data to CRF reporter, consistency check of activity data sources, completeness check and etc.

5.9.5 Category-specific recalculations

No recalculation have been done.

5.9.6 Category-specific planned improvements

Category-specific improvements are not planned.

[113] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, eq. 11.12 p. 11.27
[114] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, p. 11.27
[115] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 3, eq. 3.1, p. 3.28

5.10 CO_2 emissions from urea application (CRF 3.H)

5.10.1 Category description

Emissions from urea application in agricultural soils constituted 15.9 kt CO_2 eq. Comparing with 2019 emissions from urea application has increased by 1% in 2020.

5.10.2 Methodological issues

Inorganic N fertilizer data was obtained from database of IFA. This database gives consumption of inorganic N fertilizers for the whole time period (1990-2019) and consumption of inorganic N fertilizers by type since 2008 including data on consumption of urea. At the time of inventory preparation data on urea consumption for the year 2020 was not available, therefore to obtain missing activity data the percentage of urea consumption from total inorganic N fertilizers consumption in 2019 was used. Data for 2020 will be updated in the next submission as this data at IFA database will be available only in the October of 2022. Data on consumption of urea during the period 2005-2007 was taken from the study on fertilizers[116]. The gap of data for the period 1990-2004 was filled by taking average percentage of urea in total amount of inorganic N fertilizers in the 2005-2013 period. This percentage on average was 10.68%.

CO_2 emission from urea fertilization were estimated using the following equation[117]:

$$CO_2 - C\ Emission = M \cdot EF$$

where:

CO_2–C Emission - annual C emission from urea application, tonnes C yr^{-1};

M - annual amount of urea fertilization, tonnes urea yr^{-1};

EF - emission factor, tonnes of C (tonnes of urea)$^{-1}$.

Emission factor of 0.20 for urea was applied[118]. Estimated CO_2–C emission multiplied by 44/12 to convert CO_2–C emission into CO_2.

5.10.3 Uncertainty and time-series consistency

Activity data uncertainty

Main activity data is consumption of urea fertilizer. As most of the data was obtained based on assumptions the uncertainty value for activity data was assumed to be around ±10%.

Emission factor uncertainty

Uncertainty of EF is ±50% as given in *2006 IPCC Guidelines*[119].

Overall uncertainty

[116] Taikomojo mokslinio tyrimo „Lietuvos ūkyje naudojamų trąšų analizė ir pasiūlymai dėl nacionalinio reglamentavimo pakeitimų, atsižvelgiant į agrochemijos, saugumo ir sveikatos reikalavimus“ ataskaita (en. *Analysis on fertilizers used in Lithuanian and recommendations in pursuance of changes in national legislation, taking in to account agrochemical, safety and health requirements*). Lietuvos agrarinių ir miškų mokslo centro agrocheminių tyrimų laboratorija, Kaunas, 2010

[117] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, eq. 11.13 p. 11.32

[118] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, p. 11.32

[119] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Ch. 11, p. 11.32

Combined uncertainty was calculated using *2006 IPCC Guidelines* 3.1[120]. This approach requires uncertainty values of the main activity data used and uncertainty of emission factor. Combined uncertainty for CO_2 emissions from urea application was estimated to be ±58.3%.

5.10.4 Category-specific QA/QC and verification

General quality control procedures where applied estimating CO_2 emissions from urea application to soils: analysis of activity data trends, consistency check of calculated emissions and imported data to CRF reporter, consistency check of activity data sources, completeness check and etc.

5.10.5 Category-specific recalculations

IFA provided data on urea consumption for 2019 only in October of 2021, therefore data for 2019 was recalculated. Recalculation results are provided in the table below.

Table 5-55. Reported in previous submission and recalculated CO_2 emissions from urea application, kt

Year	2021 submission	2022 submission	Absolute difference, kt	Relative difference, %
2019	16.19	15.77	-0.42	-2.61

5.10.6 Category-specific planned improvements

Category-specific improvements are not planned.

5.11 Other Carbon-containing fertilizers (CRF 3.I)

Emissions from other Carbon-containing fertilizer in Lithuania are below the threshold of significance, therefore emission from other Carbon-containing fertilizers is reported as "NE".

[120] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 1, Ch. 3, eq. 3.1, p. 3.28

6 LAND USE, LAND-USE CHANGE AND FORESTRY (CRF 4)

6.1 Overview of LULUCF

One of greenhouse gases emissions and removals report goals is to provide observations for projecting climate change mitigation action plans. GHG report provide relevant land use distribution as well as carbon stock changes and GHG emissions data in different land use categories, providing also a possibility for land use management assessments. The most important in order to mitigate climate change is to preserve and protect areas that have high carbon sequestration capacity: forests, wetlands, peatlands and grasslands. Land Use, Land Use Change and Forestry (LULUCF) sector in Lithuania plays the important role in carbon sequestration processes as it has been constantly acting as a sink during two periods of time: 1990-1995 and 1998-2020 (Figure 6-1). Only in 1996-1997 LULUCF sector was a net GHG source due to severe storms followed by beetles' invasions and other calamities which had a huge impact in biomass loss which eventually resulted in CO_2 emissions. Storms and pests' invasions had the highest influence on forest land emissions, and since forests produce the biggest part of biomass, it resulted in overall GHG emissions from sector. However, LULUCF sector over the last 10 years in average has removed 8.04 million tonnes of CO_2 eq., with forest land contributing to the total amount with 8.2 million tonnes of CO_2 eq. removals annually. The LULUCF sink in the last few years was covering nearly 30% of the total national emissions from all other sectors, excluding LULUCF.

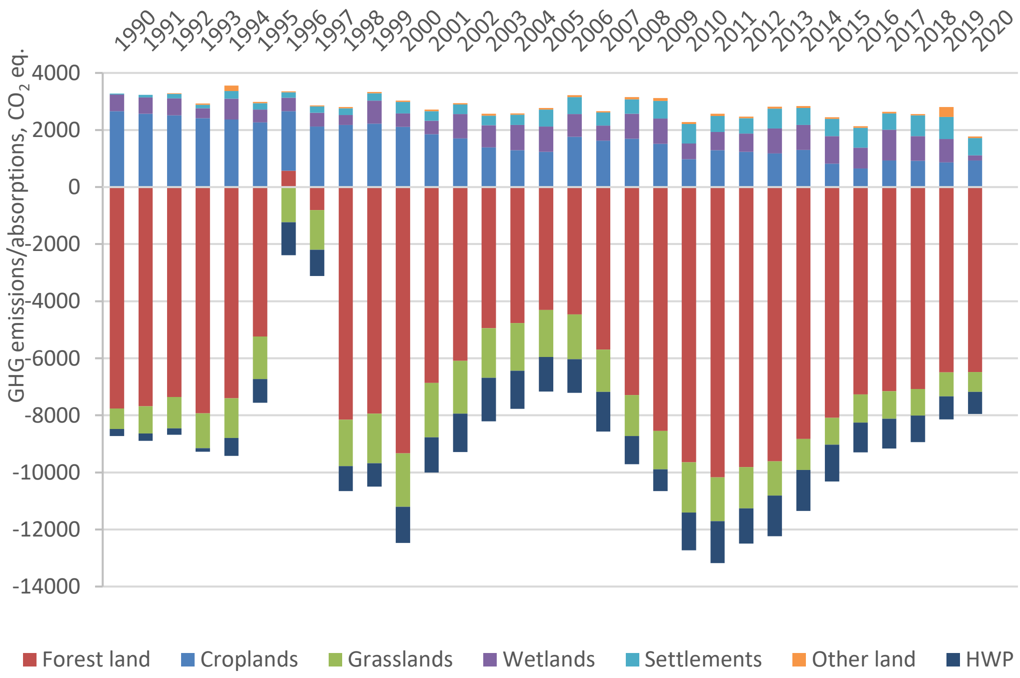


Figure 6-1. Net CO_2 eq. emissions and removals from LULUCF sector during the period 1990-2020 by land use category. The positive values show emissions and negative – removals

Lithuania has improved and made its reporting system of greenhouse gases from LULUCF sector more transparent, consistent over time, complete and comparable since 2011 when practically new accounting and reporting system has been built up and today has a clear subordination among data providers and executors. There are several organizations and data providers responsible for provision of the official data related to LULUCF reporting in Lithuania. These organizations and data providers are presented below:

- *National Land Service* (*NLS*) under the Ministry of Agriculture provides data on Lithuanian Land Fund – all private, state owned and belonging to municipalities land on Lithuanian territory. Data is distributed between relevant reporting land use categories.
- *Lithuanian State Forest Cadaster* (*LSFC*) managed by *State Forest Service* (*SFS*) provides up to date information associated with registered areas of forest land and detail information about all forest holdings regardless their ownership.
- *National Forest Inventory* (*NFI*) executed by SFS provides objective and known accuracy data associated with forest land, forest land use and forest resources (growing stock volume, annual increment, felling, dead wood and etc.). Information for this dataset is collected by using unique sampling technique already since 1998. Data presented by NFI is used for monitoring and reporting of land use and land use changes under the Convention requirements as a continuation of the implemented Studies that were conducted in order to gather missing historical information (see Chapter 6.1.1. for description). Dataset on all land use and land use changes is collected using NFI since 2012, NFI grid covering not only forest land but also other land use categories of the whole country territory since then.

Official statistics on relevant land use categories and their changes in Lithuania are provided by:

- *Statistics Lithuania* publishes all statistical information in their annual publications "Statistical Yearbook of Lithuania" and provides numerical statistical databases on their website.
- Statistical data about Lithuanian forests and forestry related issues is published in annual reports "Forest assessment", annual publications – "Lithuanian Statistical Yearbook of Forestry", periodical publications of NFI and National forest resources assessment (*FRA*) reports.
- *National Land Service* (*NLS*) publishes annual statistical information on all land use categories in Lithuania in publication "Land Fund of the Republic of Lithuania".

To ensure transparency, consistency, comparability, completeness and accuracy of the greenhouse gas accounting and reporting from LULUCF sector, several legal acts were adopted or amended in order to establish background connections between different institutions, providing data for greenhouse gas accounting:

- *Resolution on forest land conversion to other land and compensation for converted forest land*/Government resolution – regulates human induced conversion of forest land to other land and compensation for the lost forest land.
- *Regulation on National forest inventory by sampling method*/Amendment of the Order of the Minister of Environment – launches country wise sample based monitoring of all land use and land use changes.
- *Harmonized principles for data collection and reporting on LULUCF/Order of the Minister of Environment* – sets the main principles for data collection and reporting on LULUCF.
- *Rules for afforestation of non-forest land/Amendment of the Minister of Environment and Minister of Agriculture* – determines human induced afforestation/reforestation registration routines.
- *Inventory and registration of natural afforestation of non-forest land/Order of the Minister of Environment and Minister of Agriculture* – determines natural afforestation/reforestation inventory and assessment routines.

- *Regulation on State Forest Cadaster/Amendment of the Government resolution* – sets State Forest Cadaster as the main data provider for KP LULUCF.
- *Harmonized methodology for GHG emissions and removals accounting under LULUCF/Order of the Minister of Environment and Minister of Agriculture* – sets the main requirements for data collection and accounting of greenhouse gases emissions and removals under LULUCF.

These acts are constantly amended or substituted following the new requirements adopted by United Nations Framework Convention on Climate Change (UNFCCC) or EU legislation or introducing new improved methodologies for estimation of greenhouse gas emissions and removals from LULUCF sector.

Following the requirements of *2006 IPCC* Guidelines, provision of official statistics since 2012 has been improved substantially and associated land-use area changes were assessed, constantly monitored and revised, using unique net of permanent sample plots of NFI:

- For the period of 1990-2011 results are presented using data of the studies conducted;
- Since 2012 all data, concerning land use and land use changes, is based on direct annual field measurements executed by NFI.

Data sources that have been used until 2012 for determination of the total land area and for monitoring its changes were not harmonized between themselves and data presented was not always precise or did not fulfil the requirements of the UNFCCC. Most of the results were fragmented and did not fully covered the required period starting with the base year 1990. Due to different inventory methodologies and definitions of land use categories for each inventory, the presented results not only did not comply but in some cases even contradicted each other. Furthermore, land use definitions used by official statistics, on which basis land area was estimated, did not comply with the previously used *2003 IPCC* nor with current *2006 IPCC* guidelines (Table 6-5). For instance, meadows and natural pastures were assigned to croplands in national definition, though it comes under grassland category under IPCC definition. Therefore, implementing UNFCCC and its Kyoto Protocol requirements in order to comprehensively identify and quantify areas specific to LULUCF activities annually in the period of 1990-2011, two studies were launched. The study "*Forest land changes in Lithuania 1990-2011*" (*Study-1*) was addressed to recover land use changes specifically to forests and study "*Changes of areas of Croplands, Grasslands, Wetlands, Settlements and Other lands in Lithuania during 1990-2011*" (*Study-2*) was addressed to track changes of croplands, grasslands, wetlands, settlements and other lands. Thus, by implementing these studies Lithuania became able to identify land use areas and to monitor their changes for the whole time series starting with 1990. The main differences of these two studies comparing with the previous practice was recalculation of all area changes (and construction of yearly land transition matrix) using single data collection instrument – uniform network of *NFI* (launched in 1998) permanent sample plots and secondly – building all the computations and assumptions based on the data, directly collected from the individual plots. Therefore, one of the fundamental outcomes of these two studies was creation of a single and comprehensive database of land use areas in Lithuania (Figure 6-2).

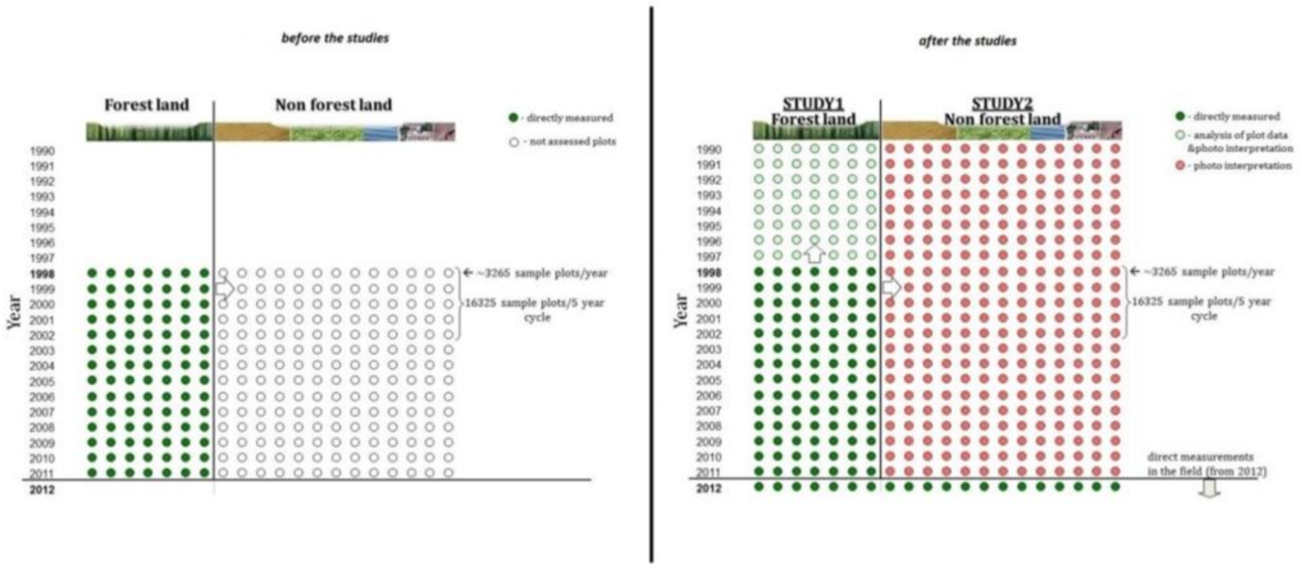


Figure 6-2. Data owned for the assessment of land-use changes before the studies were implemented (*NFI* data since 1998) and assessment of the land-use changes on *NFI* sample plots grid after the implementation of the studies for the period 1990-2011. Filled dots represent data that was owned before/after the studies

Furthermore, during the implementation of Study-1, wall-to-wall areas of afforestation, reforestation and deforestation activities, which are obliged to report under Kyoto Protocol Art. 3.3, were mapped, identified and classified. Transition matrix of yearly changes in A/R/D activities was concluded with the help of GIS techniques, historical datasets of *LSFC*, aerial photography archives, provided by *SLF,* and other available material of historical land use changes.

According to *NLS* data total land area of Lithuania is 6,528,648.3 ha, forest land occupy 33.0 %, croplands – 46.0 %, grasslands – 5.9 %, wetlands – 5.6 %, settlements and other land covers 5.3 % and 4.2 % respectively, for the date 01.01.2020. According to *NFI* data, forest land occupy 34.0 %, croplands – 30.8 %, grasslands – 23.6 %, wetlands – 5.5 %, settlements – 5.9 % and other land – 0.1 % of the total land area in Lithuania (Figure 6-3).

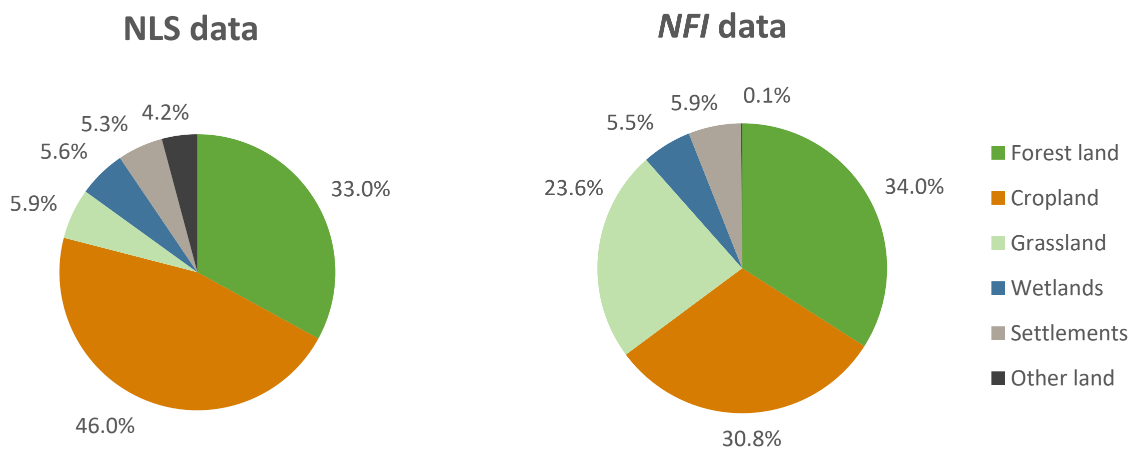


Figure 6-3. Comparison of land-use categories presented by *NLS* and latest *NFI* data. 01.01.2021

Differences between *NLS* and *NFI* data are caused by different definitions of land use categories. *NLS* uses National definitions while *NFI* data on land uses is based on those required by UNFCCC and described in *2006 IPCC Guidelines*. For the greenhouse gas reporting *NFI* data been distributed among relevant land use categories, considering total land area.

Several emission sources in the LULUCF sector are identified as key categories. They are listed in Table 6-1 (Level and Trend assessment).

Table 6-1. Key category from LULUCF in 2020

IPCC Category	***Greenhouse gas***	***Identification criteria***
4.A Forest land, Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO_2	L1, L2, T1, T2
4.A.1 Forest land remaining forest land - carbon stock change in biomass	CO_2	L1, L2, T1, T2
4.A.1 Forest land remaining forest land - net carbon stock change in dead wood	CO_2	L1, L2, T1
4.A.2 Land converted to forest land - carbon stock change in biomass	CO_2	L1, L2
4.A.2 Land converted to forest land - net carbon stock change in mineral soils	CO_2	L1, L2
4.B Cropland,Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO_2	L1, L2, T1, T2
4.B.1 Cropland remaining cropland - net carbon stock change in mineral soils	CO_2	L1, L2, T1, T2
4.B.2 Land converted to cropland - net carbon stock change in mineral soils	CO_2	L1, L2
4.B.2 Land converted to cropland- carbon stock change in biomass	CO_2	L1, L2, T1, T2
4.B.2 Land converted to cropland- net carbon stock change in dead organic matter	CO_2	L1, T1
4.C.2 Land converted to grassland - net carbon stock change in mineral soils	CO_2	L1, L2
4.C.2 Land converted to grassland - net carbon stock change in biomass	CO_2	T1, T2
4.D.1 Wetlands remaining wetlands -net carbon stock change in organic soils	CO_2	L1, L2, T1, T2
4.D.2 Land converted to wetlands	CO_2	L1, L2, T1, T2
4.E.2 Settlements	N_2O	T2
4.E.2 Land converted to settlements	CO_2	L1, T1, T2
4.G Harvested wood products	CO_2	L1, L2, T1, T2

Table 6-2. Methods and EF applied in LULUCF GHG reporting

GREENHOUSE GAS SOURCE AND SINK	**CO_2**		**CH_4**		**N_2O**	
CATEGORIES	**Method**	**EF**	**Method**	**EF**	**Method**	**EF**
4. Land use, land-use change and forestry	T1, T2	CS, D	T1, T2	D	T1, T2	CS, D
A. Forest land	T1, T2	CS, D	T1, T2	D	T1, T2	D
4.A.1 Forest Land Remaining Forest Land	T1, T2	CS, D	T1, T2	D	T1, T2	D
4.A.2 Land Converted to Forest Land	T1, T2	CS, D	T1, T2	D	T1, T2	D
B. Cropland	T1, T2	CS, D	T1	D	T1, T2	D
4.B.1 Cropland Remaining Cropland	T1, T2	CS, D	T1	D	T1, T2	D
4.B.2 Land Converted to Cropland	T1, T2	CS, D			T1, T2	D
C. Grassland	T1, T2	CS, D	T1	D	T1	D
4.C.1 Grassland Remaining Grassland	T1	D	T1	D	T1, T2	D
4.C.2 Land Converted to Grassland	T1, T2	CS, D			T1, T2	D
D. Wetlands	T1, T2	CS, D			T1	D
4.D.1.1 Peat Extraction Remaining Peat Extraction	T1	D	T1	D	T1	D
4.D.1.2 Flooded Land Remaining Flooded Land						
4.D.1.3 Other Wetlands Remaining Other Wetlands						

4.D.2 Land Converted to Wetlands	T1, T2	CS, D			T1	D
E. Settlements	T1, T2	CS, D			T1, T2	CS, D
4.E.1 Settlements Remaining Settlements						
4.E.2 Land Converted to Settlements	T1, T2	CS, D			T1, T2	CS, D
F. Other land	T2	CS			T1, T2	CS, D
4.F.1 Other Land Remaining Other Land						
4.F.2 Land Converted to Other Land	T1, T2	CS, D			T1, T2	CS, D
G. Harvested wood products	T1, T2	D				
H. Other						

6.1.1 National definitions of all categories used in the inventory

Even though requirements for greenhouse gas inventories methodology has changed, obliging parties to use *2006 IPCC Guidelines* instead of previously used *2003 IPCC Guidance*, but this had no impact on the definitions of land use categories that Lithuania has been constantly using since the beginning of the inventory nor to the area estimations. The land areas used in this inventory are consistent with those defined in *2006 IPCC Guidelines* as they are consistent with *2003 IPCC Guidance*. However, some of the national definitions of land-use areas are broader than those required by Good Practice Guidance so they were merged to fit *2006 IPCC Guidelines* (Table 6-3).

Forest land is defined according to the Law on Forests of the Republic of Lithuania. Forest – is a land area not less than 0.1 hectare in size covered with trees, the height of which in a natural site in the mature age is not less than 5 meters, other forest plants as well as thinned or vegetation-lost forest due to the acts of nature or human activities (cutting areas, burnt areas, clearings). Tree lines up to 10 meters of width in fields, at roadsides, water bodies, in living areas and cemeteries or planted at the railways protection zones as well as single trees and bushes, parks planted and grown by man in urban and rural areas are not defined as forests. The procedures for care, protection and use of these plantings shall be established by the Ministry of Environment. Forest stands with stocking level (approximately equivalent to crown cover) less than 30% are not acceptable for high productivity forestry. This threshold is used when including land areas into afforested land areas (table below).

Table 6-3. Selected parameters defining forest in Lithuania for reporting under LULUCF

Parameter	**Value**
Minimum land area	0.1 ha
Minimum crown cover	30%
Minimum height at mature age	5 m

*Cropland***.** The area of cropland comprises of the area under arable crops as well as orchards and berry plantations. According to national definitions - arable land is continuously managed or temporary unmanaged land, used and suitable to use for cultivation of agricultural crops, also fallows, inspects, plastic cover greenhouses, strawberry and raspberry plantations, areas for production of flowers and decorative plants. Arable land set aside to rest for one or several years (<5 years) before being cultivated again as part of an annual crop-pasture rotation is still included under cropland. Orchards and berry plantations are areas planted with fruit trees and fruit bushes (apple-trees, pear-trees, plum-trees, cherry-trees, currants, gooseberry, quince and others). Under this category only those orchards and berry plantations are included that are planted on other than household purpose land and mainly used for commercial purposes. Orchards and berry plantations planted in small size household areas and only used for householders' meanings are included under Settlements category. All croplands are managed land.

*Grassland***.** Grassland includes meadows and natural pastures planted with perennial grasses or naturally developed, on a regular basis used for moving and grazing. Grasslands cultivated for less than 5 years, in order to increase ground vegetation, still remain grasslands. All grasslands are considered as managed land in Lithuania.

*Wetlands***.** Wetlands include peat extraction areas and peat lands which do not fulfil the definition of other categories. Water bodies and swamps (bogs) are also included under this category. Peat extraction areas are considered as managed land. Since 2013, in line with renewed methodology, wetlands are distributed between several groups for reporting: remaining managed peat extraction sites (there were no conversions into new peat extraction sites in recent years in Lithuania, therefore land converted to peat extraction sites are not reported), remaining managed flooded land, remaining managed (other) land, which is mainly drained damaged peatlands, remaining unmanaged and land converted to flooded land.

*Settlements***.** All urban territories, power lines, traffic lines and roads are included under this category as well as orchards and berry plantations planted in small size household areas and only used for householders' meanings. Only the areas of settlements remaining settlements and lands converted to settlements are reported. All settlements are considered as managed land.

*Other land***.** All other land which is not assigned to any other category such as quarries, sand - dunes and rocky areas is defined as Other land. Carbon stock changes in living biomass, dead wood and mineral soil are reported due to the conversion from other land uses to Other land.

Table 6-4. National definitions for land use categories and relevant land use category defined in *2006 IPCC*

National definitions for land use categories and subcategories										
Agricultural land							Other land			
Arable land	Orchards and berry plantations	Meadows and natural pastures	Forest land	Roads	Settlements	Water bodies	Swamps (bogs)	Trees and bushes plantations in urban areas	Disturbed land	Unmanaged land
Relevant category in *2006 IPCC*										
Cropland		Grassland	Forest land	Settlements		Wetlands		Settlements	Other land	

The rule of defining conversions between cropland and grassland

Conversion from cropland/grassland to grassland/cropland is confirmed at the same time it happens (identified either during NFI field measurement, meaning that conversion may happen only in 1/5 of total sampling plots which are visited during the year). During the next NFI measurement conversion is either confirmed or rejected, depending on the land-use observed in the field: if land-use is the same as detected in previous NFI cycle, conversion is confirmed and land-use type remains the one it was converted to in previous NFI cycle, however, if land-use type in second NFI measurement is different from the one detected during previous measurement, conversion is rejected and land-use type should remain as before conversion for whole period (between first and second NFI measurements). Examples of possible situations are provided in the table below.

Table 6-5. National definitions for land use categories and relevant land use category defined in *2006 IPCC*

Initial land-	**NFI I (+National**	**NFI II (+National**	**Explanation**

use type	Paying Agency data)	Paying Agency data)	
c	g	g	Conversion is reported after land use change was identified (NFI I). Conversion is confirmed - new land-use type is reported since NFI I (land-use type remains same in both NFI I and NFI II).
c	(g) c	c	Conversion is reported after land use change was identified (NFI I). Conversion is rejected - land-use type should be changed to the initial in NFI I (the one before the conversion).Temporary grassland (less than 5 years) is not reported as conversion to grassland.
g	c	c	Conversion is reported after land use change was identified (NFI I). Conversion is confirmed - new land-use type is reported since NFI I (land-use type remains same in both NFI I and NFI II).
g	(c) g	g	Conversion is reported after land use change was identified (NFI I). Conversion is rejected - land-use type should be changed to the initial in NFI I (the one before the conversion). Grassland improvement is not reported as conversion to cropland.

Information on extension of reporting under Kyoto Protocol

Under the requirements of Kyoto Protocol for the second commitment period Lithuania is committed to report GHG emissions and removals under Kyoto Protocol Articles 3.3 (afforestation/reforestation/deforestation activities) and 3.4 (Forest management activities). After the second commitment period (from 2021) Article 3.4 activities cropland management and grazing land management will become obligatory as well. Therefore, European Parliament and Council decided that all European Union Member States shall prepare for upcoming reporting extension with preparing and reporting on the systems to estimate emissions from cropland management and grazing land management altogether with their compliance with 2006 IPCC methodologies and UNFCCC reporting requirements.

According to the Annex of draft decision -/CMP.1 (Land use, Land-use Change and Forestry) contained in document FCCC/CP/2001/13/Add.1 definitions of forest management and grazing land management are the following:

- *Forest management* is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.
- *Cropland management* is the system of practices on land on which agricultural crops are grown and on land that is set aside or temporarily not being used for crop production (Cropland management consists of Cropland remaining Cropland, Grassland, Settlements, Wetlands and Other land converted to Cropland, Cropland converted to Wetlands, Settlements and Other land).
- *Grazing land management* is a system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced (Grazing land management consists of Grassland remaining Grassland, Cropland, Settlements, Wetlands and Other land converted to Grassland, Grassland converted to Wetlands, Settlements and Other land).

In accordance with these definitions, all forest land, grassland and cropland in Lithuania are managed, therefore emissions/removals have to be accounted for the whole territory.

6.1.2 Land use changes

Forest coverage in Lithuania remains continuously increasing during the last decades (Figure 6-6). Natural and human induced afforestation increased forest land area by 168.1 thous. ha since 1990 (Table 6-5). Comparing todays` situation with 1946, forest area increased more than one third and in some counties forest expansion has almost doubled.

Declared croplands area in Lithuania was decreasing since 1990 to 2005. This is closely related to Lithuanian history. Significant reforms were introduced in the early 90's, particularly after the restoration of independence with the purpose of re-establishment of private ownership and management in the agriculture sector. The legislations were adopted for dismemberment of the collective farms, but they did not ensure their replacement by at least equally productive private farms or corporations. Agricultural production decreased by more than 50% from 1989 to 1994. The farms were broken into small holdings, averaging 8.8 ha in size, often not large enough to be economically viable. Area of grasslands prevailed and increased as a consequence of abandoned crop production areas.

Croplands and Grasslands area has changed dramatically in Lithuania since 2005. This is the result of introduced Single Area Payment Scheme (*SAPS*) since 2004. *SAPS* is a form of support whereby direct payment is made for agricultural land irrespective to the type of production carried out on the land, and this might be one of the reasons of decrease in grasslands area. Furthermore, in 2004 when Lithuania became the member of EU, communities Structural Funds became available. In order to use funding from EU Structural Funds efficiently, the Single Programming Document (*SPD*) of Lithuania for 2004–2006 was prepared. The strategy provided in the *SPD* was divided into priorities and implemented on the basis of one or several measures. Support for Rural and Fisheries development was provided under the measures of the 4th *SPD* priority. The main objective of the Rural and Fisheries Development priority is to develop an advanced agriculture, forestry, and fishery sector on the basis of natural resources and the traditions of inhabitants and by investing in alternative activities, traditional farming, and economic diversification. This support is a non-repayable grant of between 45% and 100% of eligible expenses. In 2004–2006, 191 million EUR was allocated to implement the measures of the Rural and Fisheries Development priority. According to the support contracts signed, the largest amount of funding (95 million EUR) was allocated to beneficiaries who submitted applications for the measure named "Investments into Agricultural Holdings". These measures resulted in agricultural land management, hence increase in croplands area and decrease in grasslands that were ploughed for agricultural purposes.

Table 6-5. National land use data for 1990-2020, thous. ha

Years	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
1990	2,054.2	2,414.7	1,287.0	381.4	347.4	43.9	6,528.6
1995	2,077.3	2,223.1	1,487.5	376.2	351.8	12.8	6,528.6
2000	2,096.1	2,020.6	1,670.0	372.6	357.4	12.0	6,528.6
2005	2,122.4	1,834.1	1,826.9	373.0	362.2	10.0	6,528.6
2010	2,154.0	1,938.3	1,681.6	371.0	373.0	10.8	6,528.6
2015	2,197.1	1,952.3	1,622.9	367.8	379.4	9.2	6,528.6
2016	2,202.3	1,944.7	1,627.3	367.0	379.0	8.4	6,528.6
2017	2,210.3	1,962.7	1,603.7	365.0	379.0	8.0	6,528.6
2018	2,212.3	1,970.3	1,594.5	363.8	380.2	7.6	6,528.6
2019	2,215.1	1,985.1	1,575.4	363.0	381.8	8.4	6,528.6
2020	2,222.3	2,010.6	1,542.2	361.4	384.2	8.0	6,528.6

Data for 1990 -2011: Forest Land – *Study-1*; Cropland, Grassland, Wetland, Settlement, Other Land – *Study-2*. Data for 2012 and subsequent years – *NFI*

Table 6-6. Land use changes between 1990 and 2020, thous. ha

Land use	1990	2020	LUC
	thous. ha		
Forest Land (FL)	2,054.2	2,222.3	168.1
Cropland (CL)	2,414.7	2,010.6	-404.1
Grassland (GL)	1,287.0	1,542.2	255.2
Wetland (WL)	381.4	361.4	-20.0
Settlements (SL)	347.4	384.2	36.7
Other Land (OL)	43.9	8.0	-35.9

6.1.3 GHG sinks and releases

Annual CO_2 emissions and removals for the period 1990-2020 are provided in Table 6-7 (evaluated net CO_2 emissions and removals from LULUCF sector). LULUCF sector in Lithuania has continuously been CO_2 sink with the only emissions of 992.1 kt CO_2 in 1996. Removals were ranging from -230.2 kt CO_2 to -10,592.6 kt CO_2 during the accounting period. On average -6,352.9 kt CO_2 are removed every year. Removal of CO_2 mainly corresponds to forest land with the smaller share from grasslands and harvested wood products since 2000.

Table 6-7. Evaluated total emissions and removals from LULUCF sector, kt CO_2 eq.

Year	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Harvested wood products	Total
1990	-7,763.91	2,655.95	-812.81	586.53	38.96	NO.NE	-252.55	-5,531.28
1995	-5,232.25	2,266.59	-1,472.23	445.03	230.07	42.68	-830.06	-4,532.63
2000	-9,325.45	2,115.80	-1,879.08	466.29	401.42	41.29	-1,268.83	-9,432.15
2005	-4,306.87	1,235.79	-1,646.64	888.68	595.96	47.46	-1,209.53	-4,378.08
2010	-9,645.13	982.57	-1,764.44	548.67	679.40	71.59	-1,317.45	-10,423.14
2015	-8,086.01	824.48	-937.88	965.10	603.80	54.16	-1,289.53	-7,844.47
2016	-7,271.91	646.91	-973.16	730.84	701.37	54.16	-1,043.37	-7,131.81
2017	-7,154.58	934.44	-960.17	1,069.85	578.66	54.16	-1,044.78	-6,498.68
2018	-7,074.94	924.53	-928.27	859.38	728.45	48.26	-934.54	-6,353.48
2019	-6,496.45	863.39	-834.17	821.28	772.09	352.37	-808.30	-5,302.10
2020	-6,485.40	934.95	-752.70	993.63	598.86	60.05	-783.96	-5,407.39

6.2 Forest Land (CRF 4.A)

Neither definition of forest land nor reporting of GHG has changed since the 1st Commitment Period in forest land category and is used as following: land area not less than 0.1 hectare in size covered with trees, the height of which in a natural site in the mature age is not less than 5 meters, other forest plants as well as thinned or temporary vegetation – lost forest due to the acts of nature or human activities (cutting areas, burnt areas, clearings). Tree lines up to 10 meters of width in fields, at roadsides, water bodies, in living areas and cemeteries or planted at the railway protection zones as well as single trees and bushes, parks planted and grown by man in urban and rural areas are not defined as forests. All forest land is considered as managed land in Lithuania.

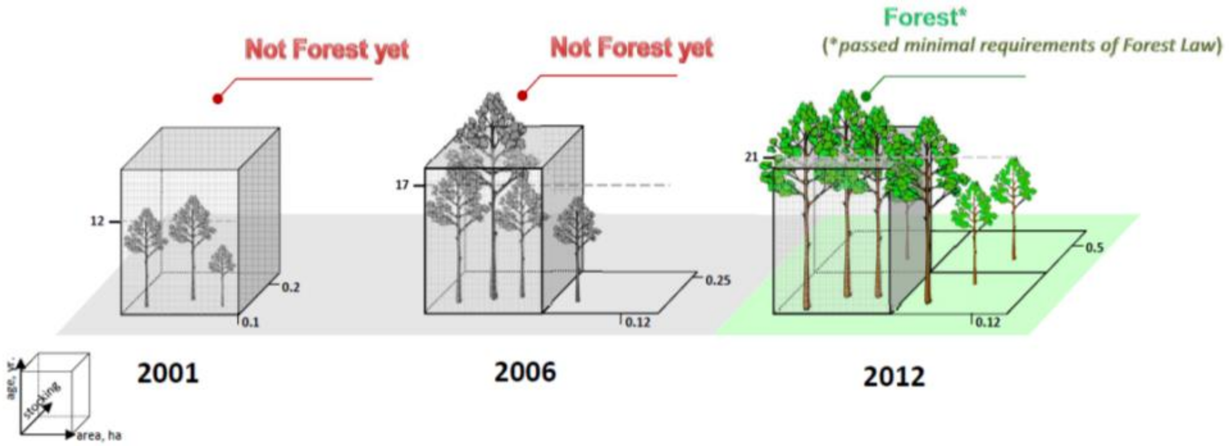


Figure 6-4. Definition of forest applied in Lithuania. Group of trees becomes forest only when reaching certain parameters

6.2.1 Category description

Forest land area

Forest coverage in Lithuania was expanding continuously since 1948 (Figure 6-5). However data on forest coverage in Lithuania during inter-war period is very limited and the exact data is still unknown.

Expert judgement made by the authors of "*The Chronicle of Lithuanian Forests. XX Century*" allowed presuming forest coverage to be around 21% in 1938, even though some authors argue that only small part of heavily afforested areas of Vilnius region (south-eastern part of Lithuania) were included into this number at that time, and around 150 thous. ha could be unaccounted.

The lowest forest coverage has been accounted during the World War II and through occupation period, because of no forest preservation policy at that time.

During the period when Lithuania was part of Soviet Union, forest accounting was rather thorough – unfortunately only in State owned forests. Forests belonging to "kolkhozes" (collective farms) and being less than 10 ha were disregarded as well as those belonging to small farms and being less than 1 ha.

After restoration of independence in 1991, there were no legal obstacles for implementation of forest accounting. However, the land reform had also started at that time, so the *SFI* has been suspended or even discontinued as less important. In 1996, when the new cycle of *SFI* has been started numerous naturally afforested areas were found that were missing in the previous inventories or in State land accounting related documents.

Although forests cover a large part of Lithuanian territory and constitute to 2,222 thous. ha which is more than 33% of the country, it is estimated and forecasted that Lithuanian forest area should account for at least 35% considering the needs of the nature frame and landscape. Despite the fact that forest land area has increased significantly and many new forests have been planted on private and State land the need for further enlargement of forest land still remains. According to the statistical data of NLS under Ministry of Agriculture, there was approximately 41 thous. ha of land that is not used for agriculture or is unsuitable for that in 2020 and part of it might already be covered with woody vegetation (natural afforestation has been started). In addition to this, a target in the General Plan for the territory of the Republic of Lithuania has been set to increase afforestation of such lands and as a conclusion country forest coverage could increase up to 37-

38%. However, this process is slowed down by incomplete land reform, problems related to the transfer of free land from the state land fund to managers of state-owned forests for afforestation, as well as legal restrictions linked with afforestation of land that has relatively high productivity. Therefore, it is reasonable to increase forest coverage by harmonizing the scope with other land use needs.

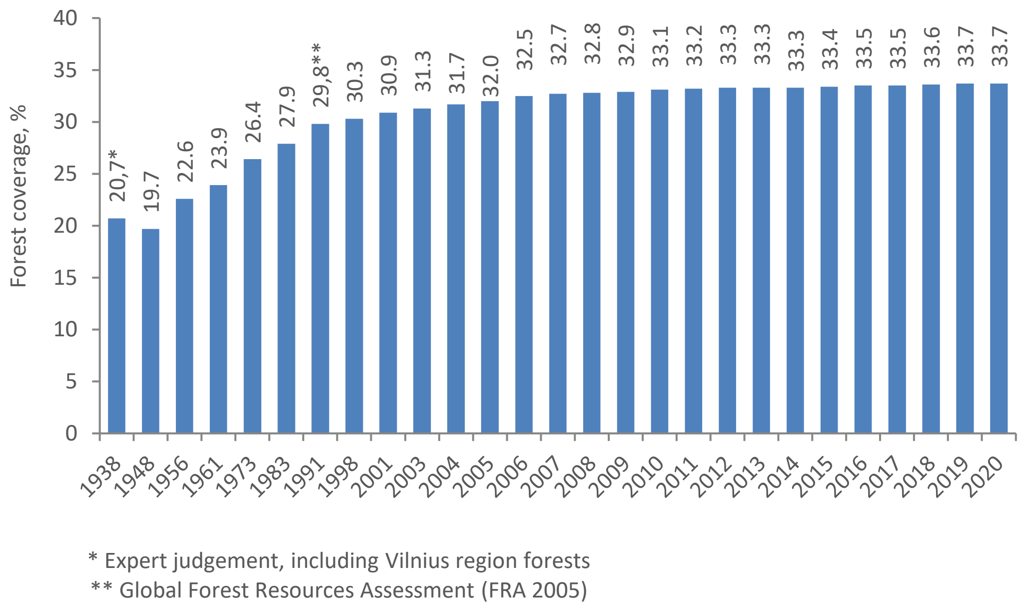


Figure 6-5. Forest coverage 1938-2020.01.01

According to Lithuanian Statistical Yearbook of Forestry by 1st of January 2020, total forest land area in 2020 was 2,222.3 thous. ha, covering 33.7 % of the country's territory. Since 2003 average forest area per capita increased from 0.59 ha to 0.79 ha. Around half of all forest land in Lithuania is of State importance – 1,110.4 thous. ha. In 2020, around 857.5 thous. ha of forests were registered as private at the State enterprise Centre of Registers. However, after intersection of layers of all forests and private holdings the estimated area of private forests was slightly readjusted to 923.8 thous. ha in the beginning of 2020. Since the 1st of January 2003, the forest land area has increased by 155 thous. ha corresponding to 2.4 % of the total forest cover. During the same period, forest stands expanded by 110.8 thous. ha to 2,061.8 thous. ha. Average annual increase in forest area is about 9 thous. ha (since 2003). Huge difference in forest coverage is explained by insufficient data previously used by Forest Assessment. As of 1st of January 2020 Forest Assessment that is based on data of *SFC* shows nearly the same forest coverage as the *NFI*, which is based on permanent sample plots data (Figure 6-6).

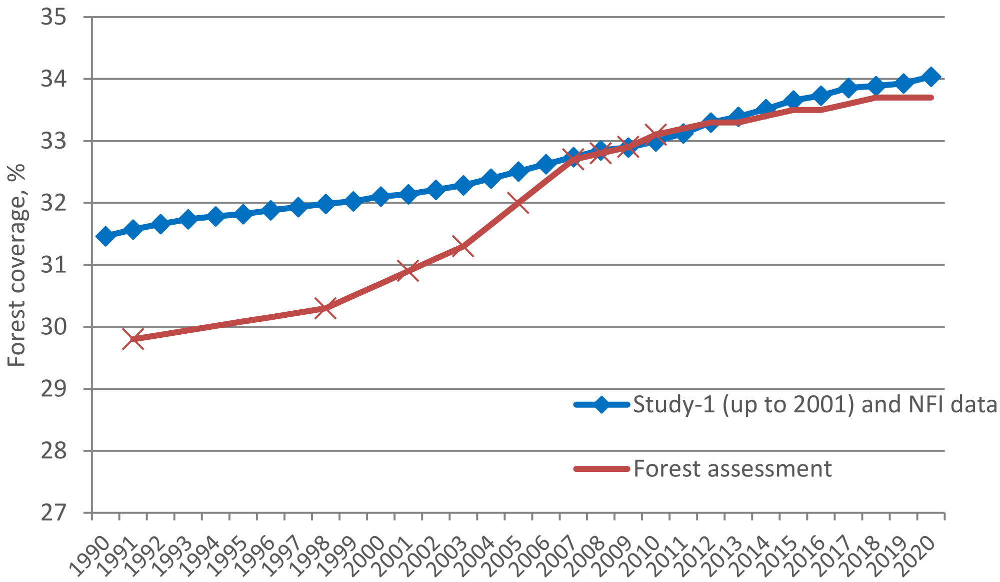


Figure 6-6. Changes in forest coverage in Lithuania 1990-2020, 2020.01.01

All Lithuanian forests are distributed into four functional groups. In the beginning of 2020, distribution of forests by functional groups was as follows: group I (strict nature reserves) – 27.1 thous. ha (1.2%); group II (ecosystems protection and recreational forests) – 256.0 thous. ha (11.6%); group III (protective forests) – 281.3 thous. ha (12.8%); and group IV (exploitable forests) – 1,635.8 thous. ha (74.3%) (Figure 6-7).

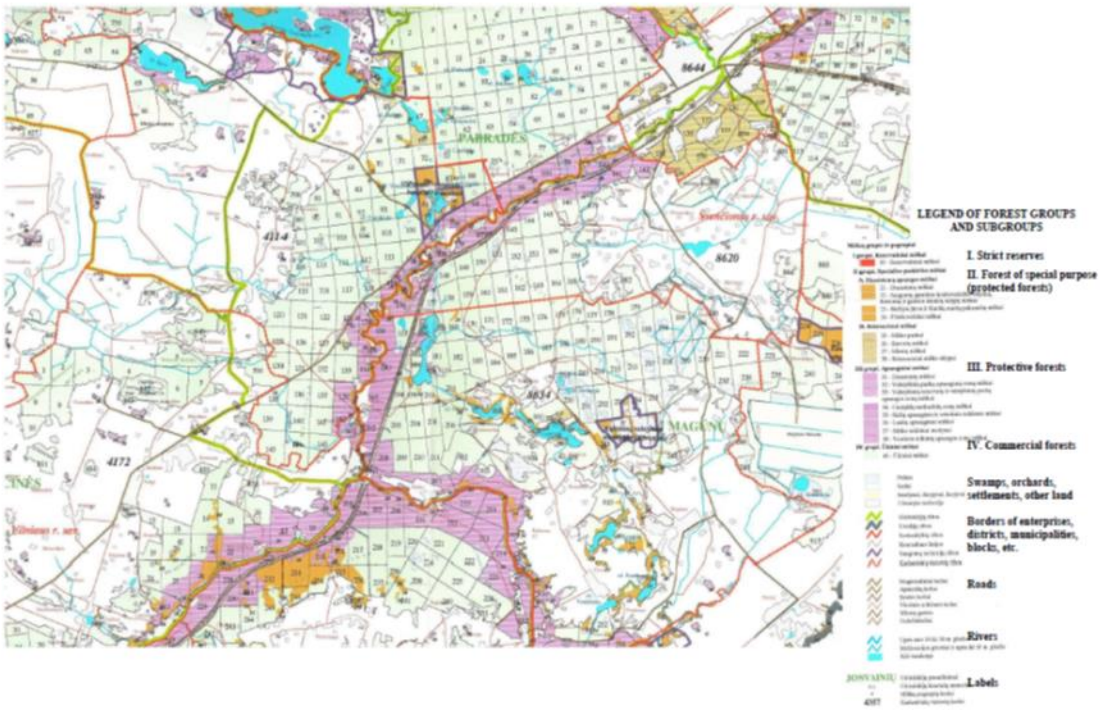


Figure 6-7. Scheme of forest distinguished by functional groups

Occupying 1,147.4 thous. ha, coniferous stands prevail in Lithuania, covering 55.7% of the forest area (Figure 6-8). They are followed by softwood deciduous forests (845.7 thous. ha, 41.0%).

Hardwood deciduous forests occupy 68.7 thous. ha (3.3%). Over the last 17 years total area of softwood deciduous forests increased by more than 147 thous. ha. The area of hardwood deciduous has decreased by 24 thous. ha over the last 17 years (mainly due to the mouth of ash woods), and coniferous forest area in last 17 years decreased by 12.5 thous. ha. Scots pine (*Pinus sylvestris*) occupies the biggest share in Lithuanian forests – 710.3 thous. ha (34.5%). Compared to 2003, the area of pine decreased by 1.2 thous. ha. Norway spruce (*Picea abies*) covers 434.8 thous. ha (21%), with a reduction of 10.5 thous. ha. Birch (*Betula pendula*) covers the largest area among deciduous trees. Since 2003, it has increased by 60.3 thous. ha and reached 452.4 thous. ha by the beginning of 2020. Area of Black alder (*Alnus glutinosa*) increased by 43.3 thous. ha to the total of 162.8 thous. ha. The area of grey alder (*Alnus incana*) decreased by 0.6 thous. ha, reaching 121.5 thous. ha. The area of aspen (*Populus tremula*) stands expanded by 38.2 thous. ha to 95.6 thous. ha. Oak (*Quercus robur*) forests increased from 35.7 thous. ha to 48.1 thous. ha. The area of ash (*Fraxinus excelsior*) stands diminished by 75.3 % to 12.7 thous. ha.

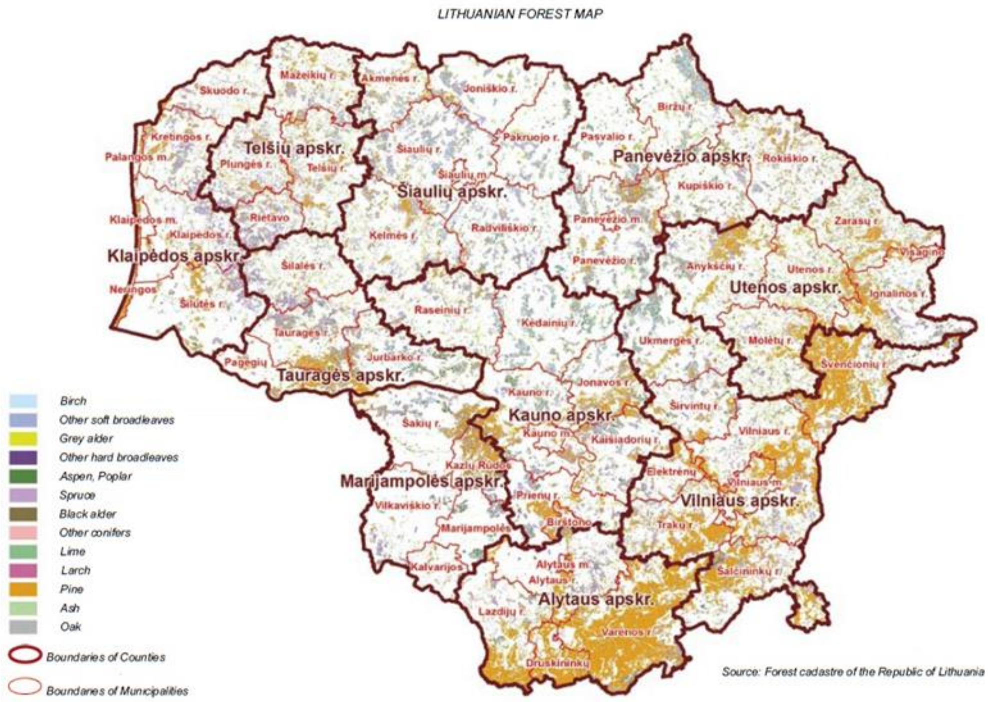


Figure 6-8. Lithuanian forest map by prevailing tree species

National Forest Inventory

National forest inventory was established in 1998 by the State Forest Management and Inventory Institute under the Ministry of Agriculture and Forestry and since then is one of the main forestry data providers (together with Standwise Forest Inventory, pre-cutting inventory and mature stands inventory). Its activity is consolidated by Forest Law of the Republic of Lithuania (2001, 2011, 2012 ed.) and it is conducted by the *SFS* following the Regulations of National Forest Inventory, approved in 2004 and revised in 2012. Data presented by *NFI* is used while making forest policy decisions (forestry related laws, forestry programmes etc.), planning forestry activities (large scale forest management planning, country forestry planning etc.), planning forest industry investments and modelling forestry related scenarios (forest resources development etc.). All the activity data, necessary for GHG reporting, is collected during *NFI*.

NFI is based on continuous, comprehensive multistage sampling and GIS integrated technology and is organized in the same manner to monitor all forests of Lithuania. Since 2012, the systematic grid (16,349 permanent sample plots) of the *NFI* of Lithuania covers all land categories (Figure 6-9) including inland waters.

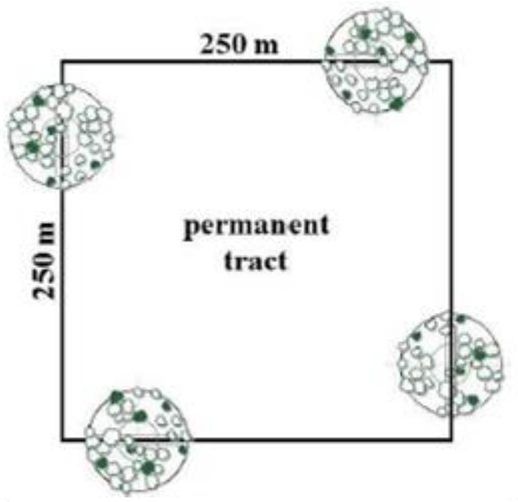


Figure 6-9. Tract of permanent sample plots

Sampling is conducted using a 4×4 km systematic grid with a random starting point. The systematic grid assures a uniform distribution of plots over the entire country and regular monitoring of conversion amongst land use categories. The sample units are arranged to square shape clusters and include four permanent, regularly measured plots (Figure 6-9).

The aim of establishment of permanent sample plots is to reliably estimate (by direct measurements) growing stock volume, gross increment, mortality and fellings, provide site and soil descriptions, to control the dynamics of forest areas in the country.

There are many different inventory parameters recorded in each of the permanent sample plots:

- Land use type (according to the position of the sample plot center;
- Stock changes in each different stands (if the stand in sample plot is not homogenous);
- Regeneration and bushes inventory;
- Natural and human induced damages of the trees, etc.

Taking into account the number of homogeneous stands (strata), minimal growing stock volume and increment estimation accuracy, 5,600 permanent sample plots were established on forest land. Approximately 1,120 permanent sample plots on forest land are re-measured each year.

Following the order of the Minister of Environment and renewed Regulations of *NFI,* field measurements in all land use categories of Lithuania were started in 2012, resulting in more than 16 thous. permanent sample plots. The *NFI* plots annually cover the entire country with the total number of plots measured over the 5-year inventory cycle reaching a sampling intensity of one sample plot per 400 ha. The main aim of non-forest land measurements is to: (a) monitor land use changes, required by UNFCCC, provide soil descriptions and (b) to measure living trees outside the forest land in order to form a database of woody biomass accumulated in non-forest land.

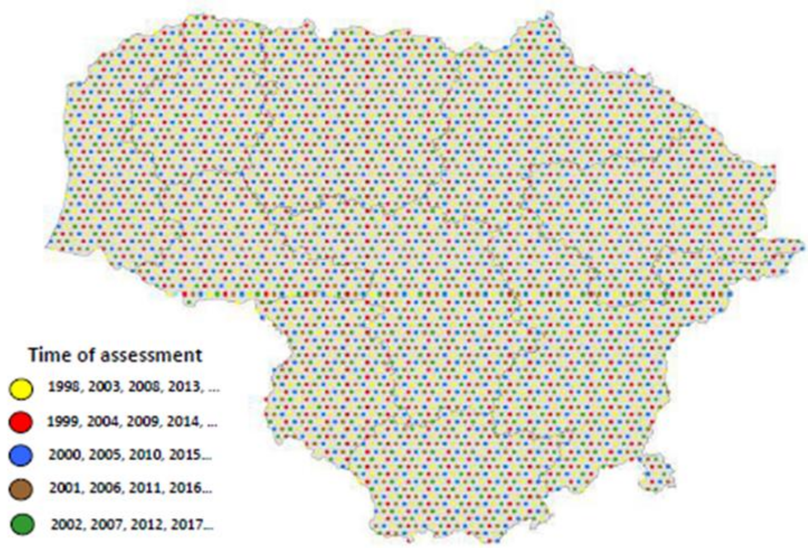


Figure 6-10. Distribution of NFI clusters of plots on Lithuanian territory

Lithuanian State Forest Cadaster

The purpose of *LSFC* is to collect, compile, process, systematize, store, use, update and provide data on Lithuanian forests. *LSFC* is a component of state registers' system. The structure of *LSFC* is based on natural-geographical principle thus forest tract is considered to be the unit of *LSFC* registration, as a result, *LSFC* is a database of forest tracts. Forest tract is considered as continuous forest land with environmental, anthropogenic boundaries or surrounded with other land use areas. State Forest Cadaster has been created employing the information of forest land compartments data base, originated from the *SFI* data.

Primary functions of *LSFC*:

- Drawing up a technical draft of *LSFC*, including:
  - regulations on separation of registration units and on attribution of code numbers to forest tracts;
  - regulations on attaching and updating attributes of forest tracts;
  - formulation of technical requirements for software;
  - regulations on data provision to stake-holders and other cadasters.
- Systematizing geographical data of forest tracts for entire country.

To work out the hierarchical system of forest tracts, the territory of Lithuania was subdivided into 6 regions, separated by the beds of the biggest rivers. Each region was divided into districts, according to a dominated forest tract, larger than 10,000 ha, then each district is subdivided into as many smaller districts as many forest tracts, having an area of 1,000-100 ha, until forest tract size is 10 ha or less. Each forest tract smaller than 10,000 ha is subordinated to the district of dominating tract and acquires a part of its code number. Such code number of a small forest tract identifies both its geographical location and hierarchical position. Records of an identified forest tract are combined with the database of forest land compartments. Each forest land compartment receives a forest tract code number besides its own number. Information on compartments serves as a basis for forest tract information summary.

An interior numbering of blocks occurs in each forest tract separately. Such approach will gradually result in a stable system of block numbers, irrespective to forest`s administrative division or its ownership category. *LSFC* database is being updated on a regular basis following the outcome of every next standwise inventory, the information from forest enterprises and other data providers about silvicultural measures applied information about ownership, administrative boundaries and other changes, information about newly planted or naturally regenerated forests during the inventory period, provided by forest enterprises and other institutions.

LSFC data are integrated with the data of other cadasters and registers such as those of real estate, protected areas, territorial administrative units, cultural values; as well as with other layers - training and experimental forests etc.

Data collection for GHG inventory reports

Organic and mineral soils

Due to the requirements of GHG inventory and reporting, *NFI* provides data on forest land distribution by forest soils (Table 6-7). According to NFI data (2nd NFI cycle 2003 - 2007), area of mineral soils amounts to 84.3% and area of organic soils – 15.7% of the total forest area. Drained organic forest soils constitute to 7.9% of the total forest land. This area consists of 2.6% infertile and 5.3% of fertile drained organic forest soils. Organic soils in Lithuania are determined by using national definition of organic soils, provided in the book of Lithuanian soil classification: soil is classified as organic if it has peat layer not thinner than 40 cm or 60 cm of poorly decomposed peat (mainly mossfibres) in bogs. In addition to this, histic horizon must contain not less than 70-75 percent of organic matter by volume. National definition of organic soils (histosols) was prepared using Food and Agriculture Organization (FAO) guidelines for soil classification (WRB, World Reference Base for soil resources).

Table 6-8. Forest land area by mineral and organic soils 1990-2020, thous. ha

Year	Mineral soils	Organic soils			Total forest land
		Not drained	Drained	Total	
1990	1,774.79	137.63	141.74	279.36	2,054.15
1995	1,794.80	139.18	143.33	282.51	2,077.32
2000	1,811.02	140.44	144.63	285.07	2,096.08
2005	1,833.79	142.20	146.45	288.65	2,122.44
2010	1,861.04	144.32	148.63	292.94	2,153.99
2015	1,898.31	147.21	151.60	298.81	2,197.11
2016	1,902.79	147.55	151.96	299.51	2,202.31
2017	1,909.69	148.09	152.51	300.60	2,210.29
2018	1,911.42	148.22	152.65	300.87	2,212.29
2019	1,913.83	148.41	152.84	301.25	2,215.08
2020	1,920.04	148.89	153.34	302.23	2,222.27

Soils are classified using Forest soils classification methods, prepared by prof. M. Vaičys. Prof. M. Vaičys studied forest soil genesis and collected abundant data on soil properties. New soil-forming processes in Lithuanian forest soils, such as lessivation and browning, were also ascertained. Later on, original methods of large-scale forest soil mapping were prepared. In the 1960 – 1970s, under the guidance of Prof. M. Vaičys, all forest soils in Lithuania were mapped and the national genetic classification of forest soils was prepared. An original classification of the humidity and fertility of forest sites based on soil-typological groups was offered by Prof. M.

Vaičys as well. While becoming a member of European Union, necessity of preparation of new Lithuanian Soils Classification, which would be harmonized with World Soil Map legend, has emerged (S 1:5,000,000, FAO – UNESCO, 1990). First version of such classification was presented in 1997 by M. Vaičys et al. Later it was developed, adjusted and finally approved in 1999. The new Lithuanian Soils Classification (LTDK-99) was quite recital, and was difficult to use for forest inventories which are based on forest soil types, therefore it was harmonized with forest soil types used in forest inventory, forestry, forest related science etc. The final harmonized forest soil type classification is presented in Figure 6-11.

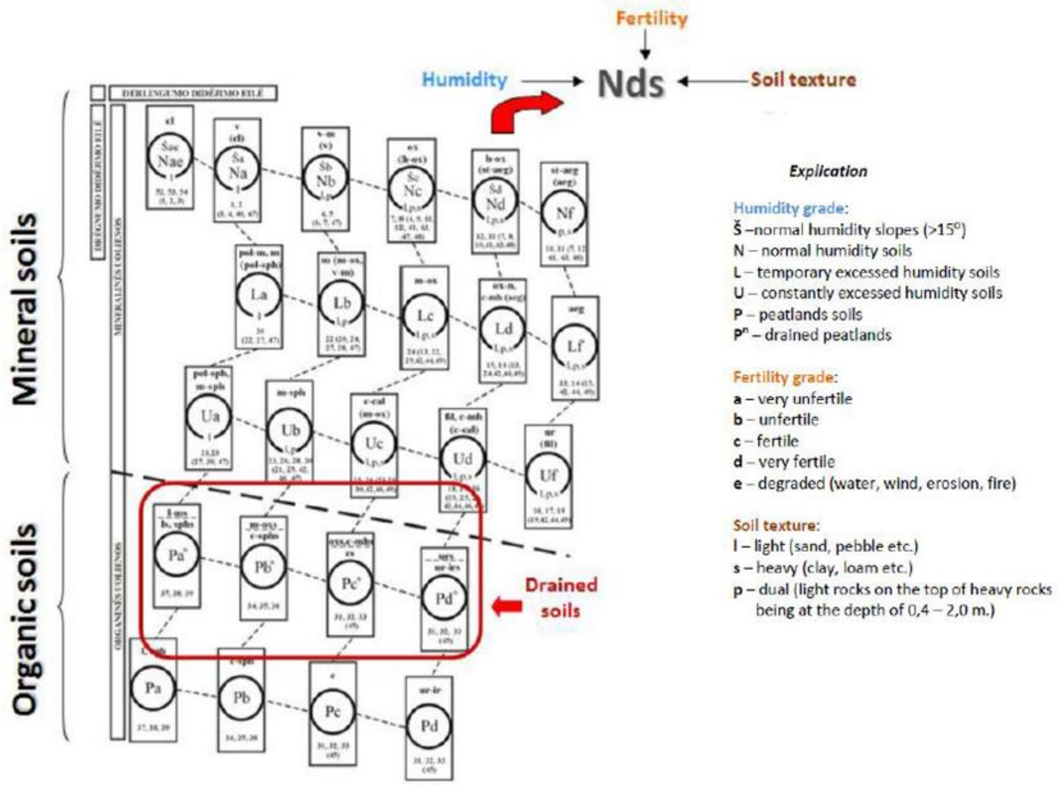


Figure 6-11. Classification of forest soil types

In this GHG inventory Lithuania defines organic soils and distributes it between drained and not drained organic soils on forest land category as they are classified in the above-mentioned soil classification system. Definition of organic soils in LTDK-99 is in line with the definition and requirements of *2006 IPCC Guidelines*, hence organic soils are identified as soils with peat and peaty soil layer equal to or more than 40 cm of the total thickness in drained conditions and not less than 60 cm of the total thickness of poorly decomposed peat in undrained bogs.

Carbon stock changes in biomass

Carbon stock changes in biomass are accounted separately for living and dead trees, both above-ground and belowground biomass. In order to account for carbon stock changes in biomass, growing stock volume changes are measured during the inventory by sampling method. Due to the fact that holistic National Forest Inventory was launched in 1998, prior growing stock volume data had to be obtained from available historical data sources. In order to gain reliable data, study on forest land changes and growing stock volume data was carried out in 2012.

Living trees volume (growing stock volume) in forest stand areas was estimated corresponding to *Study-1* "Forest Land changes in Lithuania during 1990-2011" and latest *NFI* data. For estimation of changes in growing stock volume, all the inventory years were divided in two time series: 1990-2002 and 2003-2020.

Total growing stock volume in the period of 1990-2002 was estimated using the following data sources: forest land area determined during the *Study-1*, percentage of forests stands area from total forest land area and mean growing stock volume of stands (Table 6-9). Forest stands area from total forest land area varied from 96.5% to 97% depending on the assessment year. This percentage is presenting forest land area without dead stands, clear-cut areas, forest blanks, forest roads, forest block lines, technological and fire-break belts and other small areas related to forest facilities.

Using available data six time points were selected to identify mean growing stock volume in stands: 1988, 1992, 1995, 1997, 1999 and 2000. However, growing stock volume data with known accuracy is available only since 2002, after the first cycle of NFI was finished. Therefore, volumes for the unknown years from the period of 1988-2002 were modelled using available data in the mentioned time points. Mean growing stock volume per hectare in stands for 1988 and 1999 was used from the scientific research (Kuliešis, 2000). Forest stand yield was estimated based on *SFI* data and data on fellings during the period 1922-1999. To demonstrate reliability of *SFI* data during 1958-1999, forest stand yield balance model and data from *SFI* by sampling method in 1969 was applied. Based on earlier mentioned methods mean growing stock volume in 1988 resulted to be 194 m^3/ha, in 1999 - 214 m^3/ha. Data on mean growing stock volume per hectare for 1992 and 1995 was used from Lithuanian forest resources assessment. Mean growing stock volume for 1997 was taken from Lithuanian forest statistics. Data for the year 2000 was obtained from Lithuanian Statistical Yearbook of Forestry. Note that, taking into account underestimation of mean growing stock volume for 1992, 1995, 1997 and 2000, making the harmonization of this data with the data of the research for 1988 and 1999 together with *NFI* data for 2003, it was adjusted by 13%.

Total growing stock volume for the period of 2003-2018 was estimated based on permanent NFI sample plots data. In 2002 Lithuanian *NFI* has finished establishment of permanent sample plots as well as first cycle of forest land inventory and started providing objective annual data on wood resources in Lithuanian forests (Chapter 6.2.1).

Increase in mean annual volume in 2000-2002 has been caused by accumulation of volume in stands due to restricted main use fellings after the spruce dieback in 1999.

Table 6-9. Growing stock volume identified according to Study-1, Forest assessment data and results of other researches

Year	Mean volume identified, m^3/ha	Mean annual volume change, m^3/ha	Forest land area, thous. ha.	Percentage of forest stands area, %	Total growing stock volume, thous. m^3
1988	194.0	-	-	-	-
1989	196.4	2.3	-	-	-
1990	198.7	2.3	2,061.4	97.0	397,614.2
1991	201.1	2.3	2,068.6	97.0	403,640.9
1992	203.4	2.3	2,074.6	97.0	409,540.9
1993	205.7	2.3	2,079.7	97.0	415,127.3
1994	207.9	2.3	2,082.5	97.0	420,253.1
1995	210.2	2.3	2,084.9	96.5	423,117.2
1996	209.1	-1.1	2,090.1	96.5	421,889.8
1997	207.9	-1.1	2,093.7	97.0	422,508.5
1998	211.0	3.0	2,097.3	97.0	429,503.3
1999	214.0	3.0	2,100.1	97.0	436,273.0

Year	Mean volume identified, m^3/ha	Mean annual volume change, m^3/ha	Forest land area, thous. ha.	Percentage of forest stands area, %	Total growing stock volume, thous. m^3
2000	218.1	4.1	2,105.7	96.5	443,412.2
2001	222.4	4.3	2,108.9	96.5	452,850.6
2002	226.7	4.3	-	-	-

Based on data presented above, total growing stock volume for the period of 1990-2020 was estimated (Table 6-10).

Table 6-10. Total growing stock volume estimated on growing stock volume analysis during 1988-2002 and NFI permanent sample plots data during 2003-2020

Year	Growing stock volume, thous. m^3
1990	397,306.4
1995	422,874.2
2000	443,159.8
2005	467,095.0
2010	469,471.5
2015	470,875.7
2016	476,053.5
2017	484,616.3
2018	494,285.3
2019	503,565.7
2020	511,532.6

Main differences in growing stock volume appear to be in the period of 1990-2000, especially in 1996-1999. On the first submissions total growing stock volume estimations were based mainly on expert assumptions and the rough linear trend. As the one of result of the executed *Study-1*, data on total forest area was presented, which has made an impact on total growing stock volume data as well. Decrease in annual volume change in 1996-1997 (-1,226 and 619 thous. m^3) is the result of spruce dieback, caused by bark beetle *Ips Typographus* which resulted in a huge damages for spruce stands. Even though mean annual volume change for 1997 is negative (-1.1 m^3/ha) but the total annual volume change is positive due to non-forest land converted to Forest land since 1990.

Table 6-11 presents annual growing stock volume and growing stock volume changes by tree species. The partition of total growing stock volume was made using the data of tree species composition determined during *NFI* permanent sample plots inventory. For the period of 2003-2018 annual *NFI* data was used, and for the period 1990-2002 data was modelled using *NFI* data for 2002, due to the lack of accurate annual statistical data.

There were certain changes done in growing stock volume estimation from NFI data in 2016. After the finish of Norwegian Partnership project, which was funded by the Norway Grants programme under the "Partnership project on Greenhouse gas inventory" in the framework of the programme LT10 "Capacity-building and institutional cooperation between beneficiary State and Norwegian public institutions, local and regional authorities", interpolation-extrapolation tool was used for more accurate growing stock volume changes representation. As a result of applied interpolation-extrapolation tool, growing stock volume changes in years when NFI measurements were available (2001-2014) were recalculated. Interpolation-extrapolation tool was used for NFI data only – annual change of growing stock volume between each permanent sampling group (remeasured every 5th year) between two remeasurements was calculated using linear interpolation (Figure 6-13). For the estimation of annual growing stock volume change in 2016 linear interpolation for the 2nd, 3rd and 4th sampling groups data was used, linear interpolation with preliminary NFI data of 5th sampling plot group data was used and extrapolation of NFI data of 1st sampling plot group data with adjustment on the basis of growing stock volume change trend was used. Growing stock volume change trend for the 1st sampling group is 1 %. For the transition period (2001 and 2002), growing stock volume changes were calculated using both study assessed growing stock volume change and growing stock volume change data assessed from NFI measurements in order to avoid deviations due to different methodology - study and NFI samplings - used. Differences between growing stock volume change data used for 2017 and 2016 National GHG Inventory Report are presented in Figure 6-13.

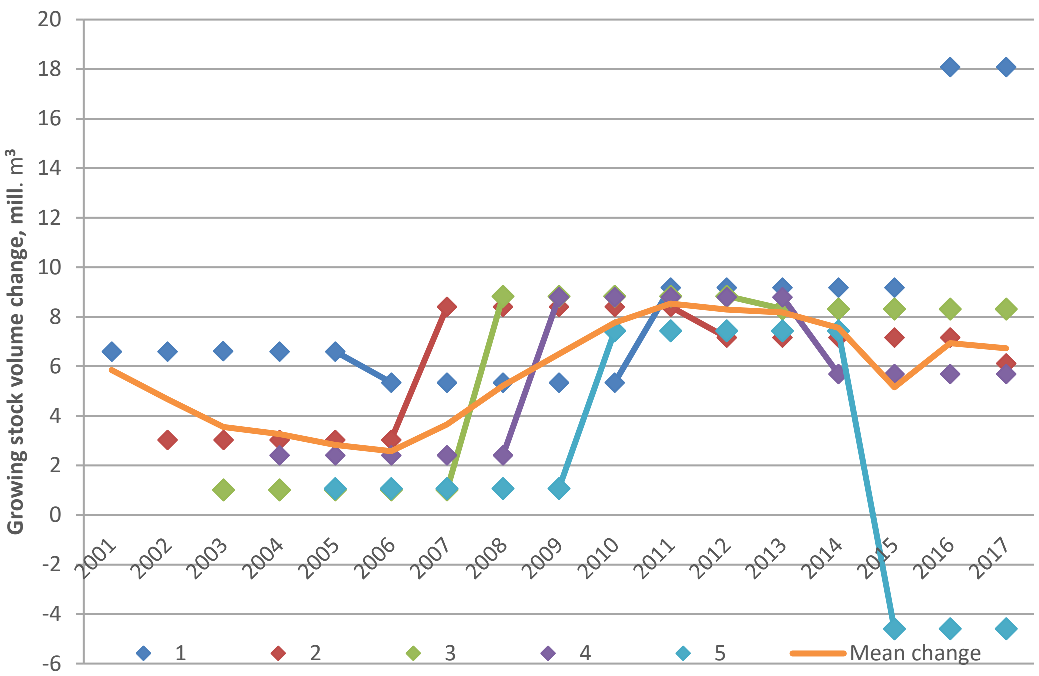


Figure 6-12. Interpolation-extrapolation of growing stock volume changes, mil. m^3

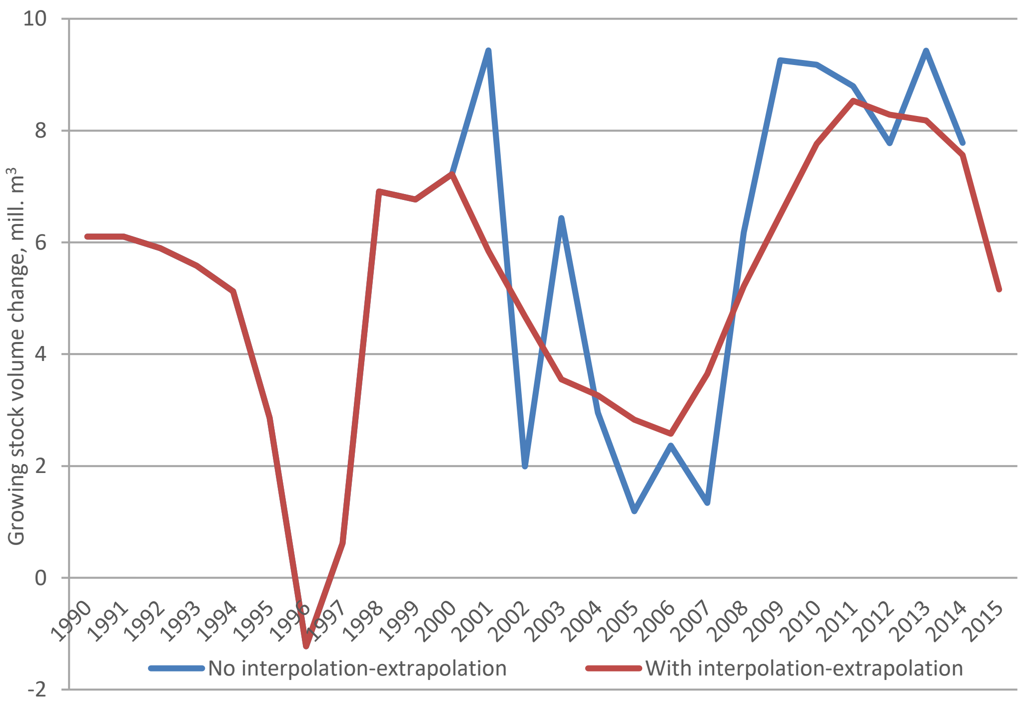


Figure 6-13. Differences in total growing stock volume changes between methods, mil. m^3

Table 6-11. Growing stock volume and annual changes of growing stock volume, thous. m^3

Year	Growing stock volume			Annual change of growing stock volume		
	Coniferous	Deciduous	Total	Coniferous	Deciduous	Total
1990	224,296.6	173,009.8	397,306.4	3,444.2	2,656.7	6,100.9
1995	227,740.9	175,666.4	403,407.3	1,616.3	1,246.7	2,863.0
2000	231,070.1	178,234.4	409,304.6	4,075.1	3,143.3	7,218.4
2005	234,222.3	180,665.8	414,888.1	2,627.0	1,98.5	2,825.5
2010	237,114.5	182,896.7	420,011.3	5,208.5	2,539.4	7,748.0
2015	238,730.8	184,143.4	422,874.2	4,624.9	2,118.9	6,743.8
2016	238,038.6	183,609.5	421,648.1	4,229.6	1,807.0	6,036.5
2017	238,387.9	183,879.0	422,266.9	4,131.5	1,821.4	5,952.9
2018	242,288.7	186,887.8	429,176.5	3,793.3	1,888.9	5,682.2
2019	246,107.8	189,833.7	435,941.5	3,551.0	1,721.0	5,272.0
2020	250,182.9	192,976.9	443,159.8	3,361.0	1,607.6	4,968.6

Note: Negative annual growing stock volume change shows decrease between two periods.

Volume of dead tree stems was assessed for two periods as well as growing stock volume. The total dead tree stems volume for the period of 1990-2002 was estimated using forest land area determined during the *Study-1*, percentage of forests stands area from the total forest land area and mean volume of dead tree stems in stands. Mean volume of dead tree stems was estimated taking into account data of spruce dieback in 1993-1996.

For the period 2003-2020 total standing and lying volume of dead tree stems was estimated using accurate data of *NFI* permanent sample plots. Deciduous and coniferous were separated using *NFI* data of dead tree stems species composition.

The foliage and needles biomass for separate tree species was estimated as a percentage from the total stem volume, using models designed by V. Usolcev. Models were adapted to Lithuanian stands taking into account forest area by dominant tree species (Lithuanian Statistical Yearbook of Forestry, 2011). Computations resulted that needles take 7% from the total stem volume and foliage share is 3% from the total stem volume. Estimated volumes of needles and foliage biomass were not included into total dead tree stems biomass (Table 6-12).

Volumes of standing and lying dead tree stems in forests were continuously increasing since 1990. The peak was recorded in the period of 1994-1997. This peak could be explained by spruce dieback, caused by the bark beetle *Ips Typographus*, when more than 13,000 thous. m^3 of dead tree stems were accumulated in forests. Volume of dead tree stems was stabilized only after 1998 for several years. Another steady increase of dead tree stems has started since 2001. There are several reasons for that: storm damages in 2000-2005, low number of commercial thinning, endorsed international environmental agreements committing to leave more deadwood in stands to maintain biodiversity (Natura 2000, etc.). In 2020, 10.8 m^3/ha of merchantable dead tree stems were accumulated in stands to decay, what is actually almost 2 times more if comparing with 1990.

Table 6-12. Total dead tree stems volume and their changes during 1990-2020, thous. m^3 yr^{-1}

Year	Dead tree stems volume			Annual change of dead tree stems volume			Mean dead tree stems volume, m^3/ha
	Coniferous	Deciduous	Total	Coniferous	Deciduous	Total	
1990	5,139.9	5,600.1	10,740.1	218.6	19.5	238.1	5.5
1995	7,586.2	5,635.0	13,221.2	777.5	-22.7	754.8	6.7
2000	6,341.0	5,691.1	12,032.1	-219.6	-14.3	-233.9	6.0
2005	7,371.2	7784.0	15,155.2	303.9	1027.8	1331.6	7.1

2010	9,622.3	11,839.9	21,462.2	213.5	127.4	341.0	10.0
2015	10,278.2	12,758.7	23,036.9	39.3	-384.0	-344.7	10.5
2016	10,607.2	12,437.6	23,044.9	329.0	-321.0	8.0	10.5
2017	11,008.5	11,199.9	22,208.4	401.2	-1237.8	-836.5	10.0
2018	11,255.7	11,345.0	22,600.7	247.2	145.1	392.3	10.2
2019	11,820.4	11,527.4	23,347.7	564.7	182.4	747.1	10.5
2020	12,478.3	11,498.1	23,976.4	658.0	-29.3	628.7	10.8

Fellings

Over 1990-1995 felling rates in all Lithuanian forests (irrespective of their ownership) were unstable, but still slightly increasing and reached the peak in 1995 with the total of 9.43 mill. m^3 of living trees felled. After 1995 felling were decreasing to 7.71 mill. m^3 of living trees felled in 1997 and then started to increase again. The highest point over the whole accounting period was reached in 2003 (10.34 mill. m^3 of living trees felled) and then started slightly to decrease until 2012 (8.05 mill. m^3 of living trees felled). Over the past years, stable increase in forest felling is observed: 10.55 mill. m^3 in 2019, although in 2020 it slightly decreased to 10.39 mill. m^3. Changes in total forest felling (living trees) for the period of 1990-2020 are presented in the Figure 6-14.

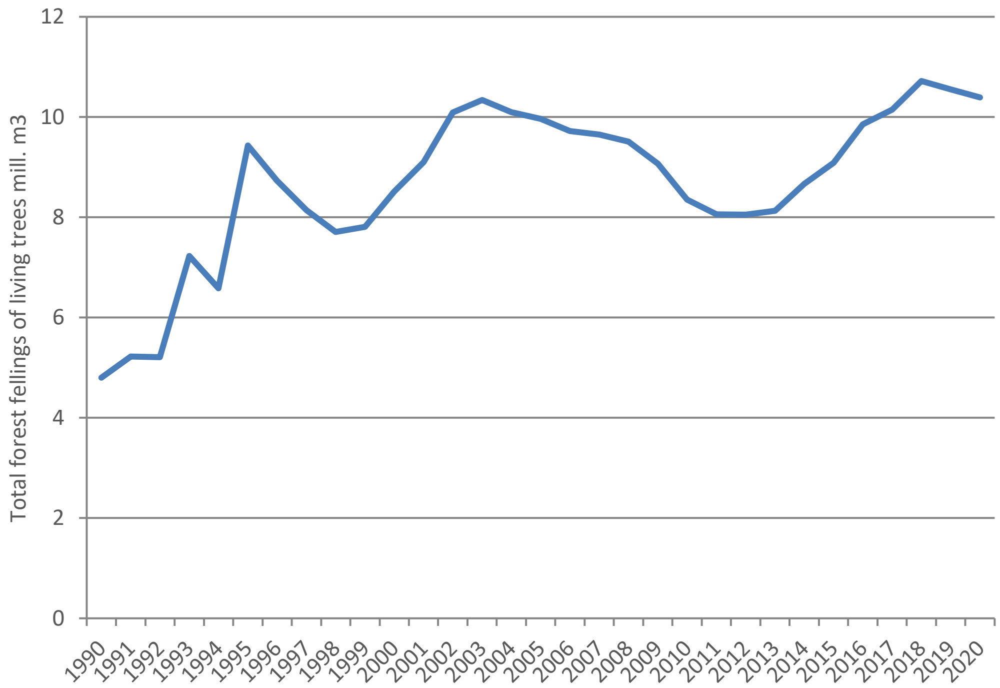


Figure 6-14. Total forest fellings (living trees) in all forests respectful of their ownership, 1990-2020

Biomass burning

Data on areas affected by forest fires is provided by the Directorate General of State Forests (*DGSF*). Directorate General of State Forests under the Ministry of Environment performs the functions of a founder of the State forest enterprises and coordinator of their activities as well as legislator of mandatory norms for them regarding reforestation, forest protection and management. It should be mentioned that all forest fires occurring in Lithuania are considered as forest wildfires as no prescribed burning of forest biomass is used, nor is allowed in Lithuania.

Lithuania is one of the few countries in Europe that has uniform system of state fire prevention measures, comprising monitoring, preventive and fire control measures that are established and maintained in forests irrespective of the forest ownership type. Every forest enterprise presents data on forest fires to the *DGSF* every year, which has the obligation to combine all the data into a single database. The amount of forest wildfires could be seen in Figure 6-15. It could be seen, that in recent years it was possible to reduce not only the number of forest fires but also the area of forest burnt in the event of wildfire, one of the reasons of such results could be the uniform and well-functioning fire prevention system in forests.

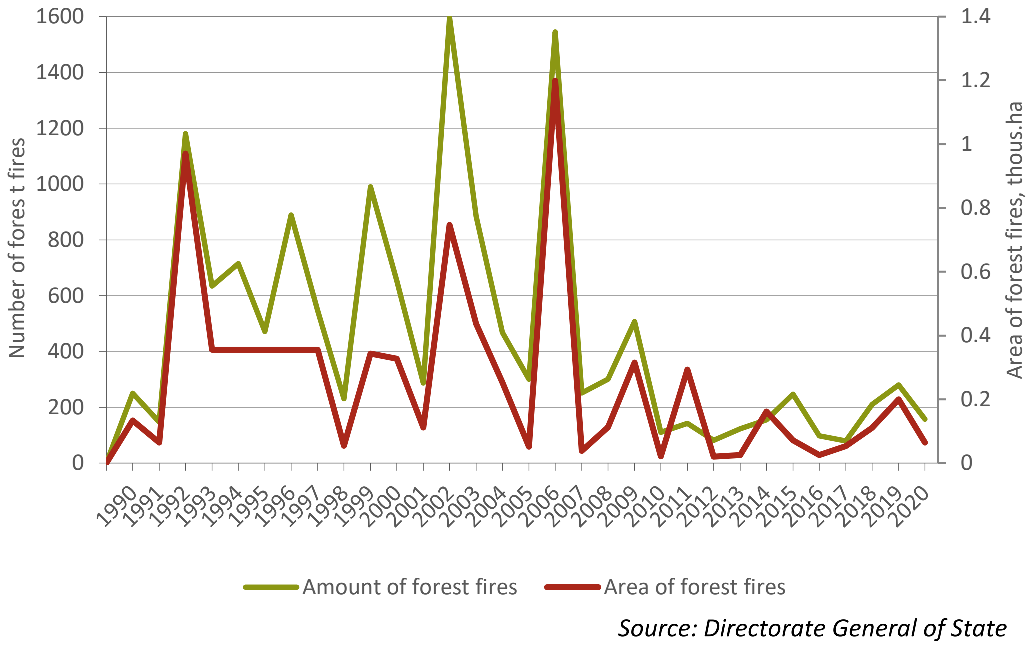


Figure 6-15. Number of forest fires and area of forest fires in Lithuania during the period 1990-2020 (*Source: Directorate General of State Forests)*

Forests in Lithuania refer to a high natural fire potentiality, however the modern fire monitoring system prevents large scale forest fires and burned areas mostly are miserable. All forests in Lithuania are distributed between three fire potentiality classes: I – high potentiality (38% of the total forest area), II – medium potentiality (22% of the total forest area) and III – low potentiality (40% of the total forest area). The distribution of forests according to natural fire potentiality classes is presented in Figure 6-16.

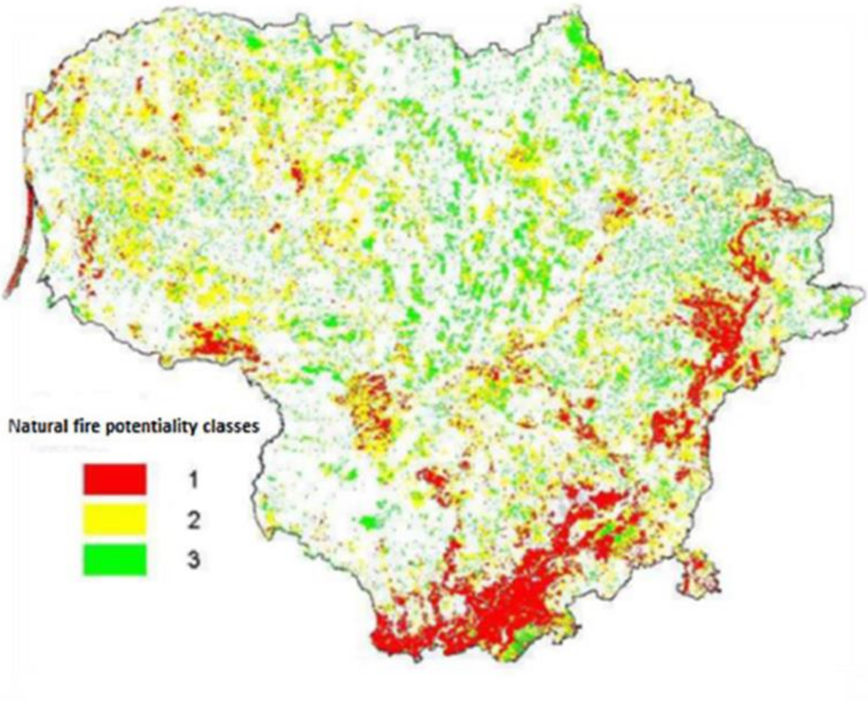


Figure 6-16. Lithuanian forests according to natural fire potentiality classes

Considering natural fire potentiality classes, which all Lithuanian forests are distributed amongst, highest number of forest wildfires also occur due to the higher natural fire potentiality class (Figure 6-17).

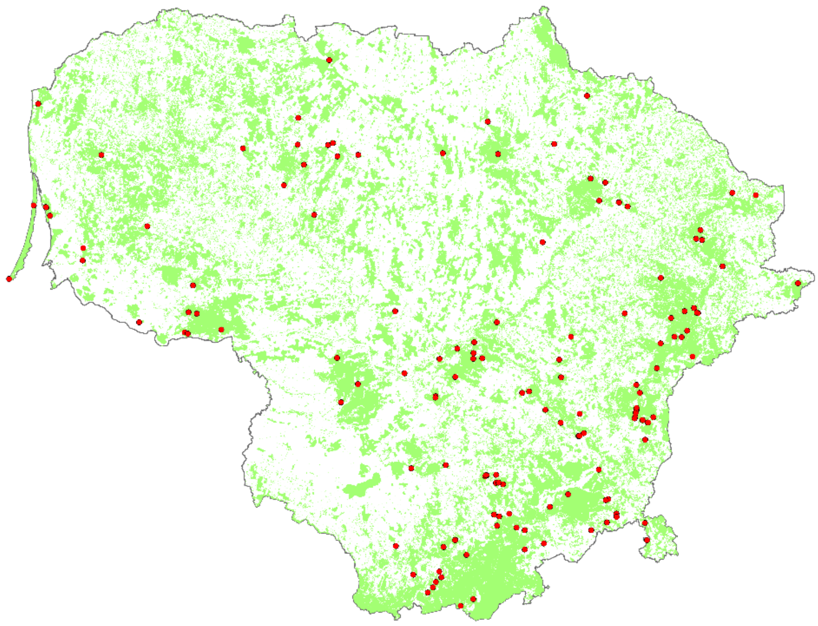


Figure 6-17. Locations of forest fires in 2020

In order to improve the GHG inventory reports under the purpose to report GHG released due to biomass burnt in forest wildfires, a unique fire assessment system has been established in Lithuania since 2013. State Forest Service together with General Directorate of State Forests has worked out a methodology to assess forest fire after-effects in terms of greenhouse gas accounting directly in situ.

Special assessment table (Table 6-13) has been established with detail information on fire. The table contains information which allows locating the event of forest fire, to determine area that was burnt and to assess damage that has been done in terms of greenhouse gases accounting. In the table below only partial information that should be filled in the forest fire assessment table is presented. The first part of this table contains information on owner of forest (State forest enterprise), unique forest fire number, date, forest district, block number, site number and coordinates.

Table 6-13. Example of fire assessment table

Area of forest fire	Type of fire	Burnt biomass (*enter code only*)*					Burnt peat (depth of burnt peat, cm)
		Merchantable wood	Dead-wood	Needles, leaves, shoots	Bark of living trees	Forest litter	

Table 6-14 listed below is presenting percentage of burnt biomass expressed by codes that are used by fire damages assessing experts from State forest enterprises or local forest districts.

Table 6-14. Codes table

Degree of burnt biomass	Intensity	Code
No burnt biomass	0%	0
Low	1-25%	1
Moderate	26-60%	2
Strong	61-99%	3
Completely burnt biomass	100%	4

Volume of burnt biomass from the area affected by forest fire is estimated by overlapping GIS layers of the center coordinate of fire location and data of the total growing stock volume and dead biomass data provided by *SFI;* afterwards burnt biomass is calculated into carbon released due to the wildfire. Burnt peat depth is expressed in centimeters of average burnt peat layer over the fire site and is estimated by persons, assessing forest fire areas. The amount of carbon released from litter and peat layer was calculated using default values of carbon in litter and peat (t/ha) from 2006 IPCC Guidelines (Vol. 4, Ch. 3, Table 3.2.1, p.3.36 and Vol. 4, Ch. 2, Table 2.3, p.2.31). Due to the lack of relevant data on biomass burnt in wildfires in 1990 - 2012, average of 2013 - 2014 mass of fuel available for combustion and combustion factor were used. Due to this evaluation, emissions from forest wildfires could be small, comparing to other years, despite the size of the area wildfire took place. Area of forest wildfires in 2016 was relatively small with much smaller proportion of biomass burnt during the wildfire, comparing to 2014, therefore amount of GHG emissions (CO_2, N_2O, CH_4) released during the forest wildfires was also small, which resulted in smaller IEF (implied emission factor in CRF) for 2016, comparing to the average.

Figure 6-18. Forest stand before and after fire

Windbreaks and windfalls

Statistical Yearbook of Forestry provides data on windbreaks and windfalls. However, according to the data collection principles used by *NFI*, volumes of windbreaks and windfalls are included in volumes of dead trees, or removals by sanitary or other fellings. Therefore, to avoid double counting, windbreaks and windfalls were not included separately in calculations for carbon losses.

Forest fertilization

Fertilization of forest land is not applicable in Lithuania. There is no available data to confirm any fertilization of forest land occurring since 1990.

Fertilization and liming of forest land is possible using biofuel ashes, but there are only several studies presented in Lithuania, evaluating impact of ashes application on forest land, however clear evidences of such application efficiency are still unknown (Ozolinčius et al., 2010).

Fertilization of forest land with other mineral fertilizers is still not economically efficient due to high prices of fertilizers and unclear benefit on forest growth in our climatic conditions.

6.2.2 Methodological Issues

6.2.2.1 Forest land remaining Forest land

The GHG inventory for Forest land remaining Forest land involves estimations of changes in carbon stock in five carbon pools (above-ground biomass, below-ground biomass, dead wood and litter, and soil organic matter) as well as estimations of non-CO_2 gases from those pools. The algorithm for assessment of carbon stock changes in carbon pools is given below:

$$\Delta C_{LU_i} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$$

where:

ΔC_{Lui} - carbon stock changes for a stratum of a land-use category;

ΔC_{AB} - annual change in carbon stock in above-ground biomass, t C yr^{-1};

ΔC_{BB} - annual change in carbon stock in below-ground biomass, t C yr^{-1};

ΔC_{DW} - annual change in carbon stock in deadwood, t C yr^{-1};

ΔC_{LI} - annual change in carbon stock in litter, t C yr^{-1};

ΔC_{SO} - annual change in carbon stock in soil, t C yr^{-1};

ΔC_{HWP} - annual change in carbon stock in harvested wood products, t C yr^{-1}.

Carbon stock changes in living biomass

Living biomass pool in greenhouse gas inventory refers to above-ground biomass and below-ground biomass. The estimation of carbon stock changes in living biomass is consistent with the Method 2 further described in the *2006 IPCC Guidelines*, which is also called as the stock change method. Estimations of carbon stock changes by using this method requires biomass carbon stock inventories for a given forest area in two points in time. Biomass change is the difference between the biomass at $time_2$ and $time_1$, divided by the number of years between the inventories, as stated in *2006 IPCC Guidelines (eq. 2.8, p. 2.12)*:

$$\Delta C_{LB} = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)} \quad \text{and} \quad C = \sum\{A_{i,j} \cdot V_{i,j} \cdot BCEF_{i,j} \cdot (1 + R_{i,j}) \cdot CF_{i,j} \quad (\textit{Eq. 2.8})$$

where:

ΔC_{LB} – annual change in carbon stock in living biomass (includes above- and belowground biomass) in total forest land, t C yr^{-1};

C_{t2} – total carbon in biomass calculated at time t_2, t C;

C_{t1} – total carbon in biomass calculated at time t_1, t C;

C – total carbon in biomass, for time t_1 to t_2

A – area of forest land remaining forest land, ha;

V – growing stock volume, m^3 ha^{-1};

i – ecological zone (ecological zones not divided)

j – climate domain (Lithuania is in one climate zone)

BCEF – biomass conversion and expansion factor for expansion of growing stock volume to above-ground biomass

R – ratio of below-ground biomass to above-ground biomass, tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$

CF – carbon fraction of dry matter (broadleaves – 0.48; coniferous – 0.51), t C (tonne d. m.)$^{-1}$, default value from *2006 IPCC* Guidelines (Vol. 4, Ch. 4, Table 4.3, p. 4.48).

BCEF = BEF · D

BEF – biomass expansion factor

D – basic wood density, t d. m. m^{-3}

Modification of the Equation 2.8 from *2006 IPCC Guidelines* is based on the decision to estimate above and below-ground biomass carbon stock changes separately, applying root-to-shoot ratio to estimate below-ground biomass carbon stock changes from above-ground biomass carbon stock changes. Annual growing stock volume (GSV) changes starting with 2003 for category Forest land remaining forest land was estimated based on *NFI* data using the following steps:

1) Annual GSV changes in all forest areas (total forest management and afforested/reforested area) are estimated using sampling method. This estimation is based on the change in GSV on the same area (re-measured permanent sample plots data $V_{rem_{t2}} - V_{rem_{t1}}$) and adding GSV increment (ΔV_{new}) of the first measurement of permanent sample plots i.e. new afforested areas or other plots which have no re-measurement data;
2) Annual GSV changes of afforested/reforested areas are estimated combining wall-to-wall and sampling methods. Area estimation is based on assessment by wall-to-wall method and mean GSV changes assessment is done using results from sampling method; average

annual GSV changes are derived using relationship between mean GSV and age of forest in permanent plots of afforested/reforested areas (Figure 11-14);

3) Estimation of annual GSV change in Forest Management area is based on the difference between all forests annual GSV changes (*step 1*) and annual GSV change of areas with natural forest expansion (*step 2*).

The equations presenting calculations on growing stock volume change in Forest land remaining Forest land are shown below:

$$\Delta FF_t = \left(\left(V_{rem_{t2}} - V_{rem_{t1}}\right)\right) - \Delta F_2$$

where:

ΔFF_t - growing stock volume change for Forest land remaining Forest land for the defined year, m^3;

V_{remt1} - growing stock volume calculated at time t_1, m^3;

V_{remt2} - growing stock volume calculated at time t_2, m^3;

ΔF_2 - growing stock volume change of new forest (land converted to forest land) areas, m^3.

Above-ground biomass

Above ground biomass refers to all living biomass above the soil including stem, stump, bark, branches, seeds and foliage. Calculation of above-ground biomass is based on volume of living trees stems with bark, basic wood density (D) and biomass expansion factor (BEF). However, *2006 IPCC* guidelines requires to use biomass conversion and expansion factor (BCEF), which is based on country specific data, but while Lithuania has no country specific values we are using previous methodology with default values to estimate above and below ground biomass.

Biomass carbon stock changes are calculated separately for above and below-ground biomass, applying root-to-shoot ratio for calculation of below-ground biomass carbon stock changes from above-ground biomass carbon stock changes. Basic wood density (D) was estimated on the basis of data provided in Table 4.14 of the *2006 IPCC Guidelines* (p. 4.71). Density values for coniferous and deciduous were calculated using species values as weighted average values related to GSV (Table 6-14).

Above ground biomass was calculated for broadleaves and coniferous separately. For the period of 2003-2020 growing stock volume data of *NFI* was used, and for the period of 1990-2002 mean value for the known time period was used.

Table 6-14. Total growing stock volume (NFI, 2020) and average basic wood density values

Species	**Total growing stock volume (mill m^3).**	**Basic wood density, tonnes d. m. m^{-3}**	
		By species	**Weighted average**
Pine	229.8	0.42	
Spruce	101.0	0.40	
Total coniferous	**330.8**		**0.41**
Birch	87.3	0.51	
Aspen	37.1	0.35	
Black alder	56.5	0.45	
Grey alder	24.3	0.45	

Oak	12.5	0.58	
Ash	2.0	0.57	
Other deciduous	9.0		
Total deciduous	**228.7**		**0.47**
Overall total	**559.6**		**0.44**

Default values of biomass expansion factor (BEF) for conversion of tree stems volume with bark to above-ground tree biomass were estimated using national tables of merchantable wood volume (for branches) and leaves-needles biomass data by Usolcev (Усольцев, В. А. 2001; 2002; 2003). Rate of BEF for coniferous was estimated to be 1.221 and 1.178 for deciduous. The rates of BEF · D estimated for Lithuania are very close to the BCEF rates presented in *2006 IPCC Guidelines* in Table 4.5 (p. 4.50), what shows the consistency between the chosen methods.

Below-ground biomass

Below-ground biomass refers to all living biomass, which is live roots. Biomass carbon stock changes are calculated separately for above and below-ground biomass, applying root-to-shoot ratio for calculation of below-ground biomass carbon stock changes from above-ground biomass carbon stock changes. Default values of root-to-shoot ratios R were estimated using data of Usolcev and Table 4.4 (*2006 IPCC*, p. 4.49): for coniferous – 0.26; for deciduous – 0.19.

Carbon fraction of dry matter

Carbon fraction (CF) value of above ground forest biomass for broadleaves forest equal to 0.48 tonne C (tonne d. m.)$^{-1}$ and 0.51 tonne C (tonne d. m.)$^{-1}$ for coniferous, provided in the *2006 IPCC Guidelines* (Table 4.3, p. 4.48), was used for estimation of CF in dry biomass matter.

Carbon stock change in dead organic matter

For the greenhouse gas inventory Lithuania defines dead organic matter (DOM) as it is described in *2006 IPCC Guidelines* (Ch. 4.2.2), which provides two types of dead organic matter pools: dead wood and litter.

Annual change in carbon stocks in dead organic matter in Forest Land remaining Forest Land is calculated following the summarizing equation for calculation of changes in dead organic matter carbon pools which is equal to the sum of carbons stock in dead wood (measured available dead wood) and carbon stock in dead wood that is left on site after fellings (BGB). Dead wood that is left on site after fellings is assumed to be below-ground biomass which is roots. After a tree is felled, its volume is removed from total living trees volume in forest land and, if its stump is left on site, its below ground biomass is included as input to the total dead wood mass. Afterwards, for each of the subsequent 5 years, 1/5 of this belowground biomass is reported as emissions due to the decay process and therefore it is assumed that BGB decays in equal parts in 5 years. Equation. 2.17 (p. 2.21) of *2006 IPCC Guidelines* has been used to calculate carbon stock change in dead organic matter:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

where:

ΔC_{DOM} - annual change in carbon stocks in dead organic matter, t C yr^{-1};

ΔC_{DW} - change in carbon stocks in dead wood (measured dead stems and below-ground biomass left on site after fellings), t C yr^{-1};

ΔC_{LT} - change in carbon stocks in litter, t C yr^{-1}.

Lithuania assumes that there are no changes in carbon stocks in litter in forest land remaining forest land, assuming that the amount of litter after the conversion period in forest remains stable and applies Tier 1 methodology provided in 2006 IPCC Guidelines. Notation key „NA“ is used in the CRF.

Annual change of biomass of dead trees stems is calculated by using stock change method and employing Equation 2.19 (p. 2.23) of *2006 IPCC Guidelines*:

$$\Delta C_{FF_{DW}} = \left[\frac{A \cdot (B_{t_2} - B_{t_1})}{T}\right] \cdot CF$$

where:

ΔC_{FFDW} - annual change in carbon stocks in dead wood in forest land remaining forest land, t C yr^{-1};

A - area of forest land remaining forest land, ha;

B_{t1} - dead wood stock at time t_1 for forest land remaining forest land, t d. m. ha^{-1};

B_{t2} - dead wood stock at time t_2 (the second time) for forest land remaining forest land, t d. m. ha^{-1};

$T (= t_2 - t_1)$ - time period between time of the second stock estimate and the first stock estimate, yr.;

CF - carbon fraction in dry biomass matter (broadleaves – 0.48; coniferous – 0.51), tonnes C (tonne d. m.)$^{-1}$ (*2006 IPCC Guidelines*, Table 4.3, p. 4.48).

$$\Delta C_{FF_{DW}} = \frac{\Delta B}{T} \cdot CF$$

where:

ΔC_{FFDW} - annual change in carbon stocks in dead wood in forest land remaining forest land, t C yr^{-1};

ΔB - dead wood stock change for forest land remaining forest land, t d. m. ha^{-1};

$T (= t_2 – t_1)$ - time period between time of the second stock estimate and the first stock estimate, yr.;

CF - carbon fraction in dry biomass matter (broadleaves – 0.48; coniferous – 0.51), tonnes C (tonne d. m.)-1 (*2006 IPCC Guidelines*, Table 4.3, p. 4.48).

$$\Delta B = B_{t_2} - B_{t_1}$$

where:

ΔB - dead wood stock change for forest land remaining forest land, t d. m. ha^{-1};

B_{t1} - dead wood stock at time t_1 for forest land remaining forest land, t d. m. ha^{-1};

B_{t2} - dead wood stock at time t_2 (the second time) for forest land remaining forest land, t d. m. ha^{-1}.

$$B_t = AGB + BGB$$

where:

AGB - above-ground biomass in dead wood stems, t d. m.;

BGB - below-ground biomass (dead wood biomass left after fellings - roots), t d. m.

$$AGB = V_{dw} \cdot D \cdot BEF$$

where:

V_{dw} - available dead wood volume, m^3;

D - basic wood density, t d. m. m^{-3};

BEF - biomass expansion factor.

Available dead wood volume consists of volume of dead stems and roots left after fellings. Dead stems are inventoried during NFI field measurements and carbon stock changes in this pool are calculated similarly to living biomass carbon stock change. Dead wood left on site after fellings are estimated using NFI field measurements of stumps, which previously were inventoried as living trees, previous volume of living trees (which are now harvested) are used to estimate below ground biomass. According to the IPCC 2003 Guidelines for LULUCF, p. 3.38, dead wood left on site after fellings (roots) decay in 5 years, therefore for the calculation of changes in below-ground biomass of dead wood left on site after fellings, for each of the sequent years after harvesting below-ground biomass is reduced by 1/5.

$$BGB = AGB \cdot R$$

where:

AGB - above-ground biomass, t d. m.;

R - root-to-shoot ratio, dimensionless.

Carbon stock change in soil organic matter

Lithuania does not report on changes in organic carbon stock change in mineral soils in forest land remaining forest land. Due to the study performed by the European Union all over its territory, the BioSoil project, shows for Lithuanian forests a slight, but not significant, increase in soil carbon stocks from 1998 to 2006 (EU-JRC, Evaluation of BioSoil Project).

Table 6-14. Mean carbon stock in forest land according to the soil monitoring in ICP-Forest sample plots *Level I* in 1998 and 2006

Year	Mean carbon stock in litter, g C/kg	Mean carbon stock in mineral soil (0-10 cm depth),g C/kg	Mean carbon stock in mineral soil (10-20 cm depth), g C/kg	Research activity
1998	370,69 ±12,8	29,1 ±4,4	15,6 ±2,8	Soil monitoring in IPC-Forests Level I sample plots (Armolaitis et al., 2001)

2006	399,0 ±96,6	29,9 ±18,2	15,8 ±11,6	Soil monitoring in IPC-Forests Level I sample plots during BioSoil project (Kuliešis et al., 2009)

Due to the abovementioned information, Lithuania has decided do not account for carbon stock changes in mineral soils in forest land remaining forest land, therefore reported as NE in CRF Table 4.A.1.

Lithuania reports carbon stock changes in soil organic matter occurring due to the drainage of organic forest soils. Carbon stock change in drained organic forest soils was calculated using Equation 2.26 (p. 2.35 of *2006 IPCC Guidelines*):

$$L_{Organic} = A_{Drainage} \cdot EF_{Drainage}$$

where:

$L_{Organic}$ - carbon loss from drained organic forest soils, t C yr^{-1};

$A_{Drainage}$ - area of drained organic forest soils, ha;

$EF_{Drainage}$ - emission factor for CO_2 from temperate climate zone forest soils, t C ha^{-1} yr^{-1}.

Default value of emission factor for drained organic soils in managed forests provided in Table 4.6 (p. 4.53 of *2006 IPCC Guidelines*) was used in calculations. Default $EF_{Drainage}$ for temperate forests is 0.68 tonnes C ha^{-1} yr^{-1}.

Carbon stock changes in organic soils in forest land remaining forest and land converted to forest land are estimated due to the drainage of organic soils and are therefore included in CRF Table 4 (II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils, reported as IE in CRF Tables 4.A.1 and 4.A.2.

Non-CO_2 emissions from drainage of forest soils

For estimation of non-CO_2 emissions from drained forest soils Lithuania uses default Tier 1 method. Tier 1 Equation 11.1 (p. 11.7 of *2006 IPCC Guidelines,* which is equal to Equation 2.26 p. 2.35 of *2006 IPCC Guidelines*) is applied with a simple disaggregation of drained forest soils into nutrient rich and nutrient poor areas and default emission factors are used.

$$N_2O_{emissions_{FF}} = \sum ((A_{FF_{organic\,IJK}} \cdot EF_{FF_{drainage,\ organic\,IJK}}) + (A_{FF_{mineral}} \cdot EF_{FF_{drainage,\ mineral}})) \cdot \frac{44}{28}$$

where:

N_2O *emissions* $_{FF}$ - annual emissions of N_2O from managed organic soils, kg N_2O yr^{-1};

$A_{FF_{organic}}$ - area of drained forest organic soils, ha;

$A_{FF_{mineral}}$ - area of drained forest mineral soils, ha;

$EF_{FF_{drainage,\ organic}}$ -emission factor for drained forest organic soils, kg N_2O-N ha^{-1} yr^{-1};

$EF_{FF\ drainage,\ mineral}$ - emission factor for drained forest mineral soils, kg N_2O-N ha^{-1} yr^{-1};

IJK - soil type, climate zone, intensity of drainage, etc. (depends on the level of disaggregation).

NFI provides data on forest land distribution by forest soils (Table 6-7). According to the most recent *NFI* data *(NFI 2014 - 2018)*, area of mineral soils amounts to 86.4 % and area of organic soils – 13.6 % of the total forest area. Drained organic forest soils constitute to 6.9% of the total forest land. This area consists of 2.2 % infertile and 4.7 % of fertile drained organic forest soils. Area of lands converted to Forest land was also included into estimations.

Lithuania is using default emission factors from *2006 IPCC Guidelines* (Table 11.1, p. 11.11, Ch. 11.2 of *2006 IPCC Guidelines*) for N_2O emission estimation due to the drainage of organic soils:

- $EF_{FF_{drainage}, organic}$ for nutrient rich forest soils - 0.6 kg N_2O-N ha^{-1} yr^{-1}
- $EF_{FF_{drainage}, organic}$ for nutrient poor forest soils - 0.1 kg N_2O-N ha^{-1} yr^{-1}

However, currently due to the lack of data and sufficient knowledge to provide default equations for Tier 1 method of other non-CO_2 greenhouse gases emission, only N_2O emissions are accounted.

Lithuania has no data on drained mineral forest soils (no drainage of mineral soils occurred in forest land), therefore emissions or removals from drained mineral forest soils are not estimated. In the emissions and removals estimation of drained organic forest soils areas of land converted to forest land are also included.

Biomass Burning

There is no prescribed biomass burning in Lithuania therefore only the events of forest wildfires are reported. Data on areas affected by forest fires on areas under the category Forest land remaining Forest land is provided by the *DGSF*. However, data on wildfires on lands converted to Forest land is not so accurate, therefore Lithuania, following recommendations made by ERT 2012, subdivides the total forest area burnt on the basis of the proportional contribution of each category to the total forest land area.

Carbon release from burnt biomass was calculated using Equation. 2.27 (p. 2.42 of *2006 IPCC Guidelines*):

$$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3}$$

where:

L_{fire} - quantity of GHG released due to fire, t of GHG;

A - area burnt, ha;

M_B - mass of 'available' fuel, tonnes ha^{-1};

C_f - combustion factor (or fraction of biomass combusted), dimensionless;

G_{ef} - emission factor, g (kg d. m.)$^{-1}$.

M_B value of 54.4 t/ha for 1990-2012 has been used, being estimated annually afterwards due to findings resulting from national forest fire assessment project: 71.6 t/ha for 2013, 52,7 t/ha for 2014, 64,2 t/ha for 2015, 63.5 t/ha for 2016, 81.1 for 2017, 70.9 for 2018, 76.37 for 2019 and 73.81 for 2020. C_f equals to 0.57 for 1990-2012 period and has been estimated annually afterwards: 0.11 for 2013, 0.67 for 2014, 0.18 for 2015, 0.18 for 2016, 0.11 for 2017, 0.19 for 2018, 0.29 for 2019 and 0.28 for 2020. Lithuanian forestry data and data of biomass burnt in forest wildfires were used. MB value is calculated using data from National Forest Inventory on mean growing stock volume (present before wildfire) and mean dead wood volume in country in the particular year; also national carbon stock value in litter. Cf is calculated as a ratio from mass of fuel available for combustion (MB) and actually burnt amount (living biomass, dead wood and litter), which is calculated from forest assessment data, collected by State Forest Enterprise.

Average values of emission factor G_{ef} for CO_2, N_2O and CH_4 gases were calculated based on the values presented in the Table 2.5 (p. 2.47 of the *2006 IPCC Guidelines*) and are equal to:

- CO_2 – 1,569 g (kg d. m.)$^{-1}$;
- CH_4 – 4.7 g (kg d. m.)$^{-1}$;
- N_2O – 0.26 (kg d. m.)$^{-1}$.

6.2.2.2 Land converted to Forest land

Land use area calculations of Land converted to Forest land are further described in chapter 6.2.1. The total area of land converted to Forest land between 1990 and 2020 were computed by using sample plots data of *NFI*.

The land-use categories from which areas have been converted to Forest land are the following: Croplands, Grasslands, Wetlands, Settlements and Other land.

Yearly land transition matrixes of conversions from one land use category to Forest land were created based on year of the conversion and the category converted.

Carbon stock changes in living biomass

For the estimation of carbon stock changes in living biomass, growing stock volume of Lands converted to Forest land was estimated using data of *NFI* permanent sample plots on mean growing stock volume of non-forest Lands converted to Forest land according to the year of conversion (Figure 6-19). Growing stock volume estimation for new measured sample plots (natural afforestation/reforestation) is executed using annual area of land converted to forest land, distributed according to the number of years after conversion, and modelled mean growing stock volume change for each of the abovementioned land converted to forest land group. 2nd order polynomial trend was used to come up with mean growing stock volume and mean growing stock volume increment of lands converted to Forest land. It means that each year growing stock volume change, corresponding to the number of years after conversion, is attributed to the same area identified in corresponding year. Use of modelled growing stock volume change for each of the groups of land converted to forest land, according to the years after conversion, was introduced in order to avoid changes in area where growing stock volume change was identified. It should be noted, that according to definition of forest in Lithuania, stands are becoming forest when reaching certain requirements for forest (e.g. age), therefore mean growing stock volume for lands converted to forest at year 1 are not equal to zero, because it is more likely that these stands will contain growing stock volume accumulated in stands for 10 or more years (presumed time-frame for reaching certain requirements for forest) (Table 6-16).

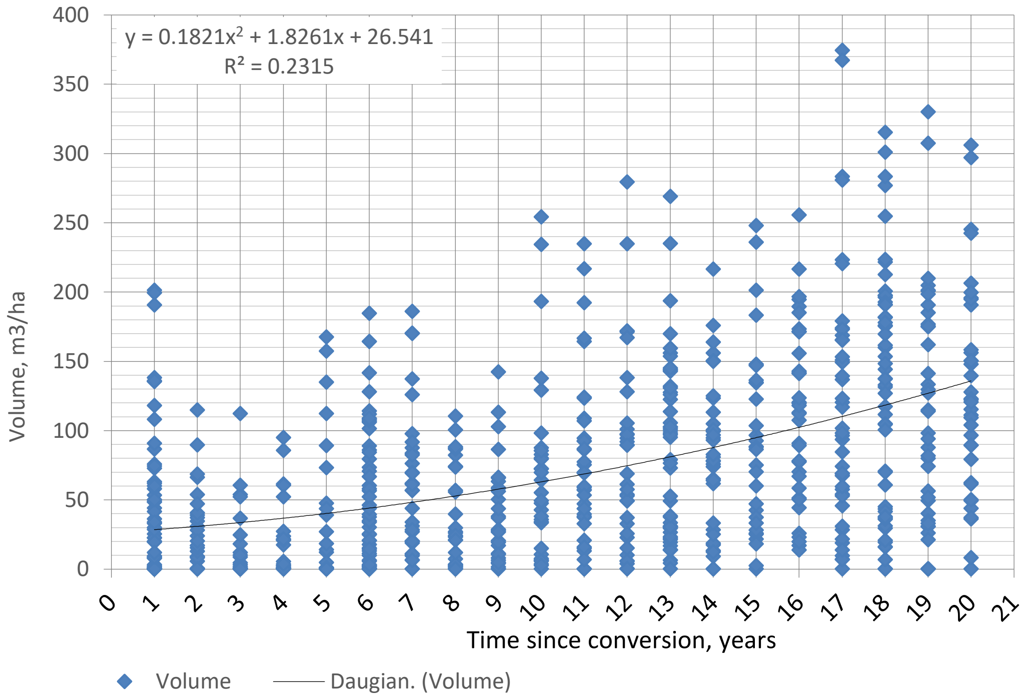


Figure 6-19. NFI data on growing stock volume of non-forest lands converted to forest land at the year of conversion to Forest land

Table 6-16. Mean GSV and GSV increment based on NFI data on lands converted to Forest land at the year of conversion

Year after conversion	Mean growing stock volume, m³/ha	Growing stock volume change, m³/ha
1	28.5	2.0
2	30.9	2.4
3	33.7	2.7
4	36.8	3.1
5	40.2	3.5

6	44.1	3.8
7	48.2	4.2
8	52.8	4.6
9	57.7	4.9
10	63.0	5.3
11	68.7	5.7
12	74.7	6.0
13	81.1	6.4
14	87.8	6.7
15	94.9	7.1
16	102.4	7.5
17	110.2	7.8
18	118.4	8.2
19	127.0	8.6
20	135.9	8.9

GSV change for land converted to Forest land was estimated by using equation presented below:

$$\Delta V = \sum \left(A_i \cdot (V_{t_2} - V_{t_1}) \right)$$

where:

ΔI - GSV change on land converted to Forest land, m^3;

A_i - area according to land use category, ha;

V_{t1} - GSV at time t_1, m^3;

V_{t2} - GSV at time t_2, m^3.

Annual change in carbon stocks in living biomass in land converted to Forest land was calculated by using Equation. 2.15 (p. 2.20 of *2006 IPCC Guidelines*):

$$\Delta C_B = \Delta C_G + \Delta C_{Conversion} - \Delta C_L$$

where:

ΔC_B - annual change in carbon stocks in living biomass in land converted to forest land, tonnes C yr^{-1};

ΔC_G - annual increase in carbon stocks in living biomass due to growth in land converted to forest land, tonnes C yr^{-1};

$\Delta C_{Conversion}$ - annual change in carbon stocks in living biomass due to actual conversion to forest land, tonnes C yr^{-1};

ΔC_L - annual decrease in carbon stocks in living biomass due to losses from harvesting, fuel wood gathering and disturbances in land converted to forest land, tonnes C yr^{-1}.

Annual change in carbon stocks in living biomass due to actual conversion to forest land was calculated employing Equation 2.16 (p. 2.20 of *2006 IPCC Guidelines*):

$$\Delta C_{Conversion} = \sum_i \left\{ \left[B_{After_i} - B_{Before_i} \right] \cdot \Delta A_{To\ forest_i} \right\} \cdot CF$$

where:

$\Delta C_{Conversion}$ - change in carbon stocks in living biomass in land annually converted to forest land, tonnes C yr^{-1};

$B_{Beforei}$ - biomass stocks on land type *i* immediately before conversion, tonnes d. m. ha^{-1};

B_{Afteri} - biomass stocks that are on land immediately after conversion of land type *i*, tonnes d. m. ha^{-1} (in other words, the initial biomass stock after artificial or natural regeneration);

$\Delta A_{To\ foresti}$ - area of land-use i annually converted to forest land, ha yr^{-1};

CF - carbon fraction of dry matter (broadleaves – 0.48; coniferous – 0.51), tonnes C (tonne d. m.)$^{-1}$ (Table 4.3, p. 4.48 of *2006 IPCC Guidelines*);

I - represent different types of land converted to forest.

B_{After} -value was modelled by using Figure 6-28.

Above-ground biomass

Above ground biomass refers to all living biomass above the soil including stem, stump, bark, branches, seeds and foliage. Calculation of above-ground biomass is based on volume of living trees stems with bark, basic wood density and biomass expansion factor. However, *2006 IPCC Guidelines* requires to use biomass conversion and expansion factor (BCEF), which is based on country specific data, but while Lithuania has no country specific values we are using previous methodology to estimate above and below ground biomass. Above-ground biomass is calculated applying Equation. 2.8, (p. 2.12 of *2006 IPCC Guidelines*), as described in section 6.2.2.1 for Forest land remaining Forest land.

Default values of biomass expansion factor (BEF) for conversion of tree stems volume with bark to above-ground tree biomass were estimated using NFI data of stems volume (NFI 2003 - 2007), national tables of merchantable wood volume (for branches) and leaves-needles biomass data by Usolcev (Усольцев, В. А. 2001; 2002; 2003). Rate of BEF for coniferous was estimated to be 1.221 and 1.178 for deciduous. The rates of BEF · D estimated for Lithuania are very close to the BCEF rates presented in Table 34.5 (p. 4.50 of *2006 IPCC Guidelines*), what is showing the consistency between the chosen methods.

Below-ground biomass

Below ground biomass refers to all living biomass of live roots. Below-ground biomass is calculated by using Equation 2.8 (p. 2.12 of *2006 IPCC Guidelines*), as described in section 6.2.2.1 for Forest land remaing Forest land, which requires data for above-ground biomass and root-to-shoot ratio. Default values of root-to-shoot ratios R were estimated using data of Usolcev and Table 4.4 (p. 4.49 of *2006 IPCC*): for coniferous – 0.26, for deciduous – 0.19.

Carbon fraction of dry matter

Default value of carbon fraction for broadleaves – 0.48 and coniferous – 0.51, tonnes C (tonne d. m.)$^{-1}$, as provided in *2006 IPCC Guidelines* (Table 4.3, p. 4.48) was used for estimation of carbon fraction (CF) in dry biomass matter.

Change in carbon stock in dead organic matter

Lithuania is applying Tier1 assumption from the *2006 IPCC Guidelines* (p. 4.36, Ch. 4, Vol. 4), which states that carbon stocks in dead wood and litter pools in non-forest land are zero (except for grassland), and that carbon in dead organic matter pools increases linearly to the value of mature forests over a specified time period. Due to the applied Tier1 assumption, Lithuania is also using a default 20 years period for litter accumulation in land converted to forest land category and afforestation/reforestation activity. Annual carbon stock changes in litter in land converted to forest land were estimated using national values of litter carbon stock, evaluated during the study conducted by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the GHG inventory partnership project between Lithuania and Norway. The average value of carbon stock in litter is 1.2 t per ha per 10 years (after the conversion from agricultural land, with no litter carbon stock was measured in cropland while in grassland litter carbon stock is estimated to be 0.4 t C per ha in litter) and 2.5 t C per ha in 20 years.). Annual carbon stock change in litter in land converted to forest land was estimated for two time periods: 0-10 years - (1.2 t C ha^{-1} /10 years (- 0.4 t C ha^{-1} in the first year for grassland converted to forest land); 11-20 years - (2.5 t C ha^{-1} - 1.2 t C ha^{-1})/10 years. Change in carbon stock in litter in land converted to Forest land was calculated using area from annual land use conversion to forest land matrix.

For Land converted to Forest Land it was assumed that there is no dead wood at the moment of conversion. After conversion, accumulated dead wood equals to the amount of dead wood used for biomass use, decayed, etc., therefore no carbon stock changes in dead wood in Land converted to Forest land are reported. After the conversion period dead wood starts to accumulate and carbon stock changes in dead wood is reported in Forest Land remaining Forest Land (after land is converted to permanent forest land).

Change in carbon stock in soil organic matter

Mineral soils

NFI provides data on forest land distribution by forest soils (Table 6-7). According to the most recent *NFI (NFI 2014 - 2018)* data, area of mineral soils amounts to 86.4 % and area of organic soils – 13.6% of the total forest area. Drained organic forest soils constitute to 6.9% of the total forest land. Due to the lack of accurate data on drained organic soils in land converted to Forest land, it was assumed that the same proportion of drained organic soils as it is accepted for Forest land remaining Forest land category refers also to lands converted to Forest land.

In 2016 Lithuanian Forest Research Institute carried out several studies regarding carbon stocks and carbon stock changes in different land-use categories, carbon stocks in mineral soils of cropland, grassland and newly afforested areas were estimated as a result. National carbon stock values in cropland, grassland and newly afforested/reforested areas were used for carbon stock changes estimation in mineral soils.

Calculations were based on Equation 2.25 (p. 2.30, Ch. 2 of *2006 IPCC Guidelines*). Country-specific C stocks were developed using the national C stock estimates in different land uses established by Lithuanian Forest Research Institute. The default 20 year time period for stock changes was used for calculations.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

where

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1}

SOC_0 - soil organic carbon stock in final land use category (forest land), tonnes C

$SOC_{(0-T)}$ - soil organic carbon stock in initial land use category (grassland and cropland), tonnes C.

SOC_0 equals 55.3 t C ha^{-1} for forests in age group of 0 to 10 years and 58.8 t C ha^{-1} for forests in age group of 11 to 20 years, the initial values of carbon stocks in grassland before conversion to cropland equals to 48.3 t C ha^{-1} and 38.2 t C ha^{-1} in cropland.

Organic soils

Carbon stock change in drained organic forest soils was calculated using Equation. 2.26 (p. 2.35 of *2006 IPCC Guidelines*):

$$\Delta C_{FOS} = A_{Drainage} \cdot EF_{Drainage}$$

where:

ΔC_{FOS} - CO_2 emissions from drained organic forest soils, t C yr^{-1};

$A_{Drainage}$ - area of drained organic forest soils, ha;

$EF_{Drainage}$ - emission factor for CO_2 from drained organic forest soils, t C ha^{-1} yr^{-1}.

Default value of emission factor for drained organic soils in managed forests provided in Table 4.6 (p. 4.53 of *2006 IPCC Guidelines*) was used in calculations. Default $EF_{Drainage}$ for temperate forests is 0.68 tonnes C ha^{-1} yr^{-1}.

Carbon stock changes in organic soils in land converted to forest land are estimated due to the drainage of organic soils and are therefore included in CRF Table 4 (II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils, reported as IE in CRF Table 4.A.2.

Biomass Burning

Data on areas affected by forest fires on areas under the category Forest land remaining Forest land is provided by the *DGSF*. However, data on wildfires on lands converted to Forest land is not so accurate, therefore Lithuania, following recommendations made by ERT 2012, subdivides the forest area burned on the basis of the proportional contribution of each category to the total forest land area.

Carbon release from burnt biomass on lands converted to Forest land was calculated using the same methodology as it was used for Forest land remaining Forest land and employing Equation 2.27 (p. 2.42 of *2006 IPCC Guidelines*):

$$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3}$$

where:

L_{fire} - quantity of GHG released due to fire, t of GHG;

A - area burnt, ha;

M_B - mass of 'available' fuel, tonnes. ha^{-1};

C_f - combustion factor (or fraction of biomass combusted), dimensionless;

G_{ef} - emission factor, g (kg d. m.)$^{-1}$.

M_B value of 54.4 t/ha for 1990-2012 has been used, being estimated annually afterwards due to findings resulting from national forest fire assessment project: 71.6 t/ha for 2013, 52,7 t/ha for 2014, 64,2 t/ha for 2015, 63.5 t/ha for 2016, 81.1 for 2017, 70.9 for 2018, 76.37 for 2019 and 73.81 for 2020. C_f equals to 0.57 for 1990-2012 period and has been estimated annually afterwards: 0.11 for 2013, 0.67 for 2014, 0.18 for 2015, 0.18 for 2016, 0.11 for 2017, 0.19 for 2018, 0.29 for 2019 and 0.81 for 2020. Lithuanian forestry data and data of biomass burnt in forest wildfires were used. MB value is calculated using data from National Forest Inventory on mean growing stock volume (present before wildfire) and mean dead wood volume in country in the particular year; also national carbon stock value in litter. Cf is calculated as a ratio from mass of fuel available for combustion (MB) and actually burnt amount (living biomass, dead wood and litter), which is calculated from forest assessment data, collected by State Forest Enterprise.

Average values of emission factor G_{ef} for CO_2, N_2O and CH_4 gases were calculated based on the values presented in the Table 2.5 (p. 2.47 of *2006 IPCC Guidelines*) and are equal to:

- CO_2 – 1,569 g (kg d. m.)$^{-1}$;
- CH_4 – 4.7 g (kg d. m.)$^{-1}$;
- N_2O – 0.26 g (kg d. m.)$^{-1}$.

Non-CO_2 emissions from drainage of forest soils

Non-CO_2 emissions from drainage of lands converted to forest land were included into calculations of non-CO_2 emissions of Forest land remaining Forest land.

6.2.3 Quantitative overview of carbon emissions/removals from the sector

The total area of forest land, Forest Land remaining Forest Land, and area of Land converted to Forest Land are provided in the Table 6-17 below.

Table 6-17. Forest land area changes (cumulative) during the period 1990-2020, thous. ha

Year	Forest land	Forest land remaining Forest land	Land converted to Forest land					
			Cropland	Grassland	Wetlands	Settlements	Other land	Total land converted to Forest land
1990	2,054.2	1,953.5	0.4	65.1	33.9	0.0	1.2	100.6
1995	2,077.3	1,969.9	2.4	68.3	34.3	0.8	1.6	107.4
2000	2,096.1	1,995.9	4.0	62.7	30.3	0.8	2.4	100.2
2005	2,122.4	2,017.8	6.4	69.5	25.2	1.2	2.4	104.6
2010	2,154.0	2,051.0	11.2	70.3	18.4	1.2	2.0	103.0
2015	2,197.1	2,074.5	16.4	85.9	17.6	1.2	1.6	122.6
2016	2,202.3	2,078.1	16.4	87.1	18.0	1.2	1.6	124.2
2017	2,210.3	2,081.3	16.0	90.2	20.0	1.2	1.6	129.0
2018	2,212.3	2,082.5	16.0	91.0	20.4	1.2	1.2	129.8
2019	2,215.1	2,085.3	15.6	92.2	19.6	1.2	1.2	129.8
2020	2,222.3	2,089.3	16.0	95.8	19.2	1.2	0.8	133.0

Carbon stock change in living biomass

Area and growing stock volume in Forest Land remaining Forest Land was increasing annually since 1990 to 2020 except 1996 when total growing stock volume resulted in losses comparing to previous years due to spruce dieback (Table 6-18). Area of land converted to forest land was decreasing from 1993 to 2003, afterwards starting to stable increase annually, despite the exceptions in 2009 and 2010. The changes of growing stock volume are also related to area changes in Land converted to Forest Land.

Table 6-18. Growing stock volume in Forest Land remaining Forest Land and Land converted to Forest Land categories

Year	Forest land remaining forest land			Land converted to forest land			Total, thous. m^3
	Coniferous thous. m^3	Deciduous, thous. m^3	Total, thous. m^3	Coniferous thous. m^3	Deciduous, thous. m^3	Total, thous. m^3	
1990	223,353.14	167,242.48	390,595.61	943.50	5,767.28	6,710.78	6,100.88
1995	237,646.04	177,512.73	415,158.76	1,084.76	6,630.71	7,715.47	2,862.97
2000	249,377.06	186,167.03	435,544.09	805.83	6,809.91	7,615.74	7,218.37
2005	263,366.74	195,788.13	459,154.87	1,050.95	6,889.18	7,940.13	1,300.37
2010	284,846.20	202,453.76	487,299.97	841.57	6,143.75	6,985.31	9,668.99
2015	311,561.38	217,816.39	529,377.77	832.49	6,835.37	7,667.86	8,158.07
2016	315,243.43	219,561.40	534,804.83	865.94	7,024.52	7,890.46	5,649.66
2017	319,387.79	218,838.81	538,226.59	1,060.03	7,221.56	8,281.59	3,812.90
2018	325,061.93	218,536.73	543,598.65	1,280.32	7,344.95	8,625.27	5,715.74
2019	329,767.21	220,767.39	550,534.60	1,222.99	7,771.70	8,994.69	7,305.37
2020	333,091.24	224,300.96	557,392.20	1,323.91	7,901.88	9,225.79	7,088.69

The total living biomass was fluctuating in Forest land remaining Forest Land from -860.7 thous. t d. m. (1996) up to 5,101.40 thous. t d. m. (2011) during the period of 1990-2020. Living biomass losses of 860.7 thous. t d. m. were inventoried in 1996, caused by huge areas of spruce dieback. The mean value of annual carbon stock change is about 1,565.8 kt in forest land remaining forest land. The largest living biomass decrease for Land converted to Forest land was observed in 1999-2003 and 2008-2011. This is related to decrease in area of Lands converted to Forest Land category. The carbon stock change values are varying between 164.33 and 226.33 kt per year in land converted to forest land (Table 6-19).

Table 6-19. Annual carbon stock change due to living biomass change in Forest Land (emissions – negative sign, removals – positive sign)

Year	Forest land remaining forest land				Land converted to forest land (≤ 20 years stands)				Total Carbon stock change, kt
	Above-ground biomass stock change, kt d. m.	Below-ground biomass stock change, kt d. m.	Total living biomass stock change, kt d. m.	Carbon stock change, kt	Above-ground biomass stock change, kt d. m.	Below-ground biomass stock change, kt d. m.	Total living biomass stock change, kt d. m.	Carbon stock change, kt	
1990	3,076.11	704.08	3,780.19	1,879.09	283.14	56.35	339.49	163.83	2,042.92
1995	1,377.13	317.19	1,694.32	843.26	324.65	64.61	389.26	188.43	1,031.69
2000	4,054.57	925.65	4,980.21	2,474.35	318.43	62.66	381.09	184.08	2,658.44
2005	1,100.98	298.49	1,399.48	719.97	324.02	64.31	388.34	187.89	907.86
2010	3,722.15	887.48	4,609.64	2,309.97	291.28	57.59	348.87	168.67	2,478.64
2015	3,160.70	760.33	3,921.03	1,968.38	327.73	64.54	392.27	189.52	2,157.90
2016	2,779.84	674.01	3,453.86	1,736.61	337.97	66.59	404.56	195.47	1,932.08
2017	2,723.19	659.29	3,382.48	1,700.20	353.49	70.06	423.56	204.87	1,905.08
2018	2,578.09	619.27	3,197.36	1,604.63	366.69	73.17	439.85	213.02	1,817.64
2019	2,349.30	567.48	2,916.79	1,465.46	381.20	75.75	456.95	221.13	1,686.59
2020	2,182.80	528.92	2,711.73	1,363.29	389.82	77.66	467.48	226.33	1,589.62

Carbon stock change in dead organic matter

Dead wood is inventoried for Forest Land remaining Forest Land, as it is assumed that before the end of conversion period (Land converted to forest land category) dead wood accumulation is insignificant and therefore reported as NO. Dead wood pool not only includes dead trees biomass (above and below-ground), but also below-ground biomass which has left on site during forest fellings (stumps and roots of felled trees). Above-ground biomass of dead wood which is available during forest fellings is assumed to be removed. Table 6-20 provides values of stock change in biomass and carbon stock change in dead wood. The data represents tendency of annual accumulation of dead wood in forest land since 1990 to 2020.

Table 6-20. Annual carbon stock change in Forest Land remaining Forest Land due to change in dead organic matter

Year	Dead wood				Dead wood from forest fellings		Total carbon stock change in dead organic matter, kt
	Above-ground biomass stock change, kt d. m.	Below-ground biomass stock change, kt d. m.	Total biomass stock change, kt d. m.	Carbon stock change, kt	Below-ground biomass stock change, kt d. m	Carbon stock change, kt	
1990	113.52	28.78	142.30	72.20	114.17	57.08	129.28
1995	354.00	92.90	446.90	228.36	430.75	215.37	443.73
2000	-111.20	-28.37	-139.57	-70.91	17.36	8.68	-62.22
2005	497.22	107.46	604.68	297.26	39.75	19.87	317.14
2010	449.75	97.90	547.65	269.59	-144.97	-72.48	197.11
2015	34.03	11.31	45.34	24.38	108.00	54.00	78.38
2016	-17.37	0.13	-17.24	-6.43	175.24	87.62	81.19
2017	-17.39	3.56	-13.83	-2.94	163.81	81.90	78.97
2018	70.11	25.28	95.38	52.24	187.59	93.79	146.03
2019	96.59	30.00	126.59	67.05	104.91	52.45	119.51
2020	313.42	70.55	383.97	190.24	39.90	19.95	210.19

Dead wood biomass changes as well as carbon stock in dead wood biomass changes depend on the rate of felling in each year, therefore total carbon stock changes vary from -134.94 kt C to 443.73 kt C.

Carbon stock change in soil

Data on organic soils is presented by *NFI*, which is assessing soil type during inventory process by using Forest soils classification methodology prepared by prof. M. Vaičys. For more detailed information see chapter 6.2.1. Due to the results of Biosoil project, it is assumed that carbon stock changes in mineral soils in forest land remaining forest land are minor and insignificant, thus carbon stock changes in mineral soils in forest land remaining forest are not accounted. Whereas, carbon stock changes in organic soils in categories forest land remaining forest land and land converted to forest land occur due to the drainage, as a result emissions from organic soils in forest land category are reported. Carbon stock changes in mineral soils in land converted to forests land was reported for the first time this year as a result of carbon stock estimation project, implemented under the "Partnership project on Greenhouse gas inventory" between Lithuania and Norway in the framework of the programme LT10 (summary of the studies on carbon stock values in forest and non-forest land is provided in the Annex X).

Table 6-21. Annual GHG emissions in Forest land remaining Forest land and land converted to Forest land from drained organic soils

Year		Land converted to Forest land		

	Forest land remaining Forest land	Area of drained organic soils , thous. Ha						Total area of drained organic soils, thous. ha	Total emissions , kt CO_2 e
	Area of drained organic soils, thous. ha	Cropland	Grassland	Wetlands	Settlements	Other land	Total		
1990	134.79	0.03	4.49	2.34	0.00	0.08	6.94	141.74	353.40
1995	135.92	0.17	4.71	2.37	0.06	0.11	7.41	143.33	357.38
2000	137.71	0.28	4.33	2.09	0.06	0.17	6.92	144.63	360.61
2005	139.23	0.44	4.79	1.74	0.08	0.17	7.22	146.45	365.14
2010	141.52	0.77	4.85	1.27	0.08	0.14	7.11	148.63	370.57
2015	143.14	1.13	5.92	1.21	0.08	0.11	8.46	151.60	377.99
2016	143.39	1.13	6.01	1.24	0.08	0.11	8.57	151.96	378.88
2017	143.61	1.10	6.23	1.38	0.08	0.11	8.90	152.51	380.26
2018	143.69	1.10	6.28	1.41	0.08	0.08	8.95	152.65	380.60
2019	143.89	1.07	6.36	1.35	0.08	0.08	8.95	152.84	381.08
2020	144.16	1.10	6.61	1.32	0.08	0.06	9.18	153.34	382.32

Carbon stock changes due to biomass burning

There is no prescribed burning in Lithuania, thus only emissions from forest wildfires are reported. The default mean burned biomass values per hectare, established after the forest fire assessment, conducted by State Forest Service together with Directorate General of State Forests, were used. Carbon emissions are related with burned area (Table 6-22). The largest carbon emissions were observed in 1992 (10.3 kt CO_2) and in 2006 (12.8 kt CO_2). This is the result of repetitive draughts (1992, 1994, 2002, 2006, Lithuanian Hydrometeorological service) and irresponsible human behaviour with fire in over-dried forests. Forest fires resulted in nearly 1 million EUR losses for State forests in 2002-2006. 97% of all forest fires in Lithuania are caused by direct human activities (transportation, littering etc.) and only 1% is caused by natural circumstances e.g. thunder. In order to avoid double reporting, it is assumed that emissions from burnt biomass (living or previously living trees) were included either in reporting of changes of living biomass or dead wood (reported as IE), therefore only carbon stock losses in litter and organic soils (peat layer) are reported. GHG emissions from fires were recalculated for 2018 submission due to the national value of carbon stock in forest litter applied.

Table 6-22. Annual CO_2 emissions due to litter and organic soils burning in forest land

Year	Area burned, ha	Emissions, kt CO_2
1990	134.0	1.42
1995	355.0	3.77
2000	327.1	3.48
2005	50.8	0.54
2010	21.5	0.23
2015	70.9	0.61
2016	26.0	0.26
2017	52.9	0.55
2018	110.3	1.32
2019	200.0	3.05
2020	64.2	1.15

6.2.4 Uncertainty assessment

Lithuanian reporting system is mostly based on sampling method therefore national methodology was employed while estimating overall uncertainty.

Information obtained during *NFI* is based on the data of especially small sampling area size. The total number of allocated permanent plots in Lithuanian forests during the *NFI* of 1998-2007 comprised only slightly more than 264 ha. Information derived from this part of forests and trees is generalized to represent more than 2.1 mill. ha of Lithuanian forests. One sample tree (in permanent plots) represents 8,000 trees. Several indices are important characterizing statistical information, namely, data accuracy and validity. Data accuracy depends on the variation of parameters of the measured object, sampling volume and measurement accuracy. Measurement accuracy may be increased by applying advanced measuring devices, more precise (often even more time saving) instrumental measurement methods and decreasing the influence of subjective "human" factor. Data validity is determined by the stability of the chosen sampling design (main parameters of which are: size of sample plots, clustering, location etc.) to assess the analysed object, as well as by methods and standards applied to estimate (measure) different parameters, elimination of any possible parameter estimation biases in the inventory system, etc. However, the obtained accurate data not necessarily guarantee the validity of the information on the analysed object. In other words, the use of highly precise up-to-date devices may not ensure sufficient data validity if they are collected, for instance, in subjectively selected sampling areas.

Lithuanian *NFI* system is developed so that the desired accuracy of results is in line with the maximum validity of information. Initial desired accuracy of *NFI* results is determined already in the first stage of *NFI* planning – prior to inventory, when the necessary sampling intensity is defined, measurement methods and tools are selected.

A two-stage sampling was tested for *NFI* sample plots, while estimating area distribution. In the first stage sample plots were allocated and assessed in the map of a satellite image. In the second stage the plots were allocated and assessed on the ground. According to a large extent first-stage sampling, forest land area may be assessed very accurately, i.e. with 0.15% precision. It would correspond to 3,000 ha forest area error in the whole country. However, forest land identified in a satellite image map failed to comply with the reality. According to ground *NFI* estimation even in 9.8% of cases, i.e. so many times forest land was not detected in nature. And on the contrary, by ground method additionally 6.6% of plots on forest land were identified, which were not recognized in the satellite image. Thus, the assessment of forest land according to satellite images is of a comparatively low accuracy and in this phase it was eliminated.

Total forest land area according to yearly measurements of plots or according to the data of plots measured over a certain number of years is estimated by using the following equations:

$$Q_m = Q \cdot p_m \quad \text{or} \quad Q_m = K_m \cdot q_R; \quad Q_m = \frac{p_m \cdot q_R}{500}$$

where:

Q - total area of Lithuanian territory (6,528,648 ha);

Q_m - forest land area, ha;

p_m - part of forest land area.

Part of forest land area is calculated using the following equation:

$$p_m = \frac{K_m}{K}$$

where:

K_m - sum of plots or their parts on forest land, ascertained during inventory;

K - total number of plots in Lithuania.

Number of sample plots is estimated:

$$K = \frac{Q}{q_R}$$

where:

Q - total area of Lithuanian territory;

q_R - area, represented by one sample plot (399.33 ha).

The error of forest land assessment is estimated:

$$P_{Q_m} = \sqrt{\frac{1 - p_m}{(K-1)p_m}} \cdot 100$$

where:

p_m - part of forest land area;

K - total number of plots in Lithuania.

Estimation accuracy of different stand parameters depends on the variation of estimated parameter (expressed by variation coefficient $V_{\%}$) in the analysed set. The most actual is growing stock volume variation in sample plots of stand communities covering a large diversity of natural conditions. This parameter in Lithuania has not been studied yet. The first reliable data on growing stock volume variation in sample plots of entire stand communities were obtained after the first five – year period of *NFI* in 1998-2002. Having re-measured permanent sample plots in 2003-2007, these data sets were supplemented with the new information both on the growing stock volume and on the variation of gross volume increment, volume change, the volume of felled and dead trees. Variation of growing stock volume in sample plots, depending on site conditions and stand parameters, were analysed in 500 m^2 size permanent and temporary sample plots allocated in stands. The dependence of growing stock volume variation coefficient on dominant tree species, stand age, stocking level, site humidity and fertility and on site index, expressed by tree height at maturity, has been determined.

Overall uncertainties were estimated by using Tier 1 method further described in *2006 IPCC Guidelines*, which is also known as simple error propagation method.

To estimate uncertainty of a product of several quantities Equation. 3.1 (p. 3.28 of *2006 IPCC Guidelines*) was used:

$$U_{Total} = \sqrt{U_1^2 + U_2^2 + \cdots U_n^2}$$

where:

U_{Total} - percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage);

U_i - percentage uncertainties associated with each of the quantities, i=1,...n.

For estimation of overall uncertainty, the following equation of *2006 IPCC Guidelines* was used (Equation 3.2, p. 3.28):

$$U_E = \frac{\sqrt{(U_E \cdot E_1)^2 + (U_2 \cdot E_2)^2 + \cdots (U_n \cdot E_n)^2}}{|E_1 + E_2 + \cdots E_n|}$$

where:

U_E - percentage uncertainty of the sum;

U_i - percentage uncertainty associated with source/sink I;

E_i - emission/removal estimate for source/sink i.

The growing stock volume per 1 ha of all Lithuanian forests, based on permanent and temporary sample plots, was estimated with 0.9% accuracy. The lowest standard error (1.3%) was estimated for pine stands (dominant tree species in Lithuania) and the highest (5.1%) for ash and oak stands (lowest prevalence). To be consistent with *2003 IPCC* uncertainties should be reported as a confidence interval giving the range within which the underlying value of an uncertain quantity is through to lie for a specific probability. 95% confidence interval is used by Lithuania in uncertainty estimations.

For Forest Land remaining Forest Land it was assumed that uncertainty of area is 2.3%. Uncertainties of emission factor were estimated using Tier 1 error propagation method described in eq. 3.2 (*2006 IPCC Guidelines*). For Forest Land remaining Forest land uncertainty of emission factor was assumed to be about 31.1%.

For Land converted to Forest Land it was assumed that uncertainty of area is 12.2%. Uncertainty of emission factor was assumed to be about 38.4%.

Table 6-28. Uncertainty values

Indicator	Land Use Category	Unit	Uncertainty, %
Growing stock volume	Forest Land remaining Forest land	m^3	2.6
	Land converted to Forest Land	m^3	11.4
Area	Forest Land remaining Forest land	ha	2.3
	Land converted to Forest Land	ha	11.2
Emission factor	Forest Land remaining Forest land	kt CO_2	31.7
	Land converted to Forest Land	kt CO_2	33.0

6.2.5 Category-specific QA/QC and verification

National Forest Inventory Department of the Lithuanian State Forest Service is responsible for reporting of greenhouse gas emissions and removals from LULUCF sector.

NFI department is managed by 15 well educated, experienced employees who are periodically trained and examined, participate in international workshops, seminars etc. 6 persons are responsible for collection of data on forest land and 4 persons on non-forest land, 2 employees are responsible for LULUCF and KP LULUCF data analysis, provision of methodological guidance and preparation of GHG reports, 2 persons are responsible for independent internal check assessments - inventory control group.

QA/QC for data collection, data processing issues, preparation of reporting tables achieved by State Forest Service, elaborated control routines of executed LULUCF activities are ensured with the help of procedures established by Environmental Protection Agency. Every GHG emissions and removals submission is presented to scientific-advisory board, where chosen methods, activity data, emission factors and other parameters are discussed and approved.

The following procedures were carried out to ensure QC/QA procedures described in *2006 IPCC Guidelines* (Ch. 4.4.3, p. 4.44):

- periodical trainings of field crews and individual training of new staff;
- data consistency and completeness control – carried out during measurements by field crews while entering data, and during processing of data after field works;
- independent internal check assessments – carried out on 5% of measured sample plots by *NFI* Control team;
- independent external check assessments and judgements of data processing procedures and algorithms used in the course of *NFI*, elaborated models, uncertainties etc. – carried out by third parties;
- cross checking of statistics gathered from permanent and temporary sample plots, comparison of *NFI* and *SFI* results;
- domestic and external expert analysis and reviews;
- data archiving (maintenance and storage) in several forms and copies in order to recover lost or corrupted data etc.

Applied QA/QC system ensures accuracy of reported information and it is in agreement with the QA/QC system requirements described in *2006 IPCC Guidelines*.

European Commission every year organizes a technical review of EU Member States' GHG inventories to ensure accuracy, reliability and transparency of information on annual GHG emissions and evaluate member state's accomplishment of EU Effort sharing regulation targets and improve GHG reporting from all relevant categories. Reviewers provide comments and recommendations to improve GHG inventory, which are taken into account for inventory compilation.

Additional internal QA/QC procedure was applied for the inventory of 2021. Forestry specialists from State Forest Service Statistics and National Forest Inventory departments have gone through the process of growing stock volume changes estimation from initial data of National Forest Inventory and identified few issues which were addressed for this submission.

6.2.6 Category-specific recalculation

Difference in total GHG removals from forest land resulted in adjustment of living biomass carbon stock change in forest land remaining forest land due to the newest growing stock volume data applied - extrapolated values for year 2017 were replaced with actual values. In addition to this, calculation errors in carbon stock changes in living biomass of forest land remaining forest land were corrected as a resulted of additional internal QA/QC procedure. This includes error in growing stock volume changes calculation for year 2016 (which resulted in corrected stock change estimate for subsequent years) and corrected algorithm of total growing stock volume collection from NFI statistics. Recalculations were done also as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation, which resulted in slightly different areas of mineral and organic soils, which affected calculation of CO_2 and N_2O emissions from drainage.

Table 6-23. Submitted and recalculated total emissions/removals in forest land category, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference %
1990	-7,764.34	-7,763.91	0.43	-0.01
1991	-7,677.21	-7,679.05	-1.84	0.02
1992	-7,347.56	-7,361.53	-13.97	0.19
1993	-7,922.98	-7,924.05	-1.07	0.01
1994	-7,401.58	-7,402.65	-1.07	0.01
1995	-5,231.20	-5,232.25	-1.05	0.02
1996	573.86	570.53	-3.33	-0.58
1997	-805.37	-806.42	-1.05	0.13
1998	-8,152.69	-8,153.91	-1.22	0.01
1999	-7,943.30	-7,944.45	-1.15	0.01
2000	-9,324.45	-9,325.45	-1.00	0.01
2001	-6,858.09	-6,859.03	-0.94	0.01
2002	-6,092.65	-6,093.84	-1.19	0.02
2003	-4,939.67	-4,940.84	-1.17	0.02
2004	-4,762.20	-4,763.44	-1.24	0.03
2005	-4,305.41	-4,306.87	-1.46	0.03
2006	-4,461.51	-4,463.00	-1.49	0.03
2007	-5,690.52	-5,692.21	-1.69	0.03
2008	-7,290.39	-7,291.94	-1.55	0.02
2009	-8,544.92	-8,546.42	-1.50	0.02
2010	-9,643.68	-9,645.13	-1.45	0.02
2011	-10,171.27	-10,172.74	-1.47	0.01
2012	-9,809.09	-9,811.27	-2.18	0.02
2013	-9,611.16	-9,613.54	-2.38	0.02
2014	-8,822.80	-8,825.23	-2.43	0.03
2015	-8,083.64	-8,086.01	-2.37	0.03
2016	-7,269.52	-7,271.91	-2.39	0.03
2017	-7,152.28	-7,154.58	-2.30	0.03
2018	-7,224.74	-7,074.94	149.80	-2.07
2019	-6,647.51	-6,496.45	151.06	-2.27

6.2.7 Category-specific planned improvements

Lithuania has applied provisional national carbon stock values in forest land, cropland and grassland mineral soils. In the next submission Lithuania is planning to further improve accuracy of LULUCF GHG inventory with implementation of different carbon stock values for different soil groups in forest land, cropland and grassland, meaning the expansion of land-use change matrix to different soil groups. Updated allocation of soil types still needs approval, however, preliminary soil carbon stock values in different soil type groups for carbon stock changes estimation is presented in Table 6-24.

Table 6-24. Carbon stocks in different land uses and soil types (with confidence intervals in brackets), t C ha^{-1}

	Forest land	Cropland	Grassland
I - sandy soils (Arenosols, Podzols).	53.2 [51.2;55.2]	70.3 [66.6;74.1]	61.0 [57.3;64.7]
II - HAC soils, normal moisture regime	69.9 [64.8;75.0]	74.4 [72.2;77.3]	78.9 [72.5;78.2]
III - HAC soils, temporary overmoistured regime	107.7 [103.3;110.0]	-	98.0 [79.8;116.3]
IV - wetland mineral soils	99.7 [93.3;115.1]	-	-
V - wetland (not drained) organic soils	180.8 [68.3;293.3]	-	180.8 [68.3;293.3]

Lithuania is planning to improve carbon stock changes estimation in forest land carbon pool, performing primary analysis of scientific studies in order to obtain reliable data of carbon stock changes in litter pool in forest land remaining forest land.

6.3 Cropland (CRF 4.B)

Historically Lithuania is treated as an agricultural country with high proportion of agricultural lands among other land use types – according to State Land Fund agricultural lands (croplands, grasslands) covered approximately 70% of country territory in 1991 and more than 50% in 2020. Solely cropland covers more than 30% of total country area in recent years (2009-2020). Furthermore, it was established that since 2006 agricultural lands in use were constantly increasing approximately 53.5 thous. ha per year until 2010, whereas abandoned agricultural land areas are decreasing (Bykoviene et al., 2014). After the collapse of Soviet Union in 1990, cropland area has been gradually decreasing from to 2,414.7 thous. ha to 1,832.9 thous. ha in 2005, thereafter it again gradually started to increase, usually substituting grassland areas (Figure 6-30) and only during 2010 - 2012 the total area of cropland was decreasing as a consequence of financial crisis. Substitution of grassland with cropland areas has a negative impact if concerning greenhouse gases – organic carbon stocks in soils are decreasing, resulting in increased CO_2 and direct N_2O emissions from mineral soils. However, in order to balance the processes Lithuania has adopted Rural development programme for 2014 - 2020, with the aim to support not only cropland, but also grassland management.

The area of cropland comprises of the area under arable crops as well as commercial orchards and berry plantations. According to the national definition – arable land is continuously managed or temporary unmanaged land, used and suitable to use for cultivation of agricultural crops, also fallows, cold frames and plastic cover greenhouses, strawberry and raspberry plantations, areas for production of flowers and decorative plants. Arable land set aside for one or several years (<5 years) before being cultivated again as part of an annual crop-pasture rotation is still included under cropland. Orchards and berry plantations are areas planted with fruit trees and fruit bushes (apple-trees, pear-trees, plum-trees, cherry-trees, currants, gooseberry, quince and others). Under this category only those orchards and berry plantations are included that are planted on other than household purpose land and mainly used for commercial purposes. Orchards and berry plantations planted in small size household areas and only used for householders' needs are included under Settlements category. All croplands are considered as managed lands in Lithuania. Several carbon stocks are considered as the most important for GHG accounting, those include biomass of woody cropland - perennial orchard plantations mainly - and organic carbon accumulated in soils - both mineral and organic.

The total net emissions from cropland had tendency to decrease since 1990 to 2005 in Lithuania, with an increasing tendency of GHG removals afterwards, which was mostly related to increasing area of ecological agriculture, having a strong impact to soil carbon sequestration due to applied practices (Figure 6-20). In 1990 net emissions from cropland were 2,582.8 kt CO_2 eq. Thus, in 2005 had decreased more than 50% (emissions reached 1,209.3 kt CO_2 eq.). In addition to this, net removals in mineral soils started to increase after 2005 (significant increase in ecological agriculture areas) and total GHG emissions decreased to 886.3 kt CO_2 eq. in 2020. Changes in CO_2 emissions from land converted to cropland could by large extent be explained by changes in grassland and cropland conversion trends, when increased conversion to cropland leads to higher emissions from category resulting from carbon loss due to loss of biomass and soil organic carbon stock disturbance, whereas decreased conversions result in decreased emissions as well.

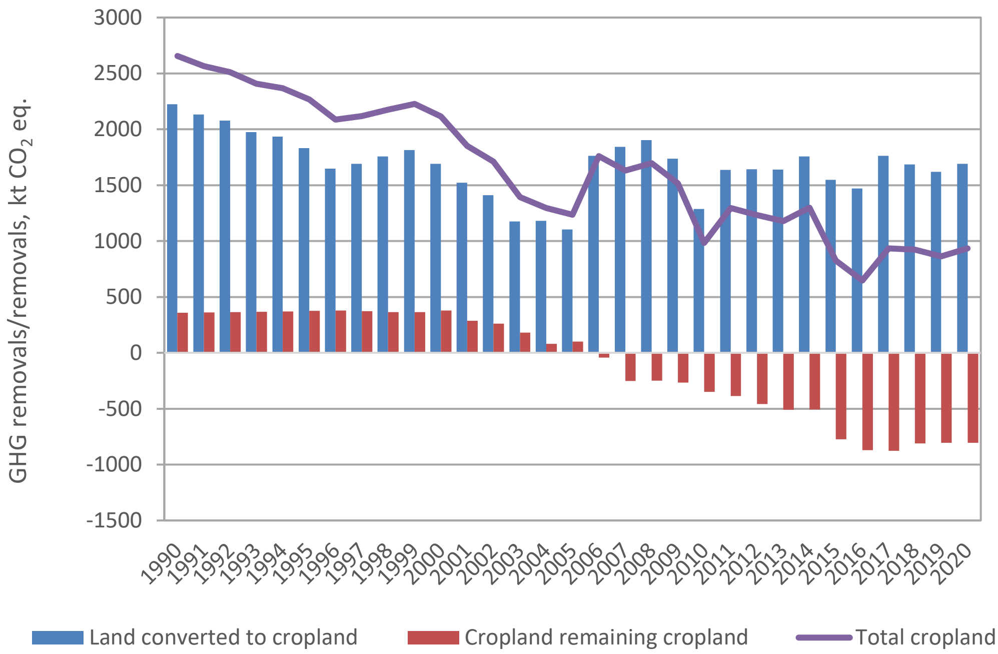


Figure 6-20. Greenhouse gas emissions in cropland, kt CO_2 eq.

Mainly grassland conversion to cropland has been increasing the net CO_2 emissions (carbon stock losses in living biomass, litter and mineral soil pools), in addition to the most significant source of emissions – drained organic soils (Table 6-25). CO_2 emitted in grassland converted to cropland (emissions from drained organic soils not included) have ranged from 586.5 to 1,225.2 kt CO_2 eq. and in 2020 CO_2 emissions have reached 954.8 kt CO_2 eq. There was only few conversions from wetlands to settlements in the reporting period, therefore CO_2 emissions from drainage of organic soils in wetlands converted to cropland were reported only during 1993 - 2012. However, small areas of settlements and other land converted to cropland has induced the CO_2 accumulation in mineral soils. Higher amounts of accumulated CO_2 have recorded in the period of 1993 - 2000. Thus, in 2016, 2017, 2018, 2019 and 2020 the conversion from settlements to cropland was rather significant and amount of CO_2 accumulated reached -27.6 and -38.6 ktCO_2 eq, accordingly.

Table 6-25. Emissions and removals in cropland, kt CO_2 eq.

Year			Land conversion to cropland

	Drainage of organic soils	Cropland remaining cropland	Grassland	Wetlands	Settlements	Other
1990	1,443.18	358.34	1,062.10	NO, IE	NO	NO
1995	1,255.56	374.55	931.51	NO, IE	-22.04	-55.71
2000	1,032.98	379.49	1,005.14	NO, IE	-22.04	-50.14
2005	824.09	99.38	602.69	NO, IE	-16.53	-33.43
2010	1,005.74	-350.62	586.47	NO, IE	-16.53	-27.86
2015	1,028.00	-772.82	799.51	NO, IE	-16.53	-5.57
2016	1,023.86	-871.28	734.62	NO, IE	-27.55	-5.57
2017	1,043.62	-876.68	1,001.25	NO, IE	-27.55	NO
2018	1,044.03	-809.84	931.37	NO, IE	-33.06	NO
2019	1,036.55	-803.86	877.76	NO, IE	-33.06	NO
2020	1,042.08	-804.39	954.80	NO, IE	-38.57	NO

6.3.1 Category description

Two source categories are accounted under this category: emissions from Cropland remaining Cropland and emissions from Land converted to Cropland. Carbon stocks, which are included in calculations of emissions and removals due to carbon stock losses and gains, are presented in the table below.

Table 6-26. Reported carbon stocks under Cropland land use category

Land Use Category	Carbon stock change in biomass	Carbon stock change in dead organic matter	Changes in soil C stocks	
			Mineral soils	Organic soils
Cropland remaining Cropland (CC)	√	NO	√	√
Land converted to Cropland (LC)	√	√	√	√

Due to the evidences from both National Forest Inventory data and national scientific research performed by the Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, in 2016 of data on dead wood and litter accumulation in orchards, Lithuania selected to use Tier 1 method with the assumption that dead wood and litter are not present or are at equilibrium in agroforestry (which is not present in Lithuania) and orchards (no dead wood was inventoried in cropland areas during the NFI measurements; no litter carbon stock was inventoried during the study of Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry). Due to substantial soil disturbance with full inversion there is assumed that no litter accumulation occur in annual crop fields. Information on data sources used for activity data collection are presented in Table 6-27.

Table 6-27. Information on data sources used for estimation of cropland area

Sources used	Source data used
Soviet kolkhozzes' land use plans	1990
Orthophoto maps	NLF: 1995-1998; 2005, 2009, 2010
Land areas and croplands declarations database	2010-2011
National Forest Inventory database	2012 and beyond

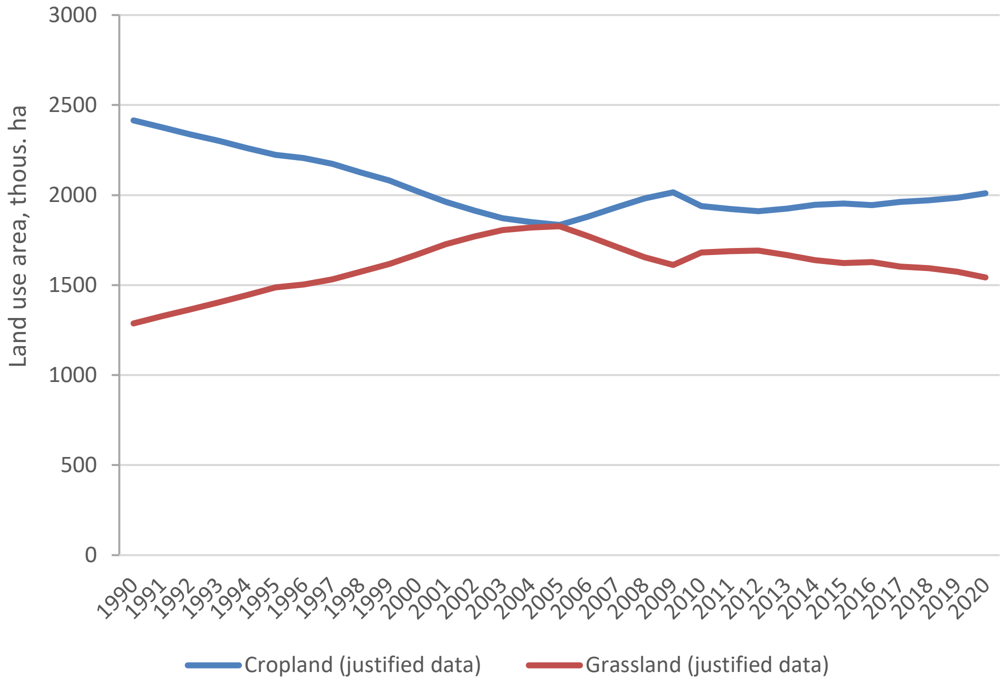


Figure 6-21. Comparison between estimated cropland and grassland area based on historical study and NFI data

By seeking methodological correctness and trying to avoid high range data jumps (with the main aim to reduce the inter-annual variations), data adjustment has been made based on the reference points (1990, 1995, 2005, 2009) for which topographical data was obtained (Figure 6-21). As is apparent from data analysis, cropland area has been constantly decreasing after the collapse of Soviet Union until 2006 (turning point after which area of cropland started to increase again - mainly due to grassland conversion to cropland) and in 2005 it had already been decreased more than 500.0 thous. ha. Such changes were beneficial for climate change mitigation as grassland area was increasing at the similar rate as cropland decreasing resulting in more carbon stored in grassland biomass, unfortunately vice versa in 2006 - 2009 and since 2014.

Main data source for activity data (areas) is National Forest Inventory, however, land use type is also defined taking into account data from the National Paying Agency of declared areas for direct payments under CAP.

6.3.2 Methodological issues

6.3.2.1 Cropland remaining Cropland

Cropland remaining cropland comprise areas continuously managed as Croplands and areas converted to Croplands after 20 consecutive years followed conversion and are reported in the category Cropland remaining Cropland (CC). The annual greenhouse gas emissions and removals from this category include:

– Estimates of annual change in C stocks from all C pools and sources;

– Estimates of annual emission of non-CO_2 GHG from all pools and sources.

C pools and sources CO_2 emissions/removals are accounted from contain carbon stock in living biomass (perennial woody crops – orchard plantations), carbon stocks in mineral and organic soils. Non-CO_2 GHG estimation comprise non-CO_2 GHG estimation from biomass burning (wildfires in the fields), direct N_2O emissions due to N mineralization/immobilization resulting from loss of carbon stock after conversion from one land use to cropland, indirect N_2O emissions from leaching and runoff after N mineralization/immobilization resulting from loss of carbon stock after conversion from other land uses to cropland.

Carbon stock changes in living biomass

The change in biomass is only estimated for perennial woody crops, as carbon stored in annual crops biomass is assumed to be equal to carbon stock loses from harvest, therefore carbon stock changes in annual biomass is assumed to be zero. Statistics Lithuania reports total area of orchards and berry plantations in Lithuania being ~45 thous. ha in 1990 to ~30 thous. ha in recent years (Statistics Lithuania, 2020). Lithuania reports only perennial woody biomass accumulated in commercial orchards (apple, pears, plums and cherries) and Salix plantations (because of significant expansion since 2012-2013), as small household gardens are included under settlements category, certain methodological issues still remain concerning carbon stock change inventory in such stands. Since 1999 reliable statistical data on areas of commercial orchards in Lithuania is obtained from annual statistical reports of the State enterprise Agricultural Information and Rural Business Centre (AIRBC). Area of commercial orchards in 1990 obtained from scientific publication of Venskutonis (1999). Data on area of commercial orchards during the period 1990-1998 was obtained using data interpolation between reliable data of 1990 and 1999 and beyond. Area of fruit-trees commercial orchards have significantly increased up to 5.0 thous. ha in recent years (2015 - 2020), with apple plantations covering over 90%.

Above-ground woody biomass

Default Tier 1 method was used to estimate carbon stock changes in woody biomass in commercial orchards, while for the estimation of carbon stock changes in other woody plantations grown in cropland (i.e. willow, poplar plantations), national and neighbouring countries' carbon stock values were applied (Tier 2 method applied). The area of perennial woody cropland was multiplied by a net estimate of biomass accumulation from growth and losses associated with harvest or gathering (gain-loss method) (Equation. 2.7, Ch. 2 of *2006 IPCC Guidelines*).

$$\Delta C_B = \Delta C_G - \Delta C_L$$

where:

ΔC_B - annual change in carbon stocks in biomass (considering only above-ground biomass in the case of changes in woody crop biomass accounting), considering total area, tonnes C yr^{-1};

ΔC_G - annual increase in carbon stocks due to biomass growth, considering the total area, tonnes C yr^{-1};

ΔC_L - annual decrease in carbon stock due to biomass loss, considering the total area, tonnes c yr^{-1}.

Losses are estimated by multiplying default value of carbon stock loss due to harvesting by the area of cropland on which perennial woody crops are being harvested, using the default values (given in *2006 IPCC Guidelines)* and country-specific values of harvest cycle and carbon stock at harvest.

Default coefficients for above-ground woody biomass growth in orchards rate were used (Table 5.1, Ch. 5 of *2006 IPCC Guidelines*):

- Above-ground biomass carbon stock at harvest – 63 tonnes C ha^{-1};
- Harvest/maturity cycle – 30 years;
- Biomass accumulation rate (G) – 2.1 tonnes C ha^{-1} yr^{-1};
- Biomass carbon loss (L) – 63 tonnes C ha^{-1} yr^{-1}.

Country specific carbon stock and harvest/maturity cycle values applied for willow and poplar plantations[121]:

- Above ground biomass carbon stock at harvest – 74.7 tonnes C ha^{-1} for willow plantations and 21.2 tonnes C ha^{-1} for poplar plantations;
- Harvest/matyrity cycle – 4 years for willow plantations and 5 years for poplar plantations;
- Biomass accumulation rate (G) – 18.7 tonnes C ha^{-1} yr^{-1} for willow plantations and 4.2 tonnes C ha^{-1} yr^{-1} for poplar plantations;
- Biomass carbon loss (L) – 74.7 tonnes C ha^{-1} yr^{-1} for willow plantations and 21.2 tonnes C ha^{-1} yr^{-1} for poplar plantations.

Below-ground biomass

The default assumption for Tier 1 is that there is no change in below-ground biomass of perennial trees in agricultural systems therefore default values for below-ground biomass for agricultural systems are not available and no carbon stock changes can be accounted in below-ground biomass. Carbon stock changes in below-ground biomass are reported as NO.

Carbon stock change in dead organic matter

The default Tier 1 method for estimation of carbon stock changes in dead organic matter was elected (*2006 IPCC Guidelines*). It is assumed that dead wood and litter stocks are not present in annual crops in Cropland category or are at equilibrium in agroforestry systems and orchards, in addition to this, no dead wood was identified in cropland during the National Forest Inventory measurements. Thus, carbon stock changes for these pools were reported as NO.

Carbon stock change in soil organic matter

Soil carbon stock change inventory includes estimations of soil organic C stock changes in mineral soils due to the land management and CO_2 emissions from organic soils due to enhanced microbial decomposition caused by drainage and associated management activity. CO_2 emissions from soils depends on many factors, however mainly on soil disturbance, soil tillage practice, organic matter input as well as on soil properties and climatic conditions (*2006 IPCC Guidelines*).

[121] Data from:
Bakšienė, E, Titova, J., Nedzinskien4, T. L, 2012. Įvairių gluosnių (Salix. L), veislių auginimo kurui tyrimai. Žemės ūkio mokslai, Nr. 2, p. 90 -97.
Kulig, B., Gacek, E., Wojciechowski, R., Oleksy, A., Kołodziejczyk, M., Szewczyk, W., Klimek-Kopyra, A., 2019. Biomass yield and energy efficiency of willow depending on cultivar, harvesting frequency and planting density. Plant Soil Environ., Vol. 65, p. 377-386. https://doi.org/10.17221/594/2018-PSE
Niemczyk, M., Wojda, T., Kaliszewski, A., 2016. Biomass productivity of selected poplar (*Populus* spp.) cultivars in short rotations in northern Poland[§] . *N.Z. j. of For. Sci.*, Vol. 46. https://doi.org/10.1186/s40490-016-0077-8

Land conversion processes result in largest changes in carbon stock in soil (Figure 6-22). It is evident that management practices also significant impact on carbon stock changes, when carbon stock in mineral soils starts to accumulate due to the management practices applied. While decreasing land conversion to cropland resulted in decreasing carbon loss and emissions, when conversions from grassland (mainly) to cropland started to increase after 2005, carbon stock losses likewise started to increase. Carbon stock changes in organic soils are directly related to land area changes, as emissions from organic soils in cropland remaining cropland and land converted to cropland categories are accounted due to the impact of enhanced microbial decomposition after drainage and cultivation, therefore emissions are directly linked to increased cultivation area.

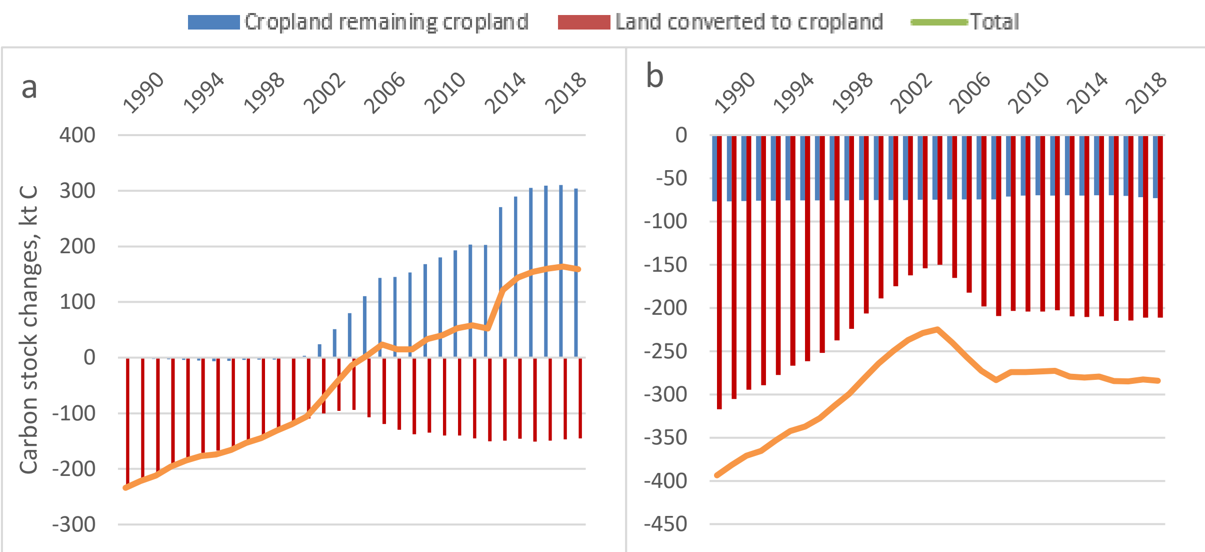


Figure 6-22. Carbon stock changes in mineral (a) and organic (b) soil in cropland

Mineral soils

Emissions and removals from mineral soils carbon stock changes are based on assumptions of soil carbon stock changes during the time, having in mind the impact of management practices, C input to the soil, etc.

Lithuania do not track individual land transitions between different cropland management practices, therefore uses Tier 1 approach (Equation 2.25, p. 2.30 of *2006 IPCC Guidelines*) and soil organic carbon stock (SOC) changes are computed for every year.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

$$SOC = \sum_{c,s,i}(SOC_{REF_{c,s,i}} \times F_{LU_{c,s,i}} \times F_{MG_{c,s,i}} \times F_{I_{c,s,i}} \times A_{c,s,i})$$

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1};

SOC_0 - soil organic carbon stock change in the last year of an inventory time period, tonnes C;

$SOC_{(0-T)}$ - soil organic carbon stock change at the beginning of the inventory time period, tonnes C;

SOC_0 and $SOC_{(0-T)}$ are calculated using the SOC equation where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T).

T - number of years over a single inventory time period, yr;

D - time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr;

C - represents the climate zones, s - the soil types, i - the set of management systems that are present in a country;

SOC_{REF} - the reference carbon stock, tonnes C ha^{-1};

F_{LU} - stock change factor for land-use systems or sub-system for a particular land-use, dimensionless;

F_{MG} - stock change factor for management regime, dimensionless;

F_I - stock change factor for input of organic matter, dimensionless;

A - land area of the stratum being estimated, ha.

SOC have been estimated for every inventory year, due to the reliable annual data of cropland management systems (certified organic cropland, perennial cropland, cropland with no tillage (since 2011)[122], other - usual intensive cropland management) using national carbon stock value (SOC_{REF} = 76.1 t C ha^{-1}, croplands) of agricultural soils (Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, 2016) and default stock change factors: Land use F_{LU}, management F_{MG}, input F_I, from Table 5.5 of *2006 IPCC Guidelines* (presented in the Table 6-28). Annual rates of carbon stock change are estimated as the difference in stocks at two points in time divided by the time dependence of the stock change factors. The default 20 year time period was used for calculations of stock changes.

The Climatic Zone layer is defined based on the classification of *2006 IPCC Guidelines*. Lithuania is in a single – cool temperate moist climate zone.

Country has limited and/or defragmented specific data on Cropland management systems. For instance national statistics provide annual bare-fallowing areas, but it is not known if it's frequent. According to overviews the area under reduced tillage has been increased in the period 1999-2004 (Šiuliauskas, Liakas, 2005), but reliable statistics for such land accounting is not available yet and therefore not included into calculations, however, it is planned to obtain such statistics in the future.

Stratification of management systems have been made based on national statistics for woody crops and available data of arable land certified as organic in national certification agency "Ekoagros" Perennial and Organic management systems were specified for Croplands and the relevant factors were used in calculations. Default carbon stock change factors used for cropland

[122] Interpolated data from Eurostat on Agricultural practices. Data from 2010 show that there were no areas without tillage in Lithuania, therefore areas with no tillage were interpolated as gradually increasing starting in 2011 to 2016 actual areas provided by Eurostat. Data obtained from: https://ec.europa.eu/eurostat/databrowser/product/page/EF_MP_PRAC

mineral soil organic carbon stock changes estimation is presented in Table 6-28 (Table 5.5 p.5.17 of *2006 IPCC Guidelines*).

Table 6-28. Information on carbon stock change factors used for organic carbon stock changes calculation

Carbon stock change factor \ **Crop type**	**Perennial crops**	**Certified organic crops**	**No tillage**	**Other crops**
Land use F_{LU}	1.0	0.69	0.69	0.69
Input F_I	1.0	1.44	1	1.0
Management F_{MG}	1.15	1.0	1.15	1.0

Croplands in Lithuania represent area that has been continuously managed over 20 years and predominantly it is annual crops. Main tillage practice is full tillage, described as substantial soil disturbance with full inversion and frequent tillage operations as well as small part of the surface covered by residues at planting time. Land mainly has medium residue return when all crop residues are returned to the field. Removals of residues are usual compensated by organic matter supplements from green manure or other type of manure, with significantly larger amounts of organic matter applied to certified ecological farming areas.

Organic soils

Methodology for estimating GHG emissions from organic soils in cropland remaining cropland category is based on assumption of drainage stimulating oxidation of organic matter (resulting in emissions of CO_2). Data on distribution between mineral and organic soils in Cropland category was obtained from permanent sample plots measured by National Forest Inventory in 2014 - 2018, when the database of all land use categories in country has been finished already and two years of remeasurements were collected as well. Organic soils constitute 1.1 % of the total cropland area (all organic soils are inventoried as drained in cropland) and it was assumed that this value is applicable to both categories – Cropland remaining Cropland and Cropland converted to other land uses.

Organic soils in Lithuania are determined by using national definition of organic soils, provided in the book of Lithuanian soil classification (Buivydaite et al., 2001): soil is classified as organic if it has peat layer not thinner than 40 cm or 60 cm of poorly decomposed peat (mainly mossfibres) in bogs. In addition to this, histic horizon must contain not less than 70 - 75 percent of organic matter by volume. National definition of organic soils (histosols) was prepared using Food and Agriculture Organization (FAO) guidelines for soil classification (World reference base for soil resources).

For carbon stock change calculation in organic soils Tier 1 method was used (Equation. 2.26 of *2006 IPCC*) and CO_2 emissions due to the drainage of organic soils were estimated. Drained organic soils, according to the NFI data, constitute 1% of the total cropland area.

$$L_{Organic} = \sum_c (A \times EF)_c$$

where:

$L_{Organic}$ - annual carbon loss from drained organic soils, tonnes C yr^{-1};

A - land area of drained organic soils in climate type c, ha;

EF - emissions factor for climate type c, 5 tonnes C ha^{-1} yr^{-1}.

Area of organic soils, determined by the data of NFI 2014 - 2018, was multiplied with default emission factor from Table 5.6 (p. 5.19 of *2006 IPCC Guidelines,* 5 tonnes C ha^{-1} yr^{-1}) for drained organic soils in cold temperate climate region.

Carbon stock changes due to the drainage of organic soils in cropland category are included in the CRF Table 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils, line Drained organic soils (Cropland), therefore reported as IE in organic soils in CRF Table 4.B.1.

Non-CO_2 greenhouse gas emissions from biomass burning

According to *2006 IPCC Guidelines*, CO_2 emissions from biomass burning do not need to be reported as it is assumed that emissions released from burning is reabsorbed by the vegetation in next growing season, whereas only non-CO_2 GHG emissions are reported: CH_4, N_2O.

There is no controlled burning of Cropland in Lithuania, emissions of non-CO_2 only results from wildfires. Cropland wildfires are infrequent and burnt area normally are small (0.2-0.3 thous. ha), but peak values can exceed 1 thous. ha (in 2005).

Emissions from Cropland category were estimated employing the Equation 2.27 (Ch. 2, p. 2.42 of *2006 IPCC Guidelines*).

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

where:

L_{fire} - amount of greenhouse gas emissions from fire, tonnes of each GHG;

A - area burnt, ha;

M_B - mass of fuel available for combustion, tonnes d. m. ha^{-1};

C_f - combustion factor, dimensionless (default value, Table 2.6 of *2006 IPCC Guidelines, 0.9*);

G_{ef} - emissions factor, g kg^{-1} dry matter burnt (default value, Table 2.5 of *2006 IPCC Guidelines*).

Table 6-29. Default emission factors used for calculation of non-CO_2 GHG emissions, g kg^{-1}, means ± SD

Category	**CO**	**CH_4**	**N_2O**	**NO_x**
Agricultural residues	92 ±84	2.7	0.07	2.5 ±1.0

National estimates of M_B (mass of fuel available for combustion (tonnes ha^{-1})) developed by Lithuanian agriculture scientists for agricultural residues (post-harvest field burning) are in a range of 1.92-2.27 t ha^{-1} dry matter for main grown cereal crops. Mean value of 2.08 (t ha^{-1}) was used for calculations of GHG emissions from burnt annual croplands and 63 t C ha^{-1} was used for estimation of GHG emissions from burnt perennial croplands, along with default emission factors given in guidelines (Table 2.5, p.2.47 of *2006 IPCC Guidelines*).

Activity data on Cropland area burnt, required for emission estimation is obtained from statistics of Fire and rescue department. Area, reported as burnt on wildfires, is divided proportionally between perennial and annual cropland, according to perennial cropland share in total cropland area.

6.3.2.2 Land converted to Cropland

Estimation of annual greenhouse gas emissions and removals from Land Converted to Cropland includes the following estimates from all other land categories except forest (grassland, wetland, settlements, other land):

– Estimates of annual change in C stocks from C pools and sources: biomass (above-ground biomass); dead organic matter (dead wood and litter) and soils (soil organic matter in mineral and organic soils);

– Estimates of non-CO_2 gases (CH_4, CO, N_2O, NO_x) from burning of above-ground biomass and direct N_2O emissions due to N mineralization.

The cumulative areas over a 20-year transition period (reported as cropland remaining cropland) and under a 20-year transition period (reported as land converted to cropland) are reported in the figure below (Figure 6-23).

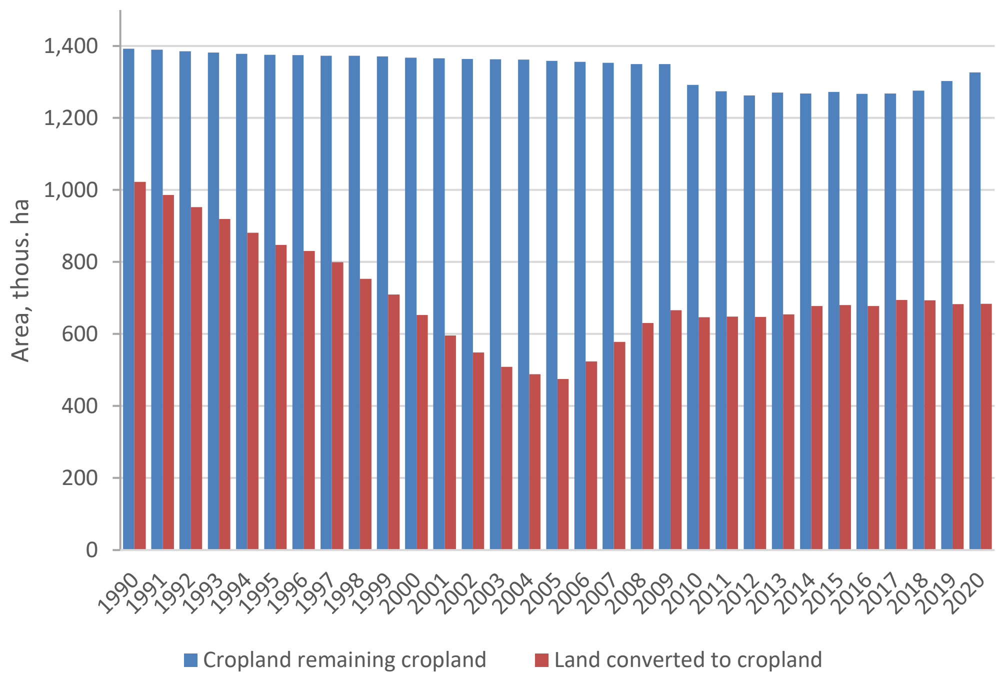


Figure 6-23. Cropland area changes during 1990-2020, thous. ha

For each year, the cumulative total area reported under the category Land converted to Cropland category is accounted as equal to the cumulative area that has been converted to that land use during the last 20 years, areas of second land-use change during the 20-year conversion period are subtracted by the cumulative total. The most part of conversions had been estimated from grassland to cropland in the period straight after Lithuania gained its Independence in 1990 until 2005 and vice versa from 2006.

According to the information obtained from *NFI*, during the last decades there have been no conversions of Forest land to Cropland, therefore no carbon stock changes in pools and sources resulting in emissions or removals from forest land converted to cropland were reported.

Carbon stock changes in living biomass

Tier 2 method was elected to estimate annual change in carbon stocks in living biomass on Land converted to Cropland employing the eq. 2.15 and 2.16 (Ch. 2, p. 2.20 of *2006 IPCC Guidelines*). Area estimates for Land Converted to Cropland were disaggregated according to prevailing vegetation. Average carbon stock change per hectare has been estimated for grassland converted to cropland Biomass carbon stock in initial land-use (B_{BEFORE} for grassland) is assumed to be 13.6 t ha^{-1} d. m. (p. 6.27, Table 6.4, Ch. 6, Vol. 4 of *2006 IPCC Guidelines*).

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

where:

ΔC_B - annual change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1};

ΔC_G - annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr^{-1};

$\Delta C_{CONVERSION}$ - initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1};

ΔC_L - annual decrease in biomass carbon stocks due to the losses from harvesting, fuel wood gathering and disturbances on land converted to other land use category, in tonnes C yr^{-1}.

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTERi} - B_{BEFOREi}) \times \Delta A_{TO\_OTHERSi}\} \times CF$$

where:

$\Delta C_{CONVERSION}$ - initial change in biomass carbon stocks on land converted to another land category, tonnes C yr^{-1};

B_{AFTERi} - biomass stocks on land type *i* immediately after the conversion, tonnes d. m. ha^{-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 other land-use category in a certain year, ha yr^{-1};

CF - carbon fraction of dry matter, tonnes C (tonnes d. m.)$^{-1}$, default value of 0.47, p. 6.29, Ch. 6, Vol. 4 of *2006 IPCC Guidelines;*

i - type of land use converted to another land-use category.

It is assumed that the prevailing vegetation is removed entirely, resulting in almost zero amount of biomass and carbon remaining in converted land area, which leads to the emissions from certain category converted to cropland. Carbon stocks in biomass are assumed to be zero immediately after conversion (B_{AFTER}), however in subsequent years change in biomass of annual crops is also considered to be zero because it is assumed that carbon gains in biomass from annual growth are offset by losses from harvesting.

Gains in living biomass carbon stock due to the conversion to new perennial cropland areas (industrial gardens) are calculated altogether with living biomass carbon stock change in cropland remaining cropland (perennial crops), therefore reported as IE in CRF Table 4.B.2.2 Carbon stock change.

Biomass carbon stock in initial land-use categories (B_{BEFORE}) is assumed to be 13 t ha^{-1} d. m. in Grassland (p. 6.27, Ch. 6, Vol. 4 of *2006 IPCC* Guidelines), 0.0 t ha^{-1} d. m. in Other Land. No default values of B_{BEFORE} were provided for wetlands and settlements converted to grassland, furthermore it was assumed that all conversions to cropland occur on lands with herbaceous vegetation for which the biomass immediately before conversion (B_{BEFORE}) can be assumed to be equal to 0, therefore no carbon stock changes in living biomass were estimated and thus reported as NE.

Carbon stock change in dead organic matter

Lithuania has no sufficient and reliable estimates of the dead wood and litter in the initial land-use systems – except for Forest land and Grassland – prior to the conversion. Therefore it is assumed that dead wood and litter stocks are not present after the conversion (no dead wood was inventoried in cropland areas during the NFI measurements; no litter carbon stock was inventoried in croplands during the national study performed by the Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry in 2016) and are reported as NO in wetlands, settlements and other land converted to cropland. When forest land and grassland are converted to cropland, all carbon stored in litter (7.65 t C ha^{-1} is stored in forest land remaining forest land; 3.56 t C ha^{-1} is stored in forest land in conversion; 0.8 t C ha^{-1} is stored in grassland) is lost at the time of conversion. The same assumption is applied for the dead wood carbon stock in lands converted to cropland – all carbon is lost at the time in conversion (carbon stock in dead wood in forest is estimated annually from National Forest Inventory measurements; 0.01 t C ha^{-1} stored in grassland (data of 2019)).

Carbon stock change in soil organic matter

Estimations of change in C stocks in mineral and organic soils in Lands converted to Cropland were based on same methodological approaches as for Cropland remaining Cropland (Tier 1 method, described in section of cropland remaining cropland GHG emission estimation from mineral soils). The same guidance, provided in Section 2.3.3 of Chapter 2 in guidelines (*2006 IPCC Guidelines*), based on assumptions of carbon stock changes in soil during the time period occurs concerning impact of land-use, management practices, C input to the soil and drainage of organic soils, was used for estimating changes in soil C stocks.

Mineral soils

Calculations of carbon stock changes in mineral soils on Lands converted to Cropland were made in order to estimate carbon stock gains or losses due to different conversion. It is estimated that mineral soils of grassland have larger organic carbon stocks comparing to cropland, while carbon stocks in mineral soils of settlements and other land are assumed to be 0. Carbon stock changes in mineral soils were calculated due to the conversions of grassland, settlements and other land to cropland.

Calculations were based on Equation 2.25 (p. 2.30, Ch. 2 of *2006 IPCC Guidelines*). Country-specific reference C stocks estimated from the study of "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land" carried out by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the "Partnership project on Greenhouse gas inventory" between Lithuania and Norway, default stock change factors (Table 5.5, p. 5.17, of *2006 IPCC*) and default 20 year time period for stock changes were used for calculations.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

where:

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1};

SOC_0 - soil organic carbon stock in final land use category (cropland), tonnes C;

$SOC_{(0-T)}$ - soil organic carbon stock in initial land use category, tonnes C;

National SOC_0 and $SOC_{(0-T)}$ values were used at each of the points in time (time = 0 (first year after conversion period - 20 years) and time = 0-T (first year of the beginning of conversion period)). Due to the lack of reliable data, it is assumed that there is no organic carbon stock accumulated in settlements and other land categories soils, therefore $SOC_{(0-T)}$ for settlements and other land were indicated as 0 in calculations. National SOC_0 values: 81 t C ha^{-1} in grassland and 76.1 C ha^{-1} in cropland.

T - number of years over a conversion period, yr;

D - time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr.

Value of annual organic carbon stock change in mineral soils was multiplied by the activity data of each year. Activity data was obtained from NFI estimations, executed by State Forest Service.

Organic soils

CO_2 emissions from carbon stock changes in organic soils were calculated due to the drainage of organic soils, in purpose to make it suitable for agricultural crop cultivation. CO_2 emissions from drainage of organic soils are the result of enhanced microbial activity, when the microorganisms decompose greater amounts of organic matter accumulated in organic soils.

According to the data of NFI (years 2014 - 2018), area of drained organic soils was assumed to be 6.2 % of Grassland converted to Croplands (it was assumed that the same share of drained organic soils in land remaining land category should be applied to the category of that land converted to other land use), 1.1 % of settlements converted to cropland (according to the total share of drained organic soils in cropland) and the whole area of Wetlands converted to Cropland. Calculation of carbon stocks in organic soils on Lands converted to Cropland were based on same methodological approaches as for Cropland remaining Cropland, described in chapter 6.3.2.1. Equation used for calculation of emissions resulting from organic soil drainage is presented below.

$$L_{Organic} = \sum_c (A \times EF)_c$$

where:

$L_{Organic}$ - annual carbon loss from drained organic soils, tonnes C yr^{-1};

A - land area of drained organic soils in climate type c, ha;

EF - emissions factor for climate type c, tonnes C ha^{-1} yr^{-1}.

Emissions from organic cropland soils were calculated using activity data obtained from NFI estimations, multiplying total grassland converted to cropland area with 6.2 %, multiplying total settlements converted to cropland area with 1.1 % and adding total wetland converted to cropland area (all wetlands are considered as organic soils), then multiplying those areas with default emission factor was used (Table 5.6 of *2006 IPCC Guidelines*, EF - 5.0 t C ha^{-1} yr^{-1}). Carbon stock changes due to the drainage of organic soils in cropland category are included in the CRF Table 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils, line Drained organic soils (Cropland), whereas reported as IE in CRF Table 4.B.2.

Non-CO_2 greenhouse gas emissions from biomass burning

Lithuania uses Tier 1 method and default emission factors for each non-CO_2 greenhouse gas, provided in the Table 6-29 to estimate non-CO_2 GHG emissions from biomass burning in Cropland (GHG emissions from biomass burning in Land converted to Cropland are included in the value of GHG emissions from biomass burning in Cropland remaining Cropland). Statistics of Fire and rescue department do not provide details on Cropland area burnt to separate areas of Cropland remaining Cropland and Land converted to Cropland, therefore all non-CO_2 greenhouse gas emissions from wildfires in cropland category are accounted under the subcategory Cropland remaining Cropland. Non-CO_2 greenhouse gas emissions from biomass burning in land converted to cropland subcategory in CRF reported are reported with notation key IE.

Direct N_2O emissions from N mineralization/immobilization

Direct N_2O emissions are produced naturally in soils through the processes of nitrification and denitrification, however, management of soils could have an impact to increase such emissions. Changes in inorganic N pool in soils, resulting in direct or indirect emissions of N_2O, could be affected by human induced net N additions to the soils (synthetic and organic fertilizers, etc.), changes of soil organic carbon (due to the drainage/management of organic soils, cultivation/land-use change on mineral soils), resulting in changes of soil C:N ratio, which in turn leads to emissions.

Direct N_2O emissions from mineral soils in LULUCF sector are resulting from changes of soil organic carbon due to the land-use change, calculating the amount of N_2O released to the atmosphere as the result of the organic N mineralization after carbon stock in soil has decreased (loss of soil organic carbon occurs after conversion). Direct N_2O emissions due to the cultivation of mineral soils (cropland remaining cropland) and drainage of organic soils in cropland and grassland categories are accounted under Agriculture sector, therefore only land converted to other land activity data is considered while calculating emissions due to carbon stock loss in mineral soils.

For the accounting of direct N_2O emissions from LULUCF sector default *2006 IPCC Guidelines* Tier 1 methodology was used (with Tier 2 requirements of disaggregation of individual land-use types while accounting direct N_2O emissions due to the loss of soil organic carbon resulting from land-use changes). Equation 11.1 (p. 11.7 of *2006 IPCC Guidelines*) was implemented:

$$N_2O_{Direct} - N = N_2O - N_{N\ Inputs} + N_2O - N_{OS} + N_2O - N_{PRP}$$

where:

$N_2O_{Direct} - N$ - annual direct N_2O-N emissions, produced from managed soils, kg N_2O-N yr^{-1};

$N_2O - N_{N\ Inputs}$ - annual direct N_2O-N emissions from N inputs to managed soils, kg N_2O-N yr^{-1};

$N_2O - N_{OS}$ - annual direct N_2O – N emissions from managed organic soils, kg N_2O-N yr^{-1} (included under Agriculture sector)

$N_2O - N_{PRP}$ - annual direct N2O – N emissions from urine and dung inputs to grazed soils, kg N_2O-N yr^{-1} (included under Agriculture sector)

$$N_2O - N_{N\ Inputs} = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \times EF_1$$

where:

F_{SN} - annual amount of synthetic fertilizer N applied to soils, kg N_2O-N yr^{-1} (included under Agriculture sector)

F_{ON} - annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N_2O-N yr^{-1} (included under Agriculture sector)

F_{CR} - annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N_2O-N yr^{-1} (included under Agriculture sector)

F_{SOM} - annual amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1};

EF_1 - emission factor for N_2O emissions from N inputs, kg N_2O-N (kg N input)$^{-1}$.

Equation 11.8 (p. 11.16 *of 2006 IPCC Guidelines*) was used for estimation of amount of N in mineral soils that is mineralized in association with loss of soil C from soil organic matter:

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,LU} \times \frac{1}{R} \right) \times 1000 \right]$$

where:

$\Delta C_{Mineral,LU}$ - average annual loss of soil carbon for each land-use type (*LU*), tonnes C (according to Tier 2 methodology, value was disaggregated by individual land-uses);

R - C:N ratio of the soil organic matter. A default value of 15 (uncertainty range from 10 to 30) for the C:N ratio (R) may be used for situations involving land-use change from Forest land or Grassland to Cropland, in the absence of more specific data for the area;

LU - land-use type.

Default emission factor used in calculations of direct N_2O emissions due to the loss of soil organic carbon:

– EF_1 – 0.01 kg N_2O-N (kg N input)$^{-1}$ (Table 11.1, p. 11.11 of *2006 IPCC Guidelines*)

Carbon stock loss after other land uses conversion to cropland was used as activity data for direct N_2O emissions estimation from N mineralization/immobilization.

Indirect N_2O emissions from leaching and runoff

Lithuania is located in surplus precipitation zone, therefore a certain amount of precipitation forms both surface and underground runoff annually. According to "Geography of Lithuanian waters" (Kilkus, Stonevicius, 2011), runoff in Lithuania varies among 25 – 50 percent of precipitation, on the basis of terrain, soil, etc. In addition to the direct N_2O emissions resulting from carbon stock change (loss) after land use change, indirect N_2O emissions also take place through runoff. Some of the inorganic (mineralized due to the carbon stock decrease after land use change) N does not take part in biological retention processes, therefore is removed with surface water flow (runoff) or through soil and afterwards is transformed into N_2O. Indirect N_2O emissions for all land use categories where direct N_2O emissions from N mineralization/immobilization due to carbon stock change after land use change occur are calculated using the same default *2006 IPCC* methodology – Equation 11.10 (Tier1 method).

$$N_2O_{(L)}\text{-}N = F_{SOM} \times Frac_{LEACH-(H)} \times EF_5$$

where:

$N_2O_{(L)}$-N - annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kg N_2O-N yr^{-1};

F_{SOM} - annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes in to land use or management in regions where leaching/runoff occurs, kg N yr^{-1} (from Equation 11.8);

$Frac_{LEACH-(H)}$ - fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$, default value, 0.3 (Table 11.3, p. 11.24 of *2006 IPCC*);

EF_5 - emission factor for N_2O emissions from N leaching and runoff, kg N_2O-N (kg N leached and runoff)$^{-1}$, default value, 0.0075 (Table 11.3, p. 11.24 of *2006 IPCC*).

6.3.3 Uncertainty assessment

The activity data were obtained from National Forest Inventory, The National Land Service (NLS) and State enterprise Agricultural Information and Rural Business Centre (AIRBC).

The emission factors were employed from *2006 IPCC Guidelines*.

The uncertainty rates for activity data and emission factors used in the estimates are reported in Table below.

Table 6-30. Values of uncertainties for Cropland

Input	**Uncertainties, %**	**References**
Activity data		
Cropland area	±2.0	*Study 2, NFI*
Emission factors		
G (biomass accumulation)	±75	p. 5.9, *2006 IPCC*
L (biomass loss)	±75	p. 5.9, *2006 IPCC*
F_{LU} F_{MG} F_I	NA	

EF (organic soils)	±90	p. 5.19, *2006 IPCC*
EF_1 (N_2O emissions from N inputs)	-70/+300	p. 11.11, *2006 IPCC*

6.3.4 Category-specific QA/QC and verification

The QC/QA is based on quality control activities described in *2006 IPCC Guidelines* (Vol 1, Chapter 6, Table 6.1). Quality control and quality assurance objectives and procedures for Lithuanian GHG inventory at the national level are presented in Chapter 1.2.3 Quality assurance, quality control and verification plan. The QA/QC of activity data from State Forest Service is explained in Chapter 6.2.5, the use of country specific data is described in the inventory report.

The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF, the comments received after QA/QC procedures while reviewing the report are taken into account and errors found were corrected.

European Commission every year organizes a technical review of EU Member States' GHG inventories to ensure accuracy, reliability and transparency of information on annual GHG emissions and evaluate member state‘s accomplishment of EU Effort sharing regulation targets and improve GHG reporting from all relevant categories. Reviewers provide comments and recommendations to improve GHG inventory, which are taken into account for inventory compilation.

Additional external QA/QC procedure was performed during the consultation with Ministry of Agriculture and different stakeholders – Association of Agricultural Companies, Lithuanian Research Centre for Agriculture and Forestry. Revision of carbon stock changes in mineral soils of cropland remaining cropland due to different management practices, which resulted in updated information of organic cropland area and stock change factors.

6.3.5 Category-specific recalculation

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation, which resulted in slightly different areas of mineral and organic soils of land converted to cropland, used to estimate carbon stock changes in mineral soils, CO_2 emissions from drainage and direct N_2O emissions due to the N mineralization/immobilization. National carbon stock value in dead wood was applied to estimate carbon stock changes in dead organic matter (dead wood) in grassland converted to cropland. In addition to the updated estimations, calculation error was corrected in carbon stock changes of organic soils in grassland converted to croplands subcategory for the year 2012 and incorrect application of areas in the estimation of carbon stock changes in mineral soils after settlements conversion to cropland.

Table 6-31. Submitted and recalculated total emissions/removals in cropland category, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference %
2002	1,709.62	1,710.44	0.82	0.05
2003	1,392.12	1,392.94	0.82	0.06
2005	1,233.34	1,235.79	2.45	0.20
2006	1,760.55	1,758.92	-1.63	-0.09
2007	1,636.54	1,630.82	-5.72	-0.35
2008	1,704.33	1,697.79	-6.54	-0.38
2009	1,522.84	1,516.30	-6.54	-0.43
2010	989.06	982.57	-6.49	-0.66
2011	1,305.14	1,296.82	-8.32	-0.64

2012	1,240.12	1,232.76	-7.36	-0.59
2013	1,183.99	1,176.87	-7.12	-0.60
2014	1,308.29	1,299.70	-8.59	-0.66
2015	836.21	824.48	-11.73	-1.40
2016	663.54	646.91	-16.63	-2.51
2017	950.09	934.44	-15.65	-1.65
2018	941.57	924.53	-17.04	-1.81
2019	896.61	863.39	-33.22	-3.71

6.3.6 Category-specific planned improvements

Lithuania has applied provisional national carbon stock values in cropland mineral soils. In the next submission Lithuania is planning to further improve accuracy of LULUCF GHG inventory with implementation of different carbon stock values for different soil groups in cropland, meaning the expansion of land-use change matrix to different soil groups. Preliminary soil carbon stock values for carbon stock changes estimation is presented in Table 6-24.

Lithuania has launched a national project regarding carbon stock value estimation in agricultural land uses (cropland and grassland) in order to qualify carbon stock values in different soils types as established from the projected carried out by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the "Partnership project on Greenhouse gas inventory" between Lithuania and Norway and, if possible, to evaluate carbon stock changes in soils over time.

6.4 Grassland (CRF 4.C)

According to national definition – grassland includes meadows and natural pastures planted with perennial grasses or naturally developed, on a regular basis used for moving and grazing. Grasslands cultivated for less than 5 years, in order to increase soil vegetation (only certain plant species suitable for grassland improvement can be planted - e. g. clover, lucerne; no wheat, barley, rape seed, etc. crops are considered as grassland improvement - wheat, barley and other crop cultivation is considered as management of cropland), still remain grasslands. All grasslands are considered as managed land in Lithuania, therefore emissions/removals are accounted for the whole area.

The area of grassland in Lithuania has been changing with different extent. Since 1990 the grassland area was increasing and 15 years later grassland area was about 1.5 times higher and reached 1,827 kha of the country land. From 2006 area of grassland has started to decrease and is still decreasing with the exception in 2010 - 2012 when the area was slightly increasing. Thus in 2020 grassland occupied 1,542 kha of total country area. The obtained data indicates that during all the period there were no emissions accounted from grassland category, however, GHG removals vary depending on land use changes (Figure 6-24). Net CO_2 absorption was increasing along the grassland area increment. In 2005 the net CO_2 absorption was 1,648.0 kt CO_2 eq. and nearly 2.5 times higher comparing with 1990. In 2020 the net CO_2 absorption reached 753.3 kt CO_2 eq. and the tendency of significantly lower CO_2 absorption since 2015 could be seen. However, CO_2 emissions from the grassland remaining grassland were not changing significantly and the average of CO_2 emissions from drainage of organic soils were 60 kt CO_2 eq. The most significant CO_2 accumulation was in cropland converted to grassland. The highest amount of CO_2 accumulated in cropland converted to grassland was 1,486.6 kt CO_2 eq. (in 2001). Thus, in 2020 the CO_2 accumulation was 668.5 kt CO_2 eq. and almost 2 times lower in comparison with intensive CO_2 accumulation period. Having in mind National Rural Development Programme for 2014-2020, the situation with grasslands should at least remain in the stable phase (the total area of grasslands should remain not smaller than in recent years) or even be improved. Area of grassland is expected to increase with special financial measures, encouraging cropland conversion to grassland in ecologically sensitive and important areas. This is further promoted since 2021 some farmers will be obligated to convert certain amount of croplands, that were previously tilled grasslands, back into grassland (Ministry of Agriculture, 2021).

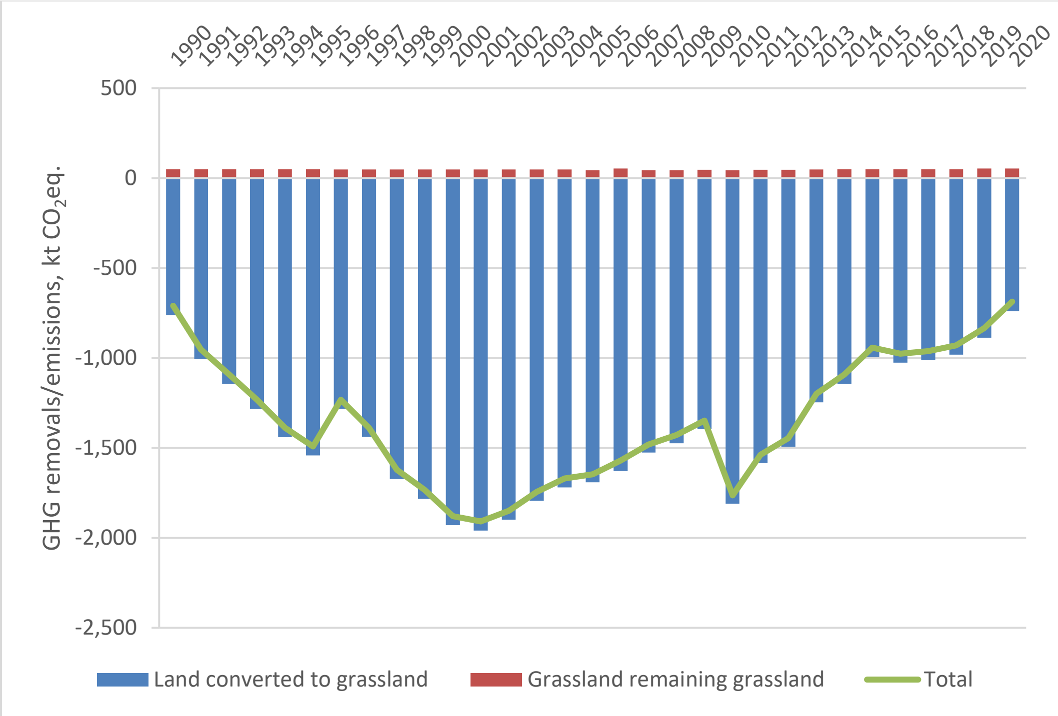


Figure 6-24. GHG emissions and removals in grassland in 1990-2020, kt CO_2 eq.

6.4.1 Category description

Two source categories are accounted under this category: emissions from Grassland remaining Grassland and emissions from Land converted to Grassland. Carbon stock changes estimated from the subcategories are presented in the table below.

Table 6-32. Estimated carbon stock changes under Grassland category

Land Use Category	CS change in biomass	CS change in dead organic matter	CS change in soils	
			Mineral soils	Organic soils
Grassland remaining Grassland	NO	NO	NO*	√
Land converted to Grassland	√	√	√	√

**Assumed to be close to zero, therefore reported as NO*

6.4.2 Methodological issues

6.4.2.1 Grassland remaining Grassland

Areas continuously managed as Grassland and areas converted to Grassland after 20 consecutive years followed conversion are reported in the category Grassland remaining Grassland (GG).

The annual greenhouse gas emissions and removals from Grassland Remaining Grassland include:

- Estimates of annual change in C stocks from C pools and sources – carbon stock changes in organic soils;
- Estimates of annual emission of non-CO_2 gases from above-ground biomass.

Carbon stock changes in living biomass

Grassland management practices in Lithuania mainly are static; therefore it do not have significant impact on herbaceous vegetation biomass changes and biomass remains in an approximate steady-state. Default Tier 1 method (p. 6.6 of *2006 IPCC Guidelines*) was elected assuming that no significant change in herbaceous vegetation biomass in Grassland Remaining Grassland occurs during the years of management.

Carbon stock changes in living biomass of woody vegetation in grassland were estimated taking into account growing stock volume change of trees in grassland measured by National Forest Inventory. Estimation of carbon stock changes was completed applying the same methodology as for forest land remaining forest land (Ch. 6.2.2.1).

Carbon stock change in dead organic matter

Default Tier 1 method was elected for evaluation of carbon stock changes in dead organic matter, assuming that the dead wood and litter stocks are at equilibrium in grassland remaining grassland, so there is no need to estimate the carbon stock changes for this pool and it is reported as NO.

Carbon stock change in soil organic matter

Carbon stock changes in soil organic matter are reported only as changes occurring due to the drainage of organic soils, Tier 1 method for carbon stock changes accounting was elected.

Area of organic and mineral soils was determined by using data of *NFI* permanent sample plots measured in 2014-2018, according to the measurements area of organic soils constitute to 6.6% and area of mineral soils 93.4% of total grassland remaining grassland area.

Grassland management data are limited in Lithuania, country experts' report (Balezentiene, Bleizgys, 2011) that due to domestic political-economic circumstances, about 50% of grasslands are abandoned and have been turning into natural habitats/climatic ecosystems during last two decades. Therefore using Tier 1 method organic C stocks changes in mineral soil over a 1990-2017 period estimated to be close to 0 and have been reported as NO.

Mineral Soils

Grasslands in Lithuania mainly represents non-degraded and sustainably managed grasslands, but without significant management improvements and impacts on soil organic carbon emissions/sequestration during the last decades.

Soil organic C stocks has been estimated for the inventory period of 1990-2018 using national carbon stock value (SOC_{REF} = 81.0 t C ha^{-1}, grasslands) for agricultural soils (Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, 2016) and the relevant stock change factors. Factors for F_{LU}, F_I and F_{MG} for different management activities on Grassland were taken from Table 6.2 (p. 6.16 of *2006 IPCC*). Relative stock change factors for grassland management used in estimations are presented in the Table below.

Table 6-33. Relative stock change factors for grassland management used in estimations

Relative stock change factors \ Management practices	**Nominally managed**	**Moderately degraded grassland**
Land use F_{LU}	1.0	1.0
Management F_{MG}	1.0	0.95
Input F_I	1.0	1.0

As grassland management activities in Lithuania are not changing, it was assumed that annual carbon stock changes in mineral soils for Grassland remaining Grassland are close to zero, therefore could be reported as NO.

Organic soils

Using data presented by National Forest Inventory permanent sample plots measured in 2014 - 2018, organic soils constitute 6.6 % from the total Grasslands area, and it was assumed that this value is equally correct to Grasslands remaining Grasslands and to Grasslands converted to other land uses. However, drained organic soils in Grassland category (both for Grassland remaining Grassland and Grassland converted to other land subcategories) constitute 6.2 % of total Grassland area, with the remaining share of organic soils being undrained, according to NFI measurements. It was assumed that share of organic soils are equal for Grassland remaining Grassland category and Grassland converted to other land use category.

Organic soils in Lithuania are determined by using national definition of organic soils, provided in the book of Lithuanian soil classification (Buivydaite et al., 2001): soil is classified as organic if it has peat layer not thinner than 40 cm or 60 cm of poorly decomposed peat (mainly mossfibres) in bogs. In addition to this, histic horizon must contain not less than 70 - 75 percent of organic matter by volume. National definition of organic soils (histosols) was prepared using Food and Agriculture Organization (FAO) guidelines for soil classification (World reference base for soil resources).

Tier 1 method was used in order to calculate carbon stock changes in organic soils in grassland remaining grassland (Equation. 2.26, p. 2.35 of *2006 IPCC Guidelines*).

$$L_{Organic} = \sum_c (A \times EF)_c$$

where:

$L_{Organic}$ - annual carbon loss from drained organic soils, tonnes C yr^{-1};

A - land area of drained organic soils in climate type c, ha;

EF - emissions factor for climate type c, tonnes C ha^{-1} yr^{-1}.

Default emission factor of 0.25 tonnes C ha^{-1} yr^{-1} for a cold temperate climate has been used for calculations (Table 6.3, p. 6.17 of *2006 IPCC Guidelines*). Emissions from drainage of organic soils are included in CRF Table 4(II) Emissions and removals from drainage and rewetting and other management of organic soils and mineral soils, line Drained organic soils (Grassland), therefore carbon stock changes in organic soils are reported as IE.

Inorganic C

No method is provided for estimation of the change in soil inorganic C stocks due to limited scientific data for derivation of stock change factors; thus the net flux for inorganic C stocks is assumed to be zero (p.2.29 of *2006 IPCC Guidelines*).

Non-CO_2 greenhouse gas emissions from biomass burning

CO_2 emissions from biomass burning in grasslands are not reported as it is assumed that all the emissions released during combustion are usually reabsorbed in the rest of biomass during the photosynthesis activity. Therefore, only non-CO_2 GHG emissions are reported: CH_4, N_2O.

In Lithuania there is no controlled burning of Grassland and emissions of non-CO_2 only results from wildfires. Grassland wildfires are infrequent and burnt area normally averaged at ≤5 thous. ha, but peak value can exceed 32.6 thous. ha (in 2006).

Emissions from Grassland category were estimated employing the Equation. 2.27 (Ch. 2, p. 2.42 of *2006 IPCC Guidelines*).

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

where:

L_{fire} - amount of greenhouse gas emissions from fire, tonnes of each GHG;

A - area burnt, ha;

M_B - mass of fuel available for combustion, tonnes d. m. ha^{-1} (default value, Table 2.4 of *2006 IPCC Guidelines*);

C_f - combustion factor, dimensionless (default value, Table 2.6 of *2006 IPCC Guidelines);*

G_{ef} - emissions factor, g kg^{-1} dry matter burnt (default value, Table 2.5 of *2006 IPCC Guidelines*).

Default emission factors used for calculation of different non-CO_2 GHG gases resulting from grassland wildfires are presented in the Table below.

Table 6-34. Default emission factors used for calculation of non-CO_2 GHG emissions, g kg-1, means ± SD

Category	**CO**	**CH_4**	**N_2O**	**NO_x**
Savanna and grassland	65 ±20	2.3 ±0.9	0.21 ±0.10	3.9 ±2.4

National estimates of Mass of Fuel Available for Combustion (M_B) are not available, therefore default data provided in Table 2.4 (Ch. 2, p. 2.45 of *2006 IPCC Guidelines*) for the mass of fuel consumed ($M_B \times C_f$) were used which equals to 4.1 tonnes d.m. ha^{-1}.

Activity data on Grassland area burnt was obtained from statistics of Fire and rescue department.

6.4.2.2 Land converted to Grassland

The cumulative areas of land converted to grassland during a 20-year transition period are reported in Figure 6-25. For each year, the cumulative total area reported under Land converted to Grassland (LG) category is accounted as equal to the cumulative area that has been converted to that land use over the last 20 years, areas of second land-use change during the 20-year conversion period are subtracted by the cumulative total.

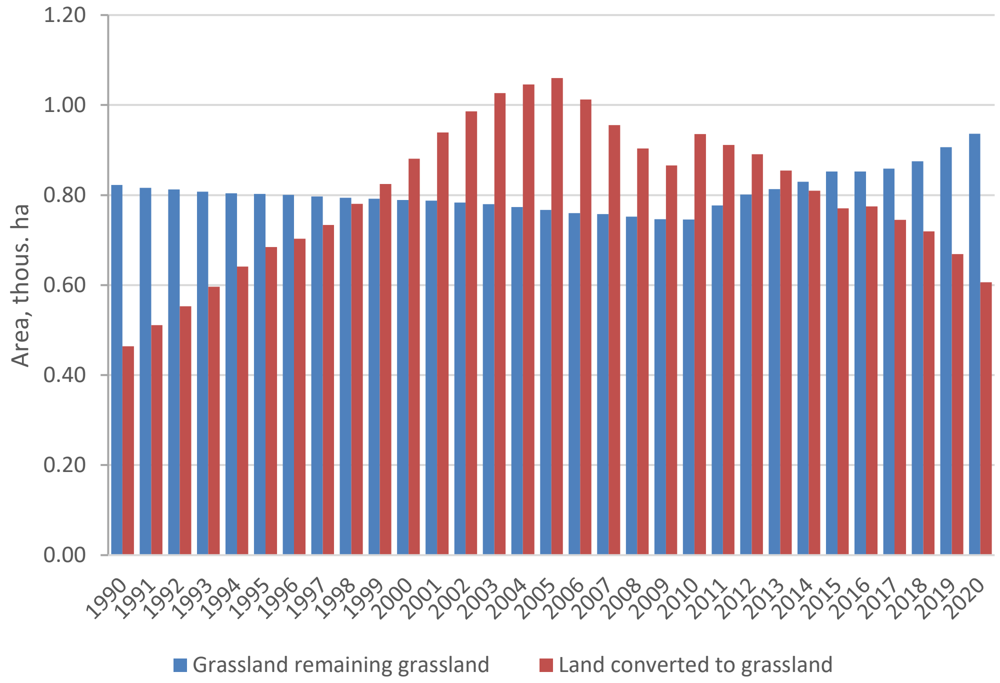


Figure 6-25. Grassland area changes during 1990-2020, thous. ha

According to the information obtained from *Study-1* and *Study-2* during the last decades there have been no conversions from Forest land to Grasslands and main conversions from 1990 to 2005 were from cropland to grassland, since 2006 conversions from cropland to grassland decreased with increasing vice versa conversions – from grassland to cropland.

Estimation of annual greenhouse gas emissions and removals from Land Converted to Grassland involves estimation of changes of carbon stock in pools: above-ground biomass and soil organic matter.

All emissions of non-CO_2 GHG resulting from biomass burning are reported under Grasslands remaining Grasslands category, because of lack of statistical data of wildfires distributed between grassland remaining grassland and land converted to grassland area.

Carbon stock changes in living biomass

Carbon stock changes in land converted to grassland contain changes in above-ground biomass. For land converted to Grassland, CO_2 emissions and removals are based on estimating the effects of previous vegetation type being replaced by grassland vegetation (Ch. 6, p. 6.5 of *2006 IPCC Guidelines*).

Tier 2 method was used to estimate annual change in carbon stocks in living biomass on Land converted to Grassland employing Equations 2.15 and 2.16 (Ch. 2, p. 2.20 of *2006 IPCC Guidelines*). Area estimates for Land Converted to Grassland were disaggregated according to original vegetation and average carbon stock change per hectare is estimated for each type of conversion.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

where:

ΔC_B - annual change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1};

ΔC_G - annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr^{-1};

$\Delta C_{CONVERSION}$ - initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1};

ΔC_L - annual decrease in biomass carbon stocks due to the losses from harvesting, fuel wood gathering and disturbances on land converted to other land use category, in tonnes C yr^{-1}.

According to the default methodology for Tier1 and Tier2, provided in p. 6.29, Ch. 6, Vol. 4 of 2006 IPCC guidelines, ΔC_G and ΔC_L equal zero.

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTERi} - B_{BEFOREi}) \times \Delta A_{TO\_OTHERSi}\} \times CF$$

where:

$\Delta C_{CONVERSION}$ - initial change in biomass carbon stocks on land converted to another land category, tonnes C yr^{-1};

B_{AFTERi} - biomass stocks on land type *i* immediately after the conversion, tonnes d. m. ha^{-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 other land-use category in a certain year, ha yr^{-1};

CF - carbon fraction of dry matter (default value of 0.47, p. 6.29, Ch. 6, Vol. 4 of *2006 IPCC* Guidelines), tonnes C (tonnes d. m.)$^{-1}$;

i - type of land use converted to another land-use category.

It is assumed that all biomass is lost immediately from the previous ecosystem after conversion and residual biomass is thus assumed to be zero, whereas following one year of conversion to grassland living biomass is equal to 13.6 tonnes d. m. ha^{-1} (p. 6.27, Ch. 6, Vol. 4 of *2006 IPCC Guidelines*) - B_{AFTER}. According with the tier1 methodology, phase 2 in the *2006 IPCC* Guidelines (p. 6.25, Ch. 6, Vol. 4), grasslands achieve their steady-state biomass during the first year following conversion, and hence, no annual growth is reported thereafter. All the changes are included in the carbon stock in biomass immediately after conversion to grassland.

Biomass carbon stock in initial land-use categories (B_{BEFORE}) is assumed to be 10 t ha^{-1} d. m. in annual Croplands (p. 6.27, Ch. 6, Vol. 4 of *2006 IPCC* Guidelines), 63 t C ha-1 in perennial Croplands (p. 5.9, Ch. 5, Vol. 4 of *2006 IPCC* Guidelines), 0.0 t ha^{-1} d. m. in Other Land. Actual share between annual and perennial cropland, as estimated each year, was applied to differentiate areas of annual and perennial cropland converted to grassland. No default values of B_{BEFORE} were provided for wetlands and settlements converted to grassland, furthermore it was assumed that all conversions to grassland occur on lands with herbaceous vegetation for which the biomass immediately before conversion (B_{BEFORE}) can be assumed to be equal to 0, therefore no carbon stock changes in living biomass were estimated and thus reported as NE.

Carbon stock changes in dead organic matter

Lithuania has no estimates of the dead wood and litter in the initial land-use systems (except Forest land and Grassland) prior to conversion. Litter and dead wood carbon stock gain was estimated in cropland, settlements and other land converted to grassland, while carbon stock loss in litter was estimated in forest land converted to grassland (such conversions occurred only in 2018, 2019 and 2020).

Equation 2.23 from p. 2.26, Ch. 2, Vol. 4 of *2006 IPCC* Guidelines was applied:

$$\Delta C_{DOM} = \frac{(C_n - C_0) \cdot A_{0n}}{T_{0n}}$$

Where:

ΔC_{DOM} – annual change in carbon stocks in dead wood or litter, tonnes C yr^{-1}

C_0 – litter/dead wood stock, under the old land-use category, tonnes C yr^{-1} (7.65 t C ha^{-1} in litter stock in forest land remaining forest land; 3.56 t C ha^{-1} in litter stock in land converted to forest land category; 0 t C ha-1 in litter and dead wood stock in cropland, settlements and other land)

C_n – litter/dead wood stock, under the new land-use category, tonnes C yr^{-1} (0.8 t C ha^{-1} in litter stock and 0.01 t C ha^{-1} in dead wood stock in grassland (data of 2019))

A_{0n} – area undergoing conversion from old to new land use category, ha

T_{0n} – time period of the transition from old to new land-use category, yr. The Tier 1 default 20 years was applied for carbon stock increases and 1 year for carbon losses.

Carbon stock changes in soil organic matter

Estimations and assumptions of change in C stocks in mineral and organic soils on Lands converted to Grassland were based on same methodological approaches as for Grassland remaining Grassland and guidance for estimating changes in soil C stocks are provided in Section 2.3.3 (Ch. 2 of *2006 IPCC Guidelines*). Activity data is provided by State Forest Service executed NFI.

Mineral soils

Calculations of carbon stock changes in mineral soils on Lands converted to Grassland were made in order to estimate carbon stock gains or losses due to different conversion. It is estimated that mineral soils of grassland have larger organic carbon stocks comparing to cropland, while carbon stocks in mineral soils of settlements and other land are assumed to be 0. Carbon stock changes in mineral soils were calculated due to the conversions of cropland, settlements and other land to cropland.

Calculation of carbon stocks in mineral soils on Lands converted to Grassland were based on eq. 2.25 (Ch. 2, p. 2.30 of *2006 IPCC Guidelines*). Country-specific reference C stocks (SOC_{REF} - 76.1 t C ha^{-1} yr^{-1} (cropland), SOC_{REF} - 81.0 t C ha^{-1} yr^{-1} (grassland)), estimated from the results of the study "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the ""Partnership project on Greenhouse gas inventory" between Lithuania and Norway and default 20 year time period for stock changes were used for calculations.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

where:

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1};

SOC_0 - soil organic carbon stock in final land use category (grassland), tonnes C;

$SOC_{(0-T)}$ - soil organic carbon stock in initial land use category, tonnes C;

Joint Research Centre estimated SOC_0 and $SOC_{(0-T)}$ values were used at each of the points in time (time = 0 (first year after conversion period - 20 years) and time = 0-T (first year of the begining of conversion period)). Due to the lack of reliable data it is assumed that there are no organic carbon stock accumulated in settlements and other land categories soils, therefore $SOC_{(0-T)}$ for settlements and other land were indicated as 0 in calculations.

T - number of years over a conversion period, yr;

D - time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr.

Activity data for accounting of CO_2 emissions due to carbon stock changes resulting from land use changes were obtained from NFI estimations.

Carbon stock changes in mineral soil in land converted to grassland resulted in largest carbon sink in grassland category, when after the conversion more carbon is stored in mineral soils of grassland, comparing to other land uses. The net change of carbon stock in mineral soils was the highest in cropland converted to grassland (in 2005 carbon stock change in cropland converted to grassland reached its peak and was 246.8 kt C). However, the lowest carbon stock increase was in settlement converted to grassland (carbon stock changes from 1991 till 2020 was in average of 26.9 kt C). Results are provided in Figure below.

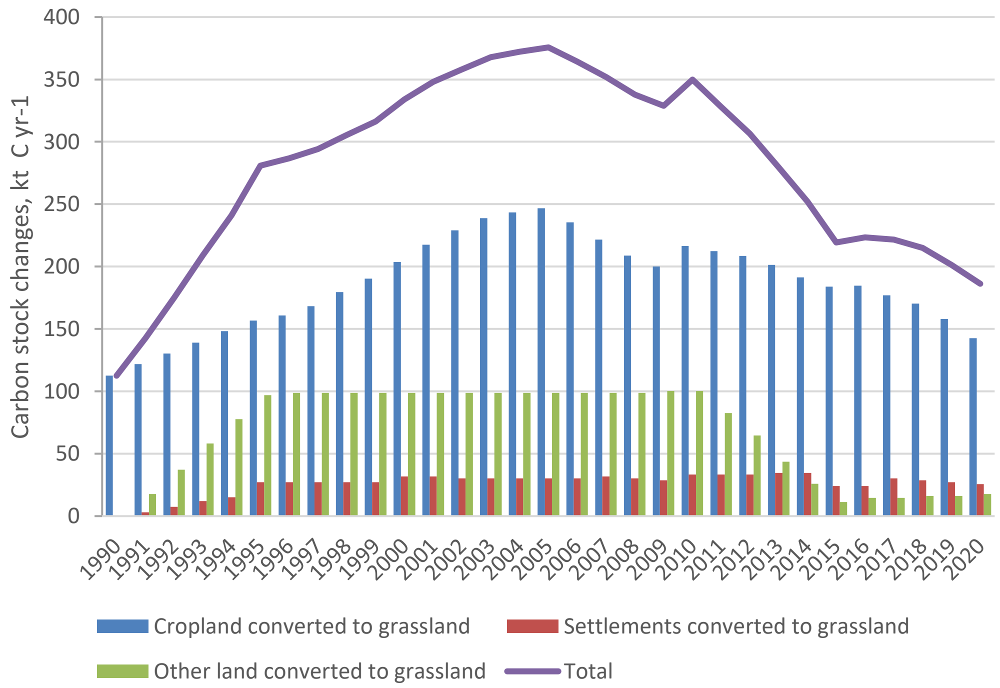


Figure 6-26. Carbon stock changes in mineral soil in land converted to grassland, kt C

Since 2018, there were conversions from forest land to grassland reported, therefore carbon stock changes were estimated in mineral and organic soils. Carbon stock change in mineral soils was estimated taking into account different initial (57.34 t C ha^{-1} in mineral soil of new forest) and final (48.33 t C ha^{-1} in mineral soil of grassland which has been converted to forest land) carbon stock, estimated in the study "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the "Partnership project on Greenhouse gas inventory" between Lithuania and Norway. The summary of this study is provided in the Annex X.

Organic soils

CO_2 emissions from organic soils were accounted as occurring due to the drainage of organic soils only. Drainage of organic soils have an impact to microbial activity which results in greater decomposition of organic matter accumulated in organic soils, which in turn leads to CO_2 emissions.

Activity data for accounting of CO_2 emissions due to the drainage of organic grassland soils was estimated based on NFI data. It was assumed that Croplands converted to Grasslands has 1.1 % share of organic soils from total area of cropland converted to grassland and Settlements converted to Grassland has a 6.6 % share of organic soils (according to the share of organic soils in Grassland category), according to the data of the most recent NFI measurement (2014 – 2018), whereas Other Land converted to Grasslands area contain only mineral soils, and finally Wetlands converted to Grasslands contain area exceptionally of organic soils.

Tier 1 method was used in order to calculate carbon stock change in organic soils due to the drainage of organic soils (Equation 2.26, p. 2.35 of *2006 IPCC Guidelines*).

$$L_{Organic} = \sum_c (A \times EF)_c$$

where:

$L_{Organic}$ - annual carbon loss from drained organic soils, tonnes C yr^{-1};

A - land area of drained organic soils in climate type c, ha;

EF - emissions factor for climate type c, tonnes C ha^{-1} yr^{-1}.

Emission factor of 0.25 tonnes C ha^{-1} yr^{-1} for a cold temperate climate has been used for calculations (Table 6.3, p. 6.17 of *2006 IPCC Guidelines*).

Emissions from drainage of organic soils are included in CRF Table 4(II) Emissions and removals from drainage and rewetting and other management of organic soils and mineral soils, line Drained organic soils (Grassland) altogether with emissions from drained organic soils in Grassland remaining Grassland. Carbon stock changes in organic soils are reported as IE (CRF Table 4.C.2).

In 2018, there were conversions from forest land to grassland reported for the first time, therefore carbon stock changes were estimated in mineral and organic soils. Carbon stock change in organic soils was estimated due to the drainage of organic soils, applying emission factor - 0.25 tonnes C ha^{-1} yr^{-1}, assigned to grassland in Table 6.3, p. 6.17 of *2006 IPCC Guidelines.*

Non-CO_2 greenhouse gas emissions from biomass burning

Same Tier 1 approach was used to estimate non-CO_2 emissions from biomass burning in Land Converted to Grassland as for Grassland Remaining Grassland.

Statistics of Fire and rescue department on Grassland area burnt do not provide details to separate Grassland remaining Grassland and Land converted to Grassland, therefore all non-CO_2 greenhouse gas emissions (both from grassland remaining grassland and land converted to grassland) are accounted in the value for GHG emissions from biomass burning in Grassland remaining Grassland.

Direct N_2O emissions from N mineralization/immobilization

Direct N_2O emissions in land converted to grassland sub-category are resulting from land-use change induced organic carbon stock changes in mineral soils, calculating the amount of N_2O released to the atmosphere as the result of the organic N mineralization after carbon stock in soil has decreased (loss of soil organic carbon occurs after conversion). Direct N_2O emissions due to the drainage of organic soils in grassland are accounted under Agriculture sector, therefore only land converted to grassland activity data is considered while calculating emissions due to carbon stock loss in mineral soils.

There were only forest land use conversion to grassland in 2018 which resulted in carbon stock loss in mineral soil during the whole reporting period, therefore direct N_2O emissions from N mineralization/immobilization after forest land use conversion were reported. Methodology of direct N_2O emissions from N mineralization/immobilization is applied as described in section 6.3.2.2 Land converted to Cropland.

6.4.3 Uncertainty assessment

Activity data was obtained from *NLS* and *NFI Study-2*. Default emission factors were employed from *2006 IPCC Guidelines*. The uncertainty rates for activity data and emission factors are reported in the table below.

Table 6-35. Values of uncertainties for Grassland category

Input	Uncertainties, %	References
Activity data		
Grassland area	±2.2	*Study 2, NFI*
Emission factors		
F_{LU} F_{MG} F_I	NA	*2006 IPCC*, p. 6.16
EF (organic soils)	±90	*2006 IPCC*, p. 6.17
EF_1 (N_2O emissions from N inputs)	-70/+300	p. 11.11*, 2006 IPCC*

6.4.4 Category-specific QA/QC and verification

The QC/QA includes the quality control activities described in *2006 IPCC Guidelines* and are reported in Chapter 6.2.5. Quality control and quality assurance objectives and procedures for Lithuanian GHG inventory at the national level are presented in Chapter 1.2.3 Quality assurance, quality control and verification plan. The QA/QC of activity data from State Forest Service is explained in Chapter 6.2.5, the use of country specific data is described in the inventory report. Country specific data used in inventory was included in the report. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF, the comments received after QA/QC procedures while reviewing the report are taken into account and errors found were corrected.

Some obscurities concerning direct N_2O emissions estimation were clarified after QA procedure performed by Norwegian LULUCF GHG inventory experts under the "Partnership project on Greenhouse gas inventory" in the framework of the programme LT10.

European Commission every year organizes a technical review of EU Member States' GHG inventories to ensure accuracy, reliability and transparency of information on annual GHG emissions and evaluate member state's accomplishment of EU Effort sharing regulation targets and improve GHG reporting from all relevant categories. Reviewers provide comments and recommendations to improve GHG inventory, which are taken into account for inventory compilation.

6.4.5 Category-specific recalculation

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation, which resulted in slightly different areas of mineral and organic soils of land converted to grassland, used to estimate carbon stock changes in mineral soils and CO_2 emissions from drainage. National carbon stock value in dead wood was applied to estimate carbon stock changes in dead organic matter (dead wood) in other land uses converted to grassland. Incorrect application of areas in the estimation of carbon stock changes in mineral soils after settlements conversion to grassland were corrected for this submission as well.

Table 6-36. Submitted and recalculated total emissions/removals in grassland category, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq	Relative difference %
1990	-709.38	-812.81	-103.43	14.58
1991	-950.99	-934.52	16.47	-1.73
1992	-1,091.74	-1,071.58	20.16	-1.85
1993	-1,231.06	-1,209.19	21.87	-1.78
1994	-1,387.91	-1,367.84	20.07	-1.45
1995	-1,490.45	-1,472.23	18.22	-1.22
1996	-1,230.98	-1,230.35	0.63	-0.05
1997	-1,387.43	-1,388.59	-1.16	0.08
1998	-1,621.32	-1,622.53	-1.21	0.07
1999	-1,741.38	-1,733.56	7.82	-0.45
2000	-1,886.25	-1,879.08	7.17	-0.38
2001	-1,902.43	-1,907.03	-4.60	0.24
2002	-1,839.73	-1,850.16	-10.43	0.57
2003	-1,714.54	-1,744.60	-30.06	1.75
2004	-1,641.47	-1,669.28	-27.81	1.69
2005	-1,634.49	-1,646.64	-12.15	0.74
2006	-1,561.28	-1,569.43	-8.15	0.52
2007	-1,463.52	-1,481.37	-17.85	1.22
2008	-1,425.14	-1,428.23	-3.09	0.22
2009	-1,332.12	-1,345.56	-13.44	1.01
2010	-1,777.59	-1,764.44	13.15	-0.74
2011	-1,538.62	-1,538.11	0.51	-0.03
2012	-1,479.27	-1,445.65	33.62	-2.27
2013	-1,163.79	-1,198.94	-35.15	3.02
2014	-1,106.74	-1,090.30	16.44	-1.49
2015	-1,005.60	-937.88	67.72	-6.73
2016	-988.94	-973.16	15.78	-1.60
2017	-992.99	-960.17	32.82	-3.30
2018	-953.94	-928.27	25.67	-2.69

2019	-861.36	-834.17	27.19	-3.16

6.4.6 Category-specific planned improvements

Lithuania has applied provisional national carbon stock values in grassland mineral soils. In the next submission Lithuania is planning to further improve accuracy of LULUCF GHG inventory with implementation of different carbon stock values for different soil groups in cropland, meaning the expansion of land-use change matrix to different soil groups. Preliminary soil carbon stock values for carbon stock changes estimation is presented in Table 6-24.

Lithuania has launched a national project regarding carbon stock value estimation in agricultural land uses (cropland and grassland) in order to qualify carbon stock values in different soils types as established from the projected carried out by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the "Partnership project on Greenhouse gas inventory" between Lithuania and Norway and, if possible, to evaluate carbon stock changes in soils over time.

6.5 Wetland (CRF 4.D)

Wetlands include peat extraction areas and peatlands which do not fulfil the definition of other categories. Water bodies, such as natural rivers and lakes, as well as reclamation canals, ponds and meres, and swamps (bogs) are also included under this category. Peat extraction areas and flooded land are considered as managed land. Differences in perception of wetland definition leads to various estimations of Lithuanian wetlands area, it varies from 243.3 to 609.7 thous. ha (Taminskas et al., 2011). However, according to the historical studies of land use changes in 1990-2011 and recent NFI data, wetland area has slightly decreased from 381 thous. ha in 1990 to 361 thous. ha in 2020.

The total CO_2 emissions from wetlands have been ranging since 1990. Even though the area of wetlands was slightly decreasing till 2020, there was the tendency of increasing CO_2 emissions. The CO_2 emissions in wetlands peaked in 2017 and were 1069.9 kt CO_2, in 2015 emissions were slightly lower and reached 965.1 kt CO_2. The largest emissions from wetlands category originate from wetlands remaining wetlands – peat extraction areas (in 2020 emissions were 809.8 kt CO_2). Emissions from conversion of grassland, cropland and forest land to flooded land were not assessed annually and were minor comparing to the total emissions.

There were minor changes made in wetland category in latest reports. Total wetland area was changed from reporting only managed wetland area (unmanaged wetlands excluding), to reporting of total wetland area in a country, including both managed and unmanaged wetlands. Total wetland area corrections resulted neither in carbon stock changes in pools, nor in changes of total CO_2 emissions from sources and removals by sinks, as emissions and removals were calculated from managed wetland area only as in previous submissions.

6.5.1 Category description

Two source categories are accounted under this category: emissions from Wetlands remaining Wetlands and emissions from Land converted to Wetlands.

Data on wetland area were taken from the *Study-2* (1990-2011) and *NFI* (since 2012). Wetlands remaining Wetlands area distributed into separate groups of unmanaged, peat extraction areas (monitored by Lithuanian Geological Service), managed flooded and other managed (degraded drained bogs). Estimated emissions are summarized in Table 6-37, emissions from unmanaged Wetlands were not estimated.

Table 6-37. Estimated GHG emissions from managed Wetlands

Land Use Category	CO_2	CH_4	N_2O
Peatlands Remaining Peatlands	√	NO	√
Land Being Converted for Peat Extraction	NO	NO	NO
Flooded Land Remaining Flooded Land	NO	NO	NO
Land Converted to Flooded Land	√	NO	√

6.5.2 Methodological issues

6.5.2.1 Peatlands remaining Peatlands

CO_2 emissions

Default Tier 1 method was used to estimate emissions from peatlands with undergoing active peat extraction (eq. 7.3, p. 7.9 of *2006 IPCC*). On-site emissions were estimated using Equation. 7.4 (p. 7.11 of *2006 IPCC Guidelines*), off-site emissions from peat extraction were estimated using Equation. 7.5 (p. 7.11 of *2006 IPCC Guidelines*).

$$CO_2 - C_{WW_{peat}} = CO_2 - C_{WW_{peat_{off-site}}} + CO_2 - C_{WW_{peat_{on-site}}}$$

where:

$CO_2 - C_{WW_{peat}}$ - - CO_2-C emissions from managed peatlands, Gg C yr^{-1};

$CO_2 - C_{WW_{peat_{off-site}}}$ - off-site emissions from peat removed for horticultural use, Gg C yr^{-1};

$CO_2 - C_{WW_{peat_{on-site}}}$ - on-site emissions from peat deposits (all production phases), Gg yr^{-1}.

$$CO_2 - C_{WW_{peat_{on-site}}} = \left[\frac{\left(A_{peatRich} \times EF_{CO_{2}peatRich}\right) + \left(A_{peatPoor} \times EF_{CO_{2}peatPoor}\right)}{1000}\right] + \Delta C_{WW_{peat_B}}$$

where:

$A_{peatRich}$ - area of nutrient-rich peat soils managed for peat extraction (all production phases), ha;

$A_{peatPoor}$ - area of nutrient-poor peat soils managed for peat extraction (all production phases), ha;

$EF_{CO_{2}peatRich}$ - CO_2 emission factors for nutrient-rich peat soils managed for peat extraction or abandoned after peat extraction, tonnes C ha^{-1} yr^{-1};

$EF_{CO_{2}peatPoor}$ - CO_2 emission factors for nutrient-poor peat soils managed for peat extraction or abandoned after peat extraction, tonnes C ha^{-1} yr^{-1};

$\Delta C_{WW_{peat_B}}$ - CO_2-C emissions from change in carbon stocks in biomass due to vegetation clearing, Gg C yr^{-1}.

$$CO_2 - C_{WW_{peat_{off-site}}} = \frac{\left(Wt_{dry\_peat} \times Cfraction_{wt\_peat}\right)}{1000}$$

where:

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 (tonne of air-dry peat)$^{-1}$.

Default emission factors from Table 7.4 (p. 7.13 of *2006 IPCC Guidelines*) were used:

– 0.2 t C ha^{-1} yr^{-1} for nutrient poor peatlands,

– 1.1 t C ha^{-1} yr^{-1} for nutrient rich peatlands.

Default emission factors from Table 7.5 (p. 7.13 of *2006 IPCC Guidelines*) were considered while estimating and using national C fraction value for peatlands of air-dry peat by weight – 0.43 tonnes C (tonne air-dry peat)$^{-1}$:

– 0.45 tonnes C (tonne air-dry peat) for nutrient poor peatlands,

– 0.40 tonnes C (tonne air-dry peat) for nutrient rich peatlands.

Off-site emissions were estimated using Equation 7.5 (p. 7.11 of *2006 IPCC Guidelines*), along with expert judgement made on weight conversion factor 0.43 tonnes C. Area of managed peatlands is continuously decreasing since 1990 (no new peat extraction sites established since then), therefore changes in C stocks in living biomass on managed peatlands are assumed to be zero.

Non-CO_2 emissions

Default Tier 1 method was applied to estimate non-CO_2 emissions from Peatlands remaining Peatlands. CH_4 emissions are assumed to be insignificant in these drained peatlands.

N_2O emissions from drained wetlands estimated using Equation 7.7 (p. 7.15 of *2006 IPCC*). Default emission factor from Table 7.6 (p. 7.16 of *2006 IPCC Guidelines*) has been used – 1.8 kg N_2O-N ha^{-1} yr^{-1} for nutrient rich peatlands.

$$N_2O_{WW_{peatExtraction}} = \left(A_{peatRich} \times EF_{N_2O-N_{peatRich}}\right) \times \frac{44}{28} \times 10^{-6}$$

where:

$N_2O_{WW_{peatExtraction}}$ - direct N_2O emissions from peatlands managed for peat extraction, Gg N_2O yr^{-1};

$A_{peatRich}$ - area of nutrient-rich peat soils managed for peat extraction, including abandoned areas in which drainage is still present, ha;

$EF_{N_2O-N_{peatRich}}$ - emission factor for drained nutrient-rich wetlands organic soils, kg N_2O-N ha^{-1} yr^{-1}.

Tier 1 method only considers nutrient-rich peatlands.

6.5.2.2 Land Being Converted for Peat Extraction

The area of managed peatlands is continuously decreasing since 1990, therefore no new areas of Land converted for peat extraction have been reported.

6.5.2.3 Flooded Land Remaining Flooded Land

The area of flooded lands covers more than 100,000 ha in Lithuania. Neither default *2006 IPCC Guidelines* methodology is provided for Flooded Land remaining Flooded Land emissions estimation, nor preliminary estimates of CH_4 emissions from this source have been developed in Lithuania, therefore no emissions or removals were reported under the subcategory of flooded land remaining flooded land.

6.5.2.4 Other wetlands Remaining Other wetlands

Other wetlands remaining other wetlands consists of unmanaged wetlands and previously managed wetlands which are damaged and currently not managed. Since no active management takes place in such areas and no default estimation methods are provided, no carbon stock changes are reported in this category.

6.5.2.5 Land Converted to Flooded Land

The area of sub-category land converted to wetland in country has been increasing with higher extent with flooding of areas with organic soils than areas with mineral soils. Mineral soil conversion to wetland was mainly related with small areas of forest and other land flooding. As for the other land-use categories, for land converted to flooded land 20 year conversion period is required to account for flooded land remaining flooded land, therefore each area of land converted to flooded land up to 20 years since conversion is accounted for land converted to flooded land sub-category. Area of land converted to flooded land is relatively small in Lithuania, consisting of 2.4 thous. ha (0.04% of country area) in 1990 and 8.4 thous. ha (0.12% of country area) in 2018.

CO_2 emissions

Carbon stock change due to land conversion to permanently flooded land was estimated employing Equation 7.10 (p. 7.20 of *2006 IPCC Guidelines*). Area estimates for Land Converted to Flooded Land were disaggregated according to prevailing vegetation and average carbon stock change in biomass per hectare was estimated for each type of conversion. It was assumed that carbon stock in biomass after conversion is zero (default value of *2006 IPCC Guidelines* was used).

$$\Delta C_{LWflood_{LB}} = \left[\sum_i A_i \times \left(B_{After_i} - B_{Before_i}\right)\right] \times CF$$

$$CO_{2\_LWflood} = \Delta C_{LWflood_{LB}} \times -\frac{44}{12}$$

where:

$\Delta C_{LWflood_{LB}}$ - annual change in carbon stocks in biomass on Land converted to Flooded land, tonnes C yr^{-1};

A_i - area of land converted annually to *Flooded land* from original land use *i*, ha yr^{-1};

B_{After_i} - biomass immediately following conversion to *Flooded land*, tonnes d. m. ha^{-1} (default = 0);

B_{Before_i} - biomass in land immediately before conversion to *Flooded land*, tonnes d. m. ha^{-1};

CF - carbon fraction of dry matter (default = 0.47, p. 6.29, Ch. 6, Vol. 4 of *2006 IPCC* Guidelines), tonnes C (tonne d. m.)$^{-1}$.

B_{Before_i} values for conversions from cropland and grassland to flooded land are used as follow: 10 tonnes d. m. ha^{-1} (annual cropland converted to flooded land), 63 t C ha^{-1} yr^{-1} (perennial cropland converted to wetlands), 13.6 tonnes d. m. ha-1 (grassland converted to flooded land). Carbon stock changes in living biomass due to forest land converted to flooded land are included in total carbon stock changes in living biomass in forest land remaining forest land subcategory, therefore reported as IE.

2006 IPCC Guidelines does not provide methodology on estimations of carbon stock changes in soils due to land conversion to Flooded Land. However, in case of forest land converted to flooded land when a disturbance (e.g. drainage ditch is excavated or widened) occur, all the carbon stock in mineral and organic soils and litter is assumed to be lost and emissions are estimated applying the national carbon stock value in mineral soils and litter in forest (82.70 t C ha^{-1} in forest land remaining forest land mineral soils, 166.44 t C ha^{-1} in forest land remaining forest land organic soils; 57.34 t C ha^{-1} in land converted to forest land mineral soils, 266.80 t C ha^{-1} in land converted to forest land organic soils; 7.65 t C ha^{-1} in litter of forest land remaining forest land; 3.56 t C ha^{-1} in litter of land converted to forest land). However, in the events when forest land is converted to peat extraction areas (occurred in 2004), carbon stock changes in soils are estimated due to the drainage of organic soils prior to the extraction of peat; if forest land is converted to swamp/bog (occurred in 2017) or any flooded land (occurred in 2009), it is assumed that no soil carbon stock is lost due to such conversion. In addition to this, carbon stock changes (loss) in dead wood and litter is estimated for conversions of grassland to flooded land, applying natonal carbon stock value in dead wood – 0.01 t C ha^{-1} – and litter – 0.8 t C ha^{-1} – in grassland category.

Non-CO_2 emissions

No preliminary estimates of CH_4 emissions from this source have yet been developed in Lithuania.

Direct N_2O emissions from N mineralization/immobilization

Direct N_2O emissions are produced naturally in soils through the processes of nitrification and denitrification, however, management of soils could have an impact to increase such emissions. Changes in inorganic N pool in soils, resulting in direct or indirect emissions of N_2O, could be affected by human induced net N additions to the soils (synthetic and organic fertilizers, etc.), changes of soil organic carbon (due to the drainage/management of organic soils, cultivation/land-use change on mineral soils), resulting in changes of soil C:N ratio, which in turn leads to emissions. The amount of N_2O released to the atmosphere is calculated as the result of the organic N mineralization after carbon stock in soil has decreased (loss of soil organic carbon occurs after conversion).

Direct N_2O emissions from mineral soils in wetlands category are resulting only from changes of soil organic carbon due to forest land converted to wetlands. Direct N_2O emissions due to the drainage of organic soils in wetland (peat extraction sites) are reported in Table 4 (II) as N_2O emissions from drainage of organic soils.

For the accounting of direct N_2O emissions from LULUCF sector default *2006 IPCC Guidelines* Tier 1 methodology was used (with Tier 2 requirements of disaggregation of individual land-use types while accounting direct N_2O emissions due to the loss of soil organic carbon resulting from land-use changes). Equation 11.1 (p. 11.7 of *2006 IPCC Guidelines*) was applied as described in section 6.3.2.2 Land converted to Cropland.

Carbon stock loss after forest land converted to wetlands was used as activity data for direct N_2O emissions estimation from N mineralization/immobilization.

Indirect N_2O emissions from leaching and runoff

Lithuania is located in surplus precipitation zone, therefore a certain amount of precipitation forms both surface and underground runoff annually. According to "Geography of Lithuanian waters" (Kilkus, Stonevicius, 2011), runoff in Lithuania varies among 25 – 50 percent of precipitation, on the basis of terrain, soil, etc. In addition to the direct N_2O emissions resulting from carbon stock change (loss) after land use change, indirect N_2O emissions also take place through runoff. Some of the inorganic (mineralized due to the carbon stock decrease after land use change) N does not take part in biological retention processes, therefore is removed with surface water flow (runoff) or through soil and afterwards is transformed into N_2O. Indirect N_2O emissions for all land use categories where direct N_2O emissions from N mineralization/immobilization due to carbon stock change after land use change occur are calculated using the same default *2006 IPCC methodology* – Equation 11.10 (Tier1 method).

$$N_2O_{(L)}\text{-}N = F_{SOM} \times Frac_{LEACH\text{-}(H)} \times EF_5$$

where:

$N_2O_{(L)}\text{-}N$ - annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where where leaching/runoff occurs, kg N_2O-N yr^{-1};

F_{SOM} - annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes in to land use or management in regions where leaching/runoff occurs, kg N yr^{-1} (from Equation 11.8);

$Frac_{LEACH\text{-}(H)}$ - fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$, default value, 0.3 (Table 11.3, p. 11.24 of *2006 IPCC Guidelines*);

EF_5 - emission factor for N_2O emissions from N leaching and runoff, kg N_2O-N (kg N leached and runoff)$^{-1}$, default value, 0.0075 (Table 11.3, p. 11.24 of *2006 IPCC Guidelines*).

6.5.3 Uncertainty assessment

Major CO_2 emissions from Wetlands were evaluated as a result of peat extraction from peat extraction areas remaining peat extraction areas. Due to the fact that there were no new permissions issued for peat extraction activities, no conversions to peat extraction areas were detected in recent years, therefore only forest land and other land conversions to Wetlands (flooded land) are reported occasionally and have an impact to the overall emissions from the category. Converted areas are relatively small and based on expert judgment it was assumed that uncertainty of activity data is about 80%. Emission factor uncertainty was assumed to be about 20%, while uncertainty of activity data of peat extraction areas is 6.1 % approximately.

For other conversions uncertainty of activity data assumed to be 50% (p. 7.17 of *2006 IPCC Guidelines*), emission factor uncertainty assumed to be about 100% (p. 7.16 of *2006 IPCC Guidelines*).

6.5.4 Category-specific QA/QC and verification

The QC/QA is based on quality control activities described in *2006 IPCC Guidelines* (Vol 1, Chapter 6, Table 6.1). Quality control and quality assurance objectives and procedures for Lithuanian GHG inventory at the national level are presented in Chapter 1.2.3 Quality assurance, quality control and verification plan. The QA/QC of activity data from State Forest Service is explained in Chapter 6.2.5, the use of country specific data is described in the inventory report.

The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF, the comments received after QA/QC procedures while reviewing the report are taken into account and errors found were corrected.

Some obscurities concerning direct N_2O emissions estimation were clarified after QA procedure performed by Norwegian LULUCF GHG inventory experts under the "Partnership project on Greenhouse gas inventory" in the framework of the programme LT10.

European Commission every year organizes a technical review of EU Member States' GHG inventories to ensure accuracy, reliability and transparency of information on annual GHG emissions and evaluate member state's accomplishment of EU Effort sharing regulation targets and improve GHG reporting from all relevant categories. Reviewers provide comments and recommendations to improve GHG inventory, which are taken into account for inventory compilation.

6.5.5 Category-specific recalculation

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation. Recalculations also include distinguishing carbon stock changes in forest land converted to flooded land (taking into account the purpose of each conversion to determine whether soil was disrupted or not) between mineral and organic soils. This includes application of national carbon stock values as obtained from study "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, for corresponding final land uses.

Table 6-38. Submitted and recalculated total emissions/removals in wetland category, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference %
1999	797.13	800.11	2.98	0.37
2003	766.61	769.67	3.06	0.40
2004	872.10	878.70	6.60	0.76
2009	896.08	890.87	-5.21	-0.58
2017	910.30	1069.85	159.55	17.53
2019	829.22	816.62	-12.60	-1.52

6.5.6 Category-specific planned improvements

Category-specific improvements include the development of land use change matrix taking into account different soil types and carbon stock changes estimation according to the land use change in particular soil type groups. Preliminary carbon stock values in different soil type groups are presented in Table 6-24.

Lithuania has launched a national project regarding carbon stock value estimation in agricultural land uses (cropland and grassland) in order to qualify carbon stock values in different soils types as established from the projected carried out by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the "Partnership project on Greenhouse gas inventory" between Lithuania and Norway and, if possible, to evaluate carbon stock changes in soils over time.

6.6 Settlement (CRF 4.E)

NLS indicates two subcategories under settlements category – built-up area and roads. All urban territories, power lines, traffic lines and roads as well as orchards and berry plantations planted in small size household areas and used only for householders' needs are included under this category.

According to national definition – urban territories are squares, playgrounds, stadiums, airports, yards, grave lands and buildings. Roads are land areas with engineering structure for transportation and traffic. In rural regions, areas with no special road cover used for mechanical and non-mechanical transport traffic and bridleways for animals were also included under settlements category.

The area of settlements in Lithuania has been increasing with low extent. In 1990 the land of settlements category had occupied 347 kha of country land, thus, till 2020 area of settlements increased by 37 kha. However, if to compare the intensity of area conversion to settlements, it was certain that area where settlements remained settlements was not changing distinctly and occupied on the average of 339 kha. The increase in the area of land converted to settlements was evident. In 1991 the area of land converted to settlements was 0.3 kha, thus, in 2020 distribution of area reached 37.5 kha (cumulative area of 20 year conversion period).

Emissions/removals of CO_2 from this land-use category is accounted only for sub-category of land converted to settlements due to the lack of sufficient and reliable data of carbon stock changes in settlements remaining settlements.

6.6.1 Category description

The carbon pools estimated for Settlements include carbon stock changes in pools – above-ground biomass and soil. Two source categories are accounted under this category: emissions from Settlements remaining Settlements and emissions from Land converted to Settlements, following methodology of *2006 IPCC Guidelines* (sections 8.2 and 8.3).

6.6.2 Methodological issues

6.6.2.1 Settlements remaining Settlements

Areas continuously managed as a Settlements and areas converted to Settlements after 20 consecutive years of conversion are reported in the category Settlements remaining Settlements (SS).

Carbon stock changes in living biomass

Lithuania has no appropriate activity data and/or developed emission factors. Therefore Tier 1 approach was used, which assumes that there is no change in carbon stocks in living biomass in Settlements Remaining Settlements; in other words, the growth and loss are in terms of balance. This method assumes that changes in biomass carbon stocks due to growth are fully offset by decreases in carbon stocks due to removals (i.e., by harvest, pruning, clipping) from both living and dead biomass (e.g. fuelwood, broken branches, etc.). Therefore, according to Tier 1 method $\Delta C_G = \Delta C_L$ for all plant components, and $\Delta C_B = 0$ (Equation 2.7, p. 2.12 of *2006 IPCC Guidelines*).

$$\Delta C_B = \Delta C_G - \Delta C_L$$

where:

ΔC_B - annual change in carbon stocks in biomass (considering only above-ground biomass in the case of changes in woody crop biomass accounting), considering total area, tonnes C yr^{-1};

ΔC_G - annual increase in carbon stocks due to biomass growth, considering the total area, tonnes C yr^{-1};

ΔC_L - annual decrease in carbon stock due to biomass loss, considering the total area, tonnes c yr^{-1}.

Carbon stock changes in dead organic matter

Tier 1 method assumes that dead wood and litter stocks are at equilibrium, there is no need to estimate carbon stock changes for these pools, so it is reported as NA.

Carbon stock changes in soil organic matter

Mineral soils

According to Tier 1 method inputs are equal to outputs and it means that soil C stocks do not significantly change in Settlements Remaining Settlements, therefore it is reported as NA.

Organic soils

No organic soils were estimated in this category, so it is reported as NO. Organic soils are accounted only under Forest Land, Croplands, Grassland, Wetlands and Settlements categories.

6.6.2.2 Land converted to Settlements

The cumulative areas during the 20 year transition period are reported in Figure 6-27. For each year, the cumulative total area reported under Land converted to Settlements category accounted as equal to cumulative area that has been converted to that land use over the last 20 years, areas of second land-use change during the 20 year conversion period subtracted by the cumulative total.

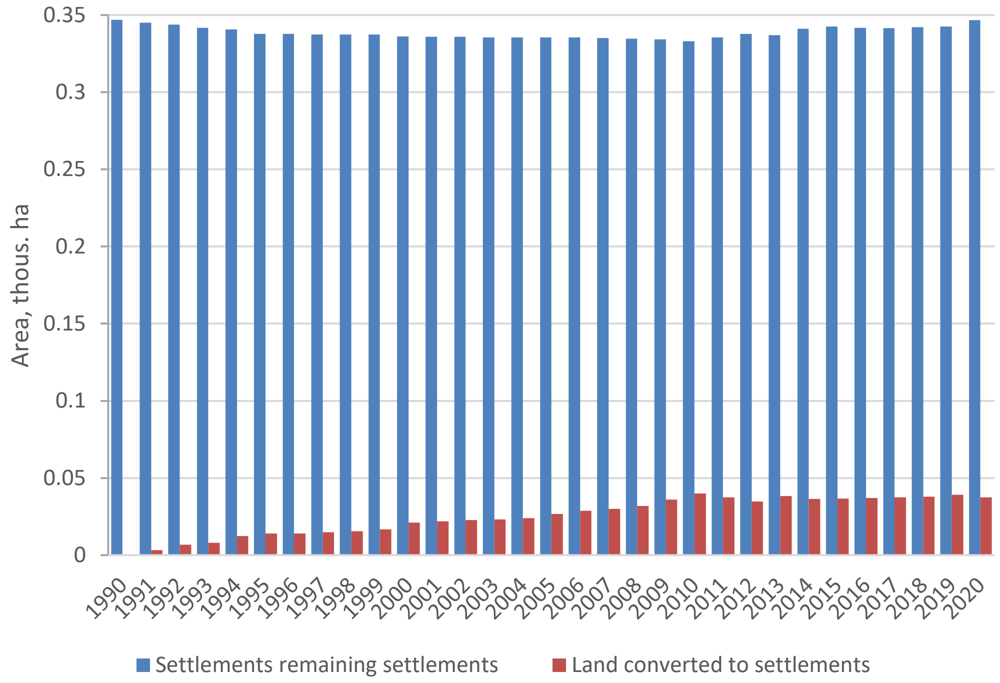


Figure 6-27. Settlements area changes during 1990 - 2020, thous. ha

All land conversions to Settlements (SL) except conversion of Forest land accounted as Land converted to Settlements.

The total CO_2 emissions from settlements in 1990 was 39.0 kt CO_2 eq. and further have been increasing (Figure 6-28). The CO_2 emissions from settlements increased significantly and reached 772.1 kt CO_2 eq. in 2019, but in 2020 it decreased to 598.9 kt CO_2 eq. Mainly cropland and grassland conversion to settlements has been increasing the net CO_2 emissions with significant addition of emissions resulting from forest conversions to settlements in the recent years. CO_2 emissions from cropland converted to settlements have been on the average of 148.7 kt CO_2 eq., thus, in 2019 and 2020 CO_2 emissions significantly decreased due to the decreased area of cropland converted to settlements as compared to the average and reached 72.7 kt CO_2 eq. in 2020. The CO_2 emissions in settlements converted from grassland were ranging in higher extent, from 16.1 (in 1990) to 477.3 kt CO_2 eq. (in 2013) and in 2020 it reached 475.3 kt CO_2 eq. As already mentioned before, due to the large areas of forest converted to settlements in recent years, where deforestation occurred due to the development of infrastructure, 149.0 kt CO_2 eq. of emissions had been added to the total in 2019, but no emissions were observable in 2020.

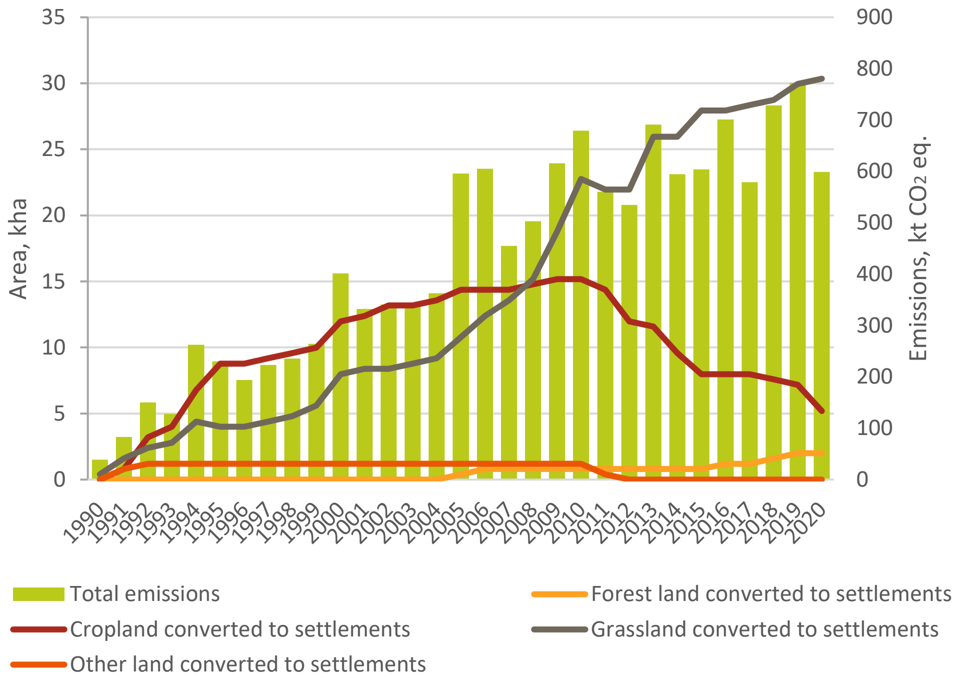


Figure 6-28. Area of land converted to settlements, thous. ha and total CO_2 emissions, kt CO_2 eq.

Carbon stock changes in living biomass

Tier 2 was used to estimate annual change in carbon stocks in living biomass on Land converted to Settlements employing the Equations 2.15 and 2.16 (Ch. 2, p. 2.20 of *2006 IPCC Guidelines*). Area estimates for Land Converted to Settlements were disaggregated according to prevailing vegetation and average carbon stock change on a per hectare basis is estimated for each type of conversion.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

where:

ΔC_B - annual change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1};

ΔC_G - annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr^{-1};

$\Delta C_{CONVERSION}$ - initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1};

ΔC_L - annual decrease in biomass carbon stocks due to the losses from harvesting, fuel wood gathering and disturbances on land converted to other land use category, in tonnes C yr^{-1}.

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTERi} - B_{BEFOREi}) \times \Delta A_{TO\_OTHERSi}\} \times CF$$

where:

$\Delta C_{CONVERSION}$ - initial change in biomass carbon stocks on land converted to another land category, tonnes C yr^{-1};

B_{AFTERi} - biomass stocks on land type *i* immediately after the conversion, tonnes d. m. ha^{-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 other land-use category in a certain year, ha yr^{-1};

CF - carbon fraction of dry matter, tonnes C (tonnes d. m.)$^{-1}$;

i - type of land use converted to another land-use category.

For calculation of carbon stock changes caused by conversion of Forest land, Wetland, Cropland and Grassland to Settlements, it was assumed that all above ground biomass as well as dead wood and organic matter from litter was removed entirely as a result of conversion.

Biomass carbon stock in initial land-use categories (B_{BEFORE}) are assumed to be 13.6 t ha^{-1} d. m. in Grasslands, 10.0 t ha^{-1} d. m. in annual Croplands and 63 t C ha^{-1} in perennial Croplands, 0.0 t ha^{-1} d. m. in Other Land. Carbon stock changes caused by conversion from Forest land to Other land were estimated according to the mean carbon stock value in above and below-ground biomass in Forest land.

Carbon stock changes in dead organic matter

Lithuania has no estimates of the dead wood and litter in the initial land-use systems (except FL and GL) prior to conversion. Therefore it is assumed that dead wood and litter stocks are not significant before the conversion to Settlements and are reported as NO in Croplands, Wetlands and Other land converted to Settlements. In the event of forest land and grassland converted to settlements all carbon stored in litter is lost immediately (7.65 t C ha^{-1} in forest land remaining forest land, 3.56 t C ha^{-1} in land converted to forest land and 0.8 t C ha^{-1} in grassland). In addition to this, annual dead wood carbon stock loss is estimated in the event of grassland converted to settlements, applying national dead wood carbon stock value – 0.01 t C ha^{-1} (data of 2019).

Carbon stock changes in soil organic matter

Estimations of change in C stocks in mineral soils and organic soils in Lands converted to Settlements were based on guidance for estimating changes in soil C stocks, provided in Section 2.3.3 (Ch. 2 of *2006 IPCC Guidelines*). Carbon stock changes in land converted to settlements were accounted due to the loss of soil organic carbon after land use change, while it is assumed that organic carbon stock in settlements category is zero, CO_2 emissions from organic soils in land converted to settlements sub-category occur due to the drainage of organic soils. Activity data is obtained from State Forest Service, compiled during NFI measurements.

In case of forest land converted to settlements when a disturbance occurs, all the carbon stock in mineral and organic soils and litter is assumed to be lost instantly due to the fact that most of the deforestation events occur due to the development of infrastructure after which soil is fully paved/covered with asphalt. Emissions are estimated applying national carbon stock values in forest: 82.70 t C ha^{-1} in forest land remaining forest land mineral soils, 166.44 t C ha^{-1} in forest land remaining forest land organic soils; 57.34 t C ha^{-1} in land converted to forest land mineral soils, 266.80 t C ha^{-1} in land converted to forest land organic soils.

Mineral soils

CO_2 emissions from mineral soils are accounted as changes of soil organic carbon stocks, multiplying the area of certain land use converted to settlements with carbon stock change factor accounted as difference between two organic carbon pools (initial land use and settlements) divided by a 20 year period of conversion.

Calculation of carbon stocks in mineral soils on Lands converted to Settlements were based on eq. 2.25 (Ch. 2, p.2.30 of *2006 IPCC*). Country-specific reference C stocks (SOC_{REF} - 76.1 t C ha^{-1} yr^{-1} (cropland), SOC_{REF} - 81.0 t C ha^{-1} yr^{-1} (grassland), SOC_{REF} - 82.70 t C ha^{-1} yr^{-1} (forest land remaining forest land), SOC_{REF} - 57.34 t C ha^{-1} yr^{-1} (land converted to forest land)), estimated from the results of the studies "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land" and "Assessment of carbon stocks in mineral and organic soils, and estimation of national carbon values in the soils after afforestation of abandoned agricultural land/reforestation", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the ""Partnership project on Greenhouse gas inventory" between Lithuania and Norway (Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, 2016) and default 20 year time period (except forest land conversions to settlements) for stock changes were used for calculations.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

where:

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1};

SOC_0 - soil organic carbon stock in final land use category (settlements), tonnes C;

$SOC_{(0-T)}$ - soil organic carbon stock in initial land use category, tonnes C;

Country specific SOC_0 and $SOC_{(0-T)}$ values were used at each of the points in time (time = 0 (first year after conversion period - 20 years) and time = 0-T (first year of the beginning of conversion period)). Due to the lack of reliable data it is assumed that there are no organic carbon stock accumulated in settlements and other land categories soils, therefore $SOC_{(0-T)}$ for settlements and other land were indicated as 0 in calculations.

T - number of years over a conversion period, yr;

D - time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr.

Activity data for accounting of CO_2 emissions due to carbon stock changes resulting from land use changes were obtained from NFI estimations.

Organic soils

CO_2 emissions from organic soils are accounted as a result of drainage enhanced microbial activity, which means greater decomposition of organic matter accumulated in organic soils and higher CO_2 emissions. Emissions from drainage of organic soils due to conversion to settlements category are accounted as a result of conversion from croplands and grasslands. There were no conversions from wetlands to settlements during the inventory period.

Tier 1 method was used in order to calculate carbon stock change in organic soils due to the drainage of organic soils (Equation 2.26, p. 2.35 of *2006 IPCC Guidelines*).

$$L_{Organic} = \sum_c (A \times EF)_c$$

where:

$L_{Organic}$ - annual carbon loss from drained organic soils, tonnes C yr^{-1};

A - land area of drained organic soils in climate type c, ha;

EF - emissions factor for climate type c, tonnes C ha^{-1} yr^{-1}.

Emission factor of 0.25 tonnes C ha^{-1} yr^{-1} for a cold temperate climate has been used for calculations of grassland converted to settlements(Table 6.3, p. 6.17 of *2006 IPCC Guidelines*) and 5 tonnes C ha^{-1} yr^{-1} for cropland converted to settlements (Table 5.6, p. 5.19 of *2006 IPCC Guidelines*) . Area of drained organic soils in land converted to settlements was estimated using the same share of drained organic soils in total initial land use category area (1.1 % in cropland converted to settlements and 6.2% in grassland converted to settlements).

Calculation of carbon stocks in organic soils of Forest land converted to Settlements were based on eq. 2.25 (Ch. 2, p.2.30 of *2006 IPCC*). Country-specific reference C stocks (SOC_{REF} - 166.44 t C ha^{-1} yr^{-1} (forest land remaining forest land), SOC_{REF} - 266.80 t C ha^{-1} yr^{-1} (land converted to forest land)), estimated from the results of the studies "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land" and "Assessment of carbon stocks in mineral and organic soils, and estimation of national carbon values in the soils after afforestation of abandoned agricultural land/reforestation", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the "Partnership project on Greenhouse gas inventory" between Lithuania and Norway (Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, 2016) were used to calculate instant carbon stock losses due to disturbance.

Non-CO_2 greenhouse gas emissions from biomass burning

There are no emissions from biomass burning reported in land converted to settlements due to no biomass available for wildfires in land converted to settlements category as it has already been removed during the conversion. All fire events in Settlements occur in building/construction materials. Due to the abovementioned information, non-CO_2 emissions from biomass burning in land converted to settlements are reported as NO.

Direct N_2O emissions due to N mineralization/immobilization

Direct N_2O emissions in land converted to settlements sub-category are resulting from land-use change induced organic carbon stock loss in mineral soils, calculating the amount of N_2O released to the atmosphere as the result of the organic N mineralization after carbon stock in soil has decreased (loss of soil organic carbon occurs after conversion).

For the accounting of direct N_2O emissions from LULUCF sector default *2006 IPCC Guidelines* Tier 1 methodology was used (with Tier 2 requirements of disaggregation of individual land-use types while accounting direct N_2O emissions due to the loss of soil organic carbon resulting from land-use changes). Equation 11.1 (p. 11.7 of *2006 IPCC Guidelines*) was implemented as described in section 6.3.2.2 Land converted to Cropland.

Indirect N_2O emissions from leaching and runoff

Lithuania is located in surplus precipitation zone, therefore a certain amount of precipitation forms both surface and underground runoff annually. According to "Geography of Lithuanian waters" (Kilkus, Stonevicius, 2011), runoff in Lithuania varies among 25 – 50 percent of precipitation, on the basis of terrain, soil, etc. In addition to the direct N_2O emissions resulting from carbon stock change (loss) after land use change, indirect N_2O emissions also take place through runoff. Some of the inorganic (mineralized due to the carbon stock decrease after land use change) N does not take part in biological retention processes, therefore is removed with surface water flow (runoff) or through soil and afterwards is transformed into N_2O. Indirect N_2O emissions for all land use categories where direct N_2O emissions from N mineralization/immobilization due to carbon stock change after land use change occur are calculated using the same default *2006 IPCC* methodology – Equation 11.10 (Tier1 method).

$$N_2O_{(L)}\text{-}N = F_{SOM} \times Frac_{LEACH\text{-}(H)} \times EF_5$$

where:

$N_2O_{(L)}$-N - annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kg N_2O-N yr^{-1};

F_{SOM} - annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes in to land use or management in regions where leaching/runoff occurs, kg N yr^{-1} (from Equation 11.8);

$Frac_{LEACH-(H)}$ - fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$, default value, 0.3 (Table 11.3, p. 11.24 of *2006 IPCC Guidelines*);

EF_5 - emission factor for N_2O emissions from N leaching and runoff, kg N_2O-N (kg N leached and runoff)$^{-1}$, default value, 0.0075 (Table 11.3, p. 11.24 of *2006 IPCC Guidelines*).

6.6.3 Uncertainty assessment

CO_2 emissions from Settlements were evaluated as a result of Land conversions to Settlements. Converted areas are relatively small, however, according to the calculations of overall activity data uncertainty for settlements, based on NFI data, it was assumed that uncertainty of activity data is about 11.1%. Emission factor uncertainty was assumed to be about 71%.

Table 6-39. Uncertainty of emission factors of direct N_2O emissions estimation

Emission factors	Uncertainties, %	References
EF_1 (N_2O emissions from N inputs)	-70/+300	p. 11.11*, 2006 IPCC*

6.6.4 Category-specific QA/QC and verification

The QC/QA is based on quality control activities described in *2006 IPCC Guidelines* (Vol 1, Chapter 6, Table 6.1). Quality control and quality assurance objectives and procedures for Lithuanian GHG subcategory inventory at the national level are presented in Chapter 1.2.3 Quality assurance, quality control and verification plan. The QA/QC of activity data from State Forest Service is explained in Chapter 6.2.5, the use of country specific data is described in the inventory report.

The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF, the comments received after QA/QC procedures while reviewing the report are taken into account and errors found were corrected.

Some obscurities concerning direct N_2O emissions estimation were clarified after QA procedure performed by Norwegian LULUCF GHG inventory experts under the "Partnership project on Greenhouse gas inventory" in the framework of the programme LT10.

European Commission every year organizes a technical review of EU Member States' GHG inventories to ensure accuracy, reliability and transparency of information on annual GHG emissions and evaluate member state's accomplishment of EU Effort sharing regulation targets and improve GHG reporting from all relevant categories. Reviewers provide comments and recommendations to improve GHG inventory, which are taken into account for inventory compilation.

6.6.5 Category-specific recalculation

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation, which resulted in slightly different areas of mineral and organic soils used to estimate carbon stock changes in mineral soils, CO2 emissions from drainage and direct N_2O emissions from N mineralization/immobilization. National carbon stock value in dead wood was applied to estimate carbon stock changes in dead organic matter (dead wood) in grassland converted to settlements and corrected estimation of dead organic matter carbon stock changes in forest land converted to settlements, since only litter carbon stock changes should be included, while dead wood carbon stock changes due to deforestation are included under forest land. Incorrect application of areas in the estimation of carbon stock changes in mineral soils after grassland and forest land conversion to settlements was corrected for this submission, which also affected estimation of direct N_2O emissions from N mineralization/immobilization.

Table 6-40. Submitted and recalculated total emissions/removals in settlements category, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference %
1990	16.56	38.96	22.40	135.28
1991	96.19	82.69	-13.50	-14.04
1992	156.17	150.10	-6.07	-3.89
1993	134.14	128.07	-6.07	-4.52
1994	268.81	262.74	-6.07	-2.26
1995	236.14	230.07	-6.07	-2.57
1996	199.71	193.64	-6.07	-3.04
1997	229.54	223.47	-6.07	-2.64
1998	241.60	235.53	-6.07	-2.51
1999	270.26	264.19	-6.07	-2.25
2000	407.50	401.42	-6.08	-1.49
2001	338.32	332.24	-6.08	-1.80
2002	347.23	341.15	-6.08	-1.75
2003	349.30	343.22	-6.08	-1.74
2004	368.93	362.84	-6.09	-1.65
2005	602.04	595.96	-6.08	-1.01
2006	611.24	605.14	-6.10	-1.00
2007	460.94	454.84	-6.10	-1.32
2008	509.06	502.96	-6.10	-1.20
2009	622.03	615.92	-6.11	-0.98
2010	685.52	679.40	-6.12	-0.89
2011	560.55	560.49	-0.06	-0.01
2012	534.71	534.65	-0.06	-0.01

2013	691.17	691.10	-0.07	-0.01
2014	594.64	594.57	-0.07	-0.01
2015	603.88	603.80	-0.08	-0.01
2016	701.45	701.37	-0.08	-0.01
2017	578.71	578.66	-0.05	-0.01
2018	728.53	728.45	-0.08	-0.01
2019	1,152.63	772.09	-380.54	-33.02

6.6.6 Category-specific planned improvements

Lithuania plans to implement subdivision of land converted to settlements subcategory according to the degree soil is exposed and damaged, as not the whole surface of settlements is built up, paved or used for road construction in Lithuania, as a result in some cases soil is not fully removed after conversion from another land use to settlements. In addition to this, in order to improve accuracy of soil carbon stock changes estimation, land use change matrix, taking into account different soil types will be prepared.

6.7 Other Land (CRF 4.F)

6.7.1 Category description

This category is included for overall land area consistency checking. All land not classified as Forest land, Croplands, Grasslands, Wetlands and Settlements were defined as Other land and reported together as a separate category in the CRF Reporter. Disturbed land and unmanaged land (such as sand dunes without any vegetation) subcategories were accounted under Other land category. Conversions to other land from forest land, cropland and grassland to other land occurred as after the quarries (sand, gravel, etc.) have been established in previous land use categories. No temporary degradation of cropland and grassland is reported under land converted to other land subcategory.

The area of other land category in Lithuania has been changing intensively only in the period from 1990 till 1995. The area of other land has been decreasing from 38 kha to 13 kha, further, till 2020 the area has been changing not intensively and further decreased to 8 kha of country land in 2020. The area of other land uses converted to other land was ranging from 0.4 to 3.2 kha in different initial land uses. Increases in forest land, cropland, grassland and settlements converted to other land have resulted in increasing total GHG emissions.

The total CO_2 emissions from other land have been ranging in not a high scope but two CO_2 emissions increase peaks were denoted in 1994 and 2019, where CO_2 eq. emissions have reached 194.7 and 352.4 kt CO_2 eq. due to forest land converted to other land. Despite the peaks, CO_2 emitted from other land area was ranging from 26.6 kt CO_2 eq. (in 1992) to 92.6 kt CO_2 eq. (in 2009), however, the total GHG emissions in 2019 were 352.4 kt CO_2 eq. when significantly large areas of forest land were deforested for the National Defence purposes, but in 2020 emissions decreased to 60.1 kt CO_2 eq. Intense CO_2 emissions at peaks event could be explained by high emissions from loss of dead organic matter (litter carbon pool) accumulated in forest and intensive mineralization of forest soil organic matter, resulting in significant decrease of organic carbon in relevant carbon stocks (Table 6-41). Direct N_2O emissions resulting from N mineralization/immobilization due to the carbon stock changes in mineral soils after conversion of land use is also a part of total GHG emissions in land converted to other land subcategory and it comprise emissions ranging from 0.9 kt CO_2 eq. in 1992 and 21.1 kt CO_2 eq. in 2020 with the peak of 11.3 kt CO_2 eq. in 1994 and 21.6 kt CO_2 eq. in 2019.

Table 6-41. Carbon stock changes in land converted to other land, kt C

Year	Forest land conversion		Cropland conversion		Grassland conversion		Net change in biomass	Total in mineral soils
	net change in biomass	in mineral soils	net change in biomass	in mineral soils	net change in biomass	in mineral soils		
1990	NO	NO	NO	NO	NO	NO	NO	NO
1995	NO	NO	-1.99	-9.02	NO	NO	-1.99	-9.02
2000	NO	NO	NO	-10.52	NO	NO	NO	-10.52
2005	NO	NO	NO	-9.02	NO	-3.02	NO	-12.04
2010	NO	NO	NO	-9.02	NO	-9.06	NO	-18.08
2015	NO	NO	NO	-1.50	NO	-12.08	NO	-13.59
2016	NO	NO	NO	-1.50	NO	-12.08	NO	-13.59
2017	NO	NO	NO	-1.50	NO	-12.08	NO	-13.59
2018	NO	NO	NO	NO	NO	-12.08	NO	-12.08
2019	NO	-57.07	NO	NO	NO	-12.08	NO	-69.15
2020	NO	NO	NO	NO	NO	-10.57	NO	-10.57

6.7.2 Methodological issues

6.7.2.1 Other Land Remaining Other Land

As it is recommended in *2006 IPCC Guidelines,* changes in carbon stocks and non-CO_2 emissions and removals are not estimated.

6.7.2.2 Land converted to Other Land

Carbon stock changes in living biomass

Carbon stock changes were assumed to occur due to the change of land use - all previous vegetation is removed during land use conversion to other land. Tier 2 method was used to estimate annual change in carbon stocks in living biomass on Land converted to Other land employing the Equations 2.15 and 2.16 (Ch. 2, p. 2.20 of *2006 IPCC Guidelines*). Area estimates for Land Converted to Other land were disaggregated according to prevailing vegetation and average carbon stock change on a per hectare basis is estimated for each type of conversion.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

where:

ΔC_B - annual change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1};

ΔC_G - annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr^{-1};

$\Delta C_{CONVERSION}$ - initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1};

ΔC_L - annual decrease in biomass carbon stocks due to the losses from harvesting, fuel wood gathering and disturbances on land converted to other land use category, in tonnes C yr^{-1}.

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTERi} - B_{BEFOREi}) \times \Delta A_{TO\_OTHERSi}\} \times CF$$

where:

$\Delta C_{CONVERSION}$ - initial change in biomass carbon stocks on land converted to another land category, tonnes C yr^{-1};

B_{AFTERi} - biomass stocks on land type *i* immediately after the conversion, tonnes d. m. ha^{-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 other land-use category in a certain year, ha yr^{-1};

CF - carbon fraction of dry matter, tonnes C (tonnes d. m.)$^{-1}$;

i - type of land use converted to another land-use category.

For calculation of carbon stock changes caused by conversion to Other land, it was assumed that all above-ground biomass as well as dead wood and organic matter from litter was removed entirely as a result of conversion.

Biomass carbon stock in initial land-use categories (B_{BEFORE}) are assumed to be 13.6 t ha^{-1} d. m. in Grasslands, 10.0 t ha^{-1} d. m. in annual Croplands, 63 t C ha^{-1} in perennial Cropland and 0.0 t ha^{-1} d. m. in Other Land.

Carbon stock changes in dead organic matter

Lithuania has no estimates of dead wood and litter in the initial land-use systems (except Forest land and Grassland) prior to conversion. Therefore only conversions from forest land and grassland to other land category were reported, resulting in CO_2 emissions due to dead organic matter pool carbon stock losses. There were only two conversions from forest land to other land category during the inventory period (1990-2020) – 0.399 thous. ha in 1994 and 0.799 thous. ha in 2019, whereas conversions from grassland to other land were more frequent.

Annual dead wood and litter carbon stock loss is estimated in the event of grassland converted to other land, applying national dead wood – 0.01 t C ha^{-1} (data of 2019) and litter – 0.8 t C ha^{-1} – carbon stock values.

Carbon stock changes in soil organic matter

Estimations of change in C stocks in mineral soils in Land converted to Other land were based on method for estimating changes in soil C stocks, provided in Section 2.3.3 (Ch. 2 of *2006 IPCC Guidelines*). Carbon stock changes in land converted to other land were accounted due to the loss of soil organic carbon after land use change, while it is assumed that organic carbon stock in other land category is zero contrary to Joint Research Centre estimated SOC_{REF} values for Lithuanian cropland and grassland mineral soils and national data of carbon stocks in forest soils. CO_2 emissions from organic soils in land converted to settlements sub-category occur due to the drainage of organic soils. Activity data is obtained from State Forest Service, compiled during NFI measurements.

In case of Forest land converted to Other land when a disturbance occur, all the carbon stock in mineral and organic soils and litter is assumed to be lost instantly, since other land is classified as quarries, dunes and rocky areas without vegetation. Emissions are estimated applying the national carbon stock value in mineral soils in forest (82.70 t C ha^{-1} in forest land remaining forest land mineral soils, 166.44 t C ha^{-1} in forest land remaining forest land organic soils; 57.34 t C ha^{-1} in land converted to forest land mineral soils, 266.80 t C ha^{-1} in land converted to forest land organic soils; 7.65 t C ha^{-1} in litter of forest land remaining forest land; 3.56 t C ha^{-1} in litter of land converted to forest land).

Mineral soils

CO_2 emissions from mineral soils are accounted as changes of soil organic carbon stocks, multiplying the area of certain land use converted to other land with carbon stock change factor accounted as difference between two organic carbon pools (initial land use and other land) divided by a 20 year period of conversion.

Calculation of carbon stocks in mineral soils on Lands converted to Settlements were based on eq. 2.25 (Ch. 2, p.2.30 of *2006 IPCC*). Country-specific reference C stocks (SOC_{REF} - 76.1 t C ha^{-1} yr^{-1} (cropland), SOC_{REF} - 81.0 t C ha^{-1} yr^{-1} (grassland), SOC_{REF} - 82.7 t C ha^{-1} yr^{-1} (forest land remaining forest land), SOC_{REF} - 57.34 t C ha^{-1} yr^{-1} (land converted to forest land)), estimated from the results of the studies "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land" and "Assessment of carbon stocks in mineral and organic soils, and estimation of national carbon values in the soils after afforestation of abandoned agricultural land/reforestation", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the ""Partnership project on Greenhouse gas inventory" between Lithuania and Norway (Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, 2016) and default 20 year time period (exept for Forest land converted to Other land) for stock changes were used for calculations.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

where:

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1};

SOC_0 - soil organic carbon stock in final land use category (grassland), tonnes C;

$SOC_{(0-T)}$ - soil organic carbon stock in initial land use category, tonnes C;

Joint Research Centre estimated SOC_0 and $SOC_{(0-T)}$ values were used at each of the points in time (time = 0 (first year after conversion period - 20 years) and time = 0-T (first year of the beginning of conversion period)). Due to the lack of reliable data it is assumed that there are no organic carbon stock accumulated in settlements and other land categories soils, therefore $SOC_{(0-T)}$ for settlements and other land were indicated as 0 in calculations.

T - number of years over a conversion period, yr;

D - Time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr.

Activity data, used for calculations of CO_2 emissions due to the loss of soil organic carbon as a result of different land use categories converted to other land, was obtained from NFI, executed by State Forest Service.

Organic soils

No organic soils were estimated under category Land converted to Other land, so it is reported as NO.

Calculation of carbon stocks in organic soils of Forest land converted to Other land were based on eq. 2.25 (Ch. 2, p.2.30 of *2006 IPCC*). Country-specific reference C stocks (SOC_{REF} - 166.44 t C ha^{-1} yr^{-1} (forest land remaining forest land), SOC_{REF} - 266.80 t C ha^{-1} yr^{-1} (land converted to forest land)), estimated from the results of the studies "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land" and "Assessment of carbon stocks in mineral and organic soils, and estimation of national carbon values in the soils after afforestation of abandoned agricultural land/reforestation", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the ""Partnership project on Greenhouse gas inventory" between Lithuania and Norway (Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, 2016) were used to calculate instant carbon stock losses due to disturbance.

Non-CO_2 greenhouse gas emissions from biomass burning

There are no emissions from biomass burning reported in land converted to other land due to no biomass available for wildfires in land converted to other land category as it has already been removed during the conversion. Due to the abovementioned information, non-CO_2 emissions from biomass burning in land converted to other land are reported as NO.

Direct N_2O emissions due to N mineralization/immobilization

Direct N_2O emissions in land converted to settlements sub-category are resulting from land-use change induced organic carbon stock loss in mineral soils, calculating the amount of N_2O released to the atmosphere as the result of the organic N mineralization after carbon stock in soil has decreased (loss of soil organic carbon occurs after conversion).

For the accounting of direct N_2O emissions from LULUCF sector default *2006 IPCC Guidelines* Tier 1 methodology was used (with Tier 2 requirements of disaggregation of individual land-use types while accounting direct N_2O emissions due to the loss of soil organic carbon resulting from land-use changes). Equation 11.1 (p. 11.7 of *2006 IPCC Guidelines*) was implemented as described in section 6.3.2.2 Land converted to Cropland.

Carbon stock loss after land converted to other land was used as activity data for direct N_2O emissions estimation from N mineralization/immobilization. Due to the lack of reliable national and default emission factors of N_2O emissions from N inputs associated with the loss of soil organic carbon due to the land use change, the same emission factors, used for calculation of direct N_2O emissions from cropland and grassland categories were used to calculate emissions from settlement category. The same default R (C:N) ratio, used in calculations of N_2O emissions from cropland and grassland category was implemented while calculating N_2O emissions from settlements category.

Indirect N_2O emissions from leaching and runoff

Lithuania is located in surplus precipitation zone, therefore a certain amount of precipitation forms both surface and underground runoff annually. According to "Geography of Lithuanian waters" (Kilkus, Stonevicius, 2011), runoff in Lithuania varies among 25 – 50 percent of precipitation, on the basis of terrain, soil, etc. In addition to the direct N_2O emissions resulting from carbon stock change (loss) after land use change, indirect N_2O emissions also take place through runoff. Some of the inorganic (mineralized due to the carbon stock decrease after land use change) N does not take part in biological retention processes, therefore is removed with surface water flow (runoff) or through soil and afterwards is transformed into N_2O. Indirect N_2O emissions for all land use categories where direct N_2O emissions from N mineralization/immobilization due to carbon stock change after land use change occur are calculated using the same default *2006 IPCC* methodology – Equation 11.10 (Tier1 method).

$$N_2O_{(L)}\text{-}N = F_{SOM} \times Frac_{LEACH\text{-}(H)} \times EF_5$$

where:

$N_2O_{(L)}$*-N* - annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kg N_2O-N yr^{-1};

F_{SOM} - annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes in to land use or management in regions where leaching/runoff occurs, kg N yr^{-1} (from Equation 11.8);

$Frac_{LEACH\text{-}(H)}$ - fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$, default value, 0.3 (Table 11.3, p. 11.24 of *2006 IPCC Guidelines*);

EF_5 - emission factor for N_2O emissions from N leaching and runoff, kg N_2O-N (kg N leached and runoff)$^{-1}$, default value, 0.0075 (Table 11.3, p. 11.24 of *2006 IPCC Guidelines*).

6.7.3 Uncertainty assessment

CO_2 emissions from Other land were evaluated as a result of conversions to Other land. Default uncertainty value of 75% for estimated CO_2 emissions/removals has been used based on expert judgment, activity data uncertainty based on the NFI data is assumed to be around 30 %.

Table 6-42. Uncertainty of emission factors of direct N_2O emissions estimation

Emission factors	Uncertainties, %	References
EF_1 (N_2O emissions from N inputs)	-70/+300	p. 11.11*, 2006 IPCC*

6.7.4 Category-specific QA/QC and verification

The QC/QA is based on quality control activities described in *2006 IPCC Guidelines* (Vol 1, Chapter 6, Table 6.1). The QA/QC of activity data from State Forest Service is explained in Chapter 6.2.5, the use of country specific data is described in the inventory report.

The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF, the comments received after QA/QC procedures while reviewing the report are taken into account and errors found were corrected. Quality control and quality assurance objectives and procedures for Lithuanian GHG inventory at the national level are presented in Chapter 1.2.3 Quality assurance, quality control and verification plan.

6.7.5 Category-specific recalculation

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation. In addition to this, national carbon stock value in litter was applied to estimate carbon stock changes in dead organic matter (litter) in grassland converted to Other land. Carbon stock changes in biomass in cropland converted to Other land were recalculated, including carbon stock losses from perennial cropland converted to Other land (the share of perennial cropland in total cropland area was applied). Recalculations also include distinguishing carbon stock changes in Forest land converted to Other land between mineral and organic soils and application of national carbon stock values as obtained from study "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry. Typing error was calculated for this submission, since carbon stock changes in mineral soils of grassland converted to other land should be reported as negative due to losses.

Table 6-43. Submitted and recalculated total emissions/removals in other land category, kt CO_2 eq.

Year	2021 submission	2022 submission	Absolute difference, kt CO_2 eq.	Relative difference %
1992	26.60	26.59	-0.01	-0.04
1993	38.32	38.31	-0.01	-0.02
1994	197.74	194.69	-3.05	-1.54
1995	42.67	42.68	0.01	0.02
1996	35.39	35.39	0.00	0.01
1997	35.39	35.39	0.00	0.01
1998	48.46	48.46	0.00	0.00
1999	41.29	41.29	0.00	0.00
2000	41.29	41.29	0.00	0.00
2001	57.84	57.84	0.00	0.00
2002	47.32	47.32	0.00	0.01
2003	63.87	63.87	0.00	0.00
2004	47.46	47.46	0.00	0.00
2005	47.46	47.46	0.00	0.00
2006	63.51	57.97	-5.54	-8.72
2007	53.00	47.46	-5.54	-10.46
2008	86.12	80.58	-5.54	-6.44
2009	98.18	92.64	-5.54	-5.64
2010	77.13	71.59	-5.54	-7.18
2011	77.13	71.59	-5.54	-7.18
2012	65.33	59.79	-5.54	-8.48
2013	70.08	64.54	-5.54	-7.90
2014	70.57	70.57	0.00	0.01
2015	54.16	54.16	0.00	0.00
2016	54.16	54.16	0.00	0.00
2017	54.16	54.16	0.00	0.00
2018	48.26	48.26	0.00	0.01
2019	363.64	352.37	-11.27	-3.10

6.7.6 Category-specific planned improvements

Category-specific improvements are not planned.

6.8 Harvested Wood Products (CRF 4.G)

6.8.1 Category description

Harvested Wood Products (HWP) accounting has been identified as mandatory for the second commitment period according to Decision 2/CMP.7 and Decision 2/CMP.8. Annual changes in carbon stocks and associated CO_2 emissions and removals from the HWP has to be accounted using *2006 IPCC Guidelines* and 2013 KP-Supplement's methodology (*2013 IPCC Revised Guidelines*).

Lithuania defines semi-finished commodities relevant for the application of the guidance on estimating the HWP emissions and removals in line with the Decision 2/CMP.7. Due to the requirements for Kyoto Protocol reporting Lithuania is reporting carbon stock changes in harvested wood products pool under the production approach - Approach B - both for UNFCCC and UNFCCC KP reporting, which means that only domestic harvest products are accounted under this pool (import is excluded).

Sawnwood (Decision 2/CMP.7 refers to this as "sawn wood"): Wood that has been produced from both domestic and imported round wood, either by sawing lengthways or by a profile-chipping process and that exceeds 6 mm in thickness. It includes planks, beams, joists, boards, rafters, scantlings, laths, boxboards and "lumber", etc., in the following forms: unplaned, planed, end-jointed, etc. It excludes sleepers, wooden flooring, mouldings (sawnwood continuously shaped along any of its edges or faces, like tongued, grooved, rebated, Vjointed, beaded, moulded, rounded or the like) and sawnwood produced by resawing previously sawn pieces. It is reported in cubic metres solid volume.

Wood-based panels (Decision 2/CMP.7 refers to this as "wood panels"): This product category is an aggregate comprising veneer sheets, plywood, particle board, and fibreboard. It is reported in cubic metres solid volume.

Paper and paperboards (Decision 2/CMP.7 refers to this as "paper"): Paper and paperboard category is an aggregate category. In the production and trade statistics, it represents the sum of graphic papers; sanitary and household papers; packaging materials and other paper and paperboard. It excludes manufactured paper products such as boxes, cartons, books and magazines, etc. It is reported in metric tonnes. HWP are divided into two groups: *solid wood products* (sawnwood, wood based panels and round wood) and *paper products* (paper and paperboards). Non-CO_2 greenhouse gases from HWP pool are reported under energy sector.

The HWP model presented in *2006 IPCC Guidelines* requires activity data since 1961, which includes: production data, imports, exports of HWP. Several sources of information were used to obtain required activity data for estimation of greenhouse gas emissions and removals from HWP pool. The general activity data on defined HWP categories (round wood, sawnwood, wood-based panels, paper and paper board) were obtained from FAOSTAT databases. However, FAOSTAT databases contain information only since 1992 up to date; therefore additional national data for historic production capacities as well as share of exports and imports was included. Production capacities from 1960 until 1990 (1992) were obtained from „The Chronicle of Lithuanian Forests. XX Century“ (LR Aplinkos ministerija, 2003). Some data presented in „The Chronicle of Lithuanian Forests. XX Century“ refers to five year time period, starting from 1955, therefore annual data was modelled (interpolated). Production capacities for 1990 – 1992 were obtained from Statistics Lithuania.

Noteworthy, that information provided by Statistics Lithuania almost equals data provided by FAOSTAT for the presented years, therefore doubts for data validity presented by Statistics Lithuania for 1990-1992 were rejected. Apparently differences in HWP production, imports and exports until 1992 are related with Lithuania's status of that period. Being the part of Soviet Union meant producing goods according to the plan, not to the real market demand, therefore production, import and export capacities were tremendous comparing to these days. However "The Chronicle of Lithuanian Forests. XX Century" testifies that there was no import of round wood in Lithuania until 1992. Additionally, IPCC model requires estimating annual rate of increase for industrial round wood production as an input parameter for historic period 1900-1961. Being no activity data available for this time span, default value for Europe, 0.0151 (Table 12.3, p. 12.18 of *2006 IPCC Guidelines*) has been chosen.

Table 6-44. Activity data used for estimations

Sawn-wood				Wood-based panels				Paper and Paperboard				Round wood			
Year	**Production, m^3**	**Imports, m^3**	**Export, m^3**	**Year**	**Production, m^3**	**Imports, m^3**	**Export, m^3**	**Year**	**Production, tonnes**	**Imports, tonnes**	**Export, tonnes**	**Year**	**Production, m^3**	**Import, m^3**	**Export, m^3**
1960	885,000.00	140,068.91	0.00	**1960**	39,800.00	3,888.49	14,726.0	**1960**	83,000.00	31,542.65	51,457.0	**1960**	1,740,000.00	968,000.00	29,637.30
1965	1,044,000.00	231,000.00	0.00	**1965**	58,400.00	5,297.40	21,608.00	**1965**	114,000.00	40,925.69	70,675.90	**1965**	2,420,000.00	1,080,000.00	41,219.80
1970	1,313,000.00	317,000.00	0.00	**1970**	91,300.00	8,281.73	33,781.00	**1970**	159,000.00	57,080.57	98,574.30	**1970**	2,814,000.00	1,066,000.00	47,930.70
1975	1,098,000.00	330,000.00	0.00	**1975**	133,900.00	12,145.93	49,543.00	**1975**	240,000.00	86,159.36	148,791.40	**1975**	2,587,000.00	1,161,000.00	44,064.30
1980	855,000.00	361,000.00	0.00	**1980**	165,500.00	15,012.33	61,235.00	**1980**	235,000.00	84,364.37	145,691.60	**1980**	2,472,000.00	699,000.00	45,000.00
1985	934,000.00	361,000.00	0.00	**1985**	168,100.00	15,248.17	62,197.00	**1985**	265,000.00	95,134.29	164,290.50	**1985**	2,648,000.00	693,000.00	44,000.00
1990	775,800.00	200,000.00	0.00	**1990**	197,900.00	17,951.30	73,223.00	**1990**	217,600.00	78,117.82	134,904.20	**1990**	2,667,000.00	456,000.00	74,000.00
1991	664,000.00	100,040.50	0.00	**1991**	185,500.00	16,826.51	68,635.00	**1991**	214,500.00	77,004.92	132,982.30	**1991**	2,908,000.00	228,475.50	179,739.00
1995	940,000.00	23,200.00	767,200.00	**1995**	156,400.00	38,200.00	104,600.00	**1995**	28,900.00	50,600.00	19,400.00	**1995**	5,960,000.00	16,200.00	1,769,900.00
2000	1,300,000.00	279,410.00	823,040.00	**2000**	270,290.00	115,380.00	211,060.00	**2000**	52,630.00	78,250.00	37,100.00	**2000**	5,500,000.00	60,570.00	1,202,850.00
2005	1,445,000.00	658,230.00	912,547.00	**2005**	398,000.00	381,124.00	170,966.00	**2005**	113,000.00	151,752.00	87,140.00	**2005**	6,045,000.00	287,906.00	1,173,919.00
2010	1,272,000.00	291,274.00	555,388.00	**2010**	716,000.00	453,130.00	311,223.00	**2010**	129,229.00	195,261.00	123,233.00	**2010**	7,096,860.00	332,142.00	1,441,955.00
2015	1,248,146.00	605,059.00	818,009.00	**2015**	888,131.00	647,019.00	287,495.00	**2015**	142,322.00	277,278.00	114,613.00	**2015**	6,414,000.00	404,945.00	1,620,910.00
2016	1,406,000.00	750,749.00	931,448.00	**2016**	919,384.00	761,085.00	371,242.00	**2016**	127,377.00	279,332.00	103,607.00	**2016**	6,747,000.00	539,142.00	1,630,716.00
2017	1,406,000.00	750,749.00	931,998.00	**2017**	919,384.00	760,586.00	352,064.00	**2017**	127,377.00	279,332.00	103,607.00	**2017**	6,747,000.00	539,142.00	1,630,716.00
2018	1,330,450.00	1,081,000.00	1,013,000.00	**2018**	852,400.00	862,600.00	149,624.00	**2018**	134,000.00	279,355.00	107,268.00	**2018**	6,683,530.00	277,575.00	1,731,256.00
2019	1,266,000.00	1,247,060.00	1,082,115.00	**2019**	853,800.00	857,440.00	144,039.00	**2019**	159,090.00	291,008.00	96,062.00	**2019**	6,688,000.00	263,156.00	2,109,848.00
2020	1,038,000.00	1,337,495.00	1,212,421.00	**2020**	850,800.00	858,560.00	137,857.00	**2020**	128,400.00	316,642.00	108,318.00	**2020**	6,366,000.00	303,423.00	2,092,365.00

The Chronicle of Lithuanian Forests. XX Century

Statistics Lithuania

FAO

Estimated changes in carbon stocks in harvested wood products consumed domestically and exported are presented in Table 6-45. According to the estimates, harvested wood products pool has been acting as a CO_2 sink in the entire reporting period from 1990 to 2020, reaching the highest amount of GHG removed in 2003 – 1518.4 kt CO_2 eq. Note that annual carbon balance of HWP's varies substantially, depending on the economic situation and market demand.

Table 6-45. Carbon stock changes in HWP, kt CO_2 eq.

Year	Sawn wood		Wood panels		Paper and paper board		Total
	Consumed domestically	Exported	Consumed domestically	Exported	Consumed domestically	Exported	
1990	-153.7	NO	-70.9	-41.6	5.2	8.4	-252.5
1995	239.8	-987.6	-23.9	-127.7	38.3	31.0	-830.1
2000	-107.0	-874.5	-24.0	-238.3	-6.0	-19.0	-1268.8
2005	-88.0	-756.4	-202.2	-123.2	6.5	-46.2	-1209.5
2010	-268.7	-349.6	-380.3	-279.4	21.0	-60.4	-1317.4
2015	50.1	-573.8	-542.4	-211.2	-16.9	4.7	-1289.5
2016	72.7	-543.4	-370.1	-243.1	-1.1	41.5	-1043.4
2017	66.2	-537.3	-383.1	-218.5	-0.9	28.7	-1044.8
2018	198.3	-612.5	-525.1	-3.8	-5.0	13.5	-934.5
2019	318.9	-626.2	-490.0	7.8	-47.7	28.9	-808.3
2020	643.6	-858.8	-570.3	-3.6	17.0	-11.8	-784.0

6.8.2 Methodological issues

Emissions and removals from harvested wood products are estimated using stock change method, and only HWP in use are considered, obtaining the information on harvested wood production made from domestic harvest from FAO databases.

The worksheet provided in *2006 IPCC Guidelines* is a tool for estimating annual carbon balance under any of the proposed HWP approaches and was used for estimation of harvested wood products in use in Lithuania. The model consists of two elements: solid wood products and paper products. Both variables have different half-life values. Greenhouse gas accounting for HWP pool in the worksheet is based on first order decay function with default half-life values (Equation. 2.8.5, p. 2.120 of *2013 IPCC Revised Guidelines*).

$$C \cdot (i+1) = e^{-k} \cdot C_{(i)} + \left[\frac{(1-e^{-k})}{k}\right] \cdot inflow(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

where:

i - year;

C(i) - the carbon stock in the particular HWP category at the beginning of year *i*, kt C;

k - decay constant of FOD for each HWP category (HWP_j) given in units yr^{-1} (k = ln(2)/HL, where HL is half-life of the HWP pool in years);

Inflow(i) - the inflow to the particular HWP category (HWP) during year *i*, kt C yr^{-1};

ΔC(i) - carbon stock change of the HWP category during year *i*, kt C yr^{-1}.

Annual change in carbon stock in "products in use" where wood came from harvest in the reporting country, including export, was estimated using Equation 12.3 (Ch. 12.2, p. 12.12 of *2006 IPCC Guidelines*).

$$Inflow_{DH} = P \times \left[\frac{IRW_H}{IRW_H + IRW_{IM} - IRW_{EX} + WCH_{IM} - WCH_{EX} + WR_{IM} - WR_{EX}}\right]$$

where:

InflowDH	- carbon in annual production of solid wood or paper products that came from wood harvested in the reporting country (that is, from domestic harvest), Gg C yr^{-1};
P	- carbon in annual production of solid wood or paper products in the reporting country, Gg C yr^{-1};
IRW_H	- industrial roundwood harvest in the reporting country, Gg C yr^{-1};
IRW_{IM} , IRW_{EX}	- industrial roundwood imports and exports, respectively, Gg C yr^{-1};
WCH_{IM}, WCH_{EX}	- wood chip imports and exports, respectively, Gg C yr^{-1};
WR_{IM}, WR_{EX}	- wood residues from wood products mills imports and exports, respectively Gg C yr^{-1}.

The HWP contribution to the total LULUCF sector emissions/removals was estimated separately for HWP produced and consumed domestically and HWP produced and exported. The annual carbon stock change was subdivided into these two groups by the proportion of exported products and total production for HWP categories, according to the data provided in FAO database:

$$C_{EXP} = C_{TOTAL} \times \frac{P_{EXP}}{P_{TOTAL}}$$

$$C_{DOM} = C_{TOTAL} \times (1 - \frac{P_{EXP}}{P_{TOTAL}})$$

where:

C_{EXP}	- carbon stock change in HWP produced and exported;
C_{DOM}	- carbon stock change in HWP produced and consumed domestically;
C_{TOTAL}	- total carbon stock change in HWP category;
P_{EXP}	- quantity of HWP exported;
P_{DOM}	- quantity of HWP consumed domestically.

Lithuania uses default half-life values for „products in use" carbon pools and associated fraction retained each year listed in the Table 6-52 (Table 12.2, p. 12.17 of *2006 IPCC Guidelines*). As Lithuania is using Tier 1 methodology for carbon stock changes estimation in Harvested Wood Products pool, therefore default factors to convert from production units to carbon, provided in KP Supplement (2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol) (Table 2.8.1 of KP Supplement, Ch. 2.8.3.1, p. 2.122) is used. Default conversion factors used in Lithuanian Harvested Wood Product carbon stock change evaluation are provided in Table 6-46.

Table 6-46. Default half-life values for „products in use“ carbon pools and associated fraction retained each year

	Sawn wood	**Wood-based panels**	**Paper and paper-board**
Half-life (years)	**30**	**25**	**2**
Carbon factor (per air dry volume)	0.229 Mg (t) C m^{-3}	0.269 Mg (t) C m^{-3}	0.385 Mg (t) C Mg $(t)^{-1}$ (per air dry tonne)

6.8.3 Uncertainty assessment

Overall activity data for HWP production, imports and exports was used from FAO databases, therefore uncertainty for such data was applied as it is suggested by *2006 IPCC Guidelines* (Table 12.6, p. 12.22) and is equal to ±15%. EF was calculated using *2006 IPCC Guidelines* (Table 12.6, p. 12.22) and is equal to ±59%.

6.8.4 Category-specific QA/QC and verification

Quality control and quality assurance objectives and procedures for Lithuanian GHG inventory at the national level are presented in Chapter 1.2.3 Quality assurance, quality control and verification plan. The activity data presented for greenhouse gas emission/removal assessment for HWP are judged to be the most reliable as there was no additional data sources founded.

The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF, the comments received after QA/QC procedures while reviewing the report are taken into account and errors found were corrected.

European Commission every year organizes a technical review of EU Member States' GHG inventories to ensure accuracy, reliability and transparency of information on annual GHG emissions and evaluate member state‘s accomplishment of EU Effort sharing regulation targets and improve GHG reporting from all relevant categories. Reviewers provide comments and recommendations to improve GHG inventory, which are taken into account for inventory compilation.

6.8.5 Category-specific recalculations

No recalculations have been done.

6.8.6 Category-specific planned improvement

Lithuania have participated in the "GHG inventory partnership project" through financial mechanism LT10 of Norway grants. As a result of this partnership Lithuania has launched the study for development of the national HWP accounting system in upcoming years, as well as to obtain feasible sufficient historical data on rate of increase for industrial round wood production required to run the model for accounting of HWP emissions/removals. Lithuania is planning to implement results of the study in the future.

7 WASTE (CRF 5)

7.1 Overview of the Sector

In Lithuania greenhouse gases (GHG) emissions from Waste Sector originate from the following sources:

- Solid Waste Disposal (including sewage sludge) (CRF 5.A);
- Biological Treatment of Solid Waste (CRF 5.B);
- Incineration and Open Burning of Waste (CRF 5.C);
- Wastewater Treatment and Discharge (CRF 5.D).

Table 7-1. Key category from Waste in 2020

IPCC Category	*Greenhouse gas*	*Identification criteria*	*Comments**
5.A Solid Waste Disposal	CH_4	L1, L2	
5.B Biological treatment of waste	CH_4	T2	
5.B Biological treatment of waste	N_2O		T2sub
5.D Wastewater Treatment and Discharge	CH_4	L1, L2, T1, T2	

*Tsub denote the categories that were identified by level and trend assessment for a subset without LULUCF

Lithuania uses *2006 IPCC Guidelines* Tier 1 and Tier 2 methodology for the calculation of CO_2, CH_4, N_2O emissions from waste sector. All assessed emissions from waste sector categories, method applied and emission factors are provided in the Table below.

Table 7-2. Methods and emissions factors used to estimate emission from waste sector

CRF	**Source**	**Emissions reported**	**Methods**	**Emission factor**
5.A	Solid Waste Disposal	CH_4	T2	D
5.B	Biological Treatment of Waste	CH_4, N_2O	T1	D
5.C	Incineration and Open Burning of Waste	CO_2, CH_4, N_2O	T1	D
5.D	Wastewater Treatment and Discharge	CH_4, N_2O	T1	D

GHG emissions from Waste Sector are summarized in Table 7-3.

Table 7-3. Summary of GHG emissions from Waste Sector, kt CO_2 eq.

Year	**Solid waste disposal**	**Sewage sludge**	**Biological treatment**	**Wastewater treatment**	**Waste incineration**	**Total**
1990	984.16	44.68	0.35	490.20	2.74	1,522.13
1995	1,054.11	48.60	0.62	426.75	2.59	1,532.67
2000	1,066.65	69.35	2.15	381.11	1.17	1,520.43
2005	1,093.30	59.04	3.43	311.93	3.71	1,471.41
2010	950.70	45.28	10.31	255.54	1.51	1,263.35
2015	741.28	34.87	34.96	191.98	5.90	1,008.99
2016	701.68	33.01	71.84	184.27	0.66	991.46
2017	701.77	31.89	76.65	181.41	1.30	993.02
2018	575.11	27.04	99.1	170.43	0.90	872.57
2019	548.98	24.12	97.35	166.41	1.73	838.60
2020	542.39	20.65	91.46	164.91	2.18	821.58

Solid waste disposal on land (including disposal of sewage sludge) is the largest GHG emission source from Waste Sector. It contributed around 68.5% of the total GHG emission from Waste Sector in 2020 (66.0% excluding disposal of sewage sludge). GHG emissions occurring due to solid waste and sewage sludge disposal on land increased slightly from 1990 to 2001 and then started to decrease due to the reduction of disposed waste, extraction of landfill gas, and anaerobic digestion of sewage sludge.

A particular increase in emissions was observed from 2001 to 2004 and was caused mainly by the disposal of large amounts of organic sugar production waste. However, in later years the producers managed to hand this waste over to farmers for utilization in the agriculture activities, and GHG emissions declined.

Variations of GHG emissions from solid waste disposal on land from 1990 to 2020 are shown in Figure 7-1.

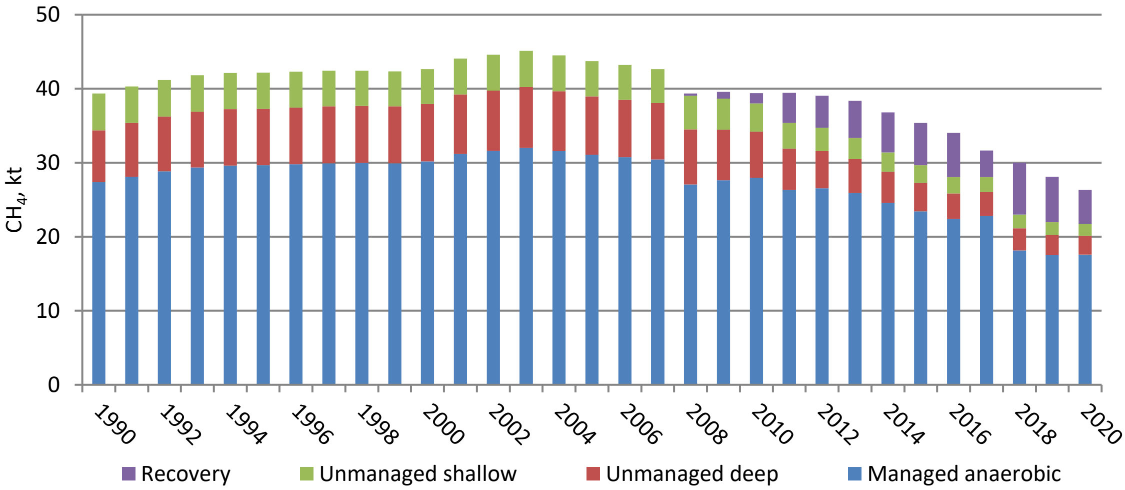


Figure 7-1. Variations of GHG emissions from solid waste disposal (1990-2020)

Biological treatment of waste includes composting and anaerobic digestion. GHG emissions from biological treatment have increased substantially after establishing the regional waste management systems in 2011 and after implementing Mechanical Biological Treatment (MBT) facilities in 2016. As a result, emissions from biological treatment reached 11.1% of the total waste sector emissions in 2020. The composting activities consisted main part of emissions from biological treatment (about 69%).

Wastewater treatment and discharge contributed around 20.1% of GHG emissions from Waste Sector in 2020. Wastewater in Lithuania is mainly treated in aerobic treatment systems with minimum CH_4 generation. However, a significant part of the population still does not connect to public sewerage systems, and emissions from sewage collected from septic tanks are significant.

Until 2015, *waste incineration* without energy recovery in Lithuania was comparatively small. During the period 1990-2014, contributed on average 0.1% of the total waste GHG emission and slightly increased to 0.6% in 2015 during the hazardous waste incineration facility testing. In 2017-2020 major part of hazardous waste was incinerated with energy recovery; these emissions are reported under the energy sector emissions. On the other hand, only small quantities of hazardous and clinical waste were incinerated without energy recovery, and corresponding emissions are included in Waste Sector.

7.2 Solid waste disposal on land (CRF 5.A)

7.2.1 Overview of waste management in Lithuania

7.2.1.1 Waste generation and disposal

Lithuania's total amount of waste treated annually is about 6 to 7 million tonnes, 6.4 million tonnes in 2020 (Table 7-4). The major part of the waste is generated in the industrial sector, of which about 208 kt - hazardous waste. Annual municipal waste generation is about 1 million tonnes (about 0.96 million tonnes in 2020).

Table 7-4. Waste treatment in 2020*, kt

		D1,D5	D2, D4, D6	S4	R1	D10	R2-R9	R10, R11	D8, D9, D14, R12,S5
01	Chemical compound wastes	0.20	NO	3.71	0.87	0.11	3.26	NO	3.20
02	Chemical preparation wastes	0.67	NO	0.67	1.81	0.77	0.26	NO	2.85
03	Other chemical wastes	0.17	1.40	0.11	2.45	0.14	28.61	0.00	18.10
05	Health care and biological wastes	NO	NO	NO	0.48	1.08	NO	NO	2.55
06	Metallic wastes	NO	NO	520.60		NO	36.59	NO	199.90
07	Non-metallic wastes	11.85	NO	139.10	14.31	NO	234.59	0.21	133.10
08	Discarded equipment	0.12	NO	4.59	0.22	0.00	2.51	NO	71.03
09	Animal and vegetal wastes	0.50	NO	20.97	4.30	NO	131.14	7.60	20.28
10	Mixed ordinary wastes	236.06	8.48	14.58	380.95	0.02	232.65	8.10	903.80
11	Common sludge	0.00	2.02	NO	14.43	NO	27.82	13.32	1.38
12	Mineral wastes	1,771.13	NO	21.39	0.71	0.07	574.86	208.29	159.17
	Total	**2,020.72**	**11.89**	**725.72**	**420.53**	**2.19**	**1,272.28**	**237.53**	**1,515.35**

*List of treatment operations is provided in Table 7-5 below.
Source: Lithuanian EPA

In the early 1990s, there were about 1000 landfills and dumps in Lithuania. In the late 1990s, waste management strategies were developed, foreseeing the development of waste management infrastructure, which included the construction of new regional landfills complying with EU requirements. In addition, it covered the closure of existing landfills and dumps and provision of the necessary equipment required for the safe and efficient operation of waste management facilities.

A list of waste treatment operations used in Lithuanian waste statistics is provided in Table 7-5.

Table 7-5. List of waste treatment operations

Waste disposal operations	
D1	Deposit into or on to land (e.g. landfill, etc.)
D2	Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)
D3	Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)

D4	Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.)
D5	Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)
D6	Release into a water body except seas/oceans
D7	Release to seas/oceans including sea-bed insertion
D8	Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12
D9	Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)
D10	Incineration on land
D11	Incineration at sea
D12	Permanent storage (e.g. emplacement of containers in a mine, etc.)
D13	Blending or mixing prior to submission to any of the operations numbered D 1 to D 12
D14	Repackaging prior to submission to any of the operations numbered D 1 to D 13
D15	Storage pending any of the operations numbered D1 to D 14 (excluding temporary storage, pending collection, on the site where the waste is produced)
Waste recovery operations	
R1	Use principally as a fuel or other means to generate energy
R2	Solvent reclamation/regeneration
R3	Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)
R4	Recycling/reclamation of metals and metal compounds
R5	Recycling/reclamation of other inorganic materials
R6	Regeneration of acids or bases
R7	Recovery of components used for pollution abatement
R8	Recovery of components from catalysts
R9	Oil re-refining or other reuses of oil
R10	Land treatment resulting in benefit to agriculture or ecological improvement
R11	Use of waste obtained from any of the operations numbered R 1 to R 10
R12	Exchange of waste for submission to any of the operations numbered R 1 to R 11
R13	Storage of waste pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where the waste is produced)
S4	Export

Source: Lithuanian EPA

During the reorganization of waste management infrastructure, all landfills and dumps not in line with the environmental protection and public health safety requirements were closed. As a result, waste disposal in the old landfills stopped in July of 2009, and since then, all waste has been disposed of in 11 regional non-hazardous waste landfills.

Recovery of landfill gas started at two landfills in 2008. Currently, landfill gas is recovered in 3 operating and six closed landfills [123].

In order to encourage waste recovery and recycling and minimize disposal in the landfills, regional waste management systems were equipped with appropriate waste management facilities, including bulky waste collection sites, green waste composting sites, etc.

[123] National Waste Management Plan

According to data provided by municipalities[124], waste collection services in 2012 were provided to 94.8% of population. Differences between provision of services in cities, towns and rural areas are decreasing. In 2018, waste collection services were provided to 98% of population[125].

The first step of MSW pre-treatment is source separation of recyclables. Containers for separate collections of recyclables are distributed in all regions of Lithuania, ensuring the supply of good quality recyclables.

Green waste from gardens and parks is not accepted in landfills and is collected separately. Several green waste composting facilities in each region already produce good quality compost suitable for agricultural application.

In 2016, mechanical pre-treatment facilities were completed in all regions of Lithuania. Currently, all MSW is pre-treated before landfilling. The treatment process in MBT facilities may include:

- separation of bulky waste;
- shredding;
- screening;
- air separation;
- separation of PVC, paper and cardboard, LDPE;
- magnetic separation;
- separation of plastics incl. PET;
- Manual sorting of recovered recyclables.

Mechanical sorting facilities from 2016 ensure the separation of recyclables and biodegradable materials from remaining mixed MSW. Biodegradable waste separated during pre-treatment undergoes either biological treatment or is incinerated.

Biological treatment include:

- anaerobic digestion, and/or
- composting.

Waste composting may comprise mechanically separated biodegradable waste (e.g. in Kaunas MBT facility) or anaerobic digestion residues (e.g. in Panevėžys MBT facility). Composted fraction typically is used for waste covering and reinforcement of landfill slopes.

Waste remaining after mechanical sorting is reported in the EPA database under code 19 12 12 Other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11. Part of it is disposed of in landfills, and others are incinerated with energy recovery, composted or used for anaerobic digestion.

Wastes accepted for disposal at the landfills are defined in the IPPC permits issued for landfills and are based on the EU List of Wastes. A typical list of wastes accepted at the landfills includes:

[124] Data collected by Environmental Protection Agency
[125] viešosios komunalinių atliekų tvarkymo paslaugos užtikrinimas, http://atliekos.gamta.lt/cms/index?rubricId=70bfc9c1-5c33-4d83-95a5-123ba8070877

03 wastes from wood processing and the production of panels and furniture, pulp, paper and cardboard

03 01 wastes from wood processing and the production of panels and furniture
03 01 99 wastes not otherwise specified
03 03 wastes from pulp, paper and cardboard production and processing
03 03 07 mechanically separated rejects from pulping of waste paper and cardboard
03 03 99 wastes not otherwise specified

04 wastes from the leather, fur and textile industries

04 02 wastes from the textile industry
04 02 99 wastes not otherwise specified

10 wastes from thermal processes

10 01 wastes from power stations and other combustion plants (except 19)
10 01 01 bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)
10 01 03 fly ash from peat and untreated wood

12 wastes from shaping and physical and mechanical surface treatment of metals and plastics

12 01 wastes from shaping and physical and mechanical surface treatment of metals and plastics
12 01 13 welding wastes
12 01 21 spent grinding bodies and grinding materials other than those mentioned in 12 01 20

19 wastes from waste management facilities, off-site waste water treatment plants and the preparation of water intended for human consumption and water for industrial use

19 01 wastes from incineration or pyrolysis of waste
19 01 12 bottom ash and slag other than those mentioned in 19 01 11
19 01 14 fly ash other than those mentioned in 19 01 13
19 08 wastes from waste water treatment plants not otherwise specified
19 08 01 screenings
19 12 wastes from the mechanical treatment of waste (for example sorting, crushing, compacting, pelletizing) not otherwise specified
19 12 12 other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11
19 12 08 textiles

20 municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions

20 01 separately collected fractions (except 15 01)
20 01 41 wastes from chimney sweeping
20 02 garden and park wastes (including cemetery waste)
20 02 03 other non-biodegradable wastes
20 03 other municipal wastes
20 03 01 mixed municipal waste*
20 03 03 waste from markets

**Mixed not pre-treated municipal waste is not accepted for disposal.*

All data on waste treatment at various treatment facilities including anaerobic digestion, composting, incineration and disposal are reported to the Lithuanian Environmental Protection Agency via Unified Product, Packaging and Waste Record Keeping Information System (GPAIS) and subsequently used for evaluation of GHG emissions.

7.2.1.2 Waste reporting

There was no recording or reporting of waste generation or disposal in Lithuania during the Soviet Rule.

After the declaration of independence in 1990 Environmental Protection Department was established, which initialized the collection of statistical data on waste generation and management. Installations generating or handling waste were obliged to record waste generation, recovery and disposal activities from 1991. The first reports covering waste management activities in 1991 were submitted to the Environmental Protection Department in 1992.

Waste generation, treatment and disposal were recorded and reported according to the waste classification categories shown in Table 7-6 and waste disposal and recovery operations listed in Table 7-7.

Table 7-6. Waste classification 1990

A. Non-hazardous waste	
A.01	Manure and animal faeces
A.02	animal-tissue waste
A.03	Green waste
A.04	Forest waste
A.05	wastes from mineral excavation
A.06	Gravel, stones
A.07	Food waste
A.08	Textile waste
A.09	Natural fibre waste
A.10	Synthetic fibre waste
A.11	Wood waste
A.12	Paper and cardboard waste
A.13	Plastic and polymer waste
A.14	Rubber waste
A.15	Glass waste
A.16	Ferrous metal waste
A.17	Non-ferrous metal waste
A.18	end-of-life vehicles, household appliances
A.19	Construction material waste
A.20	Natural leather waste
A.21	Natural fur waste
A.22	Mixed municipal waste
A.23	Other waste
B. Hazardous waste	
B.01	Sanitary wastes of medicine services
B.02	Pharmaceutical wastes (unfit medicine, narcotics, veterinary remedies)
B.03	Wood preservatives wastes (wood antiseptics with heavy metals)
B.04	Biocides and phytopharmaceutical wastes (unfit pesticides, insecticides and etc.
B.05	Organic solvent wastes
B.06	Halogenated organic substances, excluding solvents
B.07	Wastes contaminated with cyanides
B.08	Oil products wastes without water
B.09	Oil/water, hydrocarbon/water (mixtures and emulsions)
B.10	Wastes containing or contaminated with polychlorinated diphenyls, triphenyls or polybrominated diphenyls
B.11	Tarry materials arising from refining, distillation and any pyrolytic treatment
B.12	Wastes of paints, dyes, pigments

B.13	Waste of resins, latex, plasticizers, glues/adhesives
B.14	Waste of chemicals, which are not identified or are new and whose effects on man and/or environment are not known
B.15	Pyrotechnics and explosive materials waste
B.16	Photographic processing materials waste (developers, fixing agents, photo-materials)
B.17	Wastes contaminated with polychlorinated dibenzofuran
B.18	Wastes contaminated with polychlorinated dibenzo dioxin
B.19	Animal soaps, fats, waxes
B.20	Non-halogenated organic substances excluding solvents (residuals of antifreeze, solvents containing formaldehydes, residuals of organic synthesis)
B.21	Inorganic waste without heavy metals
B.22	Cinders, ashes (boilers cinders, chimney ashes)
B.23	Contaminated soil (specify contaminant)
B.24	Hardening salts without cyanides
B.25	Metallic dust (specify metals)
B.26	Catalysts waste
B.27	Solutions and sludge containing heavy metals
B.28	Spent filter materials (contaminated with chemicals)
B.29	Scrubber sludges
B.30	Sewage sludges
B.31	Decarbonisation residuals
B.32	Ion-exchange column residual
B.33	Residual from cleaning and washing of equipment
B.34	Wastes of lamps and batteries
B.35	Vegetable oil waste
B.36	Radioactive residual (waste containing radionuclides or contaminated with them)
B.37	Any other hazardous waste not mentioned above in this list

Table 7-7. Waste disposal and recovery operations 1990

Waste disposal operations	
D1	Deposit onto land (in dumps)
D2	Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc. In this case soil is only medium of wastes neutralisation. If waste is used as fertiliser, its code is R10. Biological treatment of polluted soil belongs to group D8.
D3	Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)
D4	Surface impoundment (e.g. placement of liquid or sludge discards into pits, ponds or lagoons, etc.)
D5	Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.
D6	Release into a water body except seas
D7	Release into seas
D8	Biological treatment not specified elsewhere in this table
D9	Physical chemical treatment not specified in this table. The materials which are formed during this treatment must be disposed of according table 5a
D10	Incineration without energy or incineration using additional fuel when quantity of incoming energy is not higher than additional energy
Waste recovery operations	
R1	Use as a fuel or other means to generate energy
R2	Solvent regeneration
R3	Recycling of organic substances which are not used as solvents
R4	Recycling and utilisation of metals and metal compounds
R4.1	Utilisation of metals in ceramics
R4.2	Other methods of regeneration and utilisation
R5	Regeneration of other inorganic materials (except metals and metal compounds)
R6	Regeneration of acids or bases

R7	Recovery of components used for pollution abatement
R8	Recovery of components from catalysts
R9	Used oil re-refining or other reuses of previously used oil (except using for fuel) If waste from oil products are used for fuel or energy, it belongs to group R.1.
R9.1	Regeneration of waste from oil products
R9.2	Recovery of spent oil products in ceramic production
R9.3	Other methods of recovery and recycling of spent oil products
R10	Land treatment resulting in benefit to agriculture
R12	Buying and selling of wastes for recycling or recovery
R14	Wastes usage as secondary raw materials
R15	Wastes composting
R16	Waste recovery using other methods

The Environmental Protection Department was reorganized to the Ministry of Environmental Protection in 1994, which became the Ministry of Environment in 1998. The Minister of Environment approved a new version of the Waste management regulation in 1999 (Order of the Minister of Environment No. 217 from July 14, 1999), including recording and reporting procedures modifications.

Waste management regulation 1999 transposed the EU Waste framework directive (75/442/EEC), including a list of waste and hazardous waste. Still, it established a national version of waste disposal and recovery operations (Table 7-8).

Table 7-8. Waste disposal and recovery operations 1999

1	Waste disposal
1.1	Disposal of non-hazardous waste into or onto land
1.2	Storage of non-hazardous waste more than a year
1.3	Incineration of non-hazardous waste without energy recovery
1.4	Disposal of non-hazardous waste by other methods
1.5	Disposal of hazardous waste into or onto land
1.6	Storage of hazardous waste more than three months
1.7	Incineration of hazardous waste without energy recovery
1.8	Disposal of hazardous waste by other methods
1.9	Export of wastes for disposal
2	Use of waste for energy recovery
2.1	Use of non-hazardous waste for energy recovery
2.2	Use of hazardous waste for energy recovery
2.3	Export of wastes for energy recovery
3	Waste recycling
3.1	Physical-chemical treatment of non-hazardous waste
3.2	Biological treatment of non-hazardous waste
3.3	Treatment of hazardous waste
3.4	Treatment of bulky waste
3.5	Waste export for recycling
4	Waste collection and transport
4.1	Collection of wastes from population and organizations which are not obliged to record wastes
4.2	Collection and transport of industrial waste
4.3	Loading, repacking and sorting of non-hazardous waste to be transported
4.4	Collection and transport of hazardous waste
4.5	Loading, repacking and sorting of hazardous waste to be transported
5	Brokerage in waste management sector

The Minister approved a new version of the Waste Management Regulation of Environment in December 2003 (Order of the Minister of Environment No. 722 from December 30, 2003). The new Regulation contained several changes in reporting requirements, including classification of waste treatment, recovery and disposal operations provided in Annex II to the directive 75/442/EEC. Following the new requirements, waste generation and management reports were provided by waste generating and waste managing undertakings at the beginning of 2005, covering 2004.

According to the Waste Management Regulation, waste management undertakings, including waste importing companies and waste generating industries obliged to have Integrated pollution prevention and control (IPPC) permits, must keep records of waste generation and treatment. In addition, waste recording is also mandatory for enterprises involved in the technical maintenance of vehicles and generating hazardous waste.

The waste recording log must be kept in the location of waste generation and submitted to the authorized officials of the Ministry of Environment, counties or municipalities upon their request.

Waste generation and treatment should be recorded at least once per week. If waste is generated or treated inconstantly, a separate generated or treated quantity of waste must be registered each time.

Recording should include:

- geographic origin of waste,
- industrial origin of waste,
- source name,
- waste code in Waste List,
- statistical classification code,
- waste name,
- amount of generated, received, treated or dispatched waste,
- treatment method,
- receiving facility (if waste was dispatched).

Waste recovery and disposal undertakings are obliged to provide annual reports on waste management to the environmental protection departments (EPD) of the Ministry of Environment. Likewise, waste generating industries obliged to have IPPC permits must provide annual recording reports. Both reports are very similar and have only minor differences, and must include summarized waste recording data.

The reports are collected by the environmental protection department and transferred to the Environmental Protection Agency, responsible for data processing and keeping the waste database.

In May 2011, the Minister of Environment approved new Rules on Recording and Reporting of Waste Generation and Management, which came into force in 2012. The new Rules require the submission of reports on recording and reporting waste generation and management to the EPD for undertakings that collect or transport hazardous waste or act as dealers and brokers of hazardous waste. According to the new rules, reporting started in 2013, covering waste generation and management in 2012.

In 2013 the Minister of Environment approved new regulation establishing **unified information system for products, packaging and waste accounting**[126] (GPAIS) which is currently used for waste reporting and information management.

7.2.2 Category description

7.2.2.1 Municipal waste generation and disposal

In the initial stages of data collection, waste was not weighed, and the amount of waste disposed of in landfills and dumps was evaluated on a volume basis. However, in the early 1990s, municipal waste was collected and transported to landfills by municipal waste collection companies. Their income (and the salaries of truck drivers) depended on the amount of waste delivered to landfills. Therefore, they often went to landfills with half-empty collection trucks but recorded full loads.

It is generally agreed that the amount of generated and disposed waste in early 90s was overestimated. In the report on the status of environment in Lithuania in 2001, published by the Lithuanian Ministry of Environment,[127] it was assumed that generation of municipal waste should be about 750 kt annually.

Starting from 1999 the amount of waste disposed of in landfills has stabilized at approximately 1 million tonnes. It was agreed in the discussion at the Ministry of Environment[128] that this value should be the most realistic evaluation of municipal waste disposal for the period 1990-1998.

Reliability of waste disposal data was further discussed with the leading Lithuanian experts in waste management statistics[129] at the Ministry of Environment on 27th of October 2010. During the meeting, it was agreed that even the information from waste generation and disposal were collected from 1991, but recorded data are unreliable and overestimated during 1991-1998. As it was mentioned before during this period, there was no weighing of waste at the disposal sites, and the amounts of disposed waste were estimated visually, causing substantial errors. Waste handlers were interested in showing higher amounts of collected waste and used to apply higher factors for volume-to-weight conversion.

The reliability of waste disposal data has increased with improved control and monitoring of the reporting system, the recording process, and accumulated experience. Therefore, it should be considered that waste disposal data collected from 1999 are reliable and could be used for evaluating CH4 generation in landfills.

The experts also concluded that there is no reason to believe that municipal waste generation and disposal during 1991-1998 were substantially different from generation and disposal during 1999-2008. For example, the total annual amount of municipal waste disposed of in Lithuania should have been about 1 million tonnes or about 300 kg per person per year.

[126] Order of the Minister of Environment of the Republic of Lithuania on approval of the provisions of the unified product, packaging and waste accounting information system

[127] State of the Environment 2001, p. 85th Ministry of Environment of the Republic of Lithuania, Vilnius, 2002

[128] Meeting at the Ministry of Environment with the Head of Waste Division Ingrida Kavaliauskienė and senior specialist Ingrida Rimaitytė, September 25, 2009

[129] Meeting at the Ministry of Environment with participation of Ingrida Kavaliaiuskienė, Head of the Waste Management Strategy Division of the Ministry of Environment, Audrius Naktinis, Chief Specialist of the Waste Management Division of the Ministry of Environment and Sandra Netikšaitė, Chief Specialist of the Pollution and Waste Management Accounting Division, Lithuanian Environmental Protection Agency

Based on the comparison of data variation on the gross domestic product (GDP) and waste disposal per capita (Figure 7-2), it is reasonable to assume that changes in waste generation and disposal per capita correlate with GDP changes. Still, annual changes in a waste generation are approximately ten times lower than changes in GDP.

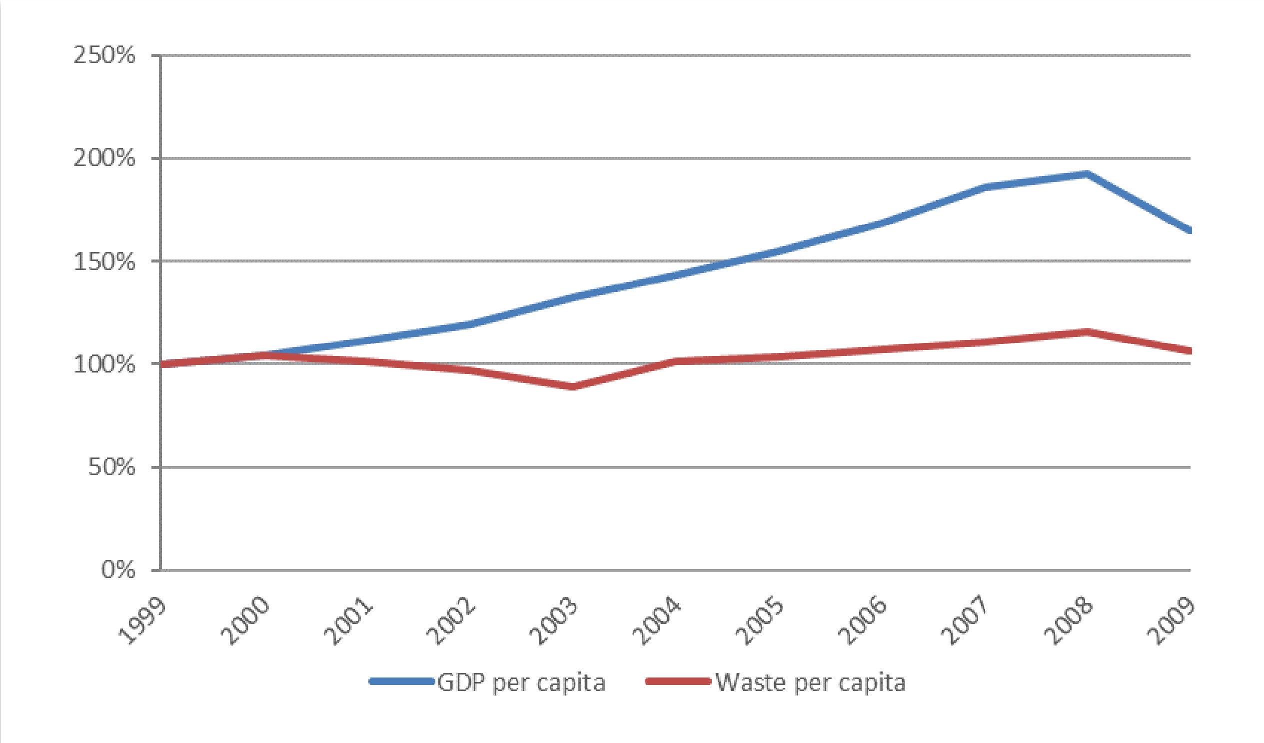


Figure 7-2. Variations of GDP and waste disposal per capita during 1999-2009

Evaluated changes of waste generation and disposal per capita during 1991-1998 based on the assumption that annual shift in waste generation and disposal comprises one-tenth of yearly variation of GDP per capita are shown in Table 7-9.

Table 7-9. Variation of GDP per capita and evaluated changes of municipal waste generation and disposal per capita

Year	**Per capita**	
	GDP, %	**Waste generation and disposal, %**
1991	-5.84	-0.58
1992	-21.14	-2.12
1993	-15.83	-1.58
1994	-9.14	-0.91
1995	5.43	0.54
1996	5.99	0.60
1997	8.26	0.83
1998	8.41	0.84

The experts at the meeting in the Ministry of Environment agreed that the calculation of waste disposal data for 1991-1998 should be based on the assumption that annual change of the amount of waste disposed to landfills per capita makes 10% of GDP per capita change. This assumption provides much more realistic information than the data collected by statistics.

Actual statistical data on municipal waste disposal to landfills were used to calculate CH4 emissions from landfills during 1999-2020. For 1990-1998 waste disposal was evaluated using estimated annual changes shown in Table 7-9 and population number provided by Statistics Lithuania.

The first regional landfill complying with the requirements of the EU landfill directive 1999/31/EC started operation in 2007. Construction of regional landfills was completed in 2009, and at the beginning of 2010, all municipal wastes were disposed of in newly constructed landfills.

7.2.2.2 Biodegradable waste of industrial and commercial origin

Together with mixed municipal waste, biodegradable waste is disposed to the landfills by industries and commercial organisations.

From 1991 when collection of data of waste handling and treatment was started, waste classification and definitions of various waste disposal and treatment operations have been changed several times. Currently waste statistical data collected by the Lithuanian Environmental Protection Agency are ordered according to two classification systems: European waste list adopted by the European Commission[130] and mainly substance-oriented waste statistical nomenclature developed by the EUROSTAT and provided in the EU waste statistics regulation (EC) No 2150/2002 as amended[131]. However, data collected prior to adoption of EU waste classification, especially during 1991-1999, cause certain difficulties in interpretation and identification of specific waste categories and disposal methods.

The following categories of industrial and commercial waste were selected from the EUROSTAT statistical nomenclature for including in calculation of CH_4 emissions from landfills:

- Paper and cardboard waste;
- Wood waste;
- Textile waste;
- Waste of food preparation and products;
- Green waste;
- Sewage sludge.

Data reported on disposal of biodegradable waste of industrial and commercial origin in landfills are provided in Table 7-10.

Table 7-10. Reported data on disposal of biodegradable waste of industrial and commercial origin in landfills in 1990-2020, kt

Year	Paper and cardboard wastes	Wood wastes	Textile wastes	Food waste	Green wastes	Sewage sludge	Total
1990	12.93	33.02	12.37	45.32	30.38	197.1	331.12
1995	4.68	42.83	1.04	15.98	26.24	308.9	399.67
2000	1.26	3.64	6.06	215.88	3.51	312.7	543.05

[130] Commission Decision of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste (2000/532/EC)
[131] *Official Journal L 332 , 09/12/2002 P. 0001 - 0036,*
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:332:0001:0036:EN:PDF

2005	0.53	24.05	2.50	1.91	22.18	135.1	186.27
2010	0.09	0.98	3.21	2.62	5.64	121.04	133.6
2015	0.79	2.43	2.44	0.62	0.00	93.96	100.2
2016	0.84	1.59	2.37	1.01	0.00	92.97	98.8
2017	0.79	2.72	2.61	1.05	0.73	22.07	30.0
2018	0.41	2.32	4.43	1.39	0.00	51.49	60.0
2019	0.54	2.37	4.78	0.90	0.00	28.91	37.5
2020	0.70	1.06	5.20	0.77	0.00	-12.65*	-4.9

**Sewage sludge accumulated at sludge storage sites has been extracted for treatment and the total amount of treated sludge exceeded sludge generation.*

The amounts of industrial waste disposed of in landfills in 1990 were assumed to be the same as in 1991.

In the early 1990s, the revenues for MSW collection companies depended on the amount of waste delivered to landfills. The loads were not weighed, and an overestimation of the weight of the loads is therefore suspected. On the other hand, industrial and commercial waste were transported by the companies generating the waste; they were subject to a fee per truckload of waste deposited, not per the weight. Therefore, the industries were interested to send trucks to landfills as full as possible. In addition, substantially smaller variations of industrial waste disposal in the early nineties also confirm that reported amounts of industrial waste were more realistic.

Higher amounts of disposed of industrial waste in the early 90s were caused by inadequate control and inspection during the first years of independence. Later, control was improved, and industries were forced to find other ways to manage their waste.

The high amount of food waste in 2000-2002 was disposed of in municipal landfills by sugar production plants, which were bought by Danish companies and increased production very significantly. Later, food waste generated in sugar production plants was used as fodder for animals, mainly swine, and its disposal stopped.

7.2.2.3 Waste Composition

The average composition of municipal solid waste was evaluated in several cases in 1996-2003 by experimental measurements carried out during the feasibility studies of the development of regional waste management system and construction of new landfills in various regions of Lithuania (Table 7-11). The data shows no significant changes in waste composition in time or by different regions. Based on this, the waste composition was assumed to be comparatively stable during the investigated period.

The data were summarized by the Ministry of Environment and published in the report "Status of the Environment 2004[132] (Table 7-12).

Samples for analysis were collected from municipal waste; industrial waste was not sampled. Analyses were performed by companies performing feasibility studies. Therefore, analytical procedures were not described in the studies. Furthermore, separate companies used different methodologies, even the components of waste composition were different. Consequently, it isn't easy to compare and summarise the results.

[132] Status of the Environment 2004, Ministry of Environment of the Republic of Lithuania, Vilnius, 2005.

The lowest fraction of biodegradable waste was found in waste collected in the rural areas of the Panevėžys region. Understandably, the biodegradable waste fraction in waste collected from rural areas is substantially lower than in urban areas. Therefore, fluctuations of average waste composition, including waste of both rural and urban origin, are less significant. However, the available data do not show any specific trends; therefore, a single set of values was selected for calculations.

In 2011 the Minister of Environment obliged Regional waste management centres responsible for landfill operation in Lithuania to analyse the composition of municipal waste in all landfills.

The waste composition was evaluated in 2012, 2013, 2016, and afterwards four times per year: in winter, spring, summer and autumn.

For sample collection, the landfill operator has to select a waste collection truck from each municipality delivering waste to landfills. Then, the waste sample for analysis is collected from five spots of the unloaded waste heap ("envelope" method). At least a 0.5-tonne sample is collected from municipalities with a population of more than 100 thou. and 0.3 tonnes from municipalities with a population less than 100 thou.

Table 7-11. Measured waste composition of various regions of Lithuania

Waste composition	**Kaunas**				**Kaunas region 2003**			**Klaipėda**	**Vilnius**			**Utena**	**Panevėžys, 2004**			
	1996	**1997**	**1998**	**1999**	**City**	**Towns**	**Rural**	**2000**	**1999**	**2001**	**County average**	**2003**	**City**	**Towns**	**Rural**	**Overall**
Biowaste	39%	46%	35%	41%	41%	53%	34%	56%	47%	52%	42%	43%	43%	39%	28%	38%
Paper	10%	7%	12%	12%	8%	10%	10%	19%	13%	9%	13%	15%	6%	9%	1%	5%
Cardboard	6%	7%	9%	1%	8%											
Plastic	7%	10%	```	10%	7%	5%	5%	8%	7%	13%	9%	8%	6%	8%	5%	6%
Glass	9%	6%	8%	8%	9%	7%	12%	9%	10%	6%	9%	6%	9%	5%	11%	9%
Metal	3%	3%	3%	4%	3%	3%	3%	2%	4%	4%	3%	3%	2%	2%	4%	3%
Wood	-	-	-	-	-	-	-	-	-	-	-	1%	-	-	-	-
Other burnable	14%	14%	16%	11%	14%	9%	9%	-	-	-	-	6%	-	-	-	-
Other non-burnable	12%	7%	6%	13%	5%	8%	18%	-	-	-	-	10%	-	-	-	-
Hazardous	-	-	-	-	1%	1%	1%	1%	-	-	-	0%	-	-	-	-
Other	-	-	-	-	4%	4%	8%	5%	19%	16%	24%	8%	34%	38%	52%	40%

Table 7-12. Average composition of MSW in Lithuania as reported in "Status of the Environment 2004"

Ingredient	**Amount**
Paper and cardboard	14%
Wood	2%
Textile	4%
Food (kitchen) waste	42%
Green waste	0%
Total biodegradable	***62%***
Plastic	9%
Metal	3%
Composite packaging	2%
Glass	9%
Leather and rubber	1%
Construction and demolition waste	4%
Sand, sweepings	4%
Hazardous waste	2%
Other	4%

Source: *"Status of the Environment 2004", Lithuanian Ministry of Environment*

Waste fractions to be identified during analysis are listed in Table 7-13.

Table 7-13. Waste fractions to be identified during municipal waste analysis

1	Paper and cardboard including packaging
2	Green waste
3	Wood waste including packaging
4	Biodegradable food production waste
5	Natural fibre waste
6	Other municipal biodegradable waste
7	Total municipal biodegradable waste
8	Plastic waste including packaging
9	Composite packaging waste
10	Metal waste including packaging
11	Glass waste including packaging
12	Inert waste (ceramics, concrete, stones, etc.)
13	Other non-hazardous waste
14	Waste electric and electronic equipment
15	Waste batteries and accumulators
16	Other hazardous waste
17	Other municipal waste

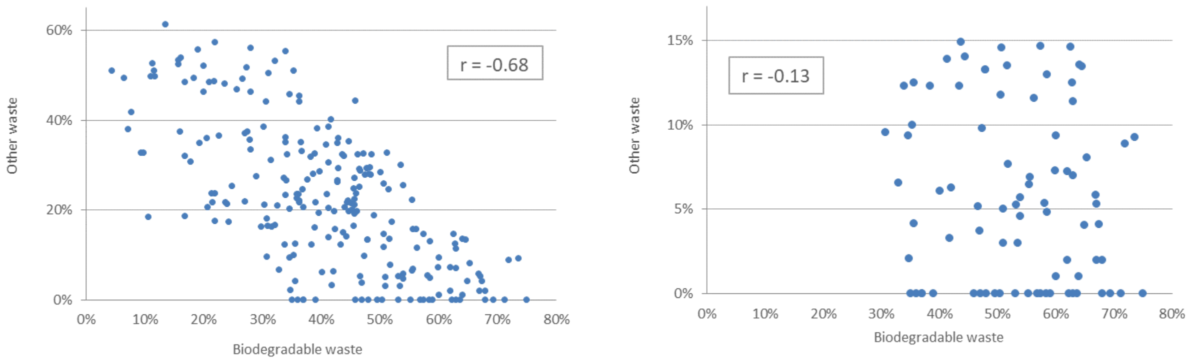
A separate PET packaging waste category was added to the list later.

Comparison of available data obtained in 2012 and 2013 showed that a significant correlation is observed between the total amount of biodegradable waste and "other municipal waste" (fraction 17) (r = -0.68). This correlation shows that biodegradable waste was not fully segregated. A certain fraction of biodegradable waste was accounted as other waste (Figure 7-3, a), indicating that a large amount of "other municipal waste" is unreliable. Therefore, data with "other municipal waste" exceeding 15% were discarded. The remaining data seemed to be more reliable, showing no correlation between the amount of biodegradable waste and other waste (r = -0.13, Figure 7-3, b). Therefore, these data were used to analyse further and evaluate average waste composition.

Summary of data on the total amount of biodegradable waste (fraction 7) reported by Marijampolė, Šiauliai, Panevėžys and Vilnius regional waste management centres is provided in Table 7-14.

2012

a ***b***



2013

a ***b***

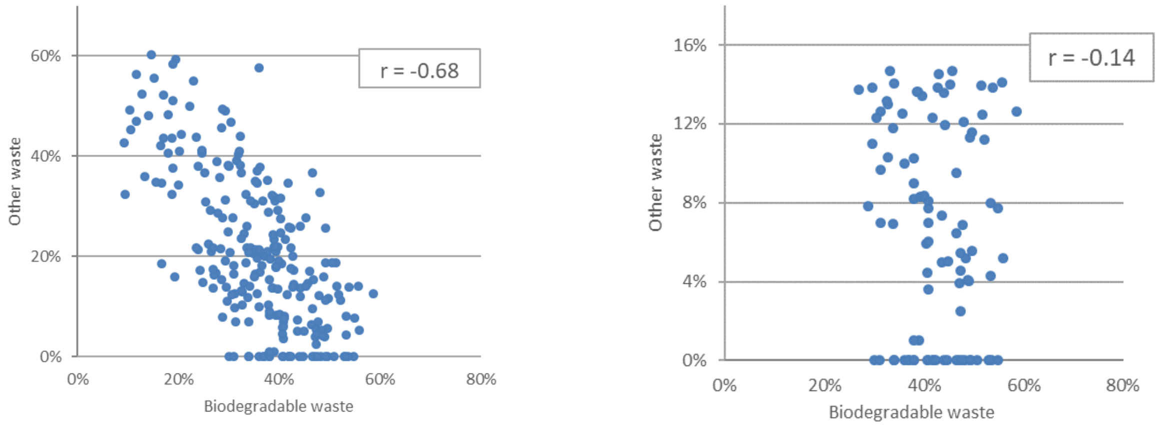


Figure 7-3. Correlation between the total fraction of biodegradable waste and unidentified fraction of "other waste" in reported data on waste composition in 2012 and 2013; a - all available data, b - data from regions in which "other waste" is less than 15

Table 7-14. Summary of data on the total amount of biodegradable waste (fraction 7) reported by Marijampolė, Šiauliai, Panevėžys and Vilnius regional waste management centres in 2012 and 2013

Parameter	Total	Cities	Towns	Spring	Summer	Autumn	Winter
Number of analyses	82	15	67	25	20	19	18
Minimum	30.8%	34.8%	30.8%	33.9%	41.3%	30.8%	32.9%
Maximum	75.0%	72.0%	75.0%	75.0%	73.6%	68.0%	71.2%
Average	53.2%	56.1%	52.6%	53.2%	56.0%	55.5%	47.9%
Standard deviation	11.3%	11.1%	11.3%	11.5%	10.0%	9.5%	12.4%

The result of data analysis (Table 7-14) showed no significant difference between data on biodegradable waste established in cities and towns or in various seasons and it was decided to use average values for calculations (Table 7-15).

Table 7-15. Summary data on municipal waste composition in 2012 and 2013

No	Ingredient	Minimum	Maximum	Average	Standard deviation
		2012			
1	Paper and cardboard including packaging	2.00%	25.60%	9.17%	4.73%
2	Green waste	0.00%	49.44%	13.33%	12.47%
3	Wood waste including packaging	0.00%	20.27%	3.08%	3.78%
4	Biodegradable food production waste	0.00%	53.73%	15.71%	11.87%
5	Natural fibre waste	0.00%	14.64%	5.59%	3.28%
6	Other municipal biodegradable waste	0.00%	38.74%	6.35%	9.53%

7	**Total municipal biodegradable waste**	**30.75%**	**74.98%**	**53.22%**	**11.32%**
8	Plastic waste including packaging	4.27%	38.81%	14.98%	6.45
9	Composite packaging waste	0.00%	11.13%	2.20%	2.50%
10	Metal waste including packaging	0.00%	10.94%	2.82%	2.32%
11	Glass waste including packaging	0.99%	33.00%	6.80%	4.59%
12	Inert waste (ceramics, concrete, stones, etc.)	0.00%	31.25%	10.20%	8.16%
13	Other non-hazardous waste	0.00%	26.11%	3.28%	5.63%
14	Waste electric and electronic equipment	0.00%	5.16%	0.40%	0.91%
15	Waste batteries and accumulators	0.00%	2.11%	0.09%	0.34%
16	Other hazardous waste	0.00%	3.00%	0.12%	0.50%
17	Other municipal waste	0.00%	14.90%	5.87%	5.10%
		2013			
1	Paper and cardboard including packaging	1.00%	25.26%	8.86%	4.18%
2	Green waste	0.00%	24.83%	6.84%	5.74%
3	Wood waste including packaging	0.00%	7.90%	2.24%	2.19%
4	Biodegradable food production waste	2.36%	44.20%	13.88%	10.60%
5	Natural fibre waste	0.00%	20.50%	5.03%	4.52%
6	Other municipal biodegradable waste	0.00%	25.58%	5.40%	6.10%
7	**Total municipal biodegradable waste**	**24.93%**	**58.64%**	**42.25%**	**7.60%**
8	Plastic waste including packaging	6.00%	36.00%	18.13%	5.28%
9	Composite packaging waste	0.00%	14.00%	4.46%	3.63%
10	Metal waste including packaging	0.00%	27.67%	4.40%	4.31%
11	Glass waste including packaging	0.30%	24.00%	9.60%	5.05%
12	Inert waste (ceramics, concrete, stones, etc.)	0.00%	38.00%	8.84%	6.72%
13	Other non-hazardous waste	0.00%	36.31%	4.52%	6.58%
14	Waste electric and electronic equipment	0.00%	6.34%	0.87%	1.26%
15	Waste batteries and accumulators	0.00%	2.80%	0.09%	0.35%
16	Other hazardous waste	0.00%	4.64%	0.14%	0.58%
17	Other municipal waste	0.00%	14.77%	6.69%	5.33%

Data on waste composition collected in 2016-2020 (Table 7-16) seem to be more reliable and show no clear dependence between biodegradable and other waste fractions (Fig. 7-4)

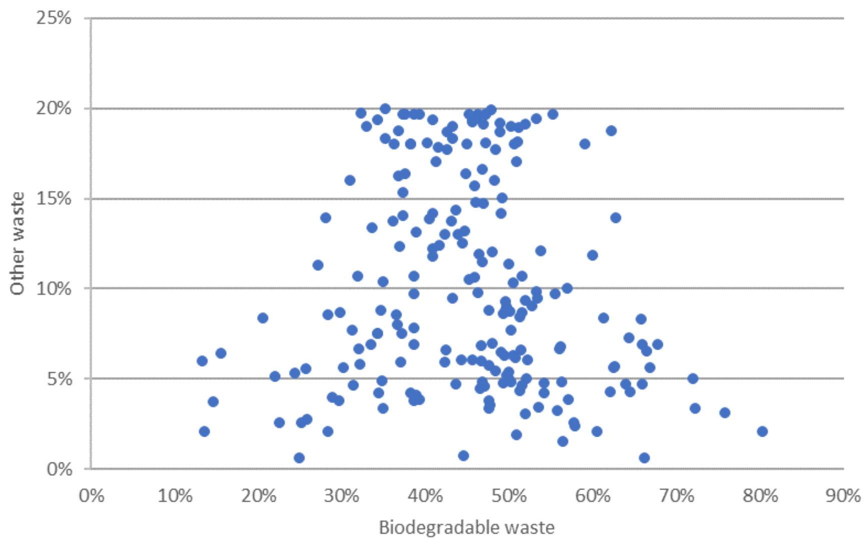


Fig. 7-4. Correlation between the total fraction of biodegradable waste and unidentified fraction of "other waste" in 2016

Composition of biodegradable waste in municipal waste stream for emission calculations was determined in the following way (Table 7-16):

- in 1990-2003: as reported by the Ministry of Environment in *"Status of the Environment 2004"*;
- in 2004-2011: established by linear interpolation of 2003 and 2012 data;
- in 2012 and 2013: assumed average composition determined in 2012 and 2013 (see Table 7-15);
- in 2014 and 2015: established by linear interpolation of 2013 and 2016 data;
- In 2016-2020: assumed average composition determined in 2016-2020 (Table 7-16).

Table 7-16 Assumed composition of municipal biodegradable waste

Year	Paper and cardboard waste, %	Wood waste, %	Textile waste, %	Food waste, %	Green waste, %
1990	14.00	2.00	4.00	42.00	0.00
1995	14.00	2.00	4.00	42.00	0.00
2000	14.00	2.00	4.00	42.00	0.00
2005	12.93	2.24	4.35	37.57	2.96
2010	10.24	2.84	5.24	26.48	10.37
2015	6.73	1.53	6.49	23.41	6.58
2016	5.66	1.18	7.23	25.48	6.45
2017	6.59	1.01	7.81	29.66	4.22
2018	6.43	0.66	7.73	28.88	4.40
2019	6.32	0.93	7.85	30.18	4.64
2020	6.22	0.94	7.73	30.81	4.66

From the beginning of 2008, a fraction of municipal waste has been sorted, separating recyclable materials, including plastics, glass, and metal. Later beginning from 2011, a gradually increasing fraction of organic biodegradable waste was separated for biological treatment. After sorting, the remaining waste was landfilled and reported in the EPA database under code 19 12 12 Other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11.

The composition of MSW is established upon delivery of untreated waste to pretreatment facilities. Therefore, it is evident that the content of biodegradable materials in landfilled wastes after pretreatment in MBT facilities is changed compared to the original composition before pretreatment. Two factors influence the content of biodegradables in disposed MSW: extraction of recyclables which increases the concentration of biodegradables, and removal of organics for composting, which reduces the concentration.

According to the judgement of the specialists of MBT facilities, approximately 50% of recyclables are extracted during the pretreatment. Therefore, it was assumed that the amount of waste sent for disposal after pretreatment is reduced by 50% of the volume of recyclables established by initial analysis causing the corresponding increase of biodegradable content. Therefore, information on the extraction of different recyclables is not required as only the total loss of waste amount during the pretreatment was taken into account.

With the extraction of recyclables, pretreatment also includes separating organic components for composting and anaerobic digestion, resulting in reducing biodegradable components in waste directed for disposal. In addition, the composition of landfilled MSW was recalculated by subtracting the number of biodegradable components directed for composting from the total amount of MSW. The recalculation resulted in an additional reduction of CH_4 emissions.

The amounts of MSW directed for disposal after sorting and its compositions are provided in Table 7-17.

Table 7-17. Amounts of waste directed for disposal after sorting and composition of degradable components

Year	Amount, kt	Degradable waste, %				
		Paper and cardboard	Wood	Textile	Food waste	Green wastes
2008	1.28	12.8%	2.9%	5.5%	34.9%	8.4%
2009	15.14	12.2%	3.1%	5.7%	32.5%	10.1%
2010	22.60	11.6%	3.2%	5.9%	30.1%	11.8%
2015	147.51	7.0%	1.6%	6.7%	24.7%	6.8%
2016	258.02	4.9%	1.0%	6.3%	23.4%	5.6%
2017	254.96	5.7%	0.9%	6.8%	27.4%	3.6%
2018	289.13	4.6%	0.5%	5.5%	22.8%	3.1%
2019	273.87	4.6%	0.7%	5.8%	24.6%	3.4%
2020	190.60	4.7%	0.7%	5.8%	25.6%	3.5%

Table 7-18 provides data on the biodegradable components of the total amount of mixed waste including waste of industrial and commercial origin (Table 7-10) and municipal waste (Tables 7-16 and 7-17).

It was assumed that amount and composition of industrial and commercial waste in 1990 was the same as in 1991.

Table 7-18. Biodegradable components in landfilled waste evaluated for calculation of CH_4 generation

Year	Paper and cardboard waste, %	Wood waste, %	Textile waste, %	Food waste, %	Green waste, %	Total, %
1990	13.5	4.4	4.6	41.1	2.4	66.1
1995	13.3	5.6	3.8	40.1	2.3	65.0
2000	11.6	1.9	3.8	51.1	0.3	68.7
2005	12.4	4.3	4.4	36.0	4.8	61.9
2010	10.2	2.9	5.5	26.5	10.8	55.8
2015	6.8	1.9	6.8	23.6	6.6	45.7
2016	5.3	1.5	7.1	23.9	5.8	43.6
2017	5.9	1.7	7.6	27.4	3.9	46.5
2018	4.7	1.1	6.9	23.1	3.1	39.0
2019	4.7	1.4	7.2	24.0	3.3	40.6
2020	6.3	1.4	9.8	30.1	4.5	52.1

There are no data and no speculations on waste composition during the historical period 1950-1989. Therefore, the assumption that waste composition in the years 1950-1990 was the same as in the later period has some background, though not very firm. At the same time, we can't assume that composition was different with a higher or lower fraction of biodegradables. Therefore, the final composition of biodegradable waste determined for 1990 was also used to calculate methane emissions in the historic years 1950-1989.

7.2.2.4 Historic waste disposal

Using the first-order decay method to calculate CH4 emissions from landfilled biodegradable waste requires historical data of waste disposal as the model considers the long-term digestion process. Therefore, information on historical waste disposal is necessary.

The amount of waste disposed to landfills during 1950-1989 was evaluated based on following considerations.

Between 1950 and 1990 Lithuanian population grew approximately 1% per year but started to decline after the restoration of independence (Figure 7-4).

Economic indicators characterizing standards of welfare in the Soviet command economy during 1950-1990 and economic indicators of the free market economy since the restoration of independence in 1990 are entirely different, and their direct comparison is not possible.

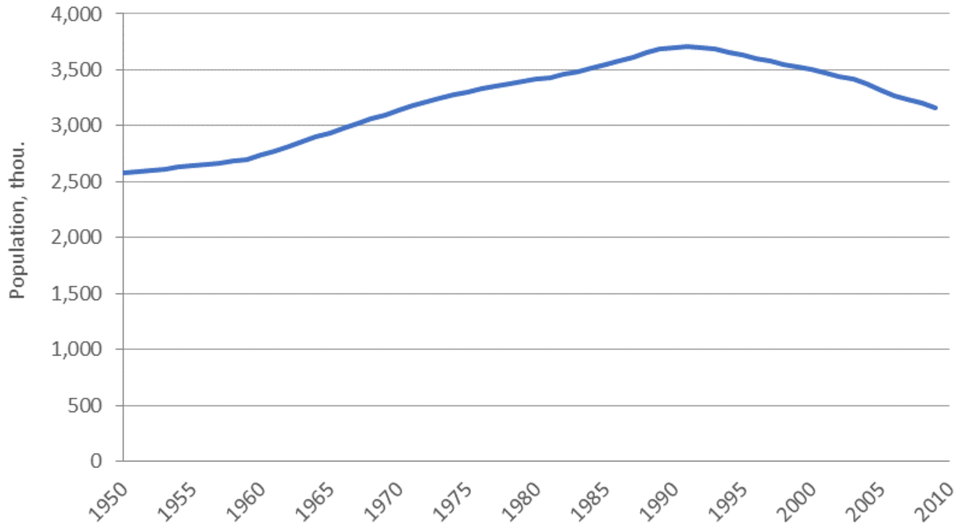


Figure 7-4. Variation of population in Lithuania in 1950-2014[133]

Economic development during the Soviet period was characterized by the "total public product". Changes of the total public product[134] evaluated by the Statistics Lithuania are shown in Figure 7-5. However, it should be noted that it was measured in current prices and did not reflect the change in living standards correctly.

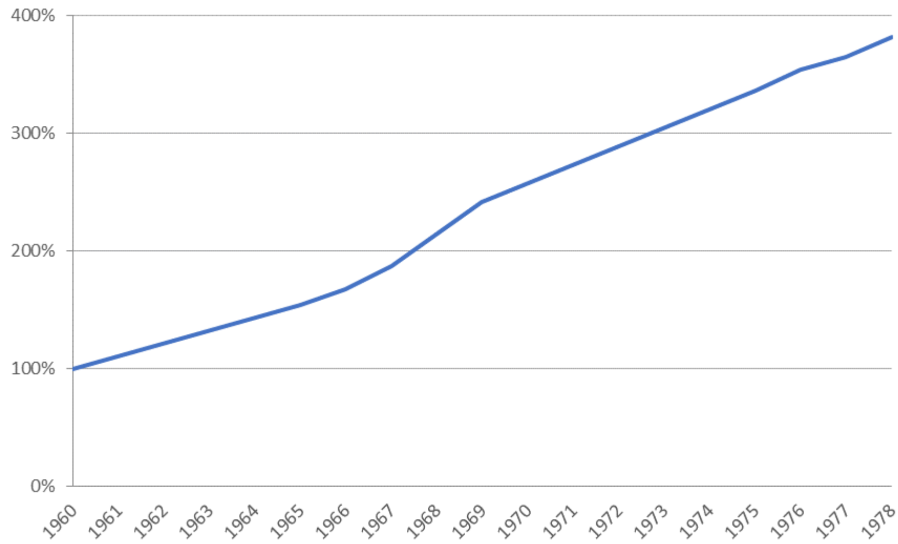


Figure 7-5. Variation of the total public product from 1960 to 1978

[133] Statistics Lithuania

[134] GDP: Conversion from material product balances to the system of national accounts in 1980-1990 at current prices. Lithuanian Department of Statistics, Vilnius, 1994

The Statistics Lithuania have recalculated economic indicators of the last decade of the Soviet power in Lithuania and obtained GDP values which are comparable to GDP after transition to free market economy[135]. Relative variations of population and GDP per capita from 1980 (1990 = 100%) are shown in Figure 7-6.

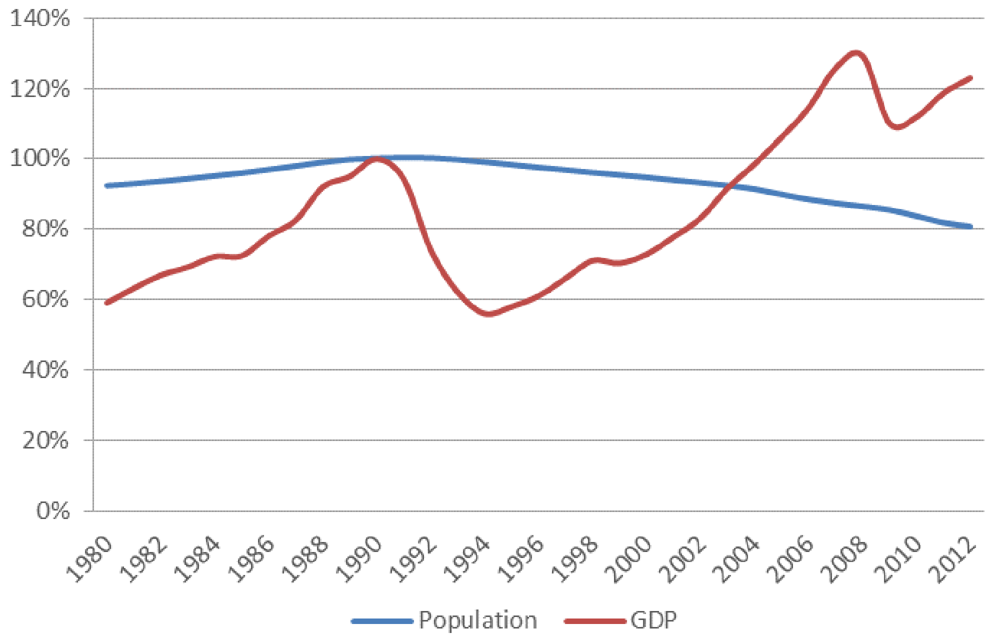


Figure 7-6. Relative variation of population and GDP per capita from 1980 (1990 = 100%)

It was assumed that the amount of waste per capita disposed of in landfills depends on consumption (standard of living) and availability of waste disposal facilities.

For evaluating waste generation, it was assumed that waste generation during the period 1950-1990 was increasing continuously. The growth rate depended on two factors: number of population and consumption. As it was quoted above, population growth during this period was close to 1.0% determining at least 1.0% growth in the total waste generation.

The period of 1950-1989 started just five years after World War II when most of Lithuania was still in ruins, facilities and infrastructure for the waste collection were non-existent. Therefore, applying the same parameters for evaluating waste disposed of in landfills in the post-war period and 1990s when waste collection and disposal facilities and infrastructure were already in place, though inadequately managed, was considered not correct.

In the 1950s, waste collection services were provided only to a small fraction of the population in major cities. Therefore, the growth of the amount of waste disposed of in landfills was instigated not so much by increasing consumption but rather by expanding waste collection areas and infrastructure. Consequently, waste disposal during this period was assumed to increase substantially faster than in the 90s.

It was also assumed that expansion of provided waste management services and improvement of living standards caused about a 1.0% annual increase of waste generation per capita.

[135] Ibid.

When extrapolating waste disposal, it was assumed that the composition of the degradable waste (in per cent), including municipal and industrial waste, was the same as in 1990.

The estimated total amounts of waste were then in a next step divided over three types of disposal sites based on the relation between the types of disposal sites and the population in major cities, smaller towns and rural areas. Finally, from 2007, out-phased of the old landfill sites and putting in operation of new landfills was considered.

Variation of municipal waste disposal (not including separately disposed biodegradable waste of industrial and commercial origin) from 1950 to 1990 is based on these assumptions and is shown in Figure 7-7.

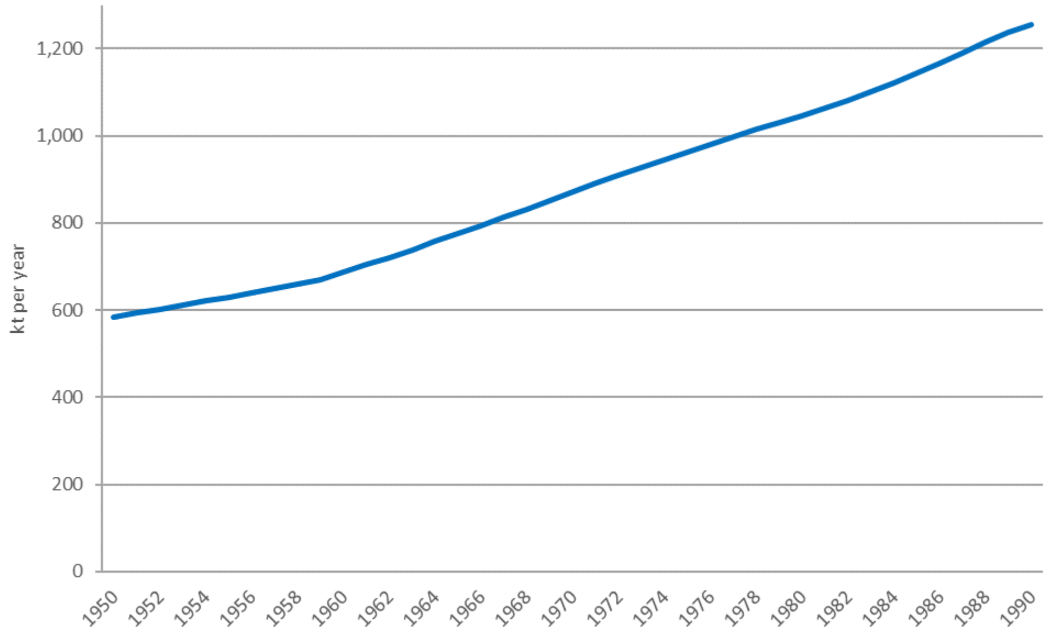


Figure 7-7. Assumed variation of municipal waste disposal from 1950 to 1990

There are no data on municipal or industrial/commercial waste disposal from 1950 to 1990. Therefore, it was not possible to distinguish between the variation of disposed of municipal and industrial/commercial wastes. Evaluation of waste disposal for the period 1950-1989 was performed applying the same methodology as for the total amount of waste, including municipal and industrial/commercial waste.

The amount of industrial and commercial waste disposed of in 1990 was assumed to be the same as in 1991. Data on disposal of industrial and commercial waste from 1991 to 1998 were taken from the database of the Environmental Protection Agency.

The final composition of biodegradable waste (including both municipal and industrial/commercial waste) determined for 1990 was used also for calculation of methane emissions in historic years 1950-1989.

7.2.2.5 Sensitivity analysis

The assumption that the amount of waste disposed of per capita in landfills in 1950-1989 was increasing annually by about 1% should be considered very rough. Most probably containing a significant error, and it is essential to evaluate whether erroneous assumptions could significantly impact the final results of methane emission.

Growth of the amount of disposed of per capita waste in 1950-1989 by 1.0% was taken as the base scenario. For comparison, methane emissions were calculated using alternative assumptions that the waste amount disposed of per capita in 1950-1989 increased by 0.5% and 2.0%.

Obviously, in the case of faster growth, to reach the same level in 1990, the initial waste amount disposed of in 1959 should be lower, and vice versa, in case of slower growth, the initial amount should be higher. Evaluated initial waste amounts that should have been disposed of in 1950 in the case of 0.5%, 1.0% and 2.0% average growth of waste per capita disposal are shown in Table 7-19.

Table 7-19. Evaluated initial amounts of waste that should have been disposed in 1950 in case of 0.5%, 1.0% and 2.0% average growth of disposed per capita waste

Parameter	**Growth 0.5%**	**Growth 1%**	**Growth 2%**
Disposal kg/person/year	277.49	226.85	151.14
Total disposal, kt per year	714.10	583.78	388.94

In the case of waste growth rate reduced by half compared to the base scenario, the initial waste amount increases only by 22.3%. In comparison, a twice higher growth rate requires a decline of the initial waste amount by 33.4%.

The impact of different growth rates of waste disposal in 1959-1989 on methane emissions in 1990-2014 is shown in Table 7-20.

Table 7-20. Impact of assumed different growth rates of waste disposal in 1959-1989 on methane emissions in 1990-2014 compared to base scenario (1% growth)

Year	**Growth 0.5%**	**Growth 2%**
1990	4.34%	-7.78%
1995	2.62%	-4.66%
2000	1.80%	-3.18%
2005	1.28%	-2.25%
2010	0.99%	-1.73%
2011	0.94%	-1.65%
2012	0.90%	-1.58%
2013	0.88%	1.54%
2014	0.88%	-1.54%

As could be seen from Table 7-20, in case of growth rate reduced by half, i.e. the more significant amount of initial and, consequently, the total amount of disposed waste, the maximum increase of methane emissions is 4.3%, average growth during the period 1990-2014 only 2.0%.

The assumption that the waste disposal growth rate in 1950-1989 was twice higher than in the base scenario results in a reduction of methane emissions by a maximum of 7.8%, on average 3.5%.

It is evident that variations of obtained results using three scenarios are comparatively small, significantly lower than the uncertainty of evaluation of methane emissions. Possible errors in estimating waste disposal in 1950-1989 could have only a minor impact on final results.

7.2.2.6 Waste disposal practices

Historically Lithuanian landfills can be divided into three categories:

- landfills of major cities (county centres),
- landfills of smaller towns, and
- small landfills and dumps in rural areas.

According to the 2006 IPCC Guidelines (Chapter 3, Table 3.1), SWDS are divided into following categories:

- Managed – anaerobic, MCF = 1.0,
- Managed – semi-aerobic, MCF = 0.5,
- Unmanaged – deep, MCF = 0.8,
- Unmanaged – shallow, MCF = 0.4, and
- Uncategorised, MCF = 0.6.

Anaerobic managed solid waste disposal sites must have controlled placement of waste and include at least one of the following:

(i) cover material;
(ii) mechanical compacting; or
(iii) levelling of the waste.

Landfills of major cities (county centres) correspond to these criteria and were assigned to managed anaerobic SWDS category.

Semi-aerobic managed solid waste disposal sites must have controlled placement of waste and include all of the following structures for introducing air to waste layer:

(i) permeable cover material;
(ii) leachate drainage system;
(iii) regulating pondage; and
(iv) gas ventilation system.

Landfills of smaller towns are comparatively deep (>5 m waste). Still, they do not meet the criteria set for anaerobic managed or semi-aerobic managed SWDS and were assigned to the unmanaged deep SWDS category.

Small landfills and dumps in rural areas do not meet the criteria of managed SWDS and have depths of less than 5 metres, and were assigned to unmanaged shallow SWDS category.

The amounts of waste disposed to the landfills of each type were evaluated in the following way.

Variations of Lithuania's urban and rural population during 2001-2011 are shown in Table 7-21. Separately data of populations in major cities and towns are not available from 1950. However, as seen from this Table, the share of major cities in the total urban population is relatively constant and makes approximately 70%. It was assumed that this ratio continued for the whole discussed period starting from 1950. Estimated variations of the population in major cities, towns and rural areas from 1950 are provided in Figure 7-8.

Table 7-21. Variations of urban and rural population (k) in Lithuania during 2001-2011

Year	Major cities	Towns	Total urban	Rural	Total
2001	1,629	694	2,323	1,148	3,471
2002	1,622	681	2,303	1,140	3,443
2003	1,616	664	2,280	1,135	3,415
2004	1,604	645	2,249	1,128	3,377
2005	1,593	619	2,212	1,110	3,323
2006	1,585	594	2,179	1,091	3,270
2007	1,580	576	2,156	1,075	3,231
2008	1,556	579	2,135	1,063	3,198
2009	1,551	561	2,112	1,051	3,163
2010	1,531	537	2,068	1,029	3,097
2011	1,499	523	2,021	1,007	3,028

Source: Statistics Lithuania

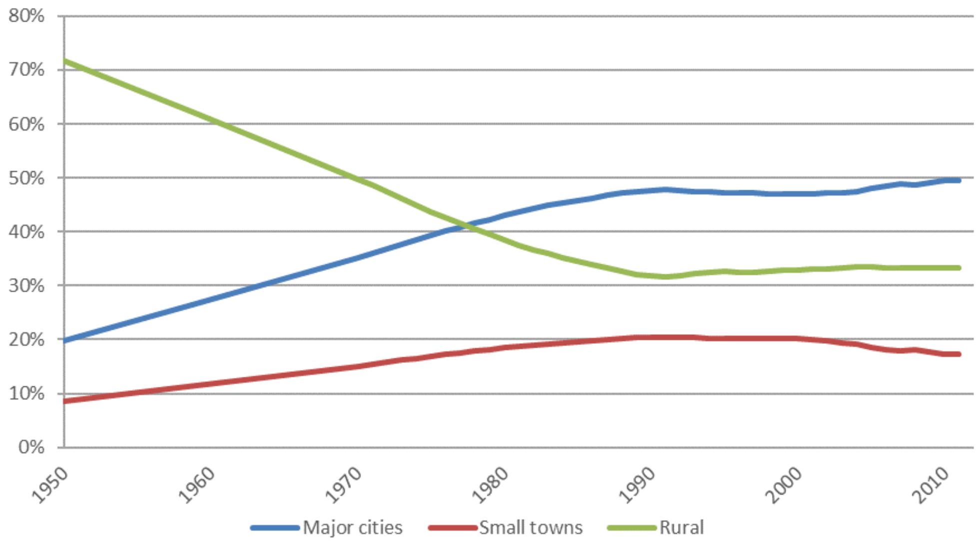


Figure 7-8. Estimated variations of population in major cities, towns and rural areas from 1950[136]

The conditions described above were applicable until 2007. However, from 2007 disposal practices started to change. Implementation of the Landfill directive 1999/31/EC required the construction of new solid waste landfills corresponding to the requirements set in the Landfill directive and closure of all existing landfills not complying with the requirements.

As a result, ten municipal waste management regions were established in Lithuania, and new landfills complying with the requirements of the Landfill directive were constructed. Old landfills and dumps were closed, and all waste, including waste from small towns and rural areas, are currently disposed of in new managed landfills. The start of waste disposal in new managed regional landfills complying with the requirements of the Landfill directive is shown in Table 7-22.

Table 7-22. The beginning of waste disposal in new managed regional landfills

Region	Start of the disposal
Alytus	January 2008
Marijampolė	April 2009
Tauragė	April 2009
Šiauliai	July 2007
Vilnius	January 2008

[136] Statistics Lithuania

Region	Start of the disposal
Telšiai	January 2008
Klaipėda	July 2008
Kaunas	July 2009
Utena	April 2008
Panevėžys	October 2009

For the transition period 2007-2009, the regional waste management companies provided data (percentage) of wastes disposed in old and new landfills. Waste disposed in old landfills was divided into 3 categories depending on population distribution in cities, towns and rural areas, waste disposed of in new landfills was assigned to deep managed category.

Evaluated disposal of municipal waste in new regional landfills are shown in Table 7-23.

Table 7-23. Disposal of municipal waste in new regional landfills during 2007-2009

Region	2007			2008			2009		
	Popu-lation, %	Disposal		Popu-lation, %	Disposal		Popu-lation, %	Disposal	
		%	kt		%	kt		%	kt
Alytus	5.29	NO	NO	5.26	100	62.56	5.23	100	56.87
Kaunas	20.01	NO	NO	20.01	86	207.73	20.02	92	200.29
Klaipėda	11.21	NO	NO	11.25	76	101.74	11.29	79	97.01
Marijampolė	5.39	NO	NO	5.38	NO	NO	5.37	59	34.46
Panevėžys	8.48	NO	NO	8.44	NO	NO	8.40	57.1	52.14
Šiauliai	10.45	50	60.36	10.39	79.7	98.54	10.33	60.5	67.98
Tauragė	3.80	NO	NO	3.78	NO	NO	3.76	78.7	32.21
Telšiai	5.16	NO	NO	5.15	100	61.27	5.15	100	55.98
Utena	5.16	NO	NO	5.13	99.7	60.80	5.09	100	55.33
Vilnius	25.05	NO	NO	25.19	90	269.72	25.37	95	262.11
Total			60.36			859.35			914.37
Fraction of the total municipal waste			5.23%			72.24%			84.07%

The amount of waste disposed of in regional landfills (60.4 kt in 2007, 859.4 kt in 2008 and 914.4 kt in 2009) were added to the amount disposed of in new managed landfills. The remaining amount was divided among the three types of landfills depending on the population in major cities, towns and rural areas. Finally, the generation of municipal waste per capita was evaluated..

During the meeting at the Ministry of Environment[137] it was agreed that the ratio of waste generation in major cities, towns and rural areas is approximately 2:1.5:1. Based on this assumption, waste disposal per capita in major cities, towns and rural areas (excluding waste disposed of in new landfills) were calculated as:

$$G_R = \frac{WT}{2 \times P_C + 1.5 \times P_T + P_R}$$

$$G_C = 2 \times G_R$$

$$G_T = 1.5 \times G_R$$

where:

[137] Meeting at the Ministry of Environment with the Head of Waste Division Ingrida Kavaliauskienė and senior specialist Ingrida Rimaitytė, September 25, 2009

G_C,G_T *and* G_R - annual amount of waste disposed in cities, towns and rural areas (kg per capita per year);

WT - the total amount of disposed waste (tonne) minus waste disposed on the new regional landfills;

P_C, P_T *and* P_R - the number of population in cities, towns and rural areas (thousands).

The amounts of waste disposed of in anaerobic, unmanaged deep and unmanaged shallow landfills (corresponding to waste delivered for disposal from major cities, towns and rural areas) were calculated by multiplying the corresponding population number with the waste generation per capita of the related category, namely for managed waste disposal sites: $2.G_R.Pc$; for unmanaged deep: $1.5\ .\ G_R.Pt$; for unmanaged shallow: $1.\ G_R.P_R$.

Data on disposal of solid municipal waste in landfills of each category are provided in Tables 7-24 and 7-25.

Table 7-24. Disposal of solid municipal waste in Lithuania

Year	Population, thou.	MSW disposal	
		thou. tonne	kg per capita
1990	3,697,84	1,119,9	302.9
1995	3,629.10	1,055.7	290.9
2000	3,499,54	1,084.2	309.8
2005	3,322.53	1,047.6	315.3
2010	3,097.28	1,072.9	346.4
2015	2,904.91	672.8	231.6
2016	2,868.23	371.2	129.4
2017	2,828.40	301.1	106.5
2018	2,801.54	330.7	118.0
2019	2,792.21	305.3	109.3
2020	2,796.03	212.5	76.01

Table 7-25. Disposal of solid municipal waste in landfills of different categories (kt)

Year	Old landfills			New regional landfills	TOTAL
	Managed anaerobic	Unmanaged deep	Unmanaged shallow		
1990	676.63	217.49	225.80	NO	1,119,92
1995	633.23	203.54	218.91	NO	1,055.68
2000	648.13	208.33	227.74	NO	1,084.20
2005	638.91	186.04	222.61	NO	1,047.57
2010	NO	NO	NO	1,072.94	1,072.94

Starting from 2010 all municipal waste was disposed of in the new regional landfills.

7.2.2.7 Sewage sludge disposal

Sewage sludge treatment methods include landfilling, incineration, anaerobic digestion, composting and application in agriculture. Data on sewage sludge production and disposal are provided in Table 7-26.

The major part of sewage sludge is disposed separately from solid waste on sites comparable to landfills but defined as storage sites in the EPA statistics. Therefore, statistical information on sewage sludge disposal is collected and stored in the same database as waste generation and management data. Data on sewage sludge disposal were provided by the Lithuanian EPA responsible for collecting and managing statistical information on waste management.

In recent years increasing volumes of sewage sludge accumulated at sludge storage sites are being extracted for treatment (increased incineration), and the amount of treated sludge exceeded generation in 2020.

Table 7-26. Sewage sludge production and disposal, kt dry substance

	Generation	Agriculture	Compost and other applications*	Landfill	Incineration	Storage
2012	45.09	7.79	12.18	-	-	24.13
2013	41.43	7.68	10.93	-	-	18.36
2014	48.02	15.73	14.74	-	-	17.55
2015	53.75	18.86	16.09	-	-	18.79
2016	53.30	20.49	14.65	2.60	-	20.76
2017	45.42	26.00	17.20	0.43	0.15	2.50
2018	57.03	19.94	27.79	0.26	1.88	7.67
2019	52.00	17.74	29.80	0.22	1.84	2.84
2020	53.90	14.98	27.02	0.00	14.43	-2.53

**Include composting and anaerobic digestion*

Before 2005, wet sewage sludge generation and management data were reported and stored in the EPA database. From 2006 some companies started reporting the amount of sludge expressed in dry matter. All data were checked and converted to wet sludge using a dry matter/wet sludge conversion factor of 0.2.[138]

Sewage sludge disposal conditions, same as solid waste, depend on the size of disposal site – in large cities large amounts of sludge are disposed, while in small towns disposal sites are smaller and thinner. A study on sewage sludge management[139] performed in 2012 concluded that about 73% of sewage sludge are disposed on shallow (depth <5 m) unmanaged sites for which use of MCF value 0.4 is recommended. Remaining 27% are disposed on deeper (depth >5 m) unmanaged deep sites for which MCF value 0.8 was recommended.

Amounts of sewage sludge (kt) disposed on land of different categories of storage sites are provided in Table 7-27.

Table 7-27. Amount of sewage sludge (kt wet weight) disposed on land sites of different categories

Year	Unmanaged deep (MCF = 0.8)	Unmanaged shallow (MCF = 0.4)	Total
1990	**53.2**	**143.9**	**197.1**
1995	**83.4**	**225.5**	**308.9**
2000	84.4	228.3	312.7
2005	36.5	98.6	135.0
2010	32.7	88.4	121.0
2015	25.4	68.6	94.0
2016	28.0	75.8	103.8
2017	2.4	19.1	12.5
2018	10.4	28.0	38.4

[138] Wet - dry conversion of sludges. ARGUS for Eurostat - Environment Statistics. Meeting of the Working Group "Statistics of the Environment", Sub-Group "Waste". Eurostat, 2008.
[139] Evaluation of methane generation from wastewater and sludge at wastewater treatment plants in Lithuania (Lietuvos nuotekų valymo įrenginių nuotekose ir dumble susidarančio metano kiekio tyrimai ir įvertinimas) Ekotermija, 2012

2019	3.8	10.4	14.2
2020	-3.4	-9.2	-12.6

7.2.2.8 Methane recovery

Landfill gas collection started in 2008 in closed Kaunas and Utena landfills. Initially, discrete data on methane recovery from landfills were not reported by Statistics Lithuania, and information on methane recovery was collected by sending questionnaires to the Regional Waste Management Centres. Later, when the number of landfill gas recovery sites and the volume of recovered gas increased, Statistics Lithuania started recording the amount of recovered landfill gas separately.

Recovered methane is used for energy purposes, and emissions from landfill gas combustion are included in the energy sector report. In order to be consistent, it was decided to use the same data for evaluating GHG emissions in both energy and waste disposal sectors.

The data on landfill gas recovered and used for energy production are reported by Statistics Lithuania in million m^3. The data are collected from the Regional Waste Management Centres and are country specific.

Amount of recovered methane in kt was calculated using the default IPCC value of 0.5 for the fraction of CH_4 in generated landfill gas (*2006 IPCC Guidelines*, Volume 5, p. 3.15) and the IPCC conversion factor of $0.67x10^{-6}$ kt/m^3 (*2006 IPCC Guidelines*, Volume 2, p. 4.12).

Recovered methane both in landfills and in wastewater treatment plants, is used for energy purposes and emissions from these electricity- and heat-producing activities are included under the energy sector and reported in the 1A sector as biogas which includes biogas generated from landfills, sewage sludge and manure.

According to the *2006 IPCC Guidelines* (v.5, p. 3.18) emissions from flaring are not significant, as the CO_2 emissions are of biogenic origin and the CH_4 and N_2O emissions are very small, so good practice in the waste sector does not require their estimation.

Data of CH_4 recovery from landfills are provided in Table 7-28.

Table 7-28. Methane recovery from landfills, kt

Year	Used for energy[140]
2008	0.30
2009	0.94
2010	1.37
2015	5.73
2016	5.96
2017	3.58
2018	7.00
2019	6.13
2020	4.59

At the municipal wastewater treatment plants methane is recovered in anaerobic digestion installations from sludge generated during wastewater treatment. Sludge for anaerobic digestion is collected separately and not accounted for together with disposed sludge. Therefore, methane recovery in anaerobic digestion plants is discussed in the wastewater handling section.

[140] Statistics Lithuania

Corresponding wastewater treatment plants operate anaerobic digestion facilities for processing sewage sludge. Because the sludge is recycled within a plant, operators are not obliged to report its generation and consumption to the EPA. Therefore, data on sewage sludge used for biogas production in anaerobic digestion facilities are unavailable.

7.2.3 Methodological issues

7.2.3.1 First Order Decay Model

CH_4 generation was evaluated using the FOD model according to Tier 2 approach (*2006 IPCC Guidelines*). The model calculations were performed using national statistics of landfill site characteristics and amounts of waste fractions deposited each year.

The basic equation for the first order decay model is made available in the Excel file containing first order decay model provided by the European Commission[141]:

$$DDOC_m = DDOC_m(0) \times e^{-kt}$$

where:

DDOC$_m$ - the mass of decomposable degradable organic carbon (DOC) at any time;

DDOC$_m$*(0)* - the mass of DOC at the start of the reaction, when t=0 and $e^{-kt}=1$;

t - time in years;

k - the reaction constant.

The default assumption is that CH_4 generation from all the waste deposited each year begins on the 1st of January in the year after deposition. This is the same as an average six month delay until substantial CH_4 generation begins (the time it takes for anaerobic conditions to become well established).

According to the first-order decay equation, the amount of degradable organic carbon disposed of during a year decreases exponentially over time, resulting in a corresponding exponential reduction of CH_4 generation. The total CH_4 generation at a given time t is a sum contribution from the degradation of organic carbon disposed of during the years from 1 to t.

Annual CH_4 emissions were calculated using formula (*2006 IPCC Guidelines*, Volume 5, p. 3.8):

$$CH_4 Emissions = \left[\sum_x CH_4 generated_{x,T} - R_T\right] \times (1 - OX_T)$$

where:

T - inventory year;

x - waste category or type/material;

R_T - recovered CH_4 in year T (kt);

141 *2006 IPCC Guidelines*, Volume 5

OX_T - oxidation factor.

FOD model provided already contains all default parameters used in calculations.

The methodology was used for the whole waste including both municipal and industrial waste.

Separate values of parameters, when available, were applied for different waste components (food waste, paper, wood, textiles, green waste and sewage sludge) and different types of landfills (deep managed, deep unmanaged, shallow unmanaged).

7.2.3.2 Methane correction factor

Waste management in landfills of major cities include controlled placement of waste, periodic covering and mechanical compacting. These landfills correspond to the definition of managed landfills with CH_4 correction factor = 1 (*2006 IPCC Guidelines*, Volume 5, p. 3.14).

Landfills of smaller towns are comparatively deep (>5 m of waste) but their management, especially in the past, was poor. These landfills correspond to the definition of deep unmanaged landfills with CH_4 correction factor = 0.8 (*2006 IPCC Guidelines*, Volume 5, p. 3.14).

Small landfills and dumps in rural areas were assigned to unmanaged shallow landfills (<5 m waste) with CH_4 correction factor = 0.4 (*2006 IPCC Guidelines*, Volume 5, p. 3.14).

7.2.3.3 Oxidation factor

According to the *2006 IPCC Guidelines* (Vol 5, Chapter 3, page 3.15), the use of the oxidation value of 0.1 is justified for covered, well-managed SWDS to estimate both diffusion through the cap and escape by cracks/fissures. As stated in the *2006 IPCC Guidelines* (Vol 5, Chapter 3, p. 3-14, Table 3.1), such disposal sites must include **at least one** of the following:

(i) cover material;
(ii) mechanical compacting; or
(iii) levelling of the waste.

Before construction of new modern landfills in 2007-2009, waste was levelled and compacted but most frequently not covered, therefore methane oxidation factor at least up to 2007 was zero.

Waste disposal in new regional landfills started in 2008. In the same time remediation of old landfills and dumps started including covering with soil.

Calculation of methane emissions up to 2007 were performed using methane oxidation factor OX = 0. Assuming that methane is oxidised during diffusion through any soil layer (daily and intermediate cover or final cap) methane emissions starting from 2008 were calculated using methane oxidation factor $OX_T = 0.1$.

7.2.3.4 Other parameters

Other parameters:

DOC (weight fraction, wet basis) (*2006 IPCC Guidelines*, Volume 5, p. 2.14):

– Food waste 0.15

– Paper	0.40
– Wood	0.43
– Textiles	0.24
– Green waste	0.20

Country specific DOC value was used in calculations of methane emissions from sewage sludge. Average DOC value reported in the study[142] performed in 2012 was evaluated at 30% of sludge dry matter based on experimental analyses performed in various wastewater treatment facilities in Lithuania. Assuming that dry matter content in sewage sludge is about 20%, DOC value 0.06 was used for calculation of methane emissions from wet sludge.

CH_4 generation rate constant was chosen for the wet climate condition under the boreal and temperate climate zone provided in the *2006 IPCC Guidelines,* Volume 5, p. 3.17. The reason for selection of this value is that Lithuania is situated in the temperate climate zone, i.e. north of subtropics and south of subarctic area, and its climate is characterized as wet, i.e. precipitation exceeds evaporation.

CH_4 generation rate constant ($years^{-1}$)(*2006 IPCC Guidelines*, Volume 5, p. 3.17)

– Food waste	0.185
– Paper	0.06
– Wood	0.03
– Textile	0.06
– Green waste	0.10
– Sewage sludge	0.185

DOC_f (fraction of DOC dissimilated)	0.5 (*2006 IPCC Guidelines*, Volume 5, p. 3.13)
Delay time (months)	6 (*2006 IPCC Guidelines*, Volume 5, p. 3.19)
Fraction of CH_4 in developed gas	0.5 (*2006 IPCC Guidelines*, Volume 5, p. 3.26)
Conversion factor C to CH_4	16/12 = 1.33 (*2006 IPCC Guidelines*, Volume 5, p. 3.37)

CO_2 emissions from combustion of landfill gas are of biogenic origin and comparatively very low, hence they were not taken into consideration.

7.2.4 Variations of emissions

Methane emissions from managed anaerobic SWDS up to 2010 were comparatively stable and close to 30 kt per year. Substantial increase of disposed waste in 2008 after the closure of old landfills and dumps and disposal of all generated wastes in newly constructed modern landfills had no impact on emissions calculated using First Order Decay method (Figure 7-9).

Gradual decline of CH_4 emissions from managed anaerobic SWDS started from 2011 and was triggered by substantial reduction of disposed waste amount caused by introduction of advanced

[142] Evaluation of methane generation from wastewater and sludge at wastewater treatment plants in Lithuania (Lietuvos nuotekų valymo įrenginių nuotekose ir dumble susidarančio metano kiekio tyrimai ir įvertinimas) Ekotermija, 2012

waste management methods such as separation of secondary materials, MBT, etc. Minor emission increase in 2017 was caused mainly by reduced methane recovery (3.58 compared to 5.96 kt in 2016) while gradual decline in 2018 was enhanced additionally by increased amount of recovered CH_4 (7.0 kt).

Slightly increased amount of disposed waste in 2018 have no impact on estimated emissions as First Order Decay method is based on the assumption that CH_4 generation from all the waste deposited each year begins on the 1st of January in the year after deposition.

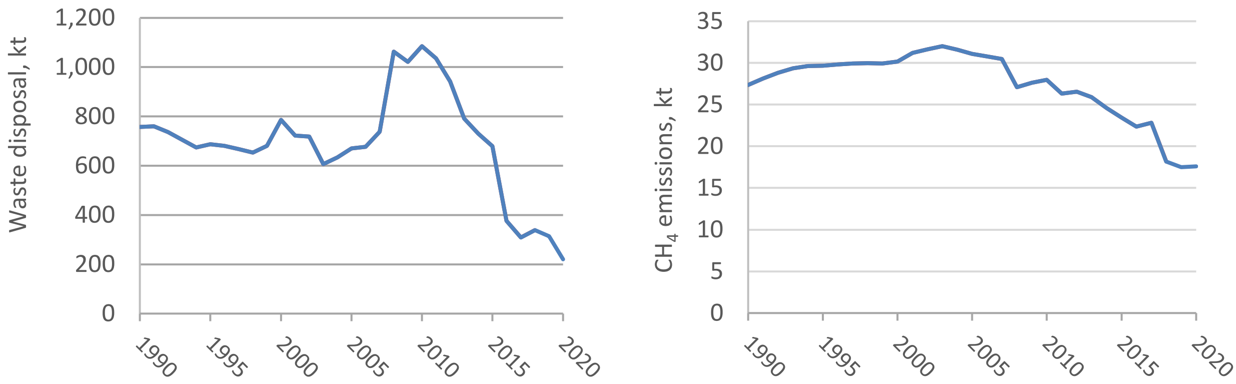


Figure 7-9. Solid waste disposal and methane emissions at managed anaerobic SWDS

Gradual decrease of CH_4 emissions at unmanaged SWDS started approximately from 2001-2002 following gradual closure of unmanaged landfills and transfer of all solid wastes (except sewage sludge) to newly constructed anaerobic SWDS (Figure 7-10). Reduction of emissions follows smooth trend as shown in Figure 7-10.

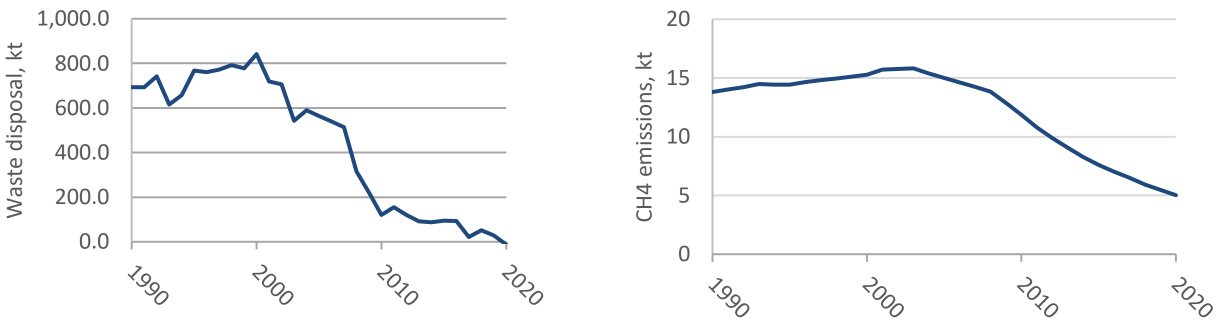


Figure 7-10. Waste disposal and methane emissions at unmanaged SWDS

7.2.5 Uncertainties and time-series consistency

7.2.5.1 Uncertainties

Uncertainty of activity data was assumed to be 30% (*2006 IPCC Guidelines*, Volume 1, Chapter 3, Table 3.5).

Uncertainties of separate input parameters for Tier 1 uncertainty analysis were taken as average values of uncertainties provided in *2006 IPCC Guidelines*, Volume 5, Chapter 3, Table 3.5 (Table 7-29).

Table 7-29. Uncertainties of separate input parameters

Parameter	IPCC 2006, v. 3, Table 3.5	Assumed average uncertainty
Degradable organic carbon	±20%	20%
Fraction of degradable organic carbon dissimilated	±20%	20%
Methane correction factor:		
MCF = 1	-10%, +0%	5%
MCF = 0.4	±30%	30%
MCF = 0.8	±20%	20%
Methane fraction in landfill gas	±5%	5%
Methane generation rate constant*	-40%, +300%	170%

* *2006 IPCC Guidelines*, Volume 3, Table 3.5 does not provide uncertainties for methane generation rate constant, therefore data from GPG 2000, p. 5.12, Table 5.2 were used in calculations)

Uncertainty of implied emission factor for three separate MCF values was established using *2006 IPCC Guidelines*, Volume 1, Chapter 3, Equation 3.1 (p. 3.28):

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2}$$

where:

U_{total} - the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage);

U_i - the percentage uncertainties associated with each of the quantities.

Uncertainties of implied emission factors calculated using values from the third column of Table 7-29 are provided in Table 7-30.

Table 7-30. Overall uncertainties of implied emission factors

Methane correction factor	Uncertainties of implied emission factor
MCF = 1	172%
MCF = 0.4	175%
MCF = 0.8	174%

The overall uncertainty of emission factor for the total CH_4 emission comprising all three types of landfills was calculated using *2006 IPCC Guidelines*, Volume 1, Chapter 3, Equation 3.2 (p. 3.28):

$$U_{total} = \frac{\sqrt{(U_1 \cdot x_1)^2 + (U_2 \cdot x_2)^2 + \ldots + (U_n \cdot x_n)^2}}{x_1 + x_2 + \ldots x_n}$$

where:

U_{total} - the percentage uncertainty in the sum of the quantities,

x_i *and* U_i - the uncertain quantities and the percentage uncertainties associated with them, respectively.

Calculated overall uncertainty of implied emission factor using average CH_4 emission values of disposed solid waste and sewage sludge over the period 1990-2020 is 123.6%.

7.2.5.2 Time-series consistency

Emissions from waste disposal on land were calculated for the whole time series using the same method and data sets.

Statistical data on waste disposal are available from 1991. However, after consultations with the specialists of the Ministry of Environment, it was assumed that data on municipal waste disposal in 1991-1997 were overestimated; and data were corrected based on correlation with GDP. In addition, historical data on waste disposal starting from 1950 were evaluated, taking into account available information on variations in population, economic development and considering expansion of waste management infrastructure.

7.2.5.3 Completeness

Inventory of emissions from solid waste disposal on land covers methane emissions occurring in the whole territory of Lithuania during the period 1990 to 2020. The inventory takes account of all existing landfills and dumps divided into three categories (deep managed, deep unmanaged and shallow unmanaged) and includes emissions from various types of biodegradable materials (food waste, paper, wood, textile, green waste, sewage sludge) disposed of with municipal, industrial and commercial waste.

7.2.6 Category-specific QA/QC and verification

Data collection and calculations were performed in accordance with the requirements outlined in Section 6 of the Quality Assurance (QA) and Quality Control (QC) Plan.

Tier 1 General Inventory Level QC was performed based on recommendations provided in *2006 IPCC Guidelines* Volume 1 Chapter 6 and outlined in the QA/QC plan.

Consistency of data between NIR and CRF has been checked.

Documentation on activity data and emission factors was crosschecked with the corresponding data in calculation model.

In case of large fluctuations in data, other experts or data providers were consulted to either provide the explanation or to identify a possible inconsistency or an error.

Explanations for recalculations were checked to ensure that they are clearly documented.

After the calculation is finished, EPA waste experts not directly involved in the emissions calculation of that year have reviewed the final report and CRF data checking the applied parameters, calculation methodology, as well as trend description in the NIR.

In addition, verification of methane emissions from solid waste disposal on land was performed by comparing per capita emission data with neighbouring countries: Latvia, Estonia, Poland, and Denmark. The results are shown in Table 7-31.

Table 7-31. Comparison of GHG emissions from solid waste disposal on land (kg per capita)

Year	Lithuania	Denmark	Latvia	Estonia	Poland
1990	10.65	13.80	5.90	5.45	11.22
1995	11.62	11.86	7.07	7.07	10.89
2000	12.19	9.56	8.07	12.81	11.36
2005	13.16	8.16	7.56	11.46	10.84
2010	13.00	6.76	9.66	9.80	9.97

2011	12.28	6.70	10.02	9.12	9.65
2012	12.26	6.35	10.34	8.48	9.44
2013	11.85	6.08	10.33	7.35	9.27
2014	11.18	5.90	10.57	6.64	9.00

As can be seen from Table 7-32, emission differences in all five neighbouring countries are not significant and evaluated emission data could be considered reliable and adequate.

Table 7-32. Comparison of minimum, maximum and average values of GHG emissions from solid waste disposal on land (kg per capita)

	Lithuania	**Denmark**	**Latvia**	**Estonia**	**Poland**
Minimum	10.65	5.90	5.90	5.45	9.00
Maximum	13.22	13.80	10.57	13.14	11.51
Average	12.20	9.58	8.06	9.59	10.68

7.2.7 Category-specific recalculations

As noted earlier, the major part of sewage sludge is disposed of separately from solid waste on sites comparable to landfills but defined as storage sites. The quantity of sewage sludge disposed of at storage sites are calculated by subtracting processed (composted, digested, applied in agriculture, incinerated) sludge from the total sludge generation. Unfortunately, sewage sludge undergoing temporary processing before submission to further recycling or disposal operations (e.g. granulation) was also subtracted in the previous submission, therefore, reducing the amount of estimated disposed of sludge.

The data on sewage sludge storage and disposal in years 2015 to 2019 were reviewed and corrected resulting in light increase of emissions. The results of recalculation are provided in Table 7-33.

Table 7-33. Impact of recalculations on CH_4 emissions from solid waste disposal sites

Year	**This submission**	**Previous submission**	**Absolute difference, kt**	**Relative difference, %**
2015	31.05	30.95	0.10	0.31%
2016	29.39	29.22	0.17	0.58%
2017	29.35	29.17	0.18	0.61%
2018	24.09	23.98	0.10	0.42%
2019	22.92	22.91	0.02	0.07%

7.2.8 Category-specific planned improvements

Category-specific improvements are not planned.

7.3 Biological treatment of waste (CRF 5.B)

7.3.1 Category description

Biological treatment of waste includes composting and anaerobic digestion.

Methane recovered in anaerobic digestion plants is used for energy production and reported in the Energy Sector. However, leakages from anaerobic digestion facilities due to process disturbances or other unexpected events are possible and are covered in this report.

Evaluated CH_4 and N_2O emissions from waste composting and anaerobic digestion are provided in Table 7-34.

Table 7-34. Evaluated CH_4 and N_2O emissions from waste composting and anaerobic digestion

Year	CH_4 emissions, kt				N_2O emissions, kt
	Composting	Anaerobic digestion		Total	
		Sewage sludge	MBT + Agriculture		
1990	0.01			0.01	0.000
1995	0.01			0.01	0.001
2000	0.03	0.04		0.07	0.002
2005	0.04	0.05	0.02	0.11	0.003
2010	0.08	0.11	0.18	0.36	0.005
2015	0.53	0.25	0.29	1.06	0.032
2016	1.19	0.26	0.56	2.02	0.072
2017	1.23	0.25	0.70	2.18	0.074
2018	1.76	0.24	0.71	2.71	0.105
2019	1.65	0.24	0.82	2.71	0.099
2020	1.48	0.25	0.87	2.60	0.089

Data on waste composting were provided by the Lithuanian EPA covering years 2004 to 2020 (Figure 7-11).

In the initial stage up to 2011, the amount of composting waste, though gradually increasing, remained comparatively low. From 2011, the establishment of regional waste management centres and the construction of new waste management facilities resulted in a significant intensification of waste composting activities. In addition, in 2016, several regional mechanical-biological treatments (MBT) facilities were put into operation, resulting in another upsurge of waste composting activities.

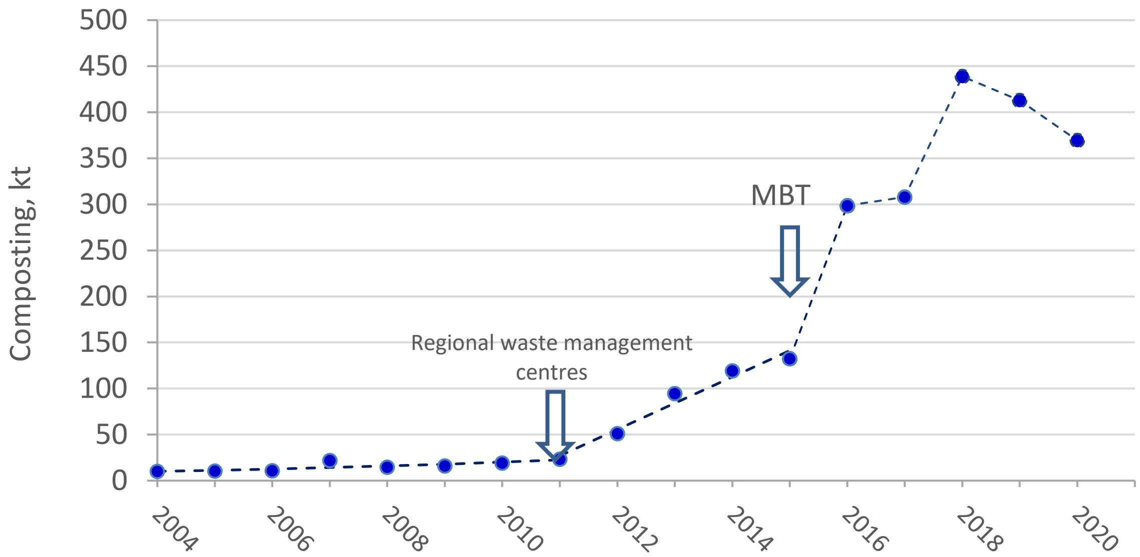


Figure 7-11. Variations of waste composting

For the period 1990-2003, for which statistical data were not available, it was assumed that composting activities were developing the same trend as in 2004 to 2011. Gradual increase of composted waste during this period was following an exponential trend, which can be described by equation

$$Y = e^{0.114*X-226.63}$$

where

Y - amount of composted waste and X is composting year. Extrapolation of this equation back to the year 1990 was used to estimate the amounts of composted waste during the period 1990 to 2004 (Figure 7-12).

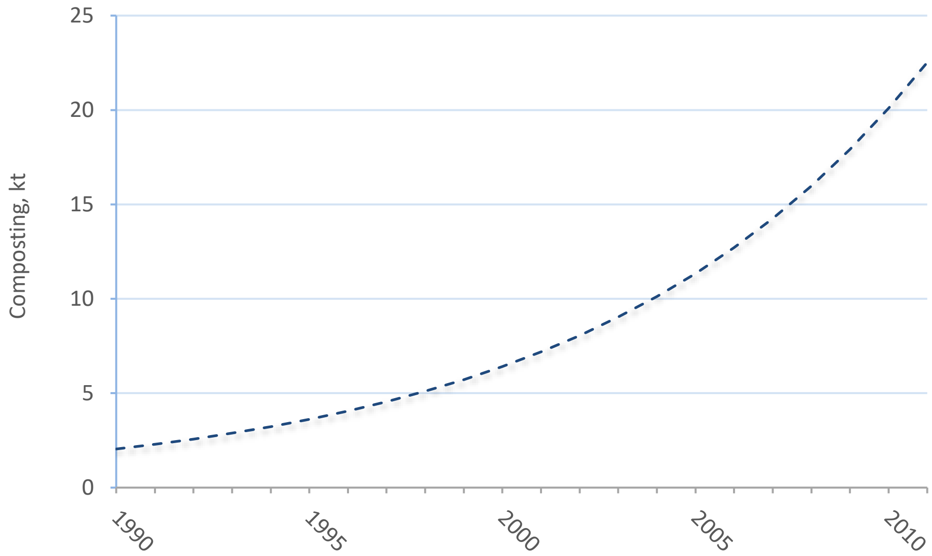


Figure 7-12. Approximation of waste composting activities 2004 to 2011 and corresponding extrapolation back to 1990.

The data on waste composting provided by the Lithuanian EPA on a wet basis were converted to dry weight, assuming a moisture content of 60% in wet waste (*2006 IPCC Guidelines*, Volume 5, Chapter 4, Table 4.1).

Composting of MSW in MBT facilities started in 2016. The major part of other waste is green waste collected from green spaces, parks and forests.

Estimated amount of composted waste is shown in Table 7-35.

Table 7-35. Estimated amount of composted waste, kt

	Municipal solid waste		**Other waste**	
	Wet weight	**Dry weight**	**Wet weight**	**Dry weight**
1990	NO	NO	2.04	0.82
1995	NO	NO	3.62	1.45
2000	NO	NO	6.41	2.56
2005	NO	NO	10.47	4.19
2010	NO	NO	19.10	7.64
2015	6.38	2.55	125.97	50.39
2016	155.81	62.33	142.89	57.16
2017	205.61	82.24	102.36	40.94
2018	259.17	103.67	179.67	71.87
2019	255.10	102.04	157.95	63.18
2020	193.89	77.56	175.71	70.20

Three types of waste are used for anaerobic digestion:

- sewage sludge from municipal wastewater treatment plants,
- biodegradable waste separated in MBT facilities, and
- agricultural waste.

For estimation of methane emissions, biogas generation in anaerobic digestion facilities was used as activity data. Information on biogas generation in anaerobic digestion facilities was obtained from the Statistics Lithuania database and yearly publications "Fuel and energy balance". According to the provided information, biogas generation from MSW in MBT facilities is reported together with biogas produced in agricultural digestion installations.

Statistical data provided by Statistics Lithuania are reported in a million m^3. The data were converted to kt using the default IPCC value of 0.5 for a fraction of CH_4 in generated landfill gas (2006 IPCC Guidelines, Volume 5, p. 3.15) and the IPCC conversion factor 0.67×10^{-6} kt/m^3 (2006 IPCC Guidelines, Volume 2, p. 4.12). Data on methane recovery are provided in Table 7-36.

Table 7-36. CH_4 recovery, kt

Year	Recovery	
	Sludge biogas	Agricultural waste* biogas
1999	0.22	NO
2000	0.84	NO
2005	0.97	0.34
2010	2.11	3.52
2015	4.92	5.76
2016	5.29	11.19
2017	5.09	13.97
2018	4.86	14.20
2019	4.79	16.42
2020	5.03	17.45

*including MSW in MBT facilities

Sewage sludge from municipal wastewater treatment plants is used in anaerobic digestion facilities for biogas production since 1999.

The data on waste and sewage sludge used for anaerobic digestion processes are available only from 2018. The data were not reported previous period as, according to the Lithuanian legislation, reporting of waste recycled inside the plants in which it is generated is not obligatory.

Anaerobic digestion of MSW started in 2016 after construction of MBT facilities. As digestion residue is used for composting, only the total amount of anaerobic digestion and composting is reported in the statistics collected by the EPA.

7.3.2 Methodological issues

The CH_4 and N_2O emissions from biological treatment can be estimated using the default method given in Equations 4.1 and 4.2 provided in *2006 IPCC Guidelines*, Volume 5, Chapter 4:

$$CH_4 emissions = \sum (M \times EF_{CH4}) \times 10^{-3}$$

$$N_2O emissions = \sum (M \times EF_{N2O}) \times 10^{-3}$$

where:

CH_4 emissions - total CH_4 emissions in inventory year, kt CH_4;

N_2O emissions - total N_2O emissions in inventory year, kt N_2O;

M - mass of organic waste treated by biological treatment, kt;

EF_{CH4} - emission factor, g CH_4/kg waste treated;

EF_{N2O} - emission factor, g N_2O/kg waste treated.

Both equations were used for calculation of emissions from waste composting. Emission factors provided in *2006 IPCC Guidelines*, Volume 5, Chapter 4, Table 4.1 were used (10 g CH_4/kg waste treated and 0.6 g N_2O/kg waste treated).

According to the *2006 IPCC Guidelines,* Volume 5, Chapter 4, emissions from anaerobic digestion facilities due to unintentional leakages during process disturbances or other unexpected events will generally be between 0 and 10% of the amount of CH_4. Default value 5% was used for estimating CH_4 emissions.

$$CH_4 emissions = CH_4 generation \times EF_{leakege}$$

where:

CH_4 emissions - total CH_4 emissions in inventory year, kt CH_4;

$EF_{leakage}$ - emission factor for leakage, %.

7.3.3 Uncertainties and time-series consistency

Uncertainty

It was assumed that uncertainty of activity data is 40%.

Uncertainties in the default emission factors were estimated using the ranges given in *2006 IPCC Guidelines,* Volume 5, Chapter 4, Table 4.1. For both CH_4 and N_2O the lower limit is close to zero and the upper limit is twice higher as average, i.e. uncertainty is 100%.

Overall uncertainties in both CH_4 and N_2O emission data are 108%.

Time-series consistency

Emissions from waste disposal on land were calculated for the whole time series using the same method and data sets. As collection of data on waste management started only in 1991, it was assumed that the amounts of generated and treated waste in 1990 were the same as in 1991.

7.3.4 Category-specific QA/QC and verification

Data collection and calculations were performed in accordance with the requirements outlined in Section 6 of the Quality Assurance and Quality Control Plan.

Tier 1 General Inventory Level QC was performed based on recommendations provided in *2006 IPCC Guidelines,* Volume 1 Chapter 6 and outlined in the QA/QC plan:

Consistency of data between NIR and CRF has been checked.

Documentation on activity data and emission factors was crosschecked with the corresponding data in calculation model.

In case of large fluctuations in data, other experts or data providers were consulted to either provide the explanation or to identify a possible inconsistency or an error.

Explanations for recalculations were checked to ensure that they are clearly documented.

After the calculation is finished, EPA waste experts not directly involved in the emissions calculation of that year have reviewed the final report and CRF data, checking the applied parameters, calculation methodology, and trend description in the NIR.

7.3.5 Category-specific recalculations

Waste biological treatment includes composting and anaerobic digestion. Some wastes can be sent for composting directly after collection (e.g. green waste) or sorting in MBT facilities. Waste remaining after completion of anaerobic digestion is also directed for composting. This portion of waste was omitted from calculations in the previous submission. In this submission, data on waste biological treatment for 2018 and 2019 were reviewed and updated (data on composting and anaerobic digestion separately are available only from 2018). Impact of recalculations on CH_4 emissions from biological treatment is provided in Table 7-37.

Table 7-37. Impact of recalculations on emissions from biological treatment of waste, kt

Year	This submission	Previous submission	Absolute difference, kt	Relative difference, %
		CH_4		
2018	2.71	2.48	0.23	9.2
2019	2.71	2.46	0.26	10.5
		N_2O		
2018	0.105	0.092	0.014	14.9
2019	0.099	0.084	0.015	18.5

7.3.6 Category-specific planned improvements

Category-specific improvements are not planned.

7.4 Waste incineration (CRF 5.C)

Emissions from waste incineration without energy recovery are reported in the Waste Sector, while emissions from incineration with energy recovery are reported in the Energy Sector.

Incineration of waste is a source of greenhouse gas emissions, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Normally, emissions of CO_2 from waste incineration are more significant than CH_4 and N_2O emissions.

Evaluated non-biogenic CO_2 emissions from waste incineration are provided in Table 7-38.

Table 7-38. Non-biogenic CO_2 emissions from waste incineration (kt)

Year	Hazardous	Clinical	Sewage sludge	Municipal	Total
1990	2.65	0.01	0.00	0.00	2.66
1995	2.50	0.01	0.00	0.01	2.52
2000	1.13	0.00	0.00	0.00	1.13
2005	3.36	0.24	0.00	0.00	3.60
2010	0.83	0.63	0.00	0.00	1.46
2015	5.43	0.29	0.00	0.00	5.72
2016	0.31	0.33	0.00	0.00	0.64
2017	0.88	0.39	0.00	0.00	1.27
2018	0.48	0.39	0.00	0.00	0.87
2019	1.08	0.60	0.00	0.00	1.68
2020	1.12	0.99	0.00	0.00	2.11

Evaluated N_2O and CH_4 emissions from waste incineration are provided in Table 7-39.

Table 7-39. N_2O and CH_4 emissions from waste incineration, tonne

Year	CH_4			N_2O		
	Biogenic	non-biogenic	Total	Biogenic	non-biogenic	Total
1990	0.12	0.04	0.16	0.19	0.07	0.26
1995	0.11	0.04	0.15	0.18	0.07	0.25
2000	0.05	0.02	0.07	0.08	0.03	0.11
2005	0.16	0.06	0.22	0.26	0.10	0.36
2010	0.07	0.02	0.09	0.11	0.04	0.15
2015	0.25	0.09	0.34	0.41	0.16	0.57
2016	0.03	0.01	0.04	0.05	0.02	0.07
2017	0.06	0.02	0.08	0.10	0.03	0.13
2018	0.04	0.01	0.05	0.07	0.02	0.09
2019	0.08	0.03	0.10	0.13	0.05	0.17
2020	0.10	0.03	0.13	0.16	0.06	0.22

7.4.1 Category description

Incineration of hazardous waste, clinical waste, sewage sludge and municipal waste is recorded in the database of the Lithuanian EPA. In 2020 GHG emissions from waste incineration comprise merely 0.26% of the total emissions in the waste sector.

Emissions from waste incineration fluctuate quite strongly. In 1990-2005 small amounts of waste were incinerated in various combustion installations not meant specifically for waste incineration. There were no dedicated waste incineration facilities in Lithuania until 2006 and waste was incinerated on random basis in existing production facilities, which means that decisions on whether to incinerate or not was taken on ad hoc basis. Incinerated waste included calorific waste such as spent oils used, for example, for heating garages, etc.

Hospital waste incineration facility with nominal capacity 200 kg per hour was put in operation in 2006 in Vilnius. The facility included rotary kiln, secondary combustion chamber and flue gas treatment unit. Temperature in the secondary combustion chamber could be raised to 1100 ^oC. Flue gas was treated by injecting soda ash and activated carbon into the gas stream and then separating them in a bag filter. Hospital waste incineration plant was closed in 2011 and is not operating since. There was no energy recovery in hospital waste incineration plant.

Construction of the hazardous waste incineration facility with nominal capacity 1000 kg per hour was completed in 2010 and test burning of hazardous waste started in November. Only about 820 tonnes of waste were incinerated in 2010 and about 4 kt in 2011. Because of contractual disputes plant operations in 2012 and 2013 were significantly reduced to approximately 1 and 0.75 kt. In 2014 the amount of incinerated waste was increased to approximately 2 kt and reached 5.4 kt in 2015.

The hazardous waste incineration facility started regular operation with energy recovery only in 2016. In 2014 and 2015 the facility still operated in test burning regime without energy recovery, therefore CO_2 emissions reported in waste sector were comparatively high. From 2016 CO_2 emissions from waste incineration with energy recovery are reported in energy sector.

The hazardous waste incineration facility comprises waste feeding unit, rotary kiln, secondary combustion chamber and flue gas treatment installation. Hazardous waste is incinerated at the minimum temperature 850^oC with at least 2 seconds residence time. If halogenated compounds are present, temperature is raised to 1100^oC. Flue gas treatment unit includes semi dry scrubber with activated carbon injection, bag filter and wet scrubber for finishing.

The data on waste incineration are reported in the framework of overall waste reporting obligations in accordance with the national waste classification in 1991-1999 and EU Waste List from 2000. As data on waste management were not collected in 1990, it was assumed that the amount of waste incinerated in 1990 was the same as incinerated in 1991.

Activity data on waste incineration were obtained from the Environment Protection Agency (EPA) waste database. Data collection and validation procedures are described in chapter 7.1.

Types and amounts of wastes incinerated without energy recovery are provided in Table 7-40.

Table 7-40. Amounts of waste incinerated without energy recovery 1990-2020, (kt)

Year	Hazardous	Clinical Health care	Sewage sludge	Municipal	Total
1990	2.63	0.01	0.01	0.00	2.65
1995	2.48	0.01	0.00	0.01	2.50
2000	1.12	0.00	0.00	0.00	1.12
2005	3.33	0.26	0.00	0.00	3.59
2010	0.82	0.69	0.00	0.00	1.51
2015	5.39	0.31	0.00	0.00	5.70
2016	0.31	0.36	0.00	0.00	0.67
2017	0.87	0.42	0.00	0.00	1.29
2018	0.47	0.43	0.00	0.00	0.90
2019	1.07	0.66	0.00	0.00	1.73
2020	1.11	1.08	0.00	0.00	2.19

7.4.2 Methodological issues

Carbon dioxide emissions

Carbon dioxide emissions from waste incineration were calculated using Equation 5.1 provided in *2006 IPCC Guidelines*, Volume 5, p. 5.7):

$$CO_{emissions} = \sum_{\mathrm{j}} (\mathrm{WF_j} \times \mathrm{dm_j} \times \mathrm{CF_i} \times \mathrm{FCF_j} \times \mathrm{OF_j}) \times {}^{44}/_{12}$$

where:

CO_2 emissions - CO_2 emissions in inventory year, kt/yr.;

WF_j - amount of incinerated waste type *j* (as wet weight);

dm_j - dry matter content in the waste type *j* (fraction);

CF_j - fraction of carbon in the dry matter (i.e., carbon content) of the waste type *j;*

FCF_j - fraction of fossil carbon in the total carbon of the waste type *j;*

OF_j - oxidation factor (fraction);

44/12 - conversion factor from C to CO_2;

j - waste type: hazardous waste, clinical waste, sewage sludge or municipal waste.

CO_2 emissions from hazardous waste and clinical waste incineration were calculated using fossil carbon content in wet waste provided in *2006 IPCC Guidelines*, Volume 5, Table 2.6, 25% for clinical waste and 27.5% (mean value of provided range) for hazardous waste.

The following set of parameters was used for calculation of CO_2 emissions from incineration of sewage sludge:

- Dry matter content 20%[143]
- Fraction of carbon in the dry matter 45% (*2006 IPCC Guidelines*, Volume 5, Table 5.2)
- Fraction of fossil carbon in the total carbon 0% (*2006 IPCC Guidelines*, Volume 5, Table 5.2)

Required parameters for calculation of CO_2 emissions from incineration of municipal waste were calculated using evaluated data on composition of MSW (see Table 7-15) and default values of dry matter content, total carbon content and fossil carbon fraction in separate waste components provided in *2006 IPCC Guidelines*, Volume 5, Table 2.4. Evaluated parameters are provided in Table 7-41.

Table 7-41. Evaluated dry matter content, total carbon content and fossil carbon fraction in MSW

Year	Dry matter content, %	Total carbon content, % of dry weight	Fossil carbon fraction, % of total carbon
1990	34.30	25.40	0.94
1995	34.30	25.40	0.94
2000	34.30	25.40	0.94
2005	33.23	24.97	1.00
2010	30.56	23.89	1.15
2015	24.55	19.23	1.37
2016	24.65	19.65	1.50
2017	26.58	20.78	1.63
2018	25.85	20.28	1.61
2019	26.69	21.04	1.63
2020	26.77	21.19	1.61

Combustion efficiency for all types of wastes is assumed to be 100% (*2006 IPCC Guidelines*, Volume 5, Sec. 5.4.1.3).

Methane and nitrous oxide emissions

As quantities of incinerated waste are very low, it was decided to calculate methane and nitrous oxide emissions from the total amount of incinerated waste not dividing them into separate streams.

Methane and nitrous oxide emissions from waste incineration were calculate using equations provided in *2006 IPCC Guidelines*, Volume 5, Sec. 5.2.2 and 5.2.3:

[143] Wet - dry conversion of sludges. ARGUS for Eurostat - Environment Statistics. Meeting of the Working Group "Statistics of the Environment", Sub-Group "Waste". Eurostat, 2008.

$$CH_4 emission = (IW \times EF_{CH_4}) \times 10^{-6}$$

$$N_2O\ emission = (IW \times EF_{N_2O}) \times 10^{-6}$$

where:

CH_4 emissions - CH_4 emissions in inventory year, kt/yr.;

N_2O emissions - N_2O emissions in inventory year, kt/yr.;

IW - amount of incinerated waste, kt/yr.;

EF_{CH4} - CH_4 emission factor (kg CH_4/kt of waste);

EF_{N2O} - N_2O emission factor (kg N_2O/kt of waste);

10^{-6} - conversion from kilogram to kilo tonnes.

Bearing in mind irregular waste incineration activities and small quantities of incinerated waste CH_4 emission factor for stoker batch type incinerators provided in *2006 IPCC Guidelines*, Volume 5, Table 5.3 (60 kg/kt waste incinerated on a wet weight basis) was selected for emission calculations.

The main part of incinerated waste is comprised of hazardous industrial waste, therefore it was decided that default N_2O emission factor for all types of incinerated industrial wastes (100 g N_2O/t waste incinerated on a wet weight basis) should be applied.

7.4.3 Uncertainties and time-series consistency

Uncertainties

Activity data uncertainty for clinical waste and sewage sludge incineration was supposed to be comparatively high and was assumed to be 30%. Statistical data on hazardous and municipal waste incineration due to presence of regularly operated industrial scale incineration facilities were considered more reliable and assumed to be 25%. As hazardous waste incineration generates major part of CH_4 and N_2O emissions, uncertainty of activity data for evaluation of CH_4 and N_2O emissions was assumed to be 25%.

Assumed uncertainties for separate input parameters used for evaluation of CO_2 emissions and calculated overall uncertainties for separate waste streams are provided in Table 7-42.

Table 7-42. Assumed uncertainties for separate input parameters used for evaluation of CO_2 emissions and calculated overall uncertainties for separate waste streams

	Hazardous waste	**Clinical waste**	**Sewage sludge**	**MSW**
Activity	25%	30%	30%	25%
Dry matter content	NA	NA	30%	30%
Fraction of carbon	NA	NA	40%	30%
Fraction of fossil carbon in the total carbon	40%	40%	30%	30%
Oxidation factor	2%	2%	2%	2%
Overall uncertainties	**47.2%**	**50.0%**	**65.6%**	**57.7%**

Evaluated uncertainty of the total CO_2 emission from waste incineration is 42.4%.

Uncertainty of emission factors for calculation of CH_4 and N_2O emissions was assumed to be 60%.

Combined uncertainties for CH_4 and N_2O emissions from waste incineration are 65%.

7.4.4 Time-series consistency

Emissions from waste incineration were calculated for the whole time series using the same method and data sets. As collection of data on waste management started only in 1991, it was assumed that the amounts of generated and treated waste in 1990 were the same as in 1991.

7.4.5 Category-specific QA/QC and verification

Data collection and calculations were performed in accordance with the requirements outlined in Section 6 of the Quality Assurance and Quality Control Plan.

Tier 1 General Inventory Level QC was performed based on recommendations provided in *2006 IPCC Guidelines,* Volume 1 Chapter 6 and outlined in the QA/QC plan:

Consistency of data between NIR and CRF has been checked.

Documentation on activity data and emission factors was crosschecked with the corresponding data in calculation model.

In case of large fluctuations in data, other experts or data providers were consulted to either provide the explanation or to identify a possible inconsistency or an error.

Explanations for recalculations were checked to ensure that they are clearly documented.

After the calculation is finished, EPA waste experts not directly involved in the emissions calculation of that year have reviewed the final report and CRF data checking the applied parameters, calculation methodology, as well as trend description in the NIR.

7.4.6 Category-specific recalculations

No recalculations have been done.

7.4.7 Category-specific planned improvements

Category-specific improvements are not planned.

7.5 Wastewater treatment and discharge (CRF 5.D)

Wastewater is a source of methane (CH_4) when treated or disposed anaerobically. It is also a source of nitrous oxide (N_2O) emissions. Carbon dioxide (CO_2) emissions from wastewater are not considered because these are of biogenic origin.

Evaluated CH_4 and N_2O emissions from wastewater are shown in Tables 7-43 and 7-44.

Table 7-43. Evaluated CH_4 emissions from wastewater treatment and discharge, kt

Year	Total	Aerobic well managed	Primary treatment	Anaerobic shallow lagoon	Untreated	Septic tanks	Latrine
1990	16.92	0.00	0.77	1.60	1.19	9.11	4.25
1995	14.40	0.00	0.59	0.12	0.58	8.94	4.17
2000	12.64	0.00	0.29	0.11	0.08	8.29	3.87
2005	9.92	0.00	0.25	0.03	0.03	6.56	3.06
2010	8.06	0.00	0.02	0.14	0.03	5.37	2.51

2015	5.86	0.00	0.06	0.00	0.01	3.94	1.84
2016	5.55	0.00	0.06	0.02	0.02	3.72	1.74
2017	5.43	0.00	0.07	0.02	0.02	3.64	1.70
2018	4.99	0.00	0.06	0.02	0.02	3.33	1.55
2019	4.81	0.00	0.02	0.02	0.03	3.23	1.51
2020	4.71	0.00	0.03	0.01	0.03	3.17	1.48

Table 7-44. Evaluated N_2O emissions from wastewater treatment and discharge

Year	Protein consumption/ kg/person/year	N2O emissions, kt
1990	27.73	0.226
1995	28.05	0.224
2000	28.38	0.219
2005	29.34	0.214
2010	26.56	0.181
2015	23.89	0.153
2016	24.23	0.153
2017	24.57	0.153
2018	24.91	0.154
2019	25.25	0.155
2020	25.59	0.157

7.5.1 Category description

Methane is generated from wastewater in anaerobic conditions while nitrous oxide can be produced as nitrification and denitrification product in both aerobic and anaerobic conditions. This section covers CH_4 emissions from wastewater transportation and treatment as well as from septic tanks used by population not connected to centralized sewerage networks. CH_4 emissions from sewage sludge formed during wastewater treatment are covered in solid waste disposal on land section.

In most cases in Lithuania industrial wastewater is discharged to centralized municipal sewage collection networks and treated together with the domestic wastewater in centralized municipal treatment plants.

According to the information provided by the Lithuanian Water Suppliers Association[144] fraction of industrial wastewater exceeds 50% in six of 38 agglomerations with population equivalent more than 10 thousand. In one of them (Pasvalys) fraction of industrial wastewater comprises 87.5% of the total wastewater discharge. On average, industrial wastewater comprises about 20% of the total load of municipal wastewater treatment systems in Lithuania.

In addition, separate evaluation of CH_4 emissions from domestic and industrial wastewater is problematic because organic load in both domestic and industrial wastewater is measured predominantly as BOD.

The Lithuanian EPA is collecting data on wastewater discharges from more than 1400 discharge points. Among them, some discharges from industries are also registered but representing only minor fraction of industrial discharges mainly from industries located in remote areas not covered by municipal sewerage collection systems. The major part of industrial wastewater is

[144] Lithuanian Water Suppliers Association. Certificate on municipal wastewater treatment plant capacity assessment, 2011.03.04.

discharged into municipal sewerage networks and cannot be separated from municipal wastewater.

It is possible to identify 3 or 4 major industrial sectors with the largest potential for CH_4 emissions but COD data cannot be collected as industrial wastewater is discharged mainly together with municipal wastewater and, in addition, in most cases only BOD data are available. Default values or expert judgement for estimating COD values can be applied for these major industries but calculation of emissions based on these values will cause double counting as discharges of these industries have already been accounted for in emissions from municipal wastewater.

Expert judgements as well as default values are associated with substantial errors and uncertainties. We have country specific instrumental measurements of wastewater discharges and organic matter (BOD) content, and we are convinced that country specific instrumental measurements provide much more reliable and precise results than default data based on conditions in other, most frequently remote countries, or expert judgements.

Information on wastewater treatment and discharge in Lithuania is collected by the Lithuanian Environmental Protection Agency (EPA). Data collection is regulated by Order No. 408 of the Minister of Environment of the Republic of Lithuania of calculation of pollutant emissions to environment of 20th December 1999 as amended on 20th September 2001 and 3rd January 2013. Pursuant to this legal act water users and/or wastewater dischargers must submit annual reports to institution subordinated to Ministry of Environment - Environmental Protection Department (EPD). EPD performs primary data check of regional level and checked data are forwarded to the EPA. The EPA performs the final validation, processing and aggregation at national level.

Collected data include both BOD and COD, however, as seen from Table 7-45 both parameters are provided for the same samples without specification of municipal or industrial wastewater sources. Therefore, there is no possibility to separate industrial and municipal wastewater streams.

Table 7-45. Number of discharge points for which data on BOD and COD are provided in the statistics

Year	Number of discharge points included in the statistics		
	BOD	COD	Both BOD and COD
1991	657	46	45
1992	674	42	40
1993	612	37	34
1994	614	29	28
1995	641	35	33
1996	694	39	36
1997	697	42	41
1998	721	53	51
1999	745	52	50
2000	766	62	60
2001	724	59	56
2002	766	95	83
2003	781	162	158
2004	781	325	323
2005	808	452	447
2006	769	436	436

Statistics on treatment and discharge of organic pollutants collected by the EPA are available from 1991. It was assumed that wastewater generation, treatment and discharge in 1990 was the same as in 1991.

As in most cases in Lithuania industrial wastewater is discharged to centralized municipal sewage collection networks and treated together with domestic wastewater in centralized municipal treatment plants, industrial wastewater discharge and corresponding emissions are not reported separately but included in the domestic wastewater, therefore notation key "IE" is used

Discharged wastewater is treated in various types of treatment plants all of which are basically aerobic though development of anaerobic conditions enabling methane formation is possible.

All wastewater treatment facilities depending on potential for development of anaerobic conditions were divided in 4 categories:

- Aerobic treatment, well managed
- Primary treatment
- Anaerobic shallow lagoon
- Untreated wastewater

Classification of wastewater treatment facilities used for reporting of pollutant discharges has been changed in 2013. Division of treatment facilities based on former and new classification is provided in Table 7-46.

Table 7-46. Assume division of wastewater treatment facilities

Classification to 2012	Classification 2013
Aerobic treatment, well managed	
313 Biological treatment with N and P removal 311 Pneumatic aeration tanks 300 Biological treatment 304 Pneumatic aeration channels 305 Mechanical aeration channels 312 Mechanical aeration tanks 302 Mechanical 307 Other biological treatment facilities	Mechanical/biological treatment with N and P removal Biological treatment with N and P removal Mechanical/biological treatment with P removal Mechanical/biological treatment with N and P removal and microfiltration Mechanical/chemical/biological treatment with N and P removal Biological treatment with N removal Biological treatment with N and P removal and microfiltration Other mechanical/biological treatment Other biological treatment
Primary treatment	
100 Mechanical treatment 200 Physical-chemical treatment 201 Primary physico-chemical treatment 303 Natural treatment methods 900 Other facilities	Mechanical treatment Mechanical/chemical treatment Chemical treatment
Anaerobic shallow lagoon	
306 Biological ponds 400 Infiltration fields 500 Infiltration fields without discharge 600 Agricultural irrigation fields	Sand filtration Microfiltration/ultrafiltration

Untreated wastewater	
0 Discharge without treatment	Discharge without treatment

Primary treatment category includes mechanical, mechanical/chemical and chemical treatment. It is assumed that during primary treatment about 40% of BOD is removed as sludge. The remaining 60% is discharged to open waters, where indirect methane emissions might occur, assuming MCF=0.1 (see 2006 *Guidelines*, Vol 5, Table 6.3).

Estimated discharge of wastewater to the treatment facilities of various types is provided in Table 7-47.

Table 7-47. Estimated discharge of wastewater to the treatment facilities of various types

Year	**Aerobic well managed**		**Primary treatment**		**Anaerobic shallow lagoon**		**Untreated**	
	BOD, kt	**% of total**	**BOD, kt**	**% of total**	**BOD, kt**	**% of total**	**BOD, kt**	**% of total**
1990	41.33	43.14	21.34	22.28	13.36	13.95	19.76	20.63
1995	31.48	53.79	16.47	28.13	0.99	1.68	9.59	16.39
2000	50.56	83.12	8.01	13.16	0.93	1.53	1.33	2.19
2005	58.16	88.48	6.91	10.51	0.21	0.32	0.45	0.69
2010	68.87	96.97	0.47	0.66	1.15	1.62	0.53	0.75
2015	75.63	97.54	1.63	2.10	0.04	0.05	0.24	0.31
2016	82.12	97.65	1.55	1.84	0.15	0.18	0.27	0.32
2017	79.19	97.20	1.84	2.26	0.14	0.17	0.30	0.37
2018	75.66	97.09	1.73	2.22	0.15	0.19	0.39	0.50
2019	79.57	98.39	0.65	0.81	0.15	0.18	0.50	0.62
2020	74.18	98.29	0.73	0.97	0.11	0.15	0.44	0.58

Substantial part of Lithuanian population is still not connected to centralized sewer networks as shown in Table 7-48.

Table 7-48. Fraction of population having no connection to sewerage networks

Year	**Fraction, %**
1999	49.50
2000	48.08
2005	40.06
2010	35.19
2015	27.55
2016	26.33
2017	26.09
2018	24.12
2019	23.47
2020	23.03

Source: Lithuanian Water Suppliers Association, Lithuanian EPA.

Data on population connected to the sewerage network were provided by the Lithuanian Water Suppliers Association and the Lithuanian EPA (2012-2020). The number of population connected to the sewerage network depends on variation of population residing in the area covered by wastewater collection services (Figure 7-13). Hence, fluctuation of percentage of population not connected to sewerage network is caused by migration of population to and from the area covered by wastewater collection services.

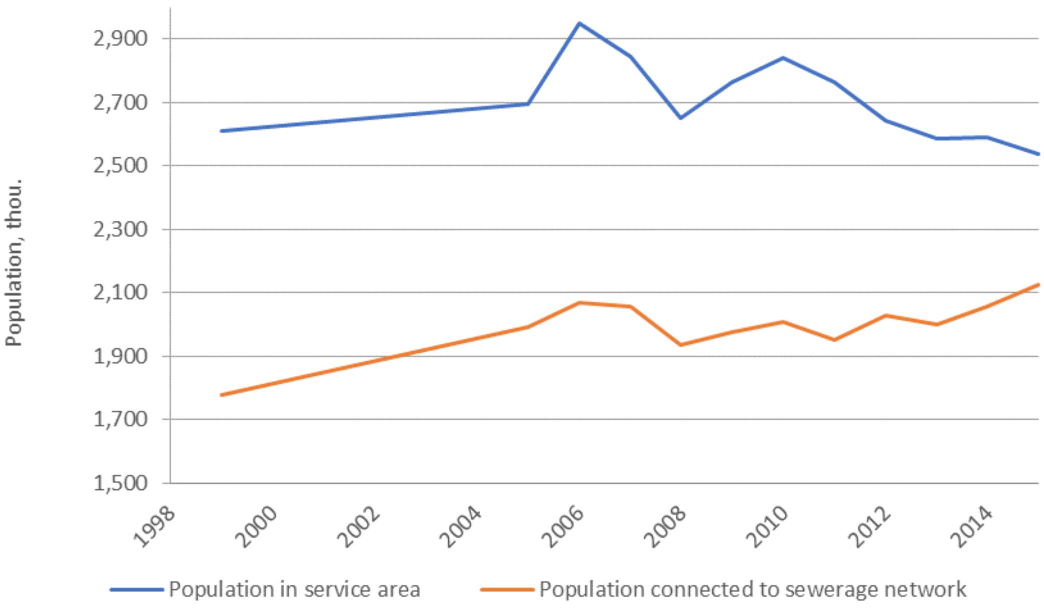


Figure 7-13. Variations of population residing in area covered by wastewater collection services and connected to sewerage network

7.5.2 Methodological issues

7.5.2.1 Methane emissions

The total amount of organically degradable material in the wastewater (TOW) is available from the EPA database.

Generation of organically degradable material by the population having no connection to sewerage networks was calculated using Equation 6.3 provided in *2006 IPCC Guidelines,* Volume 5, section 6.2.2.3:

$$TOW = P \times k \times BOD \times 0.001 \times I \times 365$$

where:

TOW - total organics in wastewater in inventory year, kg BOD/yr.;

P - country population in inventory year, (person);

k - fraction of population having no connection to sewerage networks;

BOD - per capita BOD in inventory year (60 g/person/day, *2006 IPCC Guidelines*, Volume. 5, Table 6.4);

0.001 - conversion from grams BOD to kg BOD;

I - correction factor for additional industrial BOD discharged into sewers (assumed =1).

Degree of utilisation of treatment or discharge pathway among the Lithuanian population having no connection to sewers is similar to Russian rural population as provided in Table 6.5 of the *2006 IPCC Guidelines,* Volume 5, section 6.2.2.3 (60% connected to sewers, 30% using septic tanks, and 10% using latrines). Based on these data, recalculated for population having no connection to sewerage networks, it was assumed that septic tanks are used by 75% of population not connected to sewers and about 25% use latrines.

Methane emissions were evaluated using modified *2006 IPCC Guidelines,* Volume 5, section 6.2.2.1 Equation 6.1:

$$CH_4 Emissions = \sum_i (EF_i \times (1-k) \times TOW_i)$$

where:

TOW_i - total organics in specific wastewater stream *i* (aerobic well managed, aerobic not well managed, anaerobic shallow lagoon, untreated, septic tanks, and latrines) in inventory year, kg BOD/yr.;

k - fraction of organic component removed as sludge in inventory year, kg BOD/yr., assumed = 0.3[145];

EF_i - emission factor, kg CH_4 / kg BOD.

The emission factor for each wastewater treatment and discharge pathway was calculated using Equation 6.2 (*2006 IPCC Guidelines*, Volume 5, section 6.2.2.1):

$$EF_i = B_o \times MCF_i$$

where:

B_o - maximum CH_4 producing capacity, kg CH_4/kg BOD. Default value of *B_o*, 0.6 kg CH_4/kg BOD was used (*2006 IPCC Guidelines*, Volume 5, Table 6.2);

MCF_i - methane correction factor (fraction). Default MCF values provided in *2006 IPCC Guidelines*, Volume 5, Table 6.3 was used (Table 7-49).

Table 7-49. MCF values used for calculation of methane emissions

Untreated wastewater discharged to rivers and lakes	0.1
Aerobic treatment, well managed	0.0
Primary treatment	0.1
Anaerobic shallow lagoons	0.2
Septic systems	0.5
Latrine, wet climate	0.7

7.5.2.2 Nitrous oxide emissions

The activity data that are needed for estimating N_2O emissions are nitrogen content in the wastewater effluent, country population and average annual per capita protein generation (kg/person/yr.). The total nitrogen in the effluent is estimated as follows (*2006 IPCC Guidelines*, Volume 5, section 6.3.1.3, Equation 6.8):

$$N_{EFFLUENT} = P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM} - N_{SLUDGE}$$

where:

[145] Expert judgment by the Chief Manager of the Vilnius Wastewater Treatment Plant Mr. V. Puodžiūnas.

$N_{EFFLUENT}$ - total annual amount of nitrogen in the wastewater effluent, kg N/yr.;

P - human population;

Protein - annual per capita protein consumption, kg/person/yr.;

F_{NPR} - fraction of nitrogen in protein, default = 0.16, kg N/kg protein;

$F_{NON-CON}$ - factor for non-consumed protein added to the wastewater;

$F_{IND-COM}$ - factor for industrial and commercial co-discharged protein into the sewer system;

N_{SLUDGE} - nitrogen removed with sludge (default = zero), kg N/yr.

Protein consumption per capita in Lithuania is evaluated periodicaly by the Health education and disease prevention Centre (Table 7-50). Linear interpolation of these values was used for calculation of N_2O emissions.

Table 7-50. Evaluated protein consumption in Lithuania, g/capita/day

1998	2002	2007	2013	2020
77.4	78.1	81.9	63.6	70.1

Source Lithuanian Health Education and Disease Prevention Centre

According to available studies[146] performed using WHO approved methodology protein consumption in Lithuania decreased significantly from 81.9 g/capita/day in 2007 to 63.6 g/capita/day in 2013 but increased again to 70.1 g/capita/day in 2020. The Health education and disease prevention Centre stated that changes in protein consumption can be explained by a reduction in the consumption of meat, fish and dairy products in Lithuania.

According to the Joint FAO/WHO/UNU expert consultation report[147], for adults, protein requirement per kg body weight is considered to be the same for both sexes, at all ages, and for all body weights within the acceptable range. The value accepted for the safe level of intake is 0.83 g/kg per day (p. 242). Average protein consumption in Lithuania established by the recent study corresponds to the safe requirements of a person with body weight 76.6 kg.

Default value 1.4 for non-consumed protein was used as provided in *2006 IPCC Guidelines*, Volume 5, section 6.3.1.3 for developed countries using garbage disposals.

Default $F_{IND-COM}$ value 1.25 was used (*2006 IPCC Guidelines*, Volume 5, section 6.3.1.3).

N_2O emissions from wastewater effluent were calculated using Equation 6.7 provided in *2006 IPCC Guidelines*, Volume 5, Section 6.3.1.1:

$$N_2O\ emissions = N_{EFFLUENT} \times EF_{EFFLUENT} \times 44/28$$

[146] Albertas Barzda. Suaugusių Lietuvos gyventojų faktiškos mitybos ir mitybos įpročių tyrimas ir vertinimas. Daktaro disertacija, Vilnius, 2011; Albertas Barzda, Roma Bartkevičiūtė, Ignė Baltušytė, Rimantas Stukas, Sandra Bartkevičiūtė. Suaugusių ir pagyvenusių Lietuvos gyventojų faktinės mitybos ir mitybos įpročių tyrimas. Visuomenės sveikata, 2016 No. 1(72), p. 85-94.

[147] Protein and Amino Acid Requirements in Human Nutrition. Report of Joint FAO/WHO/UNU Expert Consultation (WHO Technical Report, Series 935, Geneva, Switzerland, 2002. https://apps.who.int/iris/bitstream/handle/10665/43411/WHO_TRS_935_eng.pdf?ua=1ct

where:

N_2O emissions - N_2O emissions in inventory year, kg N_2O/yr.;

$N_{EFFLUENT}$ - nitrogen in the effluent discharged to aquatic environments, kg N/yr.;

$EF_{EFFLUENT}$ - emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N.

The factor 44/28 is the conversion of kg N_2O-N into kg N_2O.

The default emission factor for N_2O emissions from domestic wastewater nitrogen effluent is 0.005 g N_2O-N/kg N (*2006 IPCC Guidelines*, Volume 5, section 6.3.1.2).

7.5.3 Uncertainties and time-series consistency

7.5.3.1 Uncertainty

Methane emissions

The following uncertainties were assumed for activity data:

- Total organics in wastewater (TOW) 30%
- population having no connection to sewerage networks 5%
- fraction of organic component removed as sludge 40%
- per capita BOD 30%

Default uncertainty ranges provided in *2006 IPCC Guidelines*, Volume 5, p. 6.17, Table 6.7 were used for parameters determining emission factors:

- maximum CH_4 producing capacity (B_o) 30%
- MCF
    - Aerobic treatment, well managed 10%
    - Primary treatment 30%
    - Anaerobic treatment, shallow lagoon 50%
    - Untreated 30%

Evaluated uncertainties of GHG emissions in separate wastewater streams are the following:

- Aerobic treatment, well managed 66.3%
- Primary treatment 65.6%
- Anaerobic treatment, shallow lagoon 72.1%
- Untreated 82.5%
- Septic tanks and latrines 52.2%

Evaluated overall uncertainty is 49.9%.

Nitrous oxide emissions

It was assumed that uncertainty of activity data is 30% and uncertainty of emission factors is 50%. Combined uncertainty for N_2O emissions from human sewage calculated using Equation 3.1 from *2006 IPCC Guidelines*, Volume. 1, Chapter 3) is 58.3%.

7.5.3.2 Time-series consistency

Emissions from wastewater handling were calculated for the whole time series using the same method and data sets.

7.5.4 Category-specific QA/QC and verification

Data collection and calculations were performed in accordance with the requirements outlined in Section 6 of the Quality Assurance and Quality Control Plan.

Tier 1 General Inventory Level QC was performed based on recommendations provided in *2006 IPCC Guidelines,* Volume 1 Chapter 6 and outlined in the QA/QC plan:

Consistency of data between NIR and CRF has been checked.

Documentation on activity data and emission factors was crosschecked with the corresponding data in calculation model.

In case of large fluctuations in data, other experts or data providers were consulted to either provide the explanation or to identify a possible inconsistency or an error.

Explanations for recalculations were checked to ensure that they are clearly documented.

After the calculation is finished, EPA waste experts not directly involved in the emissions calculation of that year have reviewed the final report and CRF data checking the applied parameters, calculation methodology, as well as trend description in the NIR.

In order to verify the results based on the use of measured BOD amount in WWTP influent, obtained per capita BOD values were compared with the default values provided in *2006 IPCC Guidelines,* Volume 5, Table 6.4 (Table 7-51).

Table 7-51. Comparison of per capita BOD values obtained from statistical data with the default values provided in *2006 IPCC Guidelines*, Volume 5, Table 6.4

Year	BOD, g/person/day			Required correction factor	
	Connected to the network	Not connected to the network	Total population	Connected to the network	Total population
1999	111.79	60.00	86.15	1.86	1.44
2000	91.73	60.00	76.47	1.53	1.27
2005	90.42	60.00	78.23	1.51	1.30
2010	96.94	60.00	83.94	1.62	1.40
2015	99.99	61.53	89.66	1.67	1.49
2016	109.04	60.00	96.12	1.82	1.60
2017	106.81	60.00	94.60	1.78	1.58
Average	**100.45**	**59.81**	**85.29**	**1.67**	**1.42**

BOD amount measured in WWTP influent should correspond to the sum of BOD from the population connected to the sewerage network and from the industries. Calculated per capita BOD for the total population including fraction not connected to the network divided by the per capita domestic BOD generation should correspond to the correction factor I for additional industrial BOD discharged into sewers (see *2006 IPCC Guidelines,* Volume 5, eq. 6.3).

Assuming that per capita BOD discharge in Lithuania corresponds to the default value for Europe and Russia provided in *2006 IPCC Guidelines,* Volume 5, Table 6.4 (60 g/person/day), industrial BOD discharge comprises about 68% of domestic BOD generated by the population connected to the sewerage network or 42% of BOD generated by the total population.

Evaluated industrial input is higher than recommended in *2006 IPCC Guidelines,* Volume 5, Equation 6.3 (default correction factor I = 1.25), however higher than 60 g/person/day per capita domestic BOD generation should not be excluded. The range of per capita BOD for Europe and Russia provided in *2006 IPCC Guidelines,* Volume 5, Table 6.4 is 50-70 g/person/day, in Sweden it reaches 82 g/person/day, and in the USA even 120 g/person/day.

7.5.5 Category-specific recalculations

Nitrous oxide emissions for 2014-2019 were recalculated using linear interpolation of experimental protein consumption data from 2013 and new data for 2020. Impact of recalculations on CH_4 emissions from wastewater is provided in Table 7-52.

Table 7-52. Impact of recalculations on N_2O emissions from wastewater treatment, kt

Year	This submission	Previous submission	Absolute difference, kt	Relative difference, %
2014	0.152	0.150	0.002	1.4%
2015	0.153	0.148	0.004	2.8%
2016	0.153	0.146	0.006	4.2%
2017	0.153	0.144	0.008	5.5%
2018	0.154	0.143	0.010	6.8%
2019	0.155	0.143	0.012	8.1%

7.5.6 Category-specific planned improvements

Category-specific improvements are not planned.

8 OTHER (CRF 6)

Not applicable.

9 INDIRECT CO_2 AND N_2O EMISSIONS

9.1 Description of sources of indirect emissions in GHG inventory

Nitrogen oxides (NO_x = NO + NO_2), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) are not greenhouse gases, but they have an indirect effect on the climate through the formation of ozone and their effects on the lifetime of the methane emission in the atmosphere. CO via its effects on hydroxyl radical (•OH), can help to promote abundance of methane in the atmosphere as well as increase ozone formation. NO_x influence climate by their impact on other greenhouse gases. NMVOCs have some short lived direct radiative forcing properties, primarily influence climate via promotion of ozone formation and production of organic aerosols. Sulphur dioxide (SO_2) also has an indirect impact on climate, as it increases the level of aerosols with a subsequent cooling effect. Therefore, emissions of these gases are to some extent included in the inventory.

Lithuania joined the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) in 1994. As a party to the CLRTAP Lithuania is bound annually report data on emissions of air pollutants covered in the Convention and its Protocols using the Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution (EB.AIR/GE.1/2002/7). To be able to meet this reporting requirement Lithuania compiles and updates an air emission inventory of SO_2, NO_x, NMVOC, CO and NH_3, particulate matter, various heavy metals and POPs and projection.

The Informative Inventory Report (IIR) covering the inventory of air pollutant emissions from Lithuania are the source of data in this report. The report contains information on Lithuanian's inventories for 1990-2020 years. Air emission inventory is based mainly on statistics published by Statistics Lithuania (Statistical Yearbooks of Lithuania, sectoral yearbooks on energy balance, agriculture, commodities production etc.), Institute of Road Transport, Registry of Transport (State enterprise "Regitra"), emission data collected by Environment Protection Agency and other.

A large decrease in all indirect GHG emissions was caused by the structural changes in the economy after 1990 when political independence of Lithuania was restored (Figure 9-1). This led to lower emissions in energy and industrial production and to an overall decrease in the emissions from industrial processes between 1990 and 1995. In 1996 the economy began to recover and production increased. In 1994, the GDP dropped to 54% of the 1989 level but later started to increase again.

The emissions trends of indirect greenhouse gases - nitrogen oxides, carbon monoxide, non-methane volatile organic compounds and sulphur oxide (calculated as sulphur dioxide) emissions are presented in Figure 9-1.

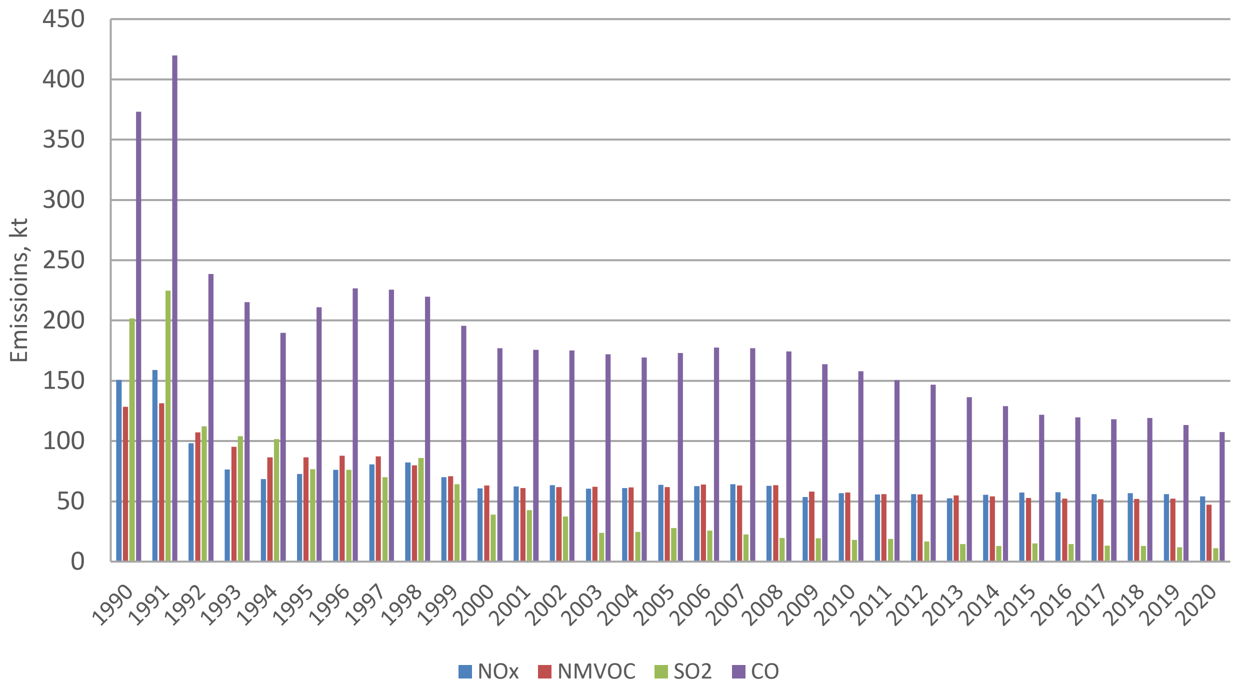


Figure 9-1. Development of non GHG gas and SO_2 emissions, 1990-2020 (*source:* LRTAP submission and NEC submissions, 2022)

A rapid decrease of indirect emissions followed the decline of the country economy in the 1990s. Since 2000, the GDP has been growing continuously. Tables 9-1 and 9-2 present results from the Level Assessment of the key source for 2005 and 2020. The sources that add up to at least 80% of the national total in 2005 and 2020 are defined as being a key source for each pollutant.

Table 9-1. Key source analysis for the main pollutants in 2005

	Key categories (Sorted from high to low and from left to right)											**Total (%)**
SOx	1.A.1.b Petroleum refining	1.A.1.a Public electricity and heat production	1.B.2.a.iv Fugitive emissions oil: Refining / storage									**81.0%**
	42.4%	22.2%	16.3%									
NOx	1.A.3.b.iii Road transport: Heavy duty vehicles	1.A.3.b.i Road transport: Passenger cars	1.A.1.a Public electricity and heat production	3.D.a.1 Inorganic N-fertilizers	1.A.3.c Railways	1.A.1.b Refining/ storage	1.A.4.b.i Residential: Stationary plants					**80.2%**
	31.4%	14.7%	10.8%	7.5%	7.1%	5.2%	3.5%					
NMVOC	1.A.4.b.i Residential : Stationary plants	1.B.2.a.iv Fugitive emissions oil: Refining and storage	1.A.3.b.i Road transport: Passenger cars	2.H.2 Food and beverages industry	3.B.1.a Manure manageme nt - Dairy cattle	3.D.a.2.a Animal manure applied to soils	2.D.3.d Coating applications	5A Biological treatment of waste	1.A.3.b.iii Road transport: Heavy duty vehicles	3.B.1.b Manure managemen t - Non-dairy cattle	3.D.e Cultivated crops	**81.5 %**
	16.8%	16.4%	10.8%	7.7%	7.1%	6.5%	4.3%	3.1%	3.1%	2.9%	2.9	
CO	1.A.4.b.i Residential : Stationary plants	1.A.3.b.i Road transport: Passenger cars										**82.5%**
	54.6%	27.9%										

Table 9-2. Key source analysis for the main pollutants in 2020

	Key categories (Sorted from high to low and from left to right)										**Total (%)**
SOx	1.B.2.a.iv Fugitive emissions oil: Refining / storage	1.A.1.b Petroleum refining	1.A.2.f Stationary combustion in manufacturing industries and construction: Non-metallic minerals	2.B.10.a Chemical industry							**83.2%**
	47.9%	20.8%	7.5%	7.0%							
NOx	1.A.3.b.iii Road transport: Heavy duty vehicles	3.D.a.1 Inorganic N-fertilizers	1.A.3.b.i Road transport: Passenger cars	1.A.1.a Public electricity and heat production	1.A.3.c Railways	1.A.4.b.i Residential: Stationary	1.A.2.f Stationary Combustion in manufacturing industries and construction	3.D.a.2.a Animal manure applied to soils			**82.2%**
	28.9%	14.7%	13.9%	10.4%	5.9%	3.0%	2.5%	2.2%			
NMVOC	1.B.2.a.iv Fugitive emissions oil: Refining / storage	1.A.4.b.i Residential: Stationary plants	2.H.2 Food and beverages industry	3.D.a.2.a Animal manure applied to soils	2.D.3.a Domestic solvent use including fungicides	3.B.1.a Manure management - Dairy cattle	3.D.e	2.D.3.d Coating applications	3.B.1.b Manure management - Non-dairy cattle	3.B.4.h Manure management - Other animals	**83.7%**
	20.1%	16.5%	9.7%	6.9%	6.6%	6.2%	4.8%	4.5	4.4%	4.3%	
CO	1.A.4.b.i Residential: Stationary	1.A.3.b.i Road transport: Passenger cars	1.A.1.a Public electricity and heat production								**81.9%**
	68.6%	6.8%	6.5%								

During the period 2005-2020, the emissions of sulphur dioxide has decreased by about 60.0%, from 27.8 kt in 2005 to 11.8 kt in 2020, conditioned by decline in energy production mainly due to substantial reduction of liquid fuel consumption. Oil products are very important fuels in Lithuania. However, their share in the primary energy balance has decreased steadily — from 42.4% in 1994 to 30.5% in 2001. This is related mostly to a reduction in the consumption of heavy fuel oil for producing electricity and district heat. The share of natural gas, the most attractive fuel over the long term, has increased. The role of coal has decreased throughout the period — from 3.7% in 1990 to 0,9% in 2001. In 2020, the most significant sectoral source of SO_x emissions was Fugitive emissions oil: Refining/storage (1.B.2a.iv) (47.9%), followed by emissions occurring from Petroleum refining (1.A.1.b) (20.8%), Stationary combustion in manufacturing industries and construction (1.A.2.f) (7.5%) and Chemical Industry (2.B.10.a) (7.0%) (Table 9-2). A combination of measures has led to the reductions in SO_x emissions in 1990-2020 almost in all sectors (Figure 9-2.). This includes fuel-switching from high-sulphur solid (e.g. coal) and liquid (e.g. heavy fuel oil) fuels to low sulphur fuels (such as natural gas) for power and heat production purposes within the energy, industry and domestic sectors, improvements in energy efficiency, and the installation of flue gas desulphurisation equipment in new and existing industrial facilities. The implementation of several directives within the EU limiting the sulphur content of fuel quality has also contributed to the decrease (UNECE, 2011).

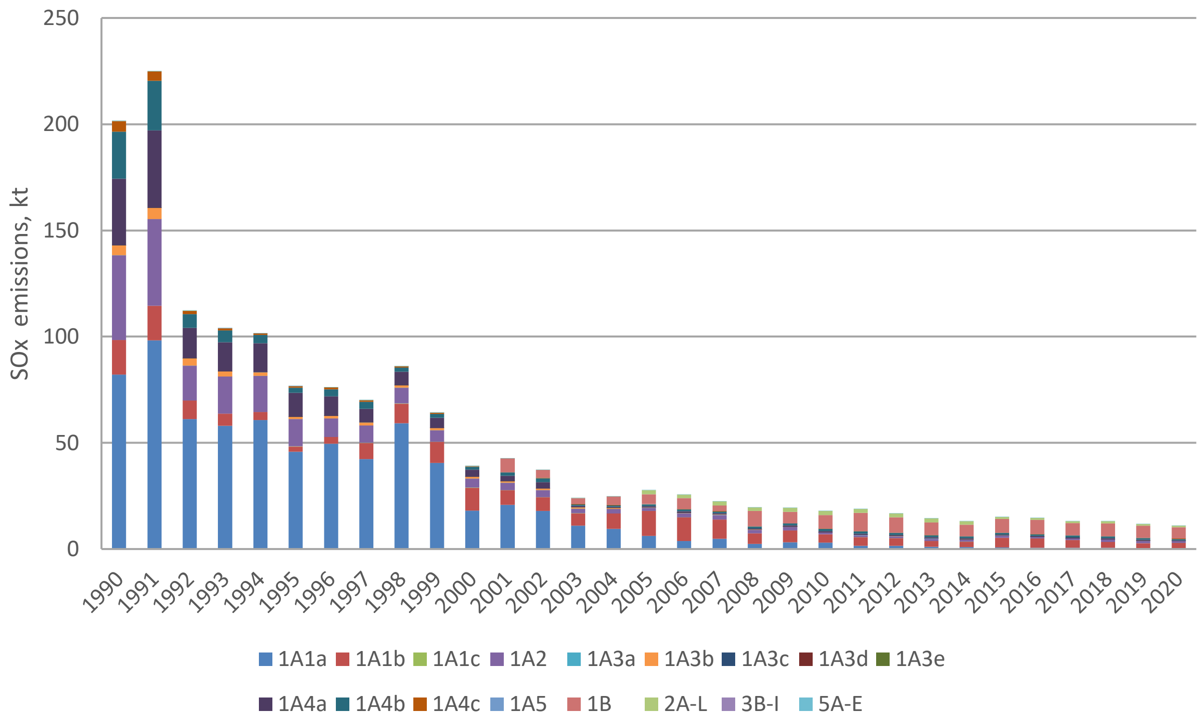


Figure 9-2. Emission trend for SO_x by sectors, 1990-2020

Total nitrogen oxides emissions have decreased by 15.1%, from 63.7 kt in 2005 to 54.0 kt in 2020 (Figure 2-14). The Road transport (1.A.3.b.i and 1.A.3.b.iii), Inorganic N-fertilizers (3.D.a.1) and Energy industry (1.A.1.a) sectors are main sources of nitrogen oxides emissions ~57.5% in 2005 and ~56.9% in 2020. The largest reduction of emissions in absolute terms since 1990 has occurred in the Stationary combustion, Electricity and heat production and Road transport sectors (Figure 9-3). The reduction was observed mainly due to decrease of energy production and fuel consumption in transport sector during the period of 1990-1994 (the consumption of gasoline by road transport reduced by 56% and diesel by 57%). Due to less effective implementation of the Euro Standards Lithuania report an increase in NO_x emissions till 2008 (Figure 9-3).

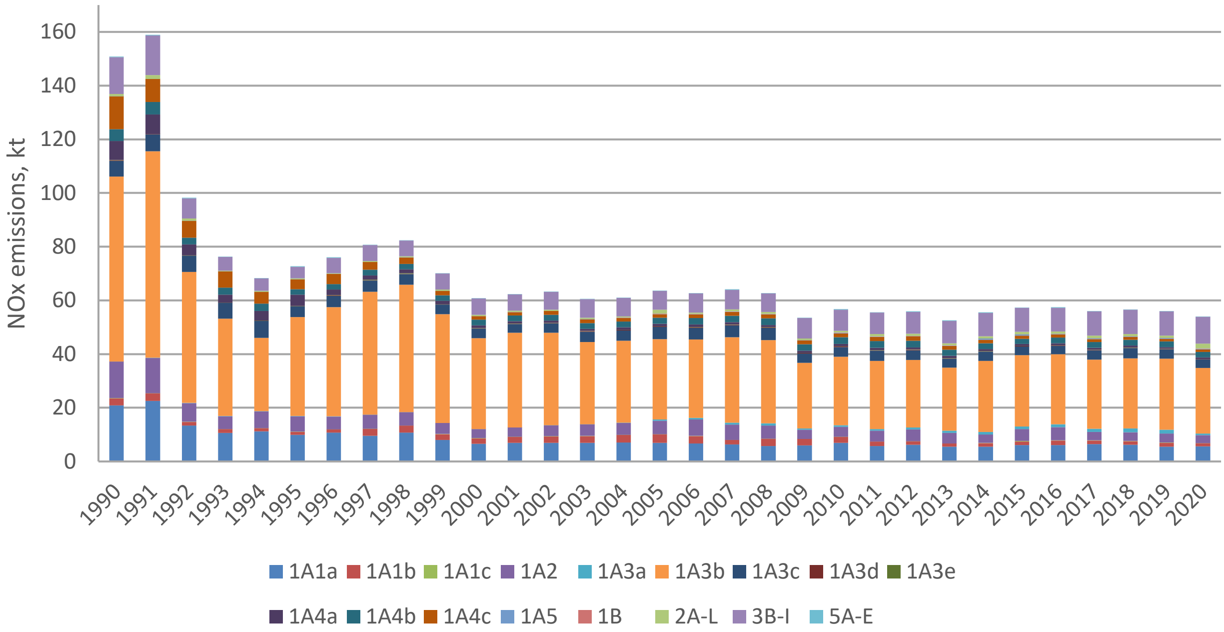


Figure 9-3. Emission trend for NO_x by sectors, 1990-2020

The reductions from 2008 have been achieved despite the general increase in activity within this sector and have primarily been achieved as a result of fitting three-way catalysts to petrol fueled vehicles (the effect of catalytic degradation in newer cars was taken into account). In the electricity/energy production sector reductions have also occurred, in these instances as a result of measures such as the introduction of combustion modification technologies.

The NMVOC emissions are determined mainly by Fugitive emissions oil: Refining / storage (1.B.2.a.iv), Residential (1.A.4.b), Food and beverage (2.H.2), Coating application (2.D.3.d), Domestic solvent use including fungicides (2.D.3.a), Animal manure applied to soils (3.D.a.2.a), Manure management (3.B.1.a-b), Manure management - Other animals (3.B.4.h). The Residential (1.A.4.b) sector produced 16.5% and 16.8% of the 2005 and 2020 total of NMVOC emissions in Lithuania. NMVOC emissions have decreased by 23.3% between 2005 and 2020 (Figure 9-4).

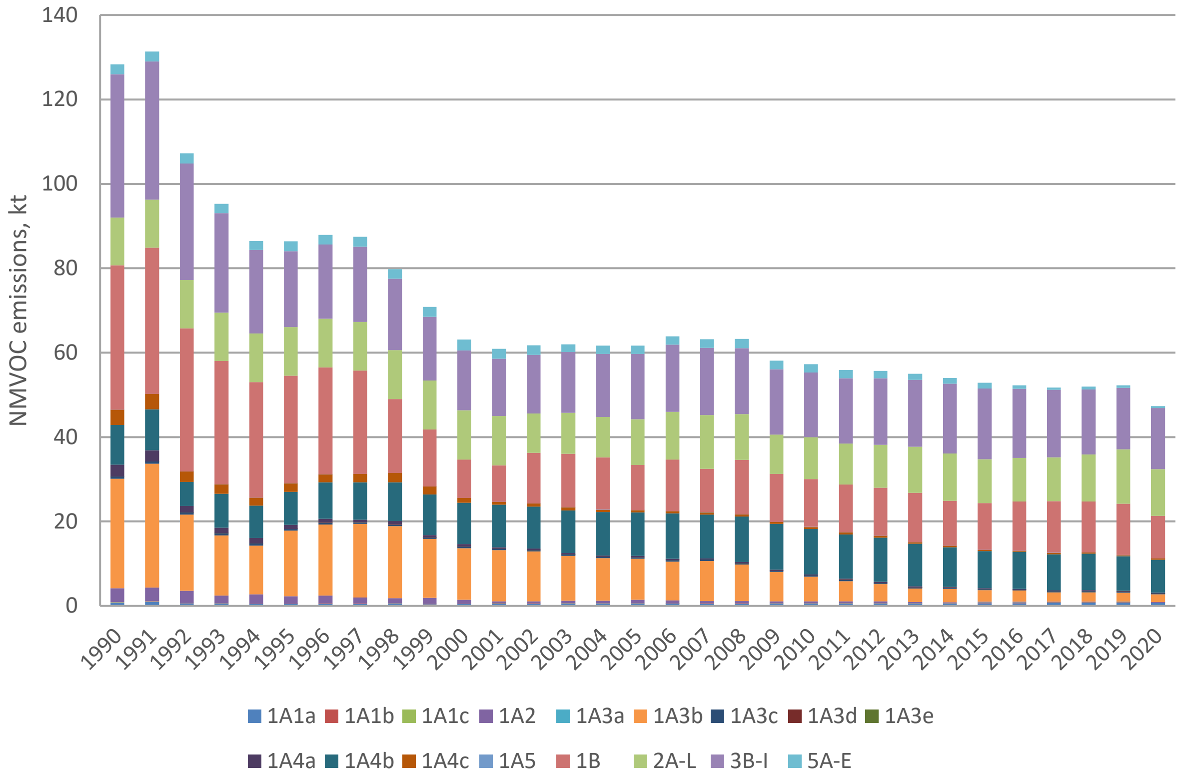


Figure 9-4. Emission trend for NMVOC by sectors, 1990-2020

Technological controls for volatile organic compounds (NMVOCs) in motor vehicles have been more successful than in the case of NO_x, and have contributed to a significant reduction in emissions from Road Transport (1.A.3.b), with the total transport sector's contribution having decreased between 2005 (29.9 kt) and 2020 (24.4 kt). Coating applications (2.D.3.d) and Food and beverages industry (2.H.2) combined sectors are another important sources, accounting for 9.7% of national total NMVOC emissions in 2020. The decline in emissions since 1990 has primarily been due to reductions achieved in the road transport sector due to the introduction of vehicle three-way catalytic converters (oxidation-reduction) and carbon canisters on petrol cars, for evaporative emission control driven by tighter vehicle emission standards, combined with limits on the maximum volatility of petrol that can be sold in EU Member States, as specified in fuel quality directives. The second reason of this change was decrease in use of motor fuel in transport sector and increase in a share of used diesel fuel compared to gasoline.

The CO emission trend also shows decrease of emissions for period 2005-2020. The total CO emission decreased from 173.1 kt in 2005 to 107.4 kt (38.0%) in 2020 (Figure 9-5).

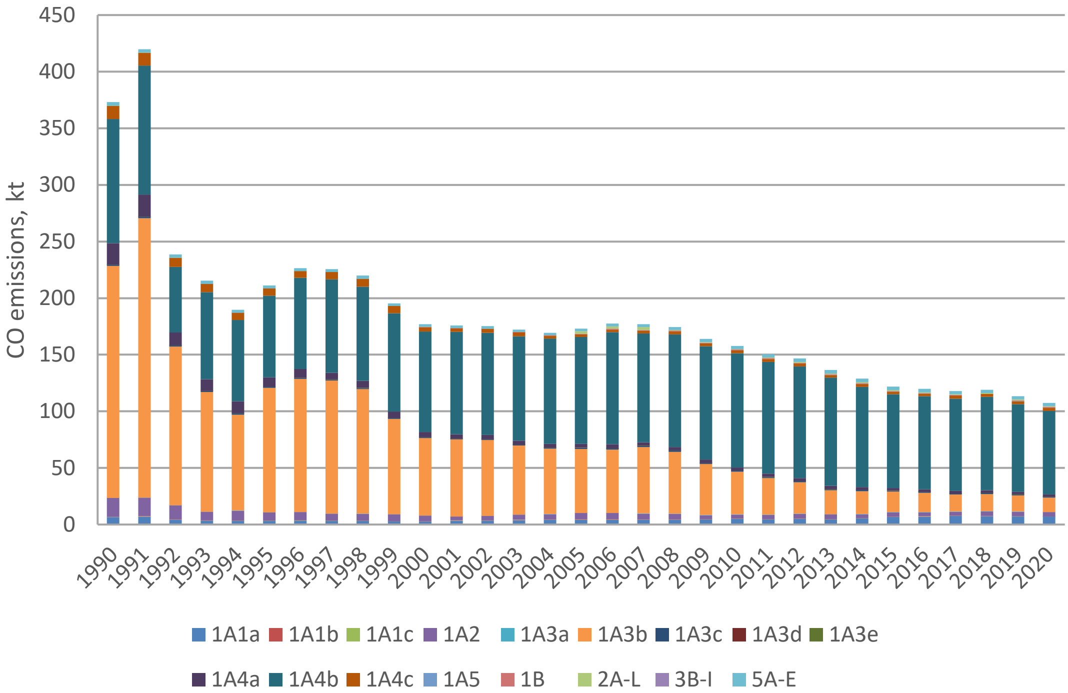


Figure 9-5. Emission trend for CO by sectors, 1990-2020

Carbon monoxide emissions, total 107.4 kt (2020), originates generally from the 1.A.4.b.i Residential: Stationary plants sector (94.5 kt). This sector generated the biggest part of the total CO emissions – 68.6% (2020). Road transport: Passenger cars (1.A.3.b.i) sector contributing by only 6.5% of national total CO emissions in 2020. Carbon monoxide emissions continue to decline, driven by major reductions due to catalysts in gasoline vehicles in Road Transport (1.A.3.b.i), which is the principal source of CO (Figure 2-16).

9.2 Methodological issues

Air emission inventory is based mainly on statistics published by Lithuanian Statistics Department (Statistical Yearbooks of Lithuania, sectoral yearbooks on energy balance, agriculture, commodities production etc.), Institute of Road Transport, Registry of Transport (State enterprise "Regitra"), emission data collected by Environment Protection Agency and other.

The point sources information system contains data that is reported by the facilities that have a pollution permit. Each facility submits data on the emissions of polluting substances together with data regarding fuel burnt, used solvents, liquid fuel distribution, etc. Data and process SNAP code are presented on each source of pollution and on the facility. The owners of point sources directly fill their calculated or measured annual emissions into the report. With regard to the calculation of emissions from road transport, the COPERT V model methodology and emission factors were used (Tier 3). Emission factors for livestock and poultry manure management were taken from EMEP/EEA air pollutant emission inventory guidebook 2016. Number of livestock and poultry was taken from Department of Statistics and State enterprise Agricultural Information and Rural Business Centre. Waste sector activity was taken from EPA. Emission factors for waste sector were taken from EMEP/EEA air pollutant emission inventory guidebook 2016.

The main source of data for all energy industries in the Lithuania for the period 1990-2020 is Statistics Lithuania. Tier 1 methods was used in 1.A.1.a, 1.A.1.b, 1.A.1.c, 1.A.2.f, 1.A.4.a, 1.A.4.b, 1.A.4.c, 1.B.2.a for all compounds and Tier 2 in 1.A.1.b for main pollutants (SO_x, NO_x, NMVOC, CO). The Tier 2 approach was applied with the activity data and the country-specific emission factors according to a country's fuel usage and installed combustion technologies in some energy sectors. In other sectors EMEP/EEA Emission guidebook 2016/2019 EF for SO_x, NO_x, CO, NMVOC was used. Emissions were estimated by multiplying heat value of combusted fuel by corresponding emission factor.

International aviation, International navigation sectors are not included in national totals of SO_x, NO_x, NMVOC, CO presented in GHG inventory.

9.3 Uncertainties and time-series consistency

The uncertainty assessment has not yet been evaluated in Lithuania. Sources not estimated (NE) have not been estimated due to lack of emission factors in methodology or activity data.

9.4 Category-specific QA/QC and verification

A quality management system has been developed to support the inventory of air pollutant emissions. The Lithuanian Quality Control (QC) system is designed to provide routine and consistent checks to ensure data correctness and completeness; identify and address errors and omissions and to document and archive inventory material. QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Before submitting data to CEIP/EEA NFR formats were checked with RepDab. Quality Assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. In the inventory preparation process, general quality control procedures have been applied. Some specific quality control procedures related to check of activity data and emission factors were carried out. Before submitting IIR to CEIP/EEA, data were reviewed and approved by the Environmental Protection Agency (EPA).

9.5 Category-specific recalculations

Based on in-depth review of emission inventories submitted under the UNECE LRTAP Convention and EU National Emissions Ceilings Directive major some renewals in calculations were applied in 2020. Correction of activity data and Tier 2 implementations were done 1990-2020. Emission factors were reviewed and corrected. Majority of activity data within all sectors were adjusted according to data used in GHG emission inventory.

9.6 Category-specific planned improvements

Category-specific improvements are not planned.

10 RECALCULATIONS AND IMPROVEMENTS

The recalculations in 2022 submission have been mainly made due to:
- updated activity data;
- errors correction;
- revisions made in response to UN/EU review process.

The information on how UN reviews recommendations were addressed is provided in the Annex XII.

10.1 Explanations and justification for recalculations, including in response to the review process

Energy sector

1.A.2.f Non-Metallic Minerals industry

Correction of activity data for other fossil fuel (waste non-biomass fraction) in 2018 and 2019 as well for waste (biomass fraction) in 2019 based on information provided by Statistics Lithuania.

1.A.2.g.i Manufacturing of machinery

Correction of CO_2 EF for other bituminous coal (2015-2019) due to previously made mistake.

1.A.2.g.iv Wood and wood products industries

Correction of activity data for other bituminous coal (in 2014) due to previously made mistake.

1.A.2.g.viii Non-Specified Industry

Correction of activity data for other fossil fuel (medical and hazardous waste) in 2019 based on revised information provided by JSC "Toksika".

1.A.3.b Road transportation

Recalculation was done for PC diesel cars in 2019 due to the correction of previously made mistake.

1.A.3.e.i Natural gas transportation in pipelines

Recalculations were done for 2019 due to updated activity data in Fugitive emissions.

1.A.4 Other sectors

Correction of activity data in 1.A.4.a.i and 1.A.4.b.i for peat in 2018 based on information provided by Statistics Lithuania.

1.B.2.b Fugitive emissions from natural gas

Correction of activity data in 1.B.2.b.4 for natural gas leakages (transmission network) in 2015, 2017 and 2019 based on updated information provided by Amber Grid AB.

Industrial Processes and Product Use

2.B.1 Ammonia production

Recalculation of CO_2 emissions from urea application (year 2019) in agriculture sector (see Chapter 5.10 (3.H CO_2 emissions from urea application)).

2.D.1 Lubricant use

Recalculation of CO_2 emissions from lubricants use (year 2019) have been done due to updated statictical activity data on consumption of lubricant oil for non energy purposes.

2.F.1.b Domestic Refrigeration

Recalculations of HFCs emissions in Domestic refrigeration have been done based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results for 1995-2019. Based on 2021 study results operation EF (0.7% is used instead of 0.4%) and the initial charge remaining at system disposal (refrigerators and freezers) were updated (90% is used instead of 80%).

2.F.1.d Transport refrigeration

Recalculations of HFCs emissions in Transport refrigeration for 2014-2019 have been done based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results. The assumptions on the distribution of refrigerants in transport refrigeration were updated: F-gases used in transport refrigeration for 1993-2014– HFC-134a and R404A, and since 2015 refrigerant R452A was included. Futhermore the operation emission factor has been updated (EF-25% since 2020) and emissions from vehicles manufacturing were included (2018-2019).

2.F.1.e Mobile Air-Conditioning

Recalculations of HFCs emissions in Mobile Air Conditioning for 2012-2019 have been done due to mistake in calculations and updated activity data on passenger carriages disposal. Based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results the assumptions on the share of vehicles equipped with mobile air conditioning systems by category and year of production since 2018 were updated

2.F.1.f Stationary Air-Conditioning

Recalculations of HFCs emissions in Stationary Air-Conditioning have been done due to updated activity data for 2019 provided by EurObserv`ER Heat Pumps Barometer.

2.F.4. Aerozols

Recalculations in subcategory Metered Dose Inhalers (CRF 2.F.4.a) have been done based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results. Activity data on metered dose inhalers with HFC-227ea use were additionally included in the NIR (2014-2019).

2.G.2. SF_6 and PFCs from other Product Use

Recalculations in this category have been done based on the report of "Analysis and verification of the inventory of fluorinated greenhouse gases" (2021 study) results. Activity data on accelerators containing F-gases use were updated (2005-2019).

Agriculture sector

3.B Manure management

CH4 and N2O emissions recalculation was performed only for the swine category for the period of 2017 – 2019 as more accurate information on usage of anaerobic digester manure management system was obtain. Also typing error in the calculation of indirect N2O emissions for horses in 2018-2019 was corrected.

3.D Agricultural soils

The following recalculation of direct N2O emissions from agriculture soils were made:

1. IFA has provided data on inorganic N fertilizers consumption for 2019 only in October of 2021, therefore emissions from the category 3.D.1.1 Inorganic N fertilizer for 2019 was recalculated;

2. Recalculations for 3.D.1.2.a Animal manure applied to soils were made due to recalculations made in CRF 3.B.2 Manure management category and the emissions from anaerobic digester system of swine category was included;

3. 3.D.1.6 Cultivation of organic soils were made due to recalculations made in the LULUCF sector for the whole period.

The following recalculation of indirect N_2O emissions from agriculture soils were made:

Recalculations in the 3.D.2.1 Atmospheric deposition and 3.D.2.2 Nitrogen Leaching and run-off categories related to the activity data update are described in the Chapter 5.6.2.5 Category-specific recalculation as the same activity data are used for the 3.D.1 Direct N_2O emissions from managed soils category estimations.

Additional recalculation was made for the 3.D.2.1 Atmospheric deposition in order to update $Frac_{GASF}$. According to the air pollutant inventory NO_x is reported as NO_2; therefore, the NO_2 emissions were multiplied by 14/46 to get the NO_X-N losses.

3.H CO_2 emissions from urea application

IFA provided data on urea consumption for 2019 only in October of 2021, therefore data for 2019 was recalculated.

Land use, land use change and forestry sector

4.A Forest land

Difference in total GHG removals from forest land resulted in adjustment of living biomass carbon stock change in forest land remaining forest land due to the newest growing stock volume data applied - extrapolated values for year 2017 were replaced with actual values. In addition to this, calculation errors in carbon stock changes in living biomass of forest land remaining forest land were corrected as a resulted of additional internal QA/QC procedure. This includes error in growing stock volume changes calculation for year 2016 (which resulted in corrected stock change estimate for subsequent years) and corrected algorithm of total growing stock volume collection from NFI statistics. Recalculations were done also as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation, which resulted in slightly different areas of mineral and organic soils, which affected calculation of CO_2 and N_2O emissions from drainage.

4.B Cropland

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation, which resulted in slightly different areas of mineral and organic soils of land converted to cropland, used to estimate carbon stock changes in mineral soils, CO_2 emissions from drainage and direct N_2O emissions due to the N mineralization/immobilization. National carbon stock value in dead wood was applied to estimate carbon stock changes in dead organic matter (dead wood) in grassland converted to cropland. In addition to the updated estimations, calculation error was corrected in carbon stock changes of organic soils in grassland converted to croplands subcategory for the year 2012 and incorrect application of areas in the estimation of carbon stock changes in mineral soils after settlements conversion to cropland.

4.C Grassland

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation, which resulted in slightly different areas of mineral and organic soils of land converted to grassland, used to estimate carbon stock changes in mineral soils and CO_2 emissions from drainage. National carbon stock value in dead wood was applied to estimate carbon stock changes in dead organic matter (dead wood) in other land uses converted to grassland. Incorrect application of areas in the estimation of carbon stock changes in mineral soils after settlements conversion to grassland were corrected for this submission as well.

4.D Wetlands

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation. Recalculations also include distinguishing carbon stock changes in forest land converted to flooded land (taking into account the purpose of each conversion to determine whether soil was disrupted or not) between mineral and organic soils. This includes application of national carbon stock values as obtained from study "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, for corresponding final land uses.

4.E Settlements

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation, which resulted in slightly different areas of mineral and organic soils used to estimate carbon stock changes in mineral soils, CO_2 emissions from drainage and direct N_2O emissions from N mineralization/immobilization. National carbon stock value in dead wood was applied to estimate carbon stock changes in dead organic matter (dead wood) in grassland converted to settlements and corrected estimation of dead organic matter carbon stock changes in forest land converted to settlements, since only litter carbon stock changes should be included, while dead wood carbon stock changes due to deforestation are included under forest land. Incorrect application of areas in the estimation of carbon stock changes in mineral soils after grassland and forest land conversion to settlements was corrected for this submission, which also affected estimation of direct N_2O emissions from N mineralization/immobilization.

4.F Other Land.

Recalculations were done as a result of continued internal land use and land-use change database review in State Forest Service. Database review was done (started in 2017) taking into account NFI field measurement data, National Paying Agency data of declared agricultural land and the initial data from studies (Study 1 and Study 2) conducted in 2012, in order to improve accuracy in land-use matrix preparation. In addition to this, national carbon stock value in litter was applied to estimate carbon stock changes in dead organic matter (litter) in grassland converted to Other land. Carbon stock changes in biomass in cropland converted to Other land were recalculated, including carbon stock losses from perennial cropland converted to Other land (the share of perennial cropland in total cropland area was applied). Recalculations also include distinguishing carbon stock changes in Forest land converted to Other land between mineral and organic soils and application of national carbon stock values as obtained from study "Evaluation of national organic carbon stocks and the determination of stock values in organic and mineral soils in forest and non-forest land", performed by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry. Typing error was calculated for this submission, since carbon stock changes in mineral soils of grassland converted to other land should be reported as negative due to losses.

Waste sector

5.A Solid waste disposal on land

As noted earlier, the major part of sewage sludge is disposed of separately from solid waste on sites comparable to landfills but defined as storage sites. The quantity of sewage sludge disposed of at storage sites are calculated by subtracting processed (composted, digested, applied in agriculture, incinerated) sludge from the total sludge generation. Unfortunately, sewage sludge undergoing temporary processing before submission to further recycling or disposal operations (e.g. granulation) was also subtracted in the previous submission, therefore, reducing the amount of estimated disposed of sludge.

The data on sewage sludge storage and disposal in years 2015 to 2019 were reviewed and corrected resulting in light increase of emissions.

5.B Biological treatment of waste

Waste biological treatment includes composting and anaerobic digestion. Some wastes can be sent for composting directly after collection (e.g. green waste) or sorting in MBT facilities. Waste remaining after completion of anaerobic digestion is also directed for composting. This portion of waste was omitted from calculations in the previous submission. In this submission, data on waste biological treatment for 2018 and 2019 were reviewed and updated (data on composting and anaerobic digestion separately are available only from 2018).

5.D Wastewater treatment and discharge

Nitrous oxide emissions for 2014-2019 were recalculated using linear interpolation of experimental protein consumption data from 2013 and new data for 2020.

10.2 Implication for emission levels

Implication for emissions levels are provided in the Table 10-1 below.

Table 10-1. Recalculations of GHG emissions between submission 2022 and submission 2021 by sector

	1. Energy		**2. Industrial Processes and product use**		**3. Agriculture**		**4. Land use, land-use change and forestry**		**5. Waste**	
Year	**kt CO_2 eq.**	**%**	**kt CO_2 eq.**	**%**	**kt CO_2 eq.**	**%**	**kt CO_2 eq.**	**%**	**kt CO_2 eq.**	**%**
1990	0.00	0.00	0.00	0.00	68.60	0.79	-80.61	1.48	0.00	0.00
1991	0.00	0.00	0.00	0.00	57.88	0.68	1.00	-0.02	0.00	0.00
1992	0.00	0.00	0.00	0.00	47.62	0.73	0.17	0.00	0.00	0.00
1993	0.00	0.00	0.00	0.00	35.75	0.68	14.99	-0.24	0.00	0.00
1994	0.00	0.00	0.00	0.00	32.79	0.71	12.22	-0.21	0.00	0.00
1995	0.00	0.00	0.18	0.01	31.71	0.74	11.55	-0.25	0.00	0.00
1996	0.00	0.00	0.16	0.01	27.56	0.62	-8.33	-0.83	0.00	0.00
1997	0.00	0.00	0.16	0.01	25.19	0.56	-7.84	3.53	0.00	0.00
1998	0.00	0.00	0.18	0.01	23.34	0.53	-7.96	0.10	0.00	0.00
1999	0.00	0.00	0.19	0.01	19.01	0.47	6.10	-0.09	0.00	0.00
2000	0.00	0.00	0.20	0.01	14.96	0.38	0.57	-0.01	0.00	0.00
2001	0.00	0.00	0.21	0.01	14.00	0.37	-11.06	0.15	0.00	0.00
2002	0.00	0.00	0.21	0.01	13.98	0.36	-16.29	0.26	0.00	0.00
2003	0.00	0.00	0.22	0.01	13.06	0.33	-30.75	0.55	0.00	0.00
2004	0.00	0.00	0.23	0.01	14.68	0.36	-23.96	0.47	0.00	0.00
2005	0.00	0.00	0.25	0.01	14.04	0.35	-14.69	0.34	0.00	0.00
2006	0.00	0.00	0.22	0.01	13.04	0.32	-20.40	0.52	0.00	0.00
2007	0.00	0.00	0.29	0.00	11.15	0.27	-36.45	0.62	0.00	0.00
2008	0.00	0.00	0.39	0.01	9.30	0.23	-22.21	0.34	0.00	0.00
2009	0.00	0.00	0.36	0.02	7.98	0.19	-37.59	0.50	0.00	0.00
2010	0.00	0.00	-0.55	-0.02	6.82	0.16	-5.81	0.06	0.00	0.00
2011	0.00	0.00	-0.16	0.00	4.70	0.11	-14.08	0.13	0.00	0.00
2012	0.00	0.00	-0.11	0.00	1.19	0.03	19.07	-0.19	0.00	0.00
2013	0.00	0.00	-0.15	0.00	1.94	0.05	-49.85	0.53	0.00	0.00
2014	1.34	0.01	0.71	0.02	6.24	0.14	5.84	-0.07	0.65	0.06
2015	11.00	0.10	-1.73	-0.05	7.71	0.17	53.87	-0.68	3.69	0.37
2016	0.00	0.00	-8.32	-0.25	16.84	0.38	-1.03	0.01	6.15	0.62
2017	-0.03	0.00	-12.81	-0.35	15.88	0.36	176.64	-2.65	6.99	0.71
2018	-4.92	-0.04	-18.42	-0.58	16.88	0.40	160.55	-2.46	15.39	1.80
2019	1.56	0.01	-34.98	-1.03	11.01	0.26	133.85	-2.46	15.16	1.84

10.3 Implications for emission trends, including time-series consistency

In submission 2021 the trend from the base year to 2019 showed a 57.5% decrease. The recalculation of GHG emissions in submission 2022 decreased the upward trend between the base year and 2019 by 75.3 kt CO_2 eq.

Table 10-2. Impact on emission trends (base year to 2019) due to recalculations of GHG emissions between submission 2022 and submission 2021. excluding LULUCF.

Gas	***Submission 2021***		***Submission 2022***		***Difference between submission 2022 and submission 2021***
	kt CO_2 eq.	***%***	***kt CO_2 eq.***	***%***	***kt CO_2 eq.***
CO_2	-21,844.64	-61.07	-21,844.43	-61.07	0.21

CH_4	-3,993.56	-57.50	-3,988.27	-57.42	5.29
N_2O	-2,160.09	-42.53	-2,205.96	-42.85	-45.87
Total	-27,424.44	-57.38	-27,49.72	-57.46	-75.28

10.4 Planned improvements

Energy sector

It is planned to include medical and hazardous waste (category 1.A.2.g.viii Non-specified industry) into the energy balance as non-biomass fraction of industrial waste in order to increase the consistency between the energy statistics and the GHG inventory activity data.

Industrial processes and product use sector

Product uses as Substitutes for ODS/Electronics industry/Other product manufacture and use

Gradual improvement of the assumptions used to estimate the emissions of F-gases is ongoing. According to Regulation (EU) No 517/2014 emissions from Domestic refrigeration equipment are expected to decline due to EU wide measures and technical changes resulting in decreased leakage. One can assume that due to the ban on HFCs in domestic refrigerators and freezers the use of (and thus emissions from) HFCs in domestic refrigeration will be phased out gradually and that mainly emissions from disposal will occur. It is expected that emissions from Commercial and Industrial refrigeration sectors will decline in 2020–2035. The projected decline in 2020 is expected due to the entering into force of the new prohibition on the use of HFCs with GWP of 2500 and more to service or maintain refrigeration equipment. Due to HFC-125 and HFC-143a gases GWP is higher than 2500, the use of these gases to service and maintain refrigeration equipment will be prohibited from 2020. Furthermore, refrigerators and freezers for commercial use that contain HFCs with GWP of 150 or more will be prohibited to place on the market from 2022 (HFC-32, HFC-134a). Implementation of F-gases quota system (EU Regulation No 517/2014) will reduce amount of HFCs placed on the market by 79% between 2015 and 2030.

Agriculture

Study to develop country-specific data on feed digestibility currently is under implementation. On 16 December 2020 a contract was signed between the Ministry of Environment and the Institute of Animal Science (Lithuanian University of Health Sciences) to develop a "Study on determination of country-specific feed digestibility values by classic in vivo method". The final study results are expected to be ready on 1 April 2022, therefore developed digestibility values will be incorporated in the 2023 inventory submission.

Land use, land use change and forestry sector

4.A Forest land

Lithuania has applied provisional national carbon stock values in forest land, cropland and grassland mineral soils. In the next submission Lithuania is planning to further improve accuracy of LULUCF GHG inventory with implementation of different carbon stock values for different soil groups in forest land, cropland and grassland, meaning the expansion of land-use change matrix to different soil groups. Updated allocation of soil types still needs approval, however, preliminary soil carbon stock values in different soil type groups for carbon stock changes estimation is presented in Table 6-24.

4.B Cropland, 4.C Grassland, 4.D Wetland

Lithuania has applied provisional national carbon stock values in cropland mineral soils. In the next submission Lithuania is planning to further improve accuracy of LULUCF GHG inventory with implementation of different carbon stock values for different soil groups in cropland, meaning the expansion of land-use change matrix to different soil groups. Preliminary soil carbon stock values for carbon stock changes estimation is presented in Table 6-24.

Lithuania has launched a national project regarding carbon stock value estimation in agricultural land uses (cropland and grassland) in order to qualify carbon stock values in different soils types as established from the projected carried out by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the "Partnership project on Greenhouse gas inventory" between Lithuania and Norway and, if possible, to evaluate carbon stock changes in soils over time.

4.E Settlements

Lithuania plans to implement subdivision of land converted to settlements subcategory according to the degree soil is exposed and damaged, as not the whole surface of settlements is built up, paved or used for road construction in Lithuania, as a result in some cases soil is not fully removed after conversion from another land use to settlements. In addition to this, in order to improve accuracy of soil carbon stock changes estimation, land use change matrix, taking into account different soil types will be prepared.

4.G Harvested wood products

Lithuania have participated in the "GHG inventory partnership project" through financial mechanism LT10 of Norway grants. As a result of this partnership Lithuania has launched the study for development of the national HWP accounting system in upcoming years, as well as to obtain feasible sufficient historical data on rate of increase for industrial round wood production required to run the model for accounting of HWP emissions/removals. Lithuania is planning to implement results of the study in the future.

11 KP-LULUCF (CRF 7)

11.1 General information

Lithuania has ratified both United Nations Framework Convention on Climate Change (in 1995) and its Kyoto Protocol in 2003 (entered into force in 2005) and so committed to reduce its greenhouse gas emissions accordingly to agreements in commitment period. Lithuania has successfully implemented its commitments under the Kyoto protocol – to reduce greenhouse gas emissions by 8% below 1990 level during the first commitment period (1st CP) of 2008 - 2012. By 2012, the greenhouse gas emissions in Lithuania have been reduced by 55% compared with 1990 (excluding LULUCF), successful implementation of commitments was achieved both due to the collapse of Soviet Union in 1990, which resulted in significant reduction of inefficient and high emissions driven industry sector, as well as enhanced environmental protection policy. Nevertheless, Lithuania is neither protected from changes in global climate nor from their consequences, therefore additional effort should be added in reduction of emissions and increase of removals, it is especially important that constant effort is added in all sectors.

Under the commitments of Kyoto Protocol Lithuania provide estimations of anthropogenic emissions by sources and removals by sinks since 1990, associated with afforestation (A), reforestation (R) and deforestation (D) activities under Article 3.3 and Forest Management (FM) under Article 3.4 of the Kyoto Protocol. For the second commitment period (2nd CP) Lithuania uses methodology provided in 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (*2013 KP-Supplement*). The *2013 KP-Supplement* describes the supplementary methods and good practice guidance for measuring, estimating and reporting of anthropogenic greenhouse gas emissions and removals resulting from land use and land use changes and forestry activities covered by Kyoto Protocol for the second commitment period agreed by CMP 7. Reporting emissions and removals from cropland management and grazing land management activities under Article 3.4 are optional for the second commitment period (2nd CP), however Lithuania has not elected those additional activities for the 2nd commitment period.

Lithuania reports activities under Article 3.3 and 3.4 including geographical boundaries of areas encompassing units of land or land only subject to a single activity by reporting *Method 2* and *Approach 3* (p. 2.15-2.18 of *2013 KP-Supplement*). Allocation of AR areas from land use declarations of National Paying Agency (NPA) and afforested/reforested areas on state owned lands, registered in State Forest Cadaster as well as deforested areas registered in State Forest Cadaster is more precise due to the relatively small areas of such activities. In order to capture areas of afforestation/reforestation and deforestation activities annually, wall-to-wall method was applied for Kyoto Protocol reporting part instead of sampling method applied for Convention reporting of land use changes. More information on restoration of historical data for 1990-2011, methods used for estimation of ARD and other areas for 1990-2011 is provided in Chapter 6.1 as well as in the text below.

Net removals from Article 3.3 activities for the 1st CP were -82.0 kt CO_2 eq. in 2012. 2nd CP has started with total emissions of 37.5 kt CO_2 eq. in 2013. Afforestation and reforestation resulted in net removals of -167.4kt CO_2 eq. and deforestation – net emissions of 204.9 kt CO_2 eq. in 2013, whereas in 2020 afforestation/reforestation rates were higher and deforestation - significantly larger (A/R - net removals of -424.6kt CO_2 eq., D - net emissions of 224.5 kt CO_2 eq.), which resulted in total removals of -200.0kt CO_2 eq. from ARD activities (Table 11-1).

Table 11-1. Net emissions/removals from ARD areas during the period 2008-2020, kt CO_2 eq.*

Year	Afforestation/ Reforestation	Deforestation	Total
2008	-86.25	30.63	-55.62
2009	-94.84	19.34	-75.50
2010	-74.16	34.54	-39.62
2011	-100.80	19.64	-81.16
2012	-150.05	68.05	-82.00
2013	-167.38	204.86	37.48
2014	-222.92	270.80	47.88
2015	-213.71	27.39	-186.33
2016	-311.40	164.55	-146.85
2017	-264.76	85.27	-179.49
2018	-401.02	1287.23	886.21
2019	-394.66	556.56	161.90
2020	-424.56	224.52	-200.04

*Including CO_2 emissions from wildfires

The area subjected to AR was 57.33 thous. ha in 2020. There could be several moments distinguished in the time series of 1990-2020 describing the AR trend line. The first time period of human induced afforestation/reforestation has started in 1990-2001 and is the consequence of the restoration of Independency in 1990's. Forest expansion was the key priority among politicians therefore afforested and reforested areas constituted to more than 500 ha annually. But this number was steadily decreasing from 1994. Another two different increase in AR area periods were recorded in 2002-2009 (stable increase approx. 1,600 ha annually) and 2010-2020 (continuously decreasing annual afforestation areas, from nearly 5 thous. ha to 1 thous. ha). Increase in afforestation/reforestation activities in State Forest Enterprises since 2001 was the result of increased funding for such activities while increase of afforestation/reforestation since 2009 is mostly due to the introduction of EU support for such activities for private land owners.

In the beginning of 2020, deforested area since 1st of January 1990 was 5,716.97 ha (Table 11-4). Deforestation was mainly caused by the forest area conversions to Settlements (road building, cities expansion, etc.), Other lands (e.g. quarry's) and Wetlands (e.g. flooding) land use categories.

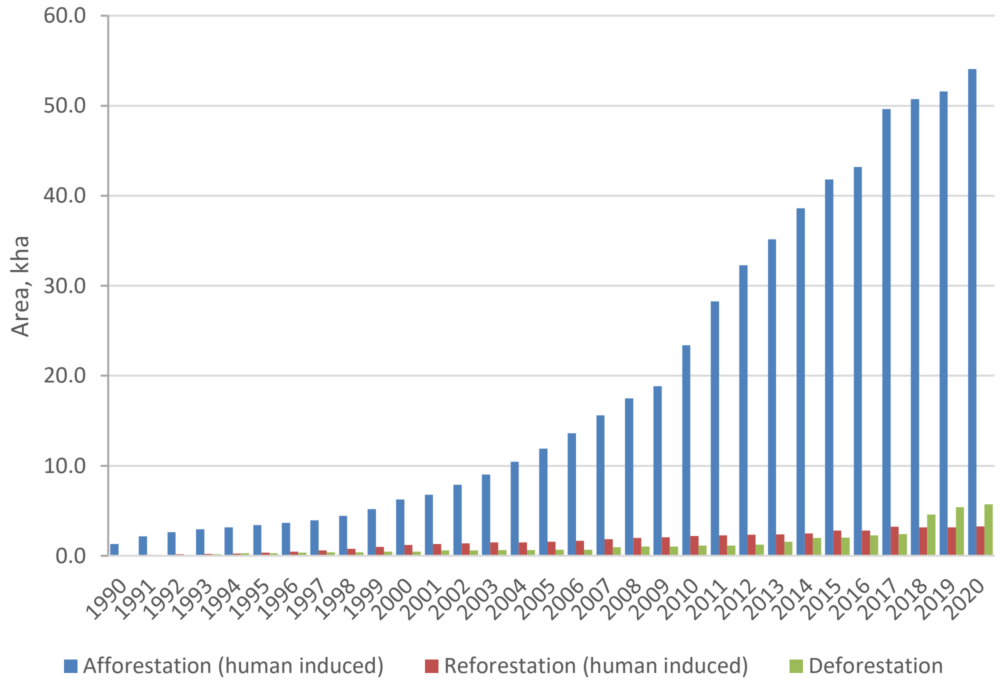


Figure 11-1. Cumulative area of afforestation, reforestation and deforestation, 1990-2020

Additionally Lithuania has distinguished naturally afforested and reforested areas combining wall-to-wall and sampling method used for Convention reporting (Figure 11-2). Neither emissions nor removals of CO_2 under the requirements of Article 3.3 of the Kyoto Protocol are calculated separately for these land areas, they are only constantly supplementing areas under Forest management (FM) and are used for overall data consistency purposes.

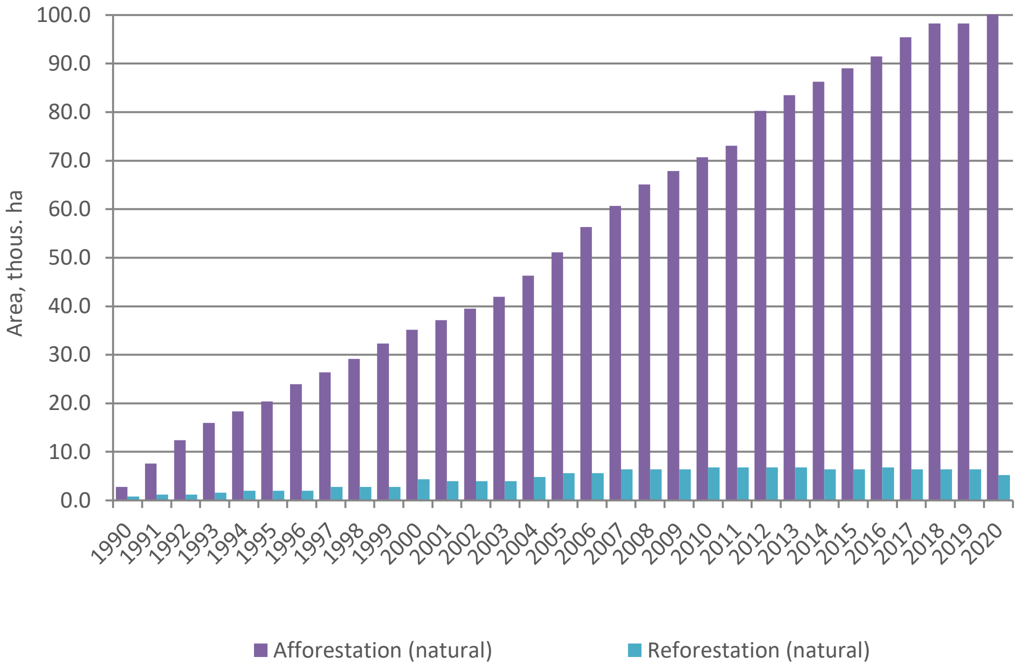


Figure 11-2. Cumulative area of naturally afforested and reforested areas, 1990-2020

Net removals from Article 3.4 activity Forest Management (FM) were -5,136.9 kt CO_2 eq. in 2020 (Table 11-17). The area subjected to FM was 2,120.14 thous. ha by the end of the 1st CP and 2,124.93 in the beginning of the 2nd CP, expanding up to 2,164.94 thous. ha in 2020 (Table 11-5).

Lithuania has elected to continue with Commitment Period accounting for KP-LULUCF.

11.1.1 Definition of forest and any other criteria

For the 2nd CP Lithuania is using the same criteria describing Forest land as was used in the 1st CP. Forest land is defined according to Forests Law of the Republic of Lithuania: "Forest – a land area not less than 0.1 hectare in size covered with trees, the height of which in a natural site in the maturity age is not less than 5 meters, other forest plants as well as thinned or vegetation-lost forest due to the acts of nature or human activities (cutting areas, burnt areas, clearings). Tree lines up to 10 meters of width in fields, at roadsides, water bodies, in living areas and cemeteries or planted at the railways protection zones as well as single trees and bushes, parks planted and grown by man in urban and rural areas are not defined as forests. The procedures for care, protection and use of these plantings shall be established by the Ministry of Environment. Forest stands with stocking level (approximately equivalent to crown cover) less than 0.3 (or crown cover less than 30%) are not acceptable for high productivity forestry". This threshold is used when including land into forest land areas (Table 11-2). The same forest parameters were used in Lithuania's Initial report under the Kyoto Protocol. The definition of Forest land is consistent with LULUCF reporting under the UNFCCC as well.

Table 11-2. Selected parameters defining forest in Lithuania for the reporting

Parameter	Range (FAO)	Values (Lithuania)
Minimum land area	0.05 – 1 ha	0.1 ha
Minimum crown cover	10 – 30 %	30 %
Minimum height at mature age	2 – 5 m	5 m

Table 11-3. Forest land area 1990-2020, thous. ha

Years	Forest land
1990	2,054.15
1995	2,077.32
2000	2,096.08
2005	2,122.44
2010	2,153.99
2015	2,197.11
2016	2,202.31
2017	2,210.29
2018	2,212.29
2019	2,215.08
2020	2,222.27

Forest land area was estimated using National definition of forest land, described in Forest Law of the Republic of Lithuania. Land areas which transition to forest land are not over yet, and which are still used as grasslands or croplands are not included in the forest land area. In 2017, internal land-use change matrix review has taken place after first inventory cycle in non-forest land was fully completed. Incorrect land-use change events were corrected in all land uses due to the more data sources available (NFI field observations, orto-photo, declarations of agricultural land use, Study-2 suggestion, etc.), however, mostly conversions between cropland and grassland were checked and corrected, if necessary. In addition, total country area was adjusted due to the more precise estimations of National Land Service, which provided that total country area has been adjusted from 6,530,023 ha to 6,528,648 ha. This adjustment resulted in recalculation of area represented by single sampling plot and thus had an impact to the total area of Forest management. Area change of afforestation/reforestation and deforestation activities is presented in Table 11-4.

Table 11-4. Area changes of afforestation, reforestation and deforestation, thous. ha

	Afforestation	Reforestation	Total AR	Deforestation
1990	1.33	0.04	1.37	0
1995	0.25	0.08	0.33	0.01
2000	1.07	0.21	1.28	0.02
2005	1.48	0.06	1.54	0.05
2010	4.54	0.12	4.66	0.07
2015	3.19	0.29	3.48	0.04
2016	1.40	0.02	1.42	0.25
2017	6.44	0.43	6.86	0.14
2018	1.09	-0.09	1.00	2.18
2019	0.87	0.03	0.90	0.81
2020	2.47	0.08	2.55	0.32
Total 1990-2020	54.07	3.26	54.07	4.70

11.1.2 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

For the 1st CP taking place in 2008-2012 Lithuania has chosen to account emissions and removals from Forest Management under Article 3.4 of the Kyoto Protocol, but did not elect Cropland Management, Grazing Land Management and Revegetation. For the second CP the same structure applies, except mandatory reporting of Harvested Wood Products (HWP). The decision is supported by the importance of forests in Lithuania and available accounting data of forest resources allowing present transparent and comprehensive results for GHG inventories. Regular information on Lithuanian forest resources is provided by *SFI* already since 1922. Lithuania has made essential improvements in data quality on forest resources since 2002, when *NFI* permanent sample plots net has completely covered all Lithuania's territory and first sufficient data from sampling method on all forest land in Lithuania were obtained.

To estimate areas required to report emissions by the Article 3.3 and 3.4 of the Kyoto Protocol, additional studies were executed in order to recover ARD activities for the period of 1990-2011. Some data sources took back to 1946. Completed studies recovered required data on ARD areas for the 1990-2011 and has made the background for the amendment, supplementation and adoption of new relevant legislation (see Chapter 6.1), in order to set the rules and also to oblige forest owners and managers to register newly afforested, reforested and deforested areas to State Forest Cadaster, which is serving as the main data provider for ARD areas identification reported under Kyoto Protocol since 2012. Thus, starting already since 2009, every deforestation case, which is under very strict regulation and control by the Forest Law, is recorded in the special database as well as afforestation and reforestation activities.

Lithuania elected *Method 2* for the reporting of lands that are subject to Article 3.3 and Article 3.4 activities, which is based on spatially explicit and complete geographical identification of all units of land subjected to Article 3.3 activities and all lands subjected to Article 3.4 activities.

ARD areas were assessed using wall-to-wall mapping and FM areas were assessed using sampling based (*NFI* sample plots grid) techniques, calculated as total forest land area (from NFI) minus afforestation/reforestation area (wall-to-wall mapping).

11.1.3 Description on 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

The definitions of afforestation (A), reforestation (R) and deforestation (D) activities are in accordance with the Decision 16/CMP.1 and *2013 KP-Supplement*.

It is considered that afforestation and reforestation is human-induced artificial forest planting in croplands, grasslands and wetlands. Separation of afforested and reforested areas requires more effort in studying archive data of *SFI* and aerial photographs up to 1940's (*Study-1*). Areas of deforestation are under very strict regulation and control legitimated by the Forest Law (original text adopted in 1994) and Lithuanian Republic Governmental Resolution (2011). In general forest conversion to other land is very rare i.e. only for road construction or settlements establishment and also requires special procedure of compensation. In Lithuanian forest law it is stated that in case of afforestation following deforestation, afforested land has to be at least three times larger than deforested land in ecosystems protection and recreational forests (functional group II) and at least two times larger in protective forests (functional group III), or a compensation of respective sum of money for those deforested lands has to be provided.

Forest Law regulates afforestation process on agricultural and other lands (swamps, peatlands, other land) as well. Afforestation of these lands could be done by artificial planting as well as by natural regeneration. The legitimated substitution of naturally afforested agricultural and other land to forest is only possible when tree crowns cover attains 30% of the area not less than 0.1 ha and the age of trees exceed 20 years. However, natural afforestation is included in area of forest management (FM). All afforested land (human induced and natural) is recorded during *SFI* and legitimated registration at State Forest Cadaster. For the estimation of A/R area (human induced afforestation/reforestation) Lithuania uses data from National Paying Agency which is responsible for administration of afforestation/reforestation activities. Natural forest expansion areas (natural A/R) are included in Forest management area as they are included in total forest land area after observation during NFI.

The main data source to identify areas for calculating emissions and removals under Article 3.3 and Article 3.4 of the Kyoto Protocol is study "Forest land changes in Lithuania during 1990-2011" (*Study-1*) (see Chapter 6.1.1) implemented in 2012 (for time series of 1990 - 2011), newly afforested/reforested area declarations from National Paying Agency and National Forest Inventory data, regarding data on Forest Management.

The main objective of the study "Forest land changes in Lithuania during 1990-2011" was to identify forest land areas and their changes in Lithuania during 1990-2011 following the requirements of *IPCC 2003*. Study revealed the following Forest land areas and their changes annually in 1990-2011:

– afforested areas with human inducement (AR) – wall-to-wall method used;
– naturally afforested areas which are included in FM – sampling method used;
– deforested areas (D) – wall-to-wall method used;
– forest management areas (FM) – sampling method used.

The *Study-1* covers all Lithuania's forest land territory (or areas, where forest land has been registered at least once) during years 1990-2011, land use determination executed using the grid of NFI sampling plots.

The main data sources used:

– Data from *NFI* which is executed on 16,325 (all Lithuania's territory with non-forest land) systematically distributed permanent sample plots, was used to estimate total land area assigned to FM activity as well as to calculate living biomass and deadwood;
– Lithuanian State Forest Cadastre (LSFC);
– Standwise forest inventory databases and maps (S 1:10°000);
– Orthophoto maps (S 1:10°000);
– National Paying Agency's data of declarations for afforested areas (2010-2011);
– Topographical maps 1973-1990 (S 1:50°000);
– Archive cartographical material backwards to 1946-1949 (S 1:10°000);
– Maps of Lithuanian forest resources (1998-1999) (S 1:50°000).

The *Study-1* resulted in the following outcomes:

– units of land subject to activities under Article 3.3, which would otherwise be included in land subject to elected activities under Article 3.4 under the provisions of paragraph 8 of the annex to decision 16/CMP.1 were identified and distinguished;
– GIS layers for Afforested, Reforested and Deforested (ARD) areas and areas remaining under FM were prepared;
– report, showing relevant land units changes, was prepared;

– proposals on land use definitions harmonization and development of the harmonized methodology for the data evaluation and estimations of emissions and removals for LULUCF sector according to the UNFCCC and the Kyoto Protocol requirements were elaborated.

The definition of FM is in accordance with *2013 KP-Supplement*. Forest land area under FM reported for KP-LULUCF calculations is provided in Table 11-5. Data source for determining area under FM activity (until 1998 when sampling based NFI started in whole forest land area in Lithuania) is *Study-1*, where FM area is assessed using *NFI* permanent sample plots data. Area of organic soils and drained organic soils is determined using data of *NFI*. *NFI* provides data on forest land distribution by forest soils, which are classified using forest site types classification prepared by M. Vaičys (Chapter 6.2.1). Area of mineral soils amounts to 86.4% and area of organic soils – 13.6% of the total forest land area. Drained organic forest soils constitute to 6.9% of the total forest land. The same proportions of organic and mineral soils were also accepted for determination of organic and drained organic soils on FM area.

Table 11-5. Area of Forest Management*, thous. ha

Year	Total area	Organic soils		
		Drained	Not drained	Total
1990	2,052.78	141.64	137.54	279.18
1995	2,073.56	143.08	138.93	282.00
2000	2,088.65	144.12	139.94	284.06
2005	2,108.95	145.52	141.30	286.82
2010	2,128.40	146.86	142.60	289.46
2015	2,152.52	148.52	144.22	292.74
2016	2,156.29	148.78	144.47	293.26
2017	2,157.42	148.86	144.55	293.41
2018	2,158.41	148.93	144.61	293.54
2019	2,160.31	149.06	144.74	293.80
2020	2,164.94	149.38	145.05	294.43

**Natural afforestation and reforestation areas are included in Forest Management area*

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

Under Article 3.4 Lithuania is reporting only FM activities therefore there is no hierarchy among Article 3.4 activities. For the consistency reasons and to be sure that reported FM activities have occurred on forest land, total land area was split into six land use categories as it is required by UNFCCC reporting, and each land area was classified under one land use category only.

11.2 Land-related information

Lithuania applies reporting *Method 2* in combination with *Approach 3* to represent areas under Article 3 of the Kyoto protocol. *Study-1* also elaborated in defining geographical borders of afforested, reforested and deforested areas required by KP-LULUCF reporting (Figure 11-3).

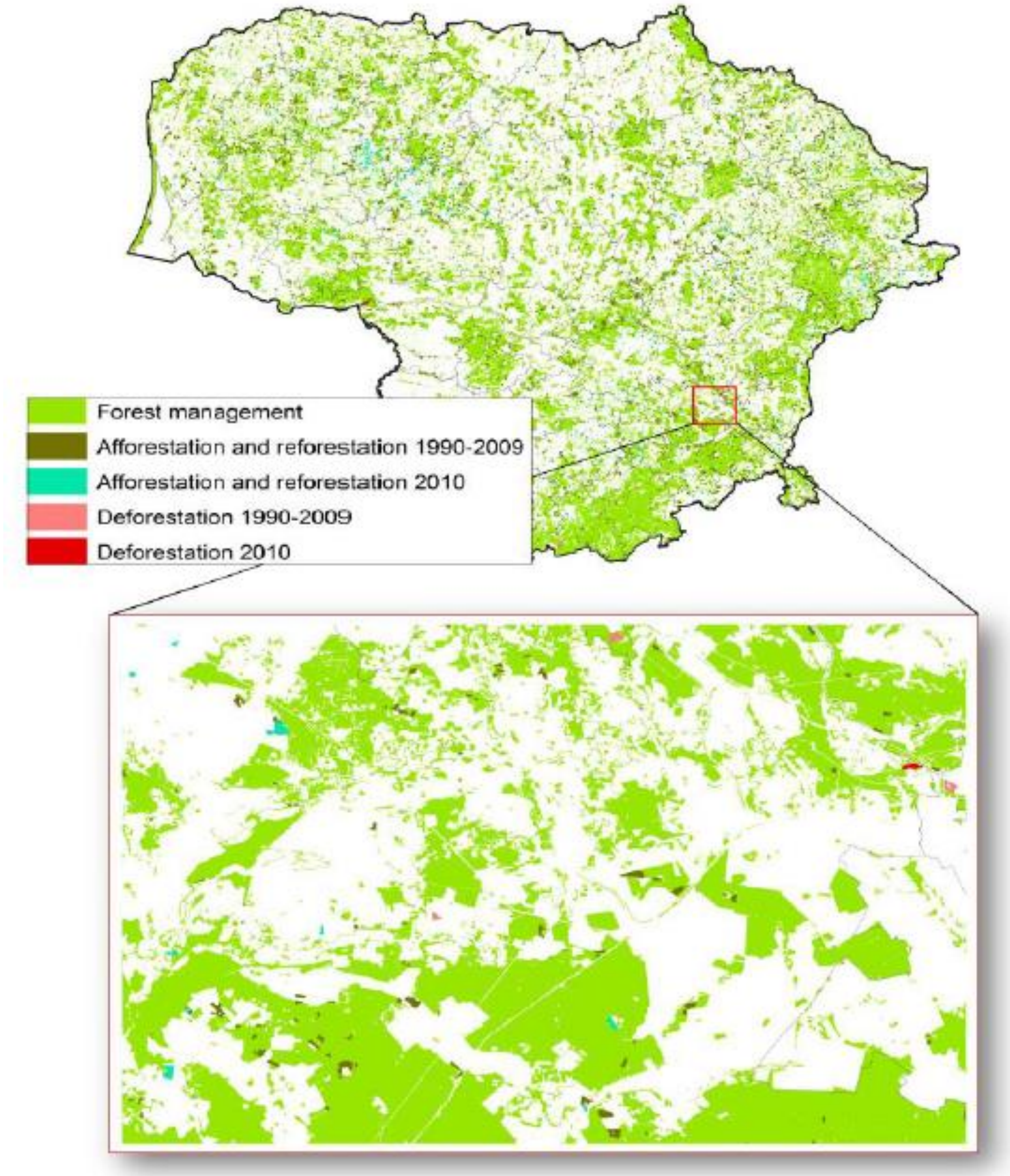


Figure 11-3. Afforestation, reforestation and deforestation activities 1990-2010

To achieve annual wall-to-wall mapping of forest land areas and to detect changes several types of source material were used. These were: SFC, National paying agency's information on agricultural land, afforestation of non-agricultural and abandoned land, Lithuanian forest resource database at a scale of 1:50°000, all available ortho-photos of the country, developed during the analysed period, satellite maps from CORINE, USGS and other projects done by the contractors.

The decision for allocation of certain land areas to relevant land use categories has been made using decision tree with named relevant sources of information and involved organizations who were providing necessary data. Such decision tree was prepared and used throughout the land areas allocation process by study executing team experts (Figure 11-4).

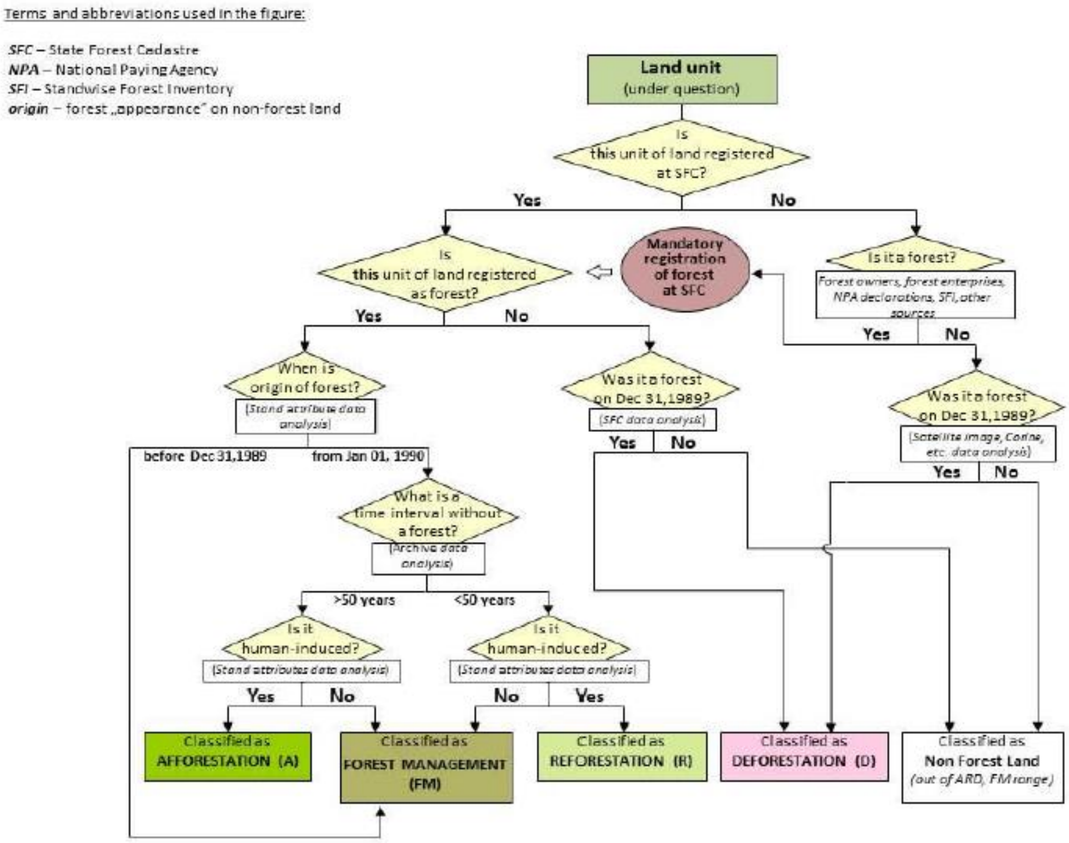


Figure 11-4. Decision tree for land units allocation to relevant land use categories

Codes that were used by experts in *Study-1* for identification of activities on forest land are presented in Table 11-6.

Table 11-6. Codes to identify Article 3.3 and 3.4 activities

Codes used	Descriptions
FM	*Forest management*
A1	*Afforestation (**human – induced**)*
A2	*Afforestation (**natural**; included in Forest management area)*
R1	*Reforestation (**human – induced**)*
R2	*Reforestation (**natural**; included in Forest management area)*
D	*Deforestation*

As could be seen from the table above, two additional groups were distinguished. A2 and R2 are naturally afforested and reforested land areas, with some of them being already included into *SFC* according to Forest Law of the Republic of Lithuania, therefore has the legal protection as a forest land as well as specific rules and restrictions for forestry activities apply in those areas. Such segregation is not required by *2013 KP-Supplement*, yet those areas are consistently supplementing FM area and are used for consistency purposes only.

Areas of human–induced afforestation and reforestation were assessed mainly relying on areas of forest plantations registered either by *SFC* or received as declarations from State Forest Enterprises (*SFE*) and private owners. All registered areas have authorizations and certified forest planting projects (Figure 11-5). Projects must be prepared according to Regulations for afforestation and reforestation (Lietuvos Respublikos Seimas, 2012). Since 2008 most of reforestation cases in Lithuania receive financial support from National Paying Agency and therefore are registered in relevant database.

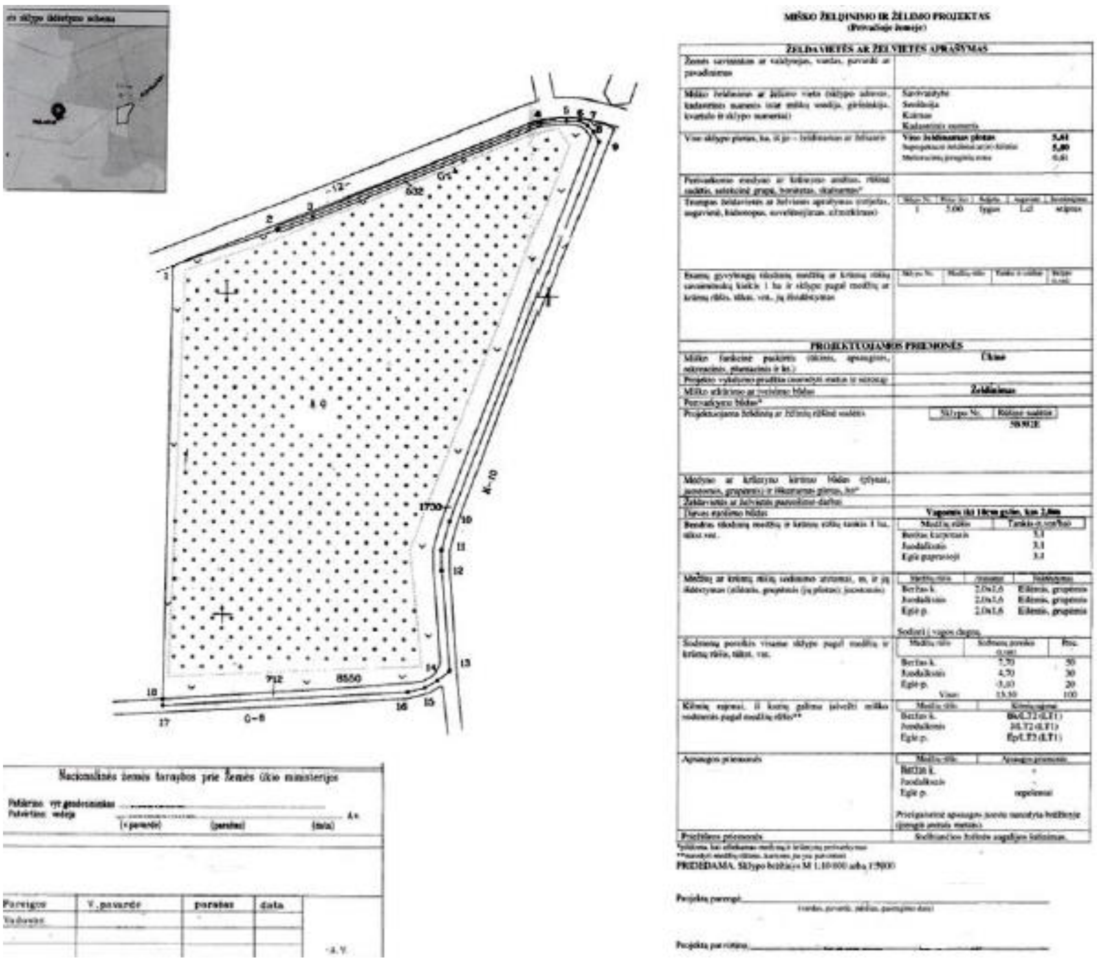


Figure 11-5. Example of forest planting (afforestation/reforestation) project provided to *SFC*

The main data source used for identification of AR and D areas was the geographic data from the *SFC*. These data sets include borders of all forest compartments in Lithuania (around 1.3 million polygons), and is associated with the data describing stand characteristics of the compartment. Age of all stands was updated to fit defined datum-line – the year 2011. Then, the year of forest stand registration to Forest Cadaster was estimated, subtracting the age of stand from 2011 (and adding 10 for naturally regenerated forests, as according to national regulations naturally regenerated forest is accounted under forest land at 10 years age). Then, the origin of each compartment was checked to identify whether the forest appeared on forest or other (i.e. non-forest) land.

Two basic and one additional criteria were used to identify the exact appearance of forest: forest was assumed to be grown on non-forest land if it was attributed in a special attribute field as grown on non-forest land. However, such identification was completely dependent on the content and quality of previously executed standwise forest inventories and there were numerous forest compartments, actually grown on non-forest land, omitted. Therefore, special spatial overlay and selection techniques were developed and applied to identify forests, which were apparently existing, but were missing 50 years ago (according to the database developed and referring to 1950's).

In case of failure ancillary solution how to identify afforestation/reforestation was determined. It was intended to use stand attribute from stand register and posit that forest compartment was first time inventoried during the last standwise forest inventory. However, such approach faced some limitations how to reflect the newly established forests, as the *SFC* data was based on the information originating from *SFI*. *SFI* in Lithuania are carried-out on a 10-years cycle basis, thus, there were some regions with quite outdated information on the compartments and missing the boundaries of stands established already after the stand-wise inventory. Several solutions were used to fill such information gaps.

First of all, information from the recent *SFI* was acquired from forest inventory contractors, which had not been officially delivered to the *SFS* yet. Next, all non-forest compartments stored in the *SFC* database were checked for the records on potentially established forests there. Simultaneously, *SFE* were asked to confirm facts on newly established forests. Data from National paying agency was acquired, to represent borders of afforested areas, which were applied for EU subsidies. Special geo-processing technique was developed to eliminate overlapping in space and time of afforested and reforested areas, resulted by repeated identification of considered areas in independent input data sets.

The decision whether the forest stand detected to be grown on non-forest land was afforestation or reforestation, was taken based on simple spatial queries testing – verifying presence or absence of the forest land at a certain area in 1950s.

Several techniques were used to detect deforested areas during the last two decades. First of all deforestation cases that were accounted under the *SFC* were taken into consideration. There were also records of the officially registered deforestations in *SFC* that were also used for this analysis. Recently non-forest land types identified as forest stands during the previous forest inventories were candidates to be assigned to the deforestation category.

Deforestation was manually mapped using available GIS, ortho-photo and satellite image data. It was assumed, that the GIS database of Lithuanian forest resources at a scale of 1:50°000 developed in 1998-1999 represents the year 1990 as it was based on SPOT satellite images from around 1990-1992 and stand-wise forest inventory maps done before 1991. The accuracy of forest cover identification in that database was confirmed by the *NFI* to be around 95%. Thus, differences between forest covers in the GIS database of Lithuanian forest resources at a scale 1:50°000 and *SFC* were reasoned by the imperfections of the first data set or the deforestation. All such areas were visually inspected and all deforestations were identified using ortho-photos available for Lithuania (referring to 4 dates in the period from 1990). Exact date of deforestation was adjusted using archive satellite data (mainly Landsat, but also coming from SPOT and DMC).

Figure 11-6. Identification of deforestation (D) case using two consecutive ortho-photos

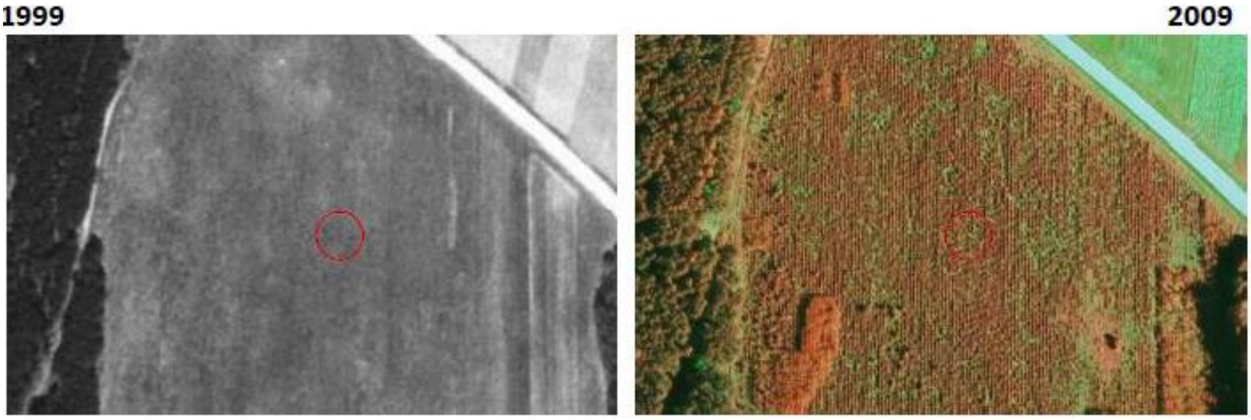


Figure 11-7. Identification of human induced afforestation (A1) based on two consecutive ortho-photos

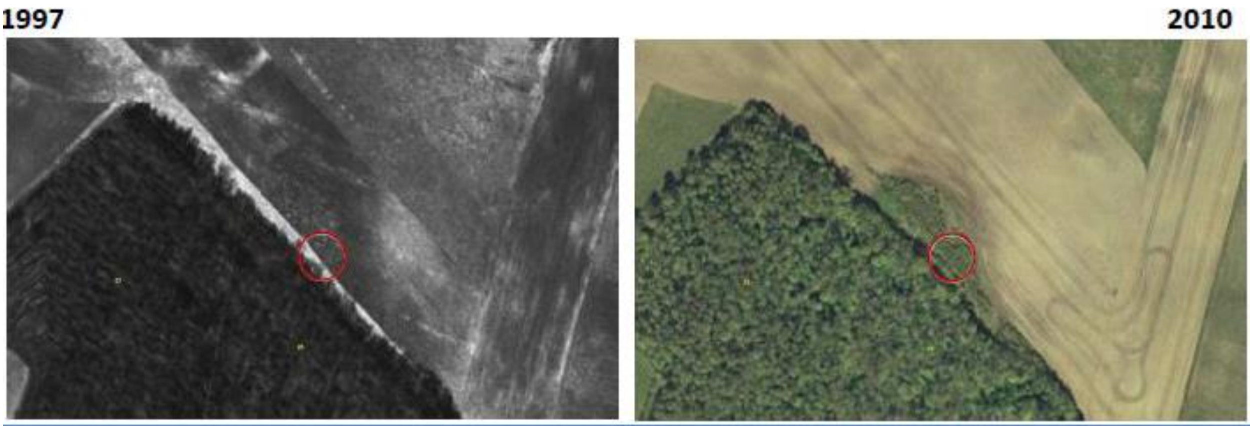


Figure 11-8. Identification of natural afforestation (A2) case using two consecutive ortho-photos

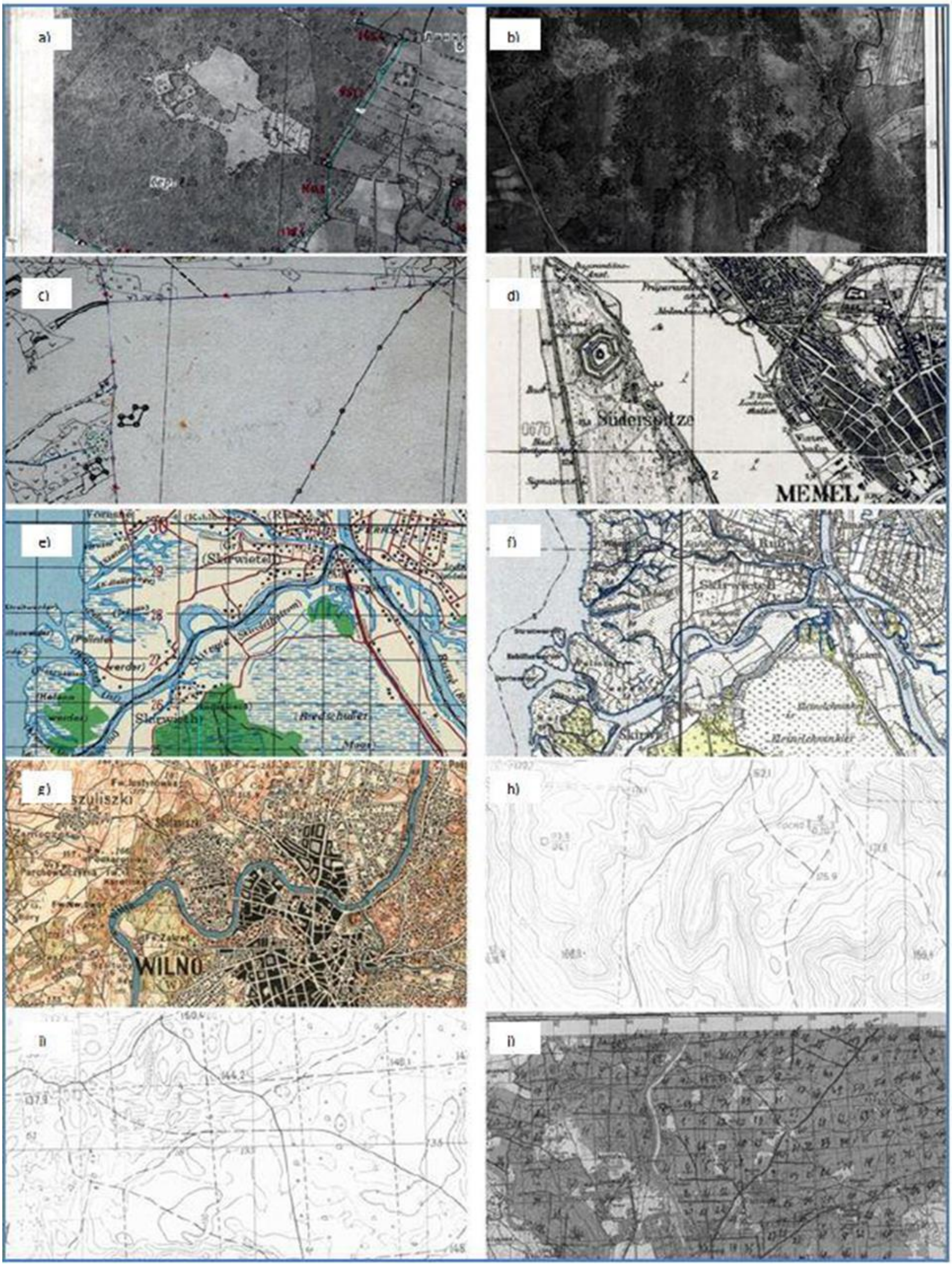


Figure 11-9. Examples of archive cartographical data used for Study-1:

a – scanned ortho-photographic map 1949-1952; b – scanned photography negative of ortho-photographic map 1949-1952; c – ground survey based map; d – German topographic maps compiled in 4-5th decade of the XX century (d - S 1:25°000; f – S1:100°000); e – US army cartography department maps compiled in 1944 (S 1:100°000); g – Polish army cartography department maps of Vilnius compiled in 1934 (S 1:25°000); h – topographical maps of different origin developed in former USSR (h – S 1:10°000; i – S 1:25°000); j – topographical maps in 1942 coordinate system (S 1:50°000)

Lithuania will consider application of high resolution satellite imagery data to validate areas and area changes of afforestation/reforestation, deforestation and forest management activities. Satellite images could be important additional data source to verify accuracy of the spatial data (GIS-layers) applied for estimation of areas of afforestation/reforestation and deforestation activities, as provided by national Paying Agency and State Forest Cadaster for annual GHG inventory.

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment unit for determining the area of land units under Article 3.3 is 0.1 ha, which is the same as the minimum area of forest.

11.2.2 Methodology used to develop the land transition matrix

Figure 11-10 represents annual afforestation and reforestation area alterations and differences between *LSFC* (wall-to-wall method) data, which was used for *Study-1*, and *NFI* (sampling method) data. As it can be seen fluctuations between these two data sources are minor, and confirm consistency among them. Therefore, *NFI* data serves for quality assurance as it rather well reiterates AR areas represented by *LSFC*. *NFI* data was used to determine total forest land area. Afforestation, reforestation and deforestation area was determined using wall-to-wall method described in Chapter 11.2. Forest management area was calculated subtracting afforested, reforested, deforested areas from the total forest land.

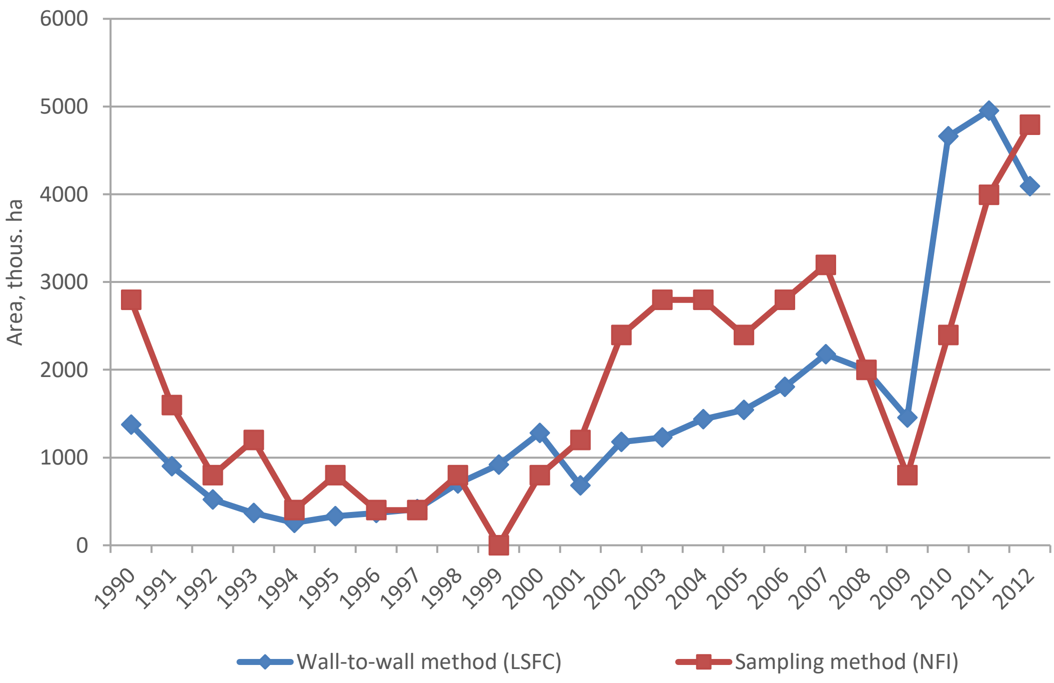


Figure 11-10. Wall-to-wall method quality assurance using *NFI* data

Decrease in afforestation and reforestation area in 2008-2009 was caused by accounting shortcomings. Data base which contains accurate data on afforested and reforested areas was created only in 2009, and some of the areas afforested in 2007-2009 were included in 2010 accounting due to unknown exact establishment date, therefore such a high increase in area in 2010 and decrease in 2008-2009 occurs.

Table 11-7 presents areas and changes in areas between previous and current inventory years.

Table 11-7. Land transition matrix for 2020, thous. ha

To current inventory year / From previous inventory year		Article 3.3 activities		Article 3.4 activities				Other	Total area at the beginning of the current inventory year
		A/R	D	FM	CM	GLM	REV		
		thous. Ha							
Article 3.3 activities	A/R	54.78	0.32						54.78
	D		5.40						5.40
Article 3.4 activities	FM		0.03	2,160.32					2,160.32
	CM	NA	NA		NA	NA	NA		NA
	GLM	NA	NA		NA	NA	NA		NA
	REV	NA			NA	NA	NA		NA
Other*		2.55	NO	4.62	NA	NA	NA	4,315.32	4,308.15
Total area at the end of the current inventory year		57.33	5.72	2,164.94	NA	NA	NA	4,300.66	6,528.65

*"Other" includes the total area of the country that has not been reported under an Article 3.3 or an elected Article 3.4 activity

During the review it was recommended that Lithuania provide additional information on the accuracy of activity data of forest land conversions to other land uses (deforestation) estimated by sampling method (NFI data) and wall-to-wall method (State Forest Cadaster data). Differences between estimated by sampling (reporting under Convention) and wall-to-wall activity data (Kyoto Protocol reporting) of deforestation (forest land converted to other land uses) are presented in the Table below. Comparison in Table 11-8 clearly shows that deforestation activities are very rare in Lithuania, therefore it is not identified every year by sampling method (NFI data source) while it might have been already registered in State Forest Cadaster. Due to the fact that each sampling plot represents 399 ha of total country area and is distributed in 4 × 4 km grid, deforestation activity data is mostly overestimated by sampling method comparing to wall-to-wall maping. It should be noted that because the average annual deforestation area (196 ha, SFC data) is considerably smaller than the area represented by sampling plot (399 ha), forest conversion to other land uses cannot be reported annually for Convention reporting. There might be deforestation activity found in particular year after the wall-to-wall estimation, however in Convention reporting the same deforestation may be tracked in one of the 5 years comprising whole NFI cycle, which leads to area reporting delay comparing to KP reporting. Total activity data difference for the 1990 - 2020 inventory period is 3,687 ha or accumulated deforested area according to NFI data is 37% bigger comparing to State Forest Cadaster (SFC). Average deforested area according to NFI data is 296 ha, while estimated by wall-to-wall method - 196 ha. Standard error for deforested area estimation by sampling method is 180% for annual conversions and 33% for the whole time series (1990 - 2020). Although all deforestation areas have to be registered in SFC according to the law, it can still be minor deforestation cases not included into it (e.g. areas under legal disputes), however accuracy of deforested areas estimated by wall-to-wall method concerning those issues cannot be clearly determined.

Table 11-8. Differences between deforestation activity data obtained by different methods, ha

Year	NFI annual AD	SFC annual AD	NFI cumulative AD	SFC cumulative AD
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	187	0	187
1994	399	97	399	284
1995	0	6	399	290
1996	0	50	399	340
1997	0	36	399	377
1998	0	24	399	401
1999	399	51	799	452
2000	0	16	799	468
2001	0	144	799	612
2002	0	4	799	616
2003	399	5	1,198	621
2004	799	11	1,997	632
2005	399	49	2,396	680
2006	399	0	2,795	680
2007	0	288	2,795	969
2008	0	47	2,795	1,016
2009	399	28	3,195	1,044
2010	0	72	3,195	1,117
2011	0	29	3,195	1,145
2012	0	103	3,195	1,248
2013	0	318	3,195	1,571
2014	0	410	3,195	1,983
2015	0	40	3,195	2,023
2016	399	248	3,594	2,271
2017	799	136	4,393	2,407
2018	1,995	1,966	6,389	4,585
2019	1,596	811	7,987	5,397
2020	1,197	316	9,185	5,717

Differences in carbon stock change in deforested areas could also occur due to the use of different data sources for growing stock volume estimation. Lithuania is using State Forest Cadaster data of growing stock volume from deforested areas starting from 2008. Previously growing stock volume in deforested areas was estimated using mean growing stock volume (m^3 ha^{-1}) from NFI and Study 1 (up to 2002), attributing to the deforestation area, since growing stock volume data from SFC for all deforested areas is available only from 2008 (approx. 10% of deforestation areas growing stock volume still missing in 2008). Mean difference between growing stock volume indicated in NFI database and SFC database for 2008 - 2020 is 13.9%, excluding 2010 with 73.5% larger growing stock volume indicated in NFI database comparing to SFC. Comparing growing stock volume difference for years 2008 - 2020, 19.2% larger GSV from NFI database was indicated.

Table 11-9. Differences between growing stock volume from different databases, m^3

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
SFC data	9,843	6,667	4,399	6,742	22,666	64,493	89,306	9,579	55,672	25,677	412,491	193,920	81,896
NFI data	10,456	6,336	16,601	6,805	24,459	78,084	98,926	9,662	61,132	33,673	514,546	213,472	84,242
Relative difference, %	5.9	-5.2	73.5	0.9	7.3	17.4	9.7	0.9	8.9	23.7	24.7	10.1	2.8

11.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

Lithuanian State Forest Cadastre

The total forest land area was estimated using *NFI* data, but for consistency *LSFC* maps (S 1:10°000) and database were used.

NFI data was used to determine total forest area and area under FM category as well as for estimations of living biomass, deadwood, area of organic soils etc. for FM and afforestation, reforestation, deforestation activities.

After the *Study-1* which was used to recover unknown information on ARD areas for the period 1990-2011, *SFC* was named as the main data provider for newly afforested, reforested and deforested areas by the Amendment of the Governmental Resolution No 1255 that was adopted in 2012. Several legal acts were also introduced in 2012 setting rules and routines and also obliging forest owners and enterprises to provide information on human induced afforestation, reforestation and deforestation as well as natural AR to *SFC*:

- *Resolution on forest land conversion to other land and compensation for converted forest land*/Government resolution – regulates human induced conversion of forest land to other land (deforestation) and compensation for lost forest land.
- *Rules for afforestation of non-forest land*/Amendment of the Minister of Environment and Minister of Agriculture – determines human induced afforestation/reforestation registration routines.
- *Inventory and registration of natural afforestation of non-forest land*/Order of the Minister of Environment and Minister of Agriculture – determines natural afforestation/reforestation inventory and assessment routines.

LSFC database is presented in Figure 11-11. The database:

- covers 100% country's forest land territory, GIS based;
- easy accessible on web for registered users;
- open for forest managers, controllers and other specialists;
- user friendly;
- up to date;
- real time.

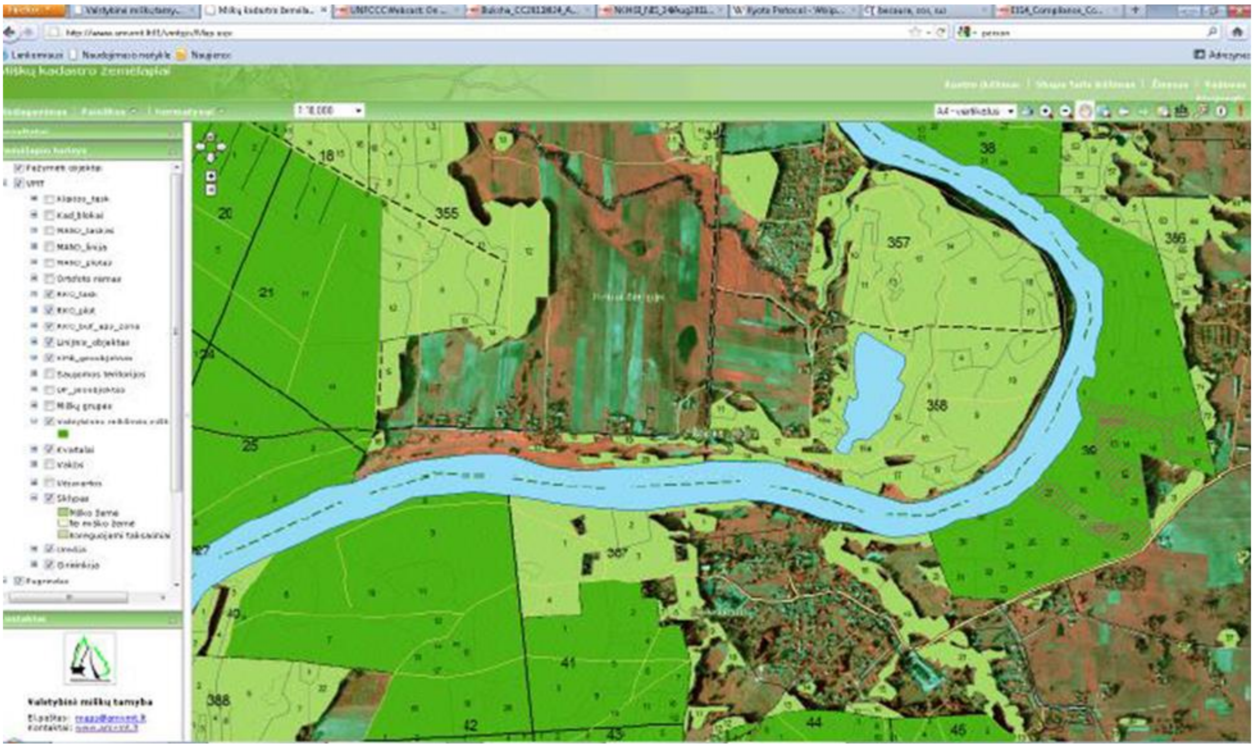


Figure 11-11. Preview of LSFC database

The main object of Lithuanian *NFI* is forest land area including all forestry related activities. The purpose of the *NFI* is strategic planning of the forest sector, control of its efficiency at the National level. Execution of *NFI* is entrusted to SFS under Ministry of Environment.

National Forest Inventory

NFI is based on continuous, multistage sampling and GIS integrated technology and is organized in the same manner for all forests of Lithuania. Lithuanian *NFI* was started in 1998. The systematic grid of the *NFI* of Lithuania covers all land classes (Figure 11-12) including inland waters.

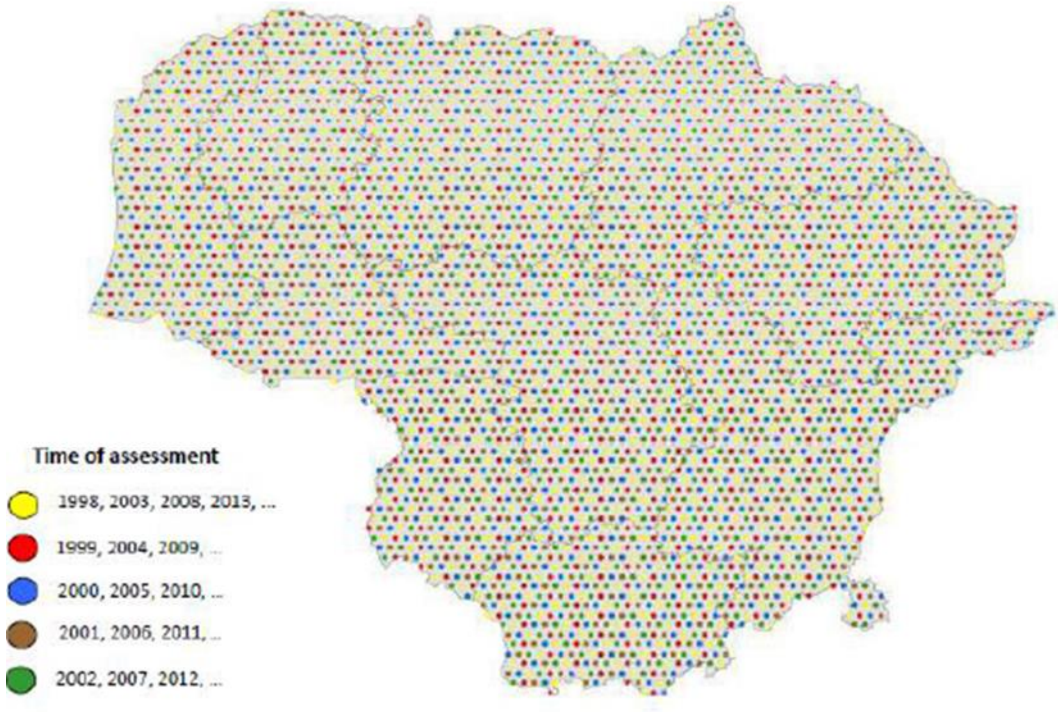


Figure 11-12. Distribution of *NFI* plots on Lithuania's territory

Sampling is conducted using a 4×4 km systematic grid with a random starting point.

The systematic grid assures a uniform distribution of group of plots over the entire country and regular monitoring of conversions amongst land use categories. The sample units are arranged to square shape clusters and include four permanent, regularly measured plots.

Taking into account number of homogeneous stands (strata), minimal growing stock volume and increment estimation accuracy, 5600 permanent sample plots were established on forest land over a 5-year period. Approximately 1120 permanent sample plots are re-measured each year. The *NFI* plots covers the entire country each year with the total number of plots measured over the 5-year inventory cycle reaching a sampling intensity of one sample plot per 400 ha.

In 2012, in total around 16000 permanent sample plots were established on Lithuanian territory using unique *NFI* sample plots net. 6000 sample plots are allocated on forest land and nearly 10000 sample plots are established on non-forest land. Allocation of each permanent sample plot to relevant land use category is presented in the Figure 11-13. Each sample plot could be allocated to only one land use category according to UNFCCC requirements. *NFI* net with all permanent sample plots covers entire Lithuanian territory. Attribution of each permanent sample plot to relevant land use category related to *IPCC 2003* is performed during the inventory, by direct measurements of *NFI* field measurements team.

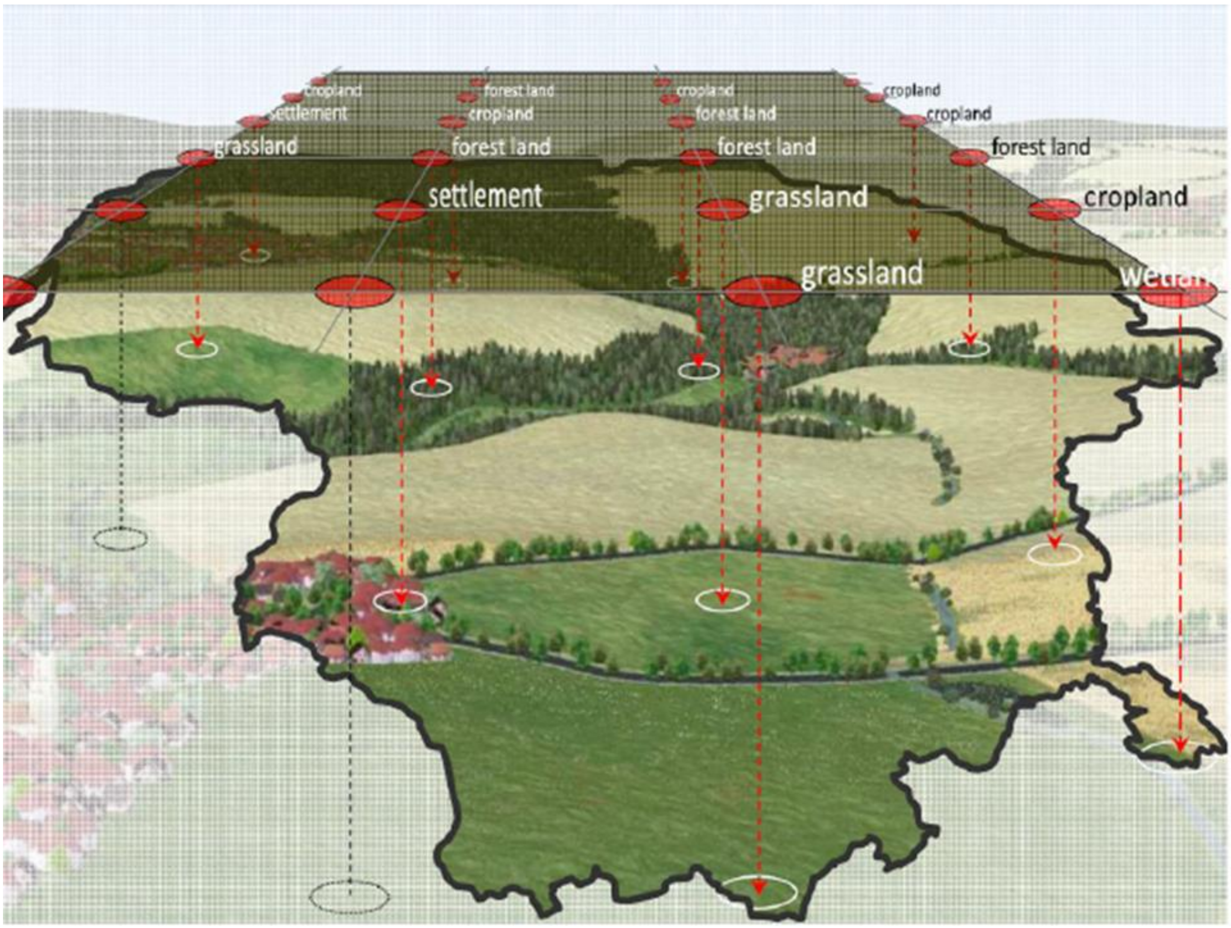


Figure 11-13. Allocation of sample plots to relevant land use category

The aim of establishment of permanent plots is reliably, by direct measurements estimate: growing stock volume, gross volume increment, mortality and felled trees, to control the dynamics of forest areas in the country.

11.3 Activity-specific information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

11.3.1.1 Description of the methodologies and the underlying assumptions used

Living biomass pool in this GHG inventory refers to aboveground biomass and belowground biomass. For the estimation of carbon stock changes in living biomass in afforested and reforested areas, growing stock volume of afforested and reforested areas estimated using data of *NFI* permanent sample plots and mean growing stock volume of afforested/reforested areas according to the year of afforestation and reforestation (Table 11-11). 3rd order polynomial trend was used to come up with the mean growing stock volume and mean growing stock volume change (Table 11-10) of afforested and reforested areas per hectare.

Above and below ground biomass for deforestation was calculated separately from emissions and removals under FM.

Growing stock volume for deforested areas was calculated using deforested area which is detected using wall-to-wall method and mean growing stock volume from State Forest Cadaster in actual deforested areas. For deforestation cases on afforested or reforested areas, actual growing stock volume, calculated from polynomial trend was used to calculate biomass carbon stock changes. However, deforestation events in afforested/reforested areas are very rare (4 ha in 2016 for example), therefore mean GSV detected by *NFI* is the same as mean GSV of FM.

Growing stock volume as well as emissions or removals of above and below ground biomass of deforested areas is calculated as losses (emissions) only as it is assumed that all above and below ground biomass is removed entirely during conversion process of Forest land to Wetlands, Settlements, Other land. One should be considered that if forest land is converted for instance to Settlements deforestation should be applied only during conversion process and this area cannot be kept as deforested forever because new green areas (parks, individual trees etc. of residential areas) usually emerge after buildings construction and starts to accumulate greenhouse gases, but Lithuania has no technical possibilities to track and to estimate such small green areas or individual trees.

Growing stock volume change for afforested and reforested areas was estimated by using equation presented below:

$$\Delta V = \sum \left[A_i \cdot \left(V_{t_2} - V_{t_1}\right)\right]$$

where:

ΔV - GSV change on afforested/reforested land, m^3;

A_i - area according to land use category, ha;

V_{t1} - GSV at time t_1, m^3;

V_{t2} - GSV at time t_2, m^3.

Annual change in carbon stocks in living biomass in land converted to Forest land was calculated by using eq. 2.15 (p. 2.20 of *IPCC 2006*):

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

where:

ΔC_B - annual change in carbon stocks in living biomass in land converted to forest land, tonnes C yr^{-1};

ΔC_G - annual increase in carbon stocks in living biomass due to growth in land converted to forest land, tonnes C yr^{-1};

$\Delta C_{CONVERSION}$ - annual change in carbon stocks in living biomass due to actual conversion to forest land, tonnes C yr^{-1};

ΔC_L - annual decrease in carbon stocks in living biomass due to losses from harvesting, fuel wood gathering and disturbances in land converted to forest land, tonnes C yr^{-1}.

Annual change in carbon stocks in living biomass due to actual conversion to forest land was calculated employing eq. 2.16 (p. 2.20 of *IPCC 2006*):

$$\Delta C_{CONVERSION} = \sum_i \left\{ \left[B_{AFTER_i} - B_{BEFORE_i} \right] \cdot \Delta A_{TO_{FORESR_i}} \right\} \cdot CF$$

where:

$\Delta C_{CONVERSION}$ - change in carbon stocks in living biomass in land annually converted to forest land, tonnes C yr^{-1};

$B_{BEFOREi}$ - biomass stocks on land type i immediately before conversion, tonnes d. m. ha^{-1};

B_{AFTERi} - biomass stocks that are on land immediately after conversion of land type i, tonnes d. m. ha^{-1} (in other words, the initial biomass stock after artificial or natural regeneration);

$\Delta A_{TO\_FORESTi}$ - area of land-use i annually converted to forest land, ha yr^{-1};

CF - carbon fraction of dry matter (broadleaves – 0.48; coniferous – 0.51), tonnes C (tonne d. m.)$^{-1}$ (Table 4.3, p. 4.48 of *IPCC 2006*);

i - represent different types of land converted to forest.

B_{BEFORE} value equals to 2.4 t d. m. ha^{-1} (Table 6.1, p. 6.8, Ch. 6, *2006 IPCC Guidelines*) in above-ground biomass in grassland and 11.2 t d. m. ha^{-1} in below-ground biomass in grassland (calculated from Tables 6.4, p. 6.27 and 6.1 p. 6.8, Ch. 6, *2006 IPCC Guidelines*) prior to the conversion to forest land and was used to calculate biomass carbon stock losses due to the conversion. In order to estimate carbon stock losses after annual and perennial cropland is converted to forest land, default above-ground biomass stock values of 10 t d. m. ha^{-1} for annual cropland (p. 6.27, Ch. 6, *2006 IPCC Guidelines*) and 63 t C ha^{-1} for perennial cropland (Table 5.1, Ch. 5, *2006 IPCC Guidelines*) were applied in eq. 2.16 as B_{BEFORE} values.

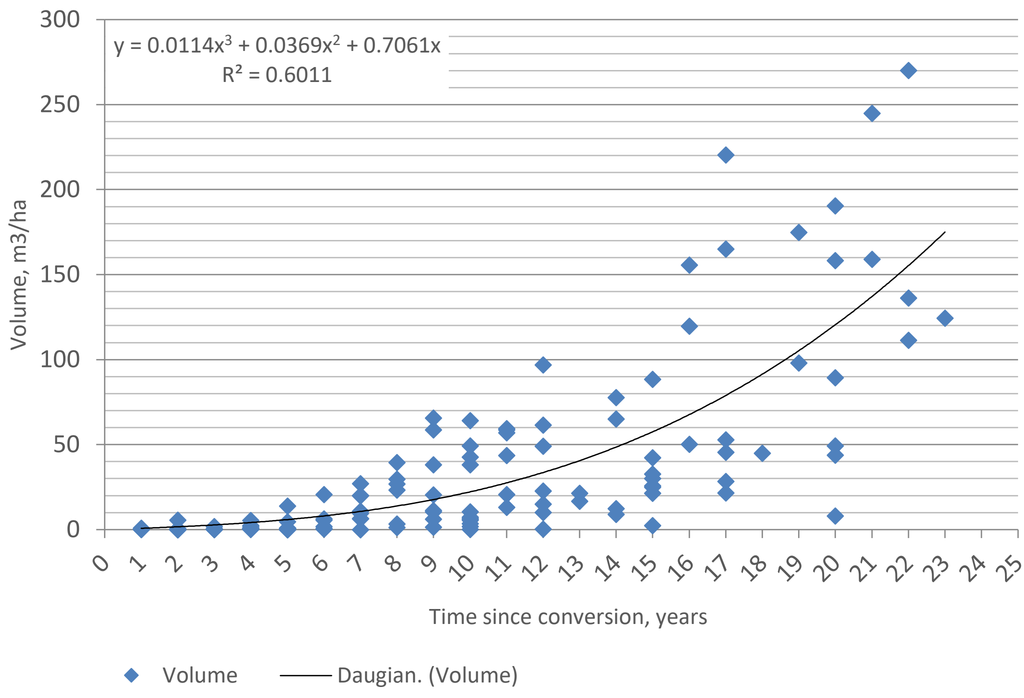


Figure 11-14. NFI data on growing stock volume of afforested and reforested (A1R1) areas

Share between coniferous and deciduous tree stands volume was used in order to estimate more accurate carbon stock change in A/R biomass. Share between coniferous and deciduous tree stands volume was calculated accordingly to the one in forest management and was equal to 61.5 percent of coniferous and 38.5 percent of deciduous in 2018. There were few deforestation events in A/R areas, therefore both area and volume of deforested A/R category was excluded from A/R.

Table 11-10. Mean growing stock volume and mean growing stock volume change per ha for afforested and reforested (A1R1) areas at the time of afforestation/reforestation

Time since conversion	Mean growing stock volume, m^3/ha	Mean growing stock volume change, m^3/ha
1	0.8	0.8
2	1.7	0.9
3	2.8	1.1
4	4.1	1.4
5	5.9	1.7
6	8.0	2.1
7	10.7	2.6
8	13.8	3.2
9	17.7	3.8
10	22.2	4.5
11	27.4	5.3
12	33.5	6.1
13	40.5	7.0
14	48.4	7.9
15	57.4	9.0
16	67.4	10.1
17	78.7	11.2
18	91.2	12.5
19	104.9	13.8
20	120.1	15.2
21	136.7	16.6
22	154.8	18.1

Time since conversion	Mean growing stock volume, m^3/ha	Mean growing stock volume change, m^3/ha
23	174.5	19.7
24	195.7	21.2
25	217.0	21.2
26	238.2	21.2
27	259.4	21.2
28	280.6	21.2
29	301.9	21.2
30	323.1	21.2

Growing stock volume changes according to the time after conversion are not provided separately for coniferous and deciduous stand due to the lack of data, however, share between coniferous and deciduous is applied as observed in forest management category. Figure 11-14 and Table 11-11 show data of growing stock volume changes in human induced afforestation and reforestation. Growing stock changes in stands of natural forest expansion are excluded from this data.

The estimation of carbon stock changes in living biomass in areas referring to FM is consistent with the *Method 2* further described in the *2013 KP-Supplement*, which is also identified as the stock change method. Estimations of carbon stock changes by using this method requires biomass carbon stock inventories for a given forest area in two points in time. Biomass change is the difference between the biomass at time$_2$ and time$_1$, divided by the number of years between the inventories (eq. 2.8, p. 2.12 of *2006 IPCC Guidelines*):

$$\Delta C_{LB} = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)} \quad \text{and} \quad \Delta C_{LB} = \sum_{i,j}\{A_{i,j} \times V_{i,j} \times BCEF_{i,j} \times (1 + R_{i,j}) \times CF_{i,j}\}$$

(eq. 2.8)

where:

ΔC_{LB} - annual change in carbon stock in living biomass (includes above- and belowground biomass) in total forest land, t C yr^{-1};

C_{t2} - total carbon in biomass calculated at time t_2, t C;

C_{t1} - total carbon in biomass calculated at time t_1, t C;

A - area of land remaining in the same land-use category, ha;

V - merchantable growing stock volume, m^3 ha^{-1}

i - ecological zone i (i = 1 to n)

j - climate domain j (j = 1 to m)

BCEF - biomass conversion and expansion factor for expansion of merchantable growing stock volume to above-ground biomass, tonnes above-ground biomass (m3 growing stock volume)$^{-1}$. Due to the national BCEFs unavailable, Lithuania is multiplying basic wood density (D, 0.41 for coniferous, 0.47 for deciduous) with biomass expansion factor (BEF, 1.221 for coniferous, 1.178 for deciduous) to get BCEF.

R - ratio of below-ground biomass to above-ground biomass, tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$, 0.26 for coniferous and 0.19 for deciduous (Table 4.4, p. 4.49 of *2006 IPCC Guidelines*)

CF - carbon fraction of dry matter (broadleaves – 0.48; coniferous – 0.51), tonnes C (tonne d. m.)$^{-1}$ (Table 4.3, p. 4.48 of *2006 IPCC Guidelines*).

Annual growing stock volume (GSV) change for FM from 2007 was estimated based on *NFI* data using the following steps:

1) Annual GSV change in all forest area (total FM and afforested/reforested area) is estimated by sampling method. This estimation is based on the change of GSV on the same area (re-measured permanent sample plots data $V_{remt2} – V_{remt1}$);
2) Annual GSV change of afforested/reforested area is estimated combining wall-to-wall and sampling methods. Estimation is based on area assessment by wall-to-wall method and mean GSV assessment by sampling method which is derived using relationship between mean GSV and age of forest in permanent plots of afforested/reforested areas (Figure 11-14);
3) Estimation of annual GSV change in FM area is based on the difference of all forest annual GSV change (step 1) and annual GSV change of afforested/reforested area (step 2).

The equations presenting calculations on growing stock volume change in FM area are shown below:

$$\Delta FF_t = \left(\left(V_{rem_{t2}} - V_{rem_{t1}}\right)\right) - \Delta A1R1$$

where:

ΔFF_t - growing stock volume change for FM for the defined year, m^3;

V_{remt1} - growing stock volume calculated at time t_1, m^3;

V_{remt2} - growing stock volume calculated at time t_2, m^3;

ΔA1R1 - growing stock volume change of afforested/reforested areas, m^3.

Carbon stock changes in dead wood, litter and soil

Lithuania is not reporting carbon stock changes in dead wood in afforestation/reforestation activities due to the lack of data on significant accumulation of dead wood (there were no dead wood elements measured during field measurements in newly afforested/reforested areas). Dead wood, which can possibly occur in newly afforested/reforested areas is small and usually decay in one year. Deadwood pool under afforestation/reforestation activities was calculated based on actual NFI measurements data, carbon stock change of dead wood would account on average only 5 tonnes of CO_2 eq. per year. Taking into account that for Lithuania threshold of significance according to paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines would account about 10 kt CO_2 eq. in 2019 and that total sum of insignificant inventory categories is around 3 – 4 kt CO_2 eq., Lithuania assumed that emissions from deadwood pool under afforestation/reforestation activities can be treated as insignificant and reported as "NO". However, carbon stock changes in living biomass of afforested/reforested areas include biomass losses due to the mortality, as carbon stock change in living biomass is calculated using data of growing stock volume changes, which includes both growing stock volume increment and mortality (modelled curve, Figure 11-14). Losses in living biomass occur also due to the biomass lost during conversion and are reported separately as losses in CRF. Carbon stock changes in dead wood pool could be reported after the significant accumulation of dead wood is observed in the areas of natural forest expansion and could be modelled for A/R activities carbon stock change evaluation. The dead wood starts to accumulate when natural mortality or thinning occur that is at the age of over 20 years.

Annual change in carbon stocks in dead organic matter in FM is calculated following the summarising equation for calculation of changes in dead organic matter carbon pools which is equal to the sum of carbons stock in dead wood (measured available dead wood) and carbon stock in dead wood that is left on site after felling (BGB). Dead wood that is left on site after felling is assumed to be below-ground biomass i.e. roots. It is assumed that BGB decays in equal parts in 5 years. Equation 2.17 (p. 2.21 of *IPCC 2006*) has been used to calculate carbon stock change in dead organic matter:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{DWH} + \Delta C_{LT}$$

where:

ΔC_{DOM} - annual change in carbon stocks in dead organic matter, t C yr^{-1};

ΔC_{DW} - change in carbon stocks in dead wood (measured available dead stems), t C yr^{-1};

ΔC_{DWH} - change in carbon stocks in dead wood (BGB left on site after felling), t C yr^{-1};

ΔC_{LT} - change in carbon stocks in litter, t C yr^{-1}.

Annual change of biomass of dead trees stems is calculated using stock change method and employing eq. 2.19 (p. 2.23 of *2006 IPCC Guidelines*).

It was assumed that carbon stock in litter in afforested and reforested areas accumulates in 20 years period and then it remains stable. The average value of carbon stock in litter is 7.39 t per ha, estimated from the national study on carbon stocks in different land uses, performed by Lithuanian Agriculture and Forestry Research Centre, Institute of Forestry. This value was accepted for Forest land and used to calculate litter carbon stock loss due to deforestation. Annual carbon stock changes in litter in land converted to forest land were estimated using national values of litter carbon stock, evaluated during the similar study for carbon stock estimation in new forests, conducted by Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry under the GHG inventory partnership project between Lithuania and Norway. The average value of carbon stock in litter is 1.2 t per ha per 10 years (after the conversion from agricultural land, which in average contains 0.4 t C per ha in litter) and 2.5 t C per ha in 20 years.). Annual carbon stock change in litter in land converted to forest land was estimated for three time periods: 0-10 years - (1.2 t C ha^{-1} - 0.4 t C ha^{-1})/10 years; 11-20 years - (2.5 t C ha^{-1} - 1.2 t C ha^{-1})/10 years; 21 – 30 years – (3.6 t C ha^{-1} – 2.5 t C ha^{-1})/10. Change in carbon stock in litter in AR areas was calculated using area from annual AR conversion matrix (Table 11-11).

Table 11-11. Aggregated data of growing stock volume and annual carbon stock changes in living biomass and litter of afforested and reforested areas

Year	A1R1 annual area, ha	A1R1 cumulative area, ha	Total volume, thous. m³	Annual volume change, thous. m³	Carbon stock change in living biomass, kt C	Carbon stock change in litter, kt C
1990	1,373.5	1,373.5	1.04	1.04	0.33	0.11
1995	331.1	3,751.4	20.17	6.12	1.96	0.30
2000	1,280.1	7,432.6	85.58	19.59	6.25	0.66
2005	1,542.1	13,494.2	263.10	49.17	15.70	1.27

2010	4,659.0	25,583.4	673.52	109.93	35.11	2.39
2015	3,482.8	44,598.8	1,541.05	220.61	70.47	4.16
2016	1,425.0	46,023.8	1,787.26	246.21	78.65	4.36
2017	6,863.3	52,887.1	2,065.48	278.22	88.88	5.01
2018	1,215.9	54,103.0	2,375.19	309.71	98.94	5.20
2019	903.5	53,633.0	2,674.36	299.17	95.57	4.68
2020	2,557.3	55,289.3	3,051.48	377.12	120.48	5.51

NFI provides data on forest land distribution by forest soils (Table 6-9, Chapter 6.2.1). According to *NFI (2nd cycle of NFI, 2003 - 2007)* data, area of mineral soils amounts to 86.4% and area of organic soils – 13.6% of the total forest area. Drained organic forest soils constitute to 6.9% of the total forest land. Due to the lack of accurate data on drained organic soils in afforested and reforested areas, it was assumed that the same proportion of drained organic soils as it is accepted for Forest land remaining Forest land category refers also to afforested and reforested areas. The proportion was distributed to afforested/reforested Croplands, Grasslands and Wetlands. It was also assumed that all area of Wetlands is under organic soils.

Carbon stock change in mineral and organic soils in afforested/reforested areas were calculated using national carbon stock values in afforested/reforested areas, cropland and grassland while carbon stock changes in wetlands converted to forest land was calculated using EF estimated by Finland (Finish NIR 2013, appendix_7g). SOC_0 equals 55.3 t C ha^{-1} for forests in age group of 0 to 10 years, 58.8 t C ha^{-1} for forests in age group of 11 to 20 years and 57.7 t C ha^{-1} for forests in age group of 21 – 30 years, the initial values of carbon stocks in grassland before conversion to cropland equals to 48.3 t C ha^{-1} and 38.2 t C ha^{-1} in cropland in mineral soils. SOC_0 values in newly afforested/reforested areas on organic soils for same three age groups are as follow: 283.9, 243.9 and 277.6 kt C ha^{-}1, initial carbon stock in cropland prior to the conversion equals 221.3 t C ha^{-1} and in grassland – 191.2 t C ha^{-1}. Carbon stock changes in organic soils were estimated separately for forested Croplands, Grasslands and Wetlands. Due to the lack of information in forest planting projects at the SFC on the exact land use before afforestation or reforestation, area of afforested/reforested Croplands, Grasslands and Wetlands was estimated using *NFI* sample plots data on land use areas distribution and assuming the same proportion of Croplands, Grasslands, Wetlands were afforested and reforested. Carbon stock changes in mineral soils for afforested/reforested Settlements and Other lands was not estimated due to the lack of data of carbon stock prior to the conversion, however, it could be assumed that carbon stock in mineral soils are equal to zero, because there is no organic soil layer on such lands before the afforestation/reforestation and carbon stock gains could be estimated in mineral soils.

Table 11-12. Carbon stock changes in soil organic matter (SOM) in lands converted to forest land mineral and organic soils, kilotonnes C per ha

Year after conversion	Cropland mineral	Cropland organic	Grassland mineral	Grassland organic	Wetlands organic
1	0.16	0.01	0.59	0.56	-0.49
2	0.26	0.01	0.98	0.92	-0.81
3	0.32	0.01	1.21	1.13	-0.99
4	0.37	0.01	1.37	1.28	-1.11
5	0.40	0.02	1.48	1.38	-1.19
6	0.44	0.02	1.62	1.52	-1.30
7	0.48	0.02	1.78	1.67	-1.42
8	0.53	0.02	1.95	1.83	-1.56
9	0.61	0.02	2.26	2.12	-1.79
10	0.71	0.03	2.65	2.49	-2.11
11	0.74	0.02	2.91	2.21	-2.54
12	0.73	0.02	3.01	1.96	-2.76

13	0.82	0.02	3.41	2.14	-3.16
14	0.93	0.03	3.86	2.42	-3.57
15	1.07	0.03	4.42	2.85	-4.05
16	1.22	0.03	5.02	3.28	-4.57
17	1.40	0.04	5.72	3.80	-5.17
18	1.61	0.05	6.57	4.44	-5.90
19	1.78	0.05	7.28	4.84	-6.56
20	1.86	0.05	7.71	4.90	-7.02
21	2.24	0.07	9.04	6.48	-8.62
22	2.72	0.09	10.78	8.38	-10.32
23	3.07	0.11	12.14	9.52	-11.69
24	3.29	0.11	13.02	10.11	-12.62
25	3.56	0.12	14.18	10.81	-13.78
26	3.81	0.13	15.26	11.43	-14.90
27	3.80	0.12	15.38	11.08	-15.27
28	4.38	0.14	17.75	12.73	-17.59
29	4.32	0.13	17.65	12.29	-17.85
30	4.26	0.13	17.47	12.08	-18.12

Carbon stock change in drained organic forest soils for FM was calculated using eq. 2.26 (p. 2.35, of *IPCC 2006*):

$$\Delta C_{FOS} = A_{Drainage} \cdot EF_{Drainage}$$

where:

ΔC_{FOS} - CO_2 emissions from drained organic forest soils, t C yr^{-1};

$A_{Drainage}$ - area of drained organic forest soils, ha;

$EF_{Drainage}$ emission factor for CO_2 from drained organic forest soils, t C ha^{-1} yr^{-1}.

Default value of EF for drained organic soils in managed forests provided in Table 4.6 (p. 4.53, of *2006 IPCC Guidelines*) was used in calculations. Default $EF_{Drainage}$ for temperate forests is 0.68 tonnes C ha^{-1} yr^{-1}.

For calculations on carbon stock changes caused by conversion (deforestation) of forest land to settlements and other lands it was assumed that all above and below ground forest biomass as well as dead wood and litter – organic matter was removed entirely as a result of conversion. For deforestation which occurred on Forest management area, mean biomass stock that is lost for the year of deforestation was used.

Lithuanian forests since 1990 showed a continuous increase in per hectare density of carbon stocks in the biomass and dead mass carbon pools; same trend is observed over the whole Baltic region. The increased amounts of living biomass and dead mass causes increasingly quantity of organic material being transferred to the litter and soil organic carbon (SOC) pools, so potentially determining an accumulation of organic carbon. Therefore, Poland, Sweden and Finland are accounting for net carbon-stock increases in both pools; while Germany have not found significant changes and is not accounting for both.

A study performed by the EU all over its territory – the *Biosoil* project; for Lithuanian forests shows a slightly, not significant, increase in soil carbon stocks from 1992 to 2006 (EU JRC, Evaluation of BioSoil Demonstration Project) (Table 11-13).

Table 11-13. Mean carbon stock in forest land according to the soil monitoring in ICP-Forest sample plots Level I 1992 and 2006

Year	Mean carbon stock in litter, g/kg	Mean carbon stock in mineral soil (0-10 cm depth), g/kg	Mean carbon stock in mineral soil (10-20 cm depth), g/kg	Research activity
1992*	370.69 ± 12.8	29.1 ± 4.4	15.6 ± 2.8	Soil monitoring in *ICP-Forests* 74 sample plots Level I
2006	399.0 ± 96.6	29.9 ± 18.2	15.8 ± 11.6	"*Biosoil*" project in *IPC-Forests* 62 sample plots Level I

**Due to some differences in sampling and analyses methods data adopted with some assumptions*

Not having proof of significant increase in mineral soils in forest land and having information that this pool is not a source, Lithuania has decided to be conservative and consequently not to account for this pool under FM (including areas of natural afforestation/reforestation, which are included into FM, see chapter 11.2) therefore reported as 'NE'. However Lithuania is calculating carbon stock changes in litter in naturally afforested/reforested areas and in drained organic forest soils which are under Forest management category (including natural AR areas).

Biomass burning

Data on areas affected by forest fires is provided by the *DGSF* (Table 11-15). *DGSF* under the Ministry of Environment performs the functions of founder of forest enterprises and coordinator of their activities as well as legislator of mandatory norms for forest enterprises regarding reforestation, protection and management of State forests.

Lithuania is one of the few Europe countries that have uniform system of state fire prevention measures, comprising monitoring, preventive and fire control measures that are established and maintained in forests irrespective of forest ownership type. Every forest enterprise provides data on forest fires to the *DGSF* every year.

A unique fire assessment system has been established in Lithuania since 2013. *SFS* together with General Directorate of State Forests has worked out a methodology to assess forest fire after-effects in terms of GHG accounting directly *in situ*.

Special assessment table has been established which has to be filled with detail information on the fire. The table contains information which allows allocating forest fire, to estimate area that was burnt and to assess damage that has been done in terms of GHG accounting. In the table below only partial information that should be filled in the forest fire assessment table is presented. The first part of this table contains information on owner of forest (*SFE*), unique forest fire number, date, forest district, block number, site number and coordinates.

Percentage of burnt biomass is expressed by codes that are used by fire damages assessing experts from SFE or local forest districts.

Volume of burnt biomass of the area affected by forest fire is estimated by overlapping GIS layers of the centre coordinate of fire location and data of the total growing stock volume by *SFI*. Burnt peat depth is expressed in centimetres of average burnt peat layer over the fire site and is estimated by assessing persons.

Prescribed or controlled burning of forest biomass is not used in Lithuania.

GHG emissions (CO_2, CH_4, N_2O) resulting from wildfires for afforestation and reforestation activities and FM were calculated separately in this submission. Data on wildfires occurring on afforested and reforested areas was received from *DGSF*. GIS layer of burnt AR areas, based on *DGSF* data, was prepared and intersected with *Study-1* GIS layer of afforested and reforested areas (A1R1), to receive complete information on areas for GHG emissions calculations. Burned area of FM was calculated by subtracting burnt area of afforested and reforested areas form the total burn forest land area.

Table 11-14. CO_2 emissions from biomass burning (kt) and area of ARD and FM that was burned (ha)*

Year	Afforestation & Reforestation		Deforestation		Forest Management	
	Area burned, ha	kt CO_2	Area burned, ha	kt CO_2	Area burned, ha	kt CO_2
2008	1.93	0.005	NO	NO	110.47	1.208
2009	3.06	0.008	NO	NO	312.24	3.394
2010	2.17	0.005	NO	NO	19.33	0.227
2011	2.78	0.007	NO	NO	290.02	3.151
2012	1.20	0.003	NO	NO	19.09	0.216
2013	NO	NO	NO	NO	24.70	0.192
2014	0.8	0.002	NO	NO	160.70	1.817
2015	0.68	0.002	NO	NO	70.17	0.609
2016	1.48	0.005	NO	NO	24.47	0.251
2017	NO	NO	NO	NO	52.86	0.556
2018	NO	NO	NO	NO	110.30	1.326
2019	41.97	0.359	NO	NO	158.21	2.733
2020	NO	NO	NO	NO	64.23	1.148

N_2O emissions from disturbances associated with land-use conversion to cropland

Not relevant for Lithuania as there are no conversion of forest land to cropland (*Study-1* and *Study-2* results). Deforestation mainly refers to conversion of forest land to Settlements, Wetlands and Other land use categories.

Non-CO_2 emissions from drainage of soils

N_2O emissions from drainage of soils

N_2O emissions were calculated using methodology used by *NFI* for distinguishing organic and drained organic soils, which refers to 13.6% of organic soils 6.9% of drained organic soils from the total forest land area. N_2O emissions were calculated for the total forest land area, thus emissions from AR were also included.

N_2O emissions from drained organic soils were calculated employing Equation 2.7 (p. 2.31 of *2013 Wet;ands Supplement* to *IPCC 2006*). Default EF of 2.8 according to Table 2.5 (p. 2.33 of *2013 Wetlands* Supplement of *IPCC 2006 Guidelines*) were used.

Considering assumption that carbon inputs and losses in mineral soil balance is equal one to another and the net changes are close to zero, there are no N_2O emissions from mineral soils (reported as 'NO').

CH_4 emissions from drainage of soils

CH_4 emissions are estimated using a simple emission factor approach further described in Equation 2.6 (Ch. 2.2.2.1, p. 2.18 of *2013 Wetlands Supplement*). CH_4 emissions are estimated for drained organic soils where ditches or drainage canals occur.

$$CH_{4\_organic} = \sum_{c,n,p} = A_{c,n,p} \cdot ((1 - Frac_{ditch}) \cdot EF_{CH4_{land\ c,n}} + Frac_{ditch} \cdot EF_{CH4_{ditch\ c,p}}))$$

where:

$CH_{4\_organic}$ - annual CH_4 loss from drained organic soils, kg CH_4 yr^{-1};

$A_{c,n,p}$ - land area of drained organic soils in a land-use category in climate zone c, nutrient status n and soil type p, ha;

$EFCH_{4\_land\ c,n}$ - emission factors for direct CH_4 emissions from drained organic soils, by climate zone c and nutrient status n, kg CH_4 ha^{-1} yr^{-1};

$EFCH_{4\_ditch\ c,p}$ - emission factors for CH_4 emissions from drainage ditches, by climate zone c and soil type p, kg CH_4 ha^{-1} yr^{-1};

$Frac_{ditch}$ - fraction of the total area of drained organic soil which is occupied by ditches (where 'ditches' are considered to be any area of man-made channel cut into the peatland).

Fertilization and liming

Information presented by *DGSF* indicates that there were no fertilization or liming of forest land in Lithuania since 1990 to 2016.

Fertilization and liming of forests could be useful applying biofuel ashes, but there are only few studies done in Lithuania, evaluating impact of application of ashes on forest land, but unfortunately there is no clear evidence on efficiency of such application (Ozolinčius et al., 2010).

Fertilization of forest land with other mineral fertilizers is still not worth economically due to high prices of fertilizers and unclear benefit for forest growth in our climatic conditions.

Windbreaks and windfalls

Accounting and data collection principles used by *SFS*, includes all timber from windbreaks and windfalls into round wood or fuel wood removals as this timber is still consumable. Therefore, to avoid double counting, windbreaks and windfalls were not included in calculations of carbon losses due to disturbances.

Information that emissions/removals from Article 3.3 are not accounted under Article 3.4

Lithuania has a clear division between A/R/D activity data and FM activity data, therefore GHG emissions and removals from A/R/D are not accounted under FM category. Lithuania uses wall-to-wall (spatial data) method to obtain activity data for A/R/D GHG accounting and sampling method to obtain activity data for FM category. Area of A/R is subtracted from total forest area to obtain FM area, deforestation is not included in forest land category while obtaining activity data (by sampling method) for Forest management activity. Growing stock volume and carbon stock change for A/R activity is calculated separately from FM category using modelled data from summarized NFI findings, carbon stock change (carbon loss) is also calculated separately in deforestation activity, using actual growing stock volume data from deforestation areas, obtained from State Forest Cadaster.

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

Based on NFI 1998-2011 data changes of dead wood are not significant in the afforested and reforested lands, as any dead wood in young forest stands usually are fine (trees from natural losses or thinning residues) and decay in one year. For estimation of carbon stock change of dead wood it was assumed to be zero and reported as 'NO'. This was based on calculations from actual NFI measurements data, carbon stock change of dead wood would account on average only 5 tonnes of CO_2 eq. per year. Taking into account that for Lithuania threshold of significance according to paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines would account about 10 kt CO_2 eq. in 2019 and that total sum of insignificant inventory categories is around 3 – 4 kt CO_2 eq., Lithuania assumed that emissions from deadwood pool under afforestation activities can be treated as insignificant and reported as "NO".

11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

No factoring out has been performed in the estimates of emissions and removals.

11.3.1.4 Uncertainty estimates

Uncertainty values for Article 3.3 and Article 3.4 assessment are represented in Table 11-15.

Table 11-15. Uncertainty assessment values

Indicator	Category	Unit	Uncertainty
Growing stock volume	AR	m^3	15.6%
	D	m^3	2.6%
	FM	m^3	2.6%
Dead trees volume	AR	m^3	15.6%
	FM	m^3	2.6%
Area	FL	ha	2.3%
	AR	ha	3.8%
	D	ha	3.8%
	FM	ha	2.2%
Emission factor	AR	kt CO_2	39.1%
	D	kt CO_2	62%
	FM	kt CO_2	34%

11.3.1.5 Information on other methodological issues

For the 2nd CP Lithuania has continuously chosen to account for the emissions and removals under Articles 3.3 and 3.4 (forest management) and HWP at the end of CP. In the 1st CP Lithuania has made major improvements in its data collection, required for GHG assessment under Kyoto Protocol, referring to reconstruction of historical data and improved way forward for further accounting with additional requirements during the 2nd CP.

11.3.1.6 The year of the onset of an activity, if after 2008

After finalizing *Study-1* Lithuania became able to identify areas of Article 3.3 and Article 3.4 under Kyoto Protocol activities since 1990, using wall-to-wall (Article 3.3 activities) and sampling (Article 3.4 activities) methods. The relevant area sizes of Article 3.3 activities that began after 2008 are represented in Table 11-4. The relevant area sizes of Article 3.4 activities that began after 2008 are represented in Table 11-5.

11.4 Article 3.3

11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

Reported deforestation activities are directly human-induced. Areas of deforestation are under very strict regulation and control of forest lands legitimated by the Forest Law and Lithuanian Republic Government Resolution No 1131 dated on 28th September 2011. According to these acts forest land can be converted to non-forest land only using special procedure of compensation. Main way of compensation is re-establishment of forest land on non-forest land on area up to 3 times larger as compared with area of land converted to non-forest land.

Reported afforestation and reforestation activities are defined only as human-induced activities without natural forest expansion. Forest Law regulates afforestation process in agricultural lands and other lands (swamps, peatlands, other land) as well. Afforestation of these lands could be done by artificial way as well as by natural way. The legitimation of changes of agricultural and other land to forest land by natural afforestation are obligatory if trees crown cover attains 30% of an area not less than 0.1 ha and age of trees exceed 20 years. Natural afforestation is included in area of FM. For the estimation of A/R area Lithuania uses data from National Paying Agency which is responsible for administration of afforestation/reforestation activities. National Paying Agency provide support for land owners to plant new forest in agricultural and other land uses using seeds or seedlings (human-induced afforestation/reforestation), therefore we get exact area of new afforestation/reforestation activities annually as well as spatial data where such activities took place. Natural forest expansion areas (natural A/R) are included in Forest management area as they are included in total forest land area after observation during NFI.

Data of afforestation, reforestation and deforestation for the period 1990-2011 estimated as the result of the *Study-1*. Special methodology and descriptive codes (Table 11-6) were used to identify natural and human induced activities under Article 3.3.

Using wall-to-wall method (*LSFC*) together with *SFI* data, areas of ARD were determined. As quality assurance data from *NFI* was used to compare with results received from *Study-1*. Comparison revealed that differences are minor and the common trend retained over the study period (1990-2011).

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

According to Lithuanian Forest Law the clear cut areas should be reforested during 3 years and are under strict control of forest management and State inspection.

Temporarily unstocked areas after harvesting remain forests and are not accounted as deforestation. Every deforestation case must be reported to *LSFC* and is very rare. Any deforested area must follow the afforestation of three time larger area than the one was deforested.

All forest land, where forest was growing in 1990 according to *LSF* Resources Database (LTDBK50000-V) scale 1:50°000, but was not fixed in *LSFC* were visually checked, simultaneously inspecting *LSFC* data (MKAD, MKAD_ARCH and MKAD_2012 databases) as well as all ortho-photo maps compiled in the last two decades on Lithuania's territory together with satellite images from CORINE land cover database (Figure 11-15).

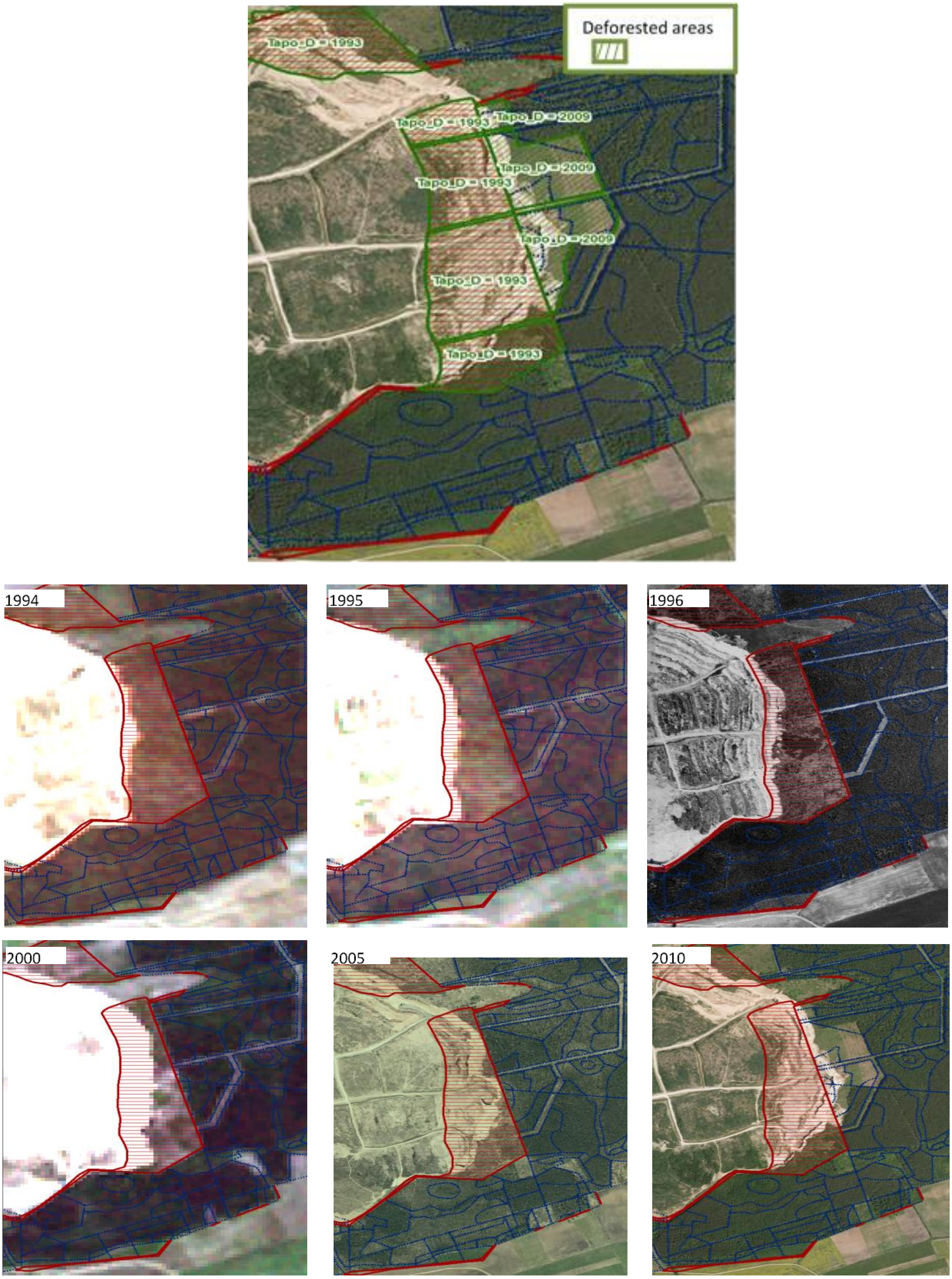


Figure 11-15. Technical procedure of identification of deforested areas 1994-2010

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Clear-cut area in forests land (temporarily unstocked areas) is not considered as deforestation in Lithuania. In 2011 area of clear felling was 16535 ha, in 2012 – 17154 ha. Every clear felling is planned according to forest management plan prepared by forestry expert, and is applied to the area which meets the requirements approved in the Rules for forest felling (Seimas of the Republic of Lithuania, 2010). Permission for clear felling is mandatory despite clear felling being prepared according to forest management plan and could be issued at Regional Environmental Protection Agency after provision of responsible officer in situ.

11.4.4 Emissions and removals under Article 3.3

Afforestation and reforestation activities in total were a net sink over the 1st CP absorbing in average 226.5 kt CO_2 annually (Table 11-16). For afforestation and reforestation it was assumed that carbon inputs and losses in dead wood balance are equal and net change is close to zero (reported as NO). Deforestation activities were a continuous net source of in average 222.3 kt CO_2 annually (Table 11-17).

Table 11-16. Carbon stock change and emission/removals of CO_2 in afforestation and reforestation, kt

Year	Carbon stock change in living biomass		Carbon stock change in dead organic matter		Carbon stock change in soil		Total carbon stock change	Emissions/ removals of CO_2
	Above-ground	Below-ground	Dead wood	Forest litter	Mineral soil	Organic soil		
2008	16.54	-2.19	NO	1.82	9.13	-1.53	25.97	-87.64
2009	21.04	-4.61	NO	1.98	9.65	-1.92	32.83	-96.34
2010	18.40	-9.73	NO	2.39	11.39	-1.89	25.7	-75.99
2011	22.71	-9.63	NO	2.8	13.62	-1.62	33.35	-102.98
2012	30.02	-5.37	NO	3.18	15.35	-1.81	45.88	-152.52
2013	38.42	-10.07	NO	3.46	16.46	-2.14	59.52	-170.05
2014	43.02	-0.81	NO	3.82	17.9	-2.57	65.31	-225.98
2015	49.70	-11.18	NO	4.16	19.24	-3.04	74.91	-216.97
2016	60.83	4.74	NO	4.36	19.35	-3.76	92.08	-314.68
2017	57.28	-7.36	NO	5.01	22.33	-4.36	80.47	-268.52
2018	77.75	10.04	NO	5.20	22.16	-5.06	115.69	-404.86
2019	75.69	11.60	NO	4.68	21.93	-5.55	112.47	-398.92
2020	92.33	4.69	NO	5.51	21.61	-7.24	116.90	-428.64

Table 11-17. Carbon stock change and emission/removals of CO_2 in deforestation, kt

Year	Carbon stock change in living biomass		Carbon stock change in dead organic matter		Carbon stock change in soil		Total carbon stock change	Emission/ removals of CO_2
	Above-ground	Below-ground	Dead wood	Forest litter	Mineral soil	Organic soil		
2008	-2.52	-0.64	-0.14	-0.35	-3.36	-1.06	-8.07	29.58
2009	-1.72	-0.41	-0.09	-0.21	-2.03	-0.64	-5.10	18.71
2010	-1.13	-0.28	-0.22	-0.53	-5.17	-1.64	-8.98	32.93
2011	-1.72	-0.44	-0.09	-0.21	-2.06	-0.65	-5.18	19.00
2012	-5.96	-1.24	-0.33	-0.76	-7.32	-2.32	-17.94	65.77
2013	-16.82	-3.82	-1.04	-2.35	-22.70	-7.19	-53.92	197.70
2014	-23.45	-4.97	-1.37	-3.03	-29.27	-9.27	-71.36	261.63
2015	-2.49	-0.59	-0.13	-0.30	-2.83	-0.90	-7.23	26.50
2016	-14.53	-3.29	-0.80	-1.81	-17.43	-5.52	-43.38	159.04
2017	-6.63	-1.59	-0.43	-1.00	-9.70	-3.07	-22.43	82.24
2018	-105.87	-26.53	-6.30	-14.53	-140.49	-44.51	-338.23	1240.17
2019	-50.21	-11.91	-2.67	-5.98	-57.79	-18.31	-146.86	538.47
2020	-21.20	-4.98	-1.07	-2.33	-22.56	-7.15	-59.29	217.41

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

Forest area at the end of 2011 was estimated by using *Study-1* data (see chapter 6.1.1.). Forest land area for the end of 1989 was followed by adding deforested areas and subtracting afforested and reforested areas. Forest land areas that were forests on the 1st of January 1990 were included under FM category, since Lithuania considers that all forest land is managed.

11.5.2 Information relating to Cropland Management, Grazing Land Management, Revegetation and Wetland Drainage and Rewetting if elected, for the base year

Lithuania has not chosen to account emissions and removals from Cropland Management, Grazing Land Management and Revegetation under Article 3.4 of the Kyoto Protocol.

11.5.3 Information relating to Forest Management

Objective information related to FM is received from *NFI*. Permanent sample plots are hidden, what means that they can only be identified during *NFI* measurements and are not visible and known for forest owners or managers, who could subjectively influence forest management results.

The main sink of GHG in forest management activity is living biomass, similarly to forest land remaining forest land subcategory under Convention reporting. In order to estimate carbon stock changes in living biomass under forest management activity annual NFI data of growing stock volume is used to calculate growing stock volume changes. Total growing stock volume and growing stock volume change, obtained from NFI measurements during accounting period is provided in the Table below.

Table 11-18. Growing stock volume and its changes in the areas under forest management activity

Year	Total growing stock volume, m^3/ha	Growing stock volume change, m^3/ha
2008	223.8	2.4
2009	227.6	3.0
2010	231.9	3.6
2011	235.8	3.9
2012	238.7	3.8
2013	242.8	3.7
2014	245.7	3.4
2015	248.8	3.0
2016	250.9	2.7
2017	252.5	2.6
2018	254.9	2.5
2019	257.8	2.3
2020	260.3	2.1

Net GHG removals and emissions resulting from Forest management activity are provided in Table 11-19.

Table 11-19. Net emissions/removals from FM during the period 2008-2020, kt

Year	Net CO_2 removals	CH_4 emissions	N_2O emissions	Total (CO_2 eq.)
2008	-7,400.62	1.17	0.41	-7,248.79
2009	-8,511.41	1.20	0.41	-8,358.23
2010	-9,429.84	1.16	0.41	-9,278.32
2011	-9,525.81	1.20	0.41	-9,372.40

2012	-8,926.12	1.16	0.41	-8,773.82
2013	-9,263.68	1.16	0.41	-9,111.24
2014	-8,231.89	1.19	0.42	-8,078.07
2015	-7,162.43	1.17	0.42	-7,009.15
2016	-6,143.36	1.17	0.42	-5,989.91
2017	-6,005.80	1.17	0.42	-5,852.24
2018	-5,859.04	1.18	0.42	-5,705.20
2019	-5,530.36	1.19	0.42	-5,375.99
2020	-5,807.55	1.18	0.42	-5,653.25

11.5.3.1 Information that the definition of forest for this category conforms with the definition in item 11.1 above

In accordance with definitions in item 11.1 above. all forest land is managed and there is no unmanaged forest land in Lithuania. Only for accounting under Kyoto Protocol purposes all forest land is split into ARD and FM according to *IPCC 2006*.

11.5.3.2 Information that forest management is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity). economic and social functions of the forest in a sustainable manner (paragraph 1 (f) of the annex to decision 16/CMP.1 (Land use. land –use change and forestry)

Forest represents one of the major Lithuanian natural resources serving for the welfare of the state and its citizens. preserving stability of the landscape and environmental quality. Despite the forest ownership form. forest. primarily. is the national property that shall be preserved for the future generations at the same time meeting ecological. economic and social needs of the society. Being a source of supply of timber and other forest products. forest is the essential factor of the ecological balance providing living places for numerous animals and plant species. stopping the soil erosion. absorbing the carbon dioxide and purifying the air. protecting the ground and the surface waters. providing opportunities for recreation of the urban and rural people.

With the purpose of ensuring a sustainable forestry development. satisfying forest-related needs of various groups of the society. and ensuring preservation of forests for further generations. acknowledging a long forest growth duration. and with respect to the differences of the ownership forms and their relationships. by promoting conditions for proper management of forests with the purpose of economic benefits for the country. a long-term forestry policy has been formed in Lithuania in compliance with policies of other branches of the economy of the country. based on the traditions of the country and requirements of the European Union legal norms. international conventions. resolutions. agreements. programmes. and national legal acts.

The following instruments are used for the purpose of implementation of the forestry policy: well-organized. qualified forestry administration independent from any temporal political changes; the Forest Law and other legal acts; taxes revenues and financial support; education and training; management of the forestry information; public relations.

The Lithuanian forestry policy is being formed upon the following principles:

- *responsibility* for the continuous and sustainable use of the forest resources. Considering forests as the major renewable natural resource for the society. forestry policy ensures the responsibility of forest owners. forest governors and users as well as sustainable use of these resources and their restoration. The state. execute state regulation functions on all forests of the country. develop forest infrastructure. forest protection against natural calamities. widespread diseases and pests. provide legal. financial and other preconditions for the preservation of forests. ensure rational use of forest resources. meeting social needs of the society and environmental protection;

- *compliance* to the national legal system and international agreements. Lithuanian forestry policy is formed following the Constitution of the Republic of Lithuania and other legal acts. as well as the Convention on the Conservation of European Wildlife and Natural Habitat. signed in 1979 in Bern. the Biodiversity Convention signed in Rio de Janeiro in 1992. and Forest Protection Principles adopted at the United Nations conference "Environment and Development". the Strasbourg 1990. Helsinki 1993. and Lisbon 1998 resolutions of the Ministerial Conferences on Protection of Forests in Europe . the principles of the European Union forestry strategies. European Union directives on forestry and environmental protection issues;
- *participation* and co-operation of all interested groups of the society. The policy takes into regard the opinion of all interested groups of the society. complies and balances interests of forest owners. forest governors and users. wood processors. environmental protection organisations. and other social groups related to forest and forestry-related economy. All major forestry policy statements shall be in compliance with separate stakeholders and submitted for public consideration of the society;
- *variety* of forest ownership forms and their equality of rights. The equality of rights for economic activities in forests of all ownership forms is implemented. Equal legal and other conditions both for the management and economic activities in private as well as state-owned forests are created. During the development of the Lithuania forestry. the market economy relationship and free competition principles are strengthened at the private as well as in the state-owned forestry sector;
- *complexity* of forestry. Forestry is being developed in a complex manner upon the basis of multiple use taking into regard its significance and relations to the consumers of forest products and services. wood processing industry structures as well as other groups of society having their interests in forests and forestry;
- *continuation* of the forestry traditions. Lithuanian forestry has traditions tested through the course of time. which are taken into consideration while transferring experience of foreign countries. Forestry reforms and reorganisations. implementation of novelties on forestry management and other issues shall be performed consistently. taking into consideration the practical know-how of the specialists. public opinion. and interests of the state.

Mission of the State in forestry development is:

- To form and implement a rational forestry development policy. which would ensure ecologically. economically and socially balanced development of forestry sector;
- To ensure the stability of forest ecosystems. preservation of biodiversity. increase in forest productivity. improve forest quality and healthiness;
- To preserve valuable forest genetic fund by using the national forest genetic resources for the establishment and creation of new objects of forest seed basis;
- To increase forest coverage of Lithuania by planting forests on uncultivated and poor-quality soils as well as other non-used land areas where forest planting would contribute to the formation of Lithuanian natural carcass;
- To ensure the variety of forest ownership forms and the efficiency of state forestry regulation;

- To ensure meeting general forest-related social needs of the society;
- To create a favourable legal. economic and institutional environment for the effective and competitive functioning of the forest economy. wood industry and a variety of forest business enterprises in a free market;
- To encourage innovations. competitiveness. development of markets and establishment of working places;
- To ensure the maintenance of the scientific potential and its rational application as well as preparation of high-qualification forestry specialists.

The main legal acts forming forest policy in Lithuania since 1990:

- Forest Law of the Republic of Lithuania No IX-240. Adopted on 10th April 2001;
- Land Law of the Republic of Lithuania No IX-1983. Adopted on 27th January 2004;
- Land reform Law of the Republic of Lithuania No VIII-370. Adopted on 2nd July 1997;
- Law on territory planning of the Republic of Lithuania No X-1962. Adopted on 15th January 2004.

Recently adopted legal acts to improve KP-LULUCF accounting:

- Order of the Minister of Environment and Minister of Agriculture No D1-987/3D-927 on Approval of Action plan to improve LULUCF reporting of Lithuania. Adopted on 16th December 2011;
- Order of the Minister of Environment No D1/27 on Approval of Harmonized Principles for data collection and reporting on LULUCF. Adopted on 12th January 2012;
- Order of the Minister of Environment No D1-59 to amend order No D1-570 on National forest inventory by sampling method. Adopted on 24th January 2012;
- Government Resolution No 570 to amend resolution No 1255 on State Forest Cadaster. Adopted on 23rd May 2012;
- Order of the Minister of Environment and Minister of Agriculture No 3D-239/D1-285 to amend order No 3D-130/D1-144 on Rules for afforestation of non-forest land. Adopted on 3rd April 2012;
- Order of the Minister of Environment and Minister of Agriculture No D1-409/3D-331 on Inventory and Registration of natural afforestation of non-forest land. Adopted on 8th May 2012.

11.5.3.3 Forest Management Reference Level (FMRL)

Lithuania's forest management reference level is -4.139 Mt CO_2 eq (with instant oxidation applied for HWP) and -4.552 Mt CO_2 eq (with HWP included as first-order decay function) as inscribed in the appendix to the annex to decision 2/CMP.7.

11.5.3.4 Technical Corrections of FMRL

Lithuania has already applied technical correction to the forest management reference level which is equal to -922.0 kt CO_2 eq. G4M and EFISCEN models, used for FMRL estiamtion, were updated with more recent NFI data to calculate technical correction. The main changes were larger forest area for both models and a larger increment rate and growing stock and a higher share of wood coming from thinning in total wood removals for EFISCEN as compared to data used originally for the FMRL calculations. With the updated input data G4M and EFISCEN project a CO_2 sink in the range of 5.4-9.0 $MtCO_2$/year in 2020. Both models agree on the declining trend of the biomass forest management emissions.

For the FMRL projection in 2011 EFISCEN model was initialized with the National Forest Inventory (NFI) data referring to the year 2000 and respective age structure while G4M was initialized with age structure projected by EFISCEN for 2010. For the technical correction projection EFISCEN model was initialized with data from the 2010-2012 (2010 midpoint) NFI measurements while G4M used the same initial age structure as for the FMRL.

Additional changes applied in EFISCEN model for the technical correction:

- The new NFI contained fewer tree species. The forest area in NFI deviated from the area reported for forest management, a simple scaling factor of 2052183 ha / 2123129 ha = 0.967 was used to correct for this difference in area;
- updated forest management regimes (rotation lengths) were provided and incorporated, but this adjustment was not related with the change of FM policy;
- updated carbon content of tree species; carbon content of coniferous species was set to 51% and for broadleaved species to 48% (was 50% for all species in initial FMRL);
- share of thinning in total removals was indicated to be 40% (i.e. 60% comes from final harvest) (was 33% in initial FMRL);
- No changes were made to other parameters (e.g. species-specific biomass distribution factors, harvest losses, future deforestation rates).

2.5.3.5. Comparison of historical data between Forest Management under KP and Forest Management Reference Level (FMRL)

2020 is the last year of Kyoto Protocol's LULUCF accounting, thus, it is reasonable to compare historical data used in Forest Management reporting and for projection of FMRL. To model FMRL, two models were used: EFISCEN and G4M. Relevant information was submitted to JRC in 2011 with several updates later, with latest given in 2017. This updated information is the newest and proposes FMRL to be -4.552 kt CO_2 eq. (with HWP included as first-order decay function) including technical correction of -922 kt CO_2 eq., making it -5.474 kt CO_2 eq. in total. This average was taken from both models and graph below (Figure 11-16) shows how it corresponds to current historical data from FM activities.

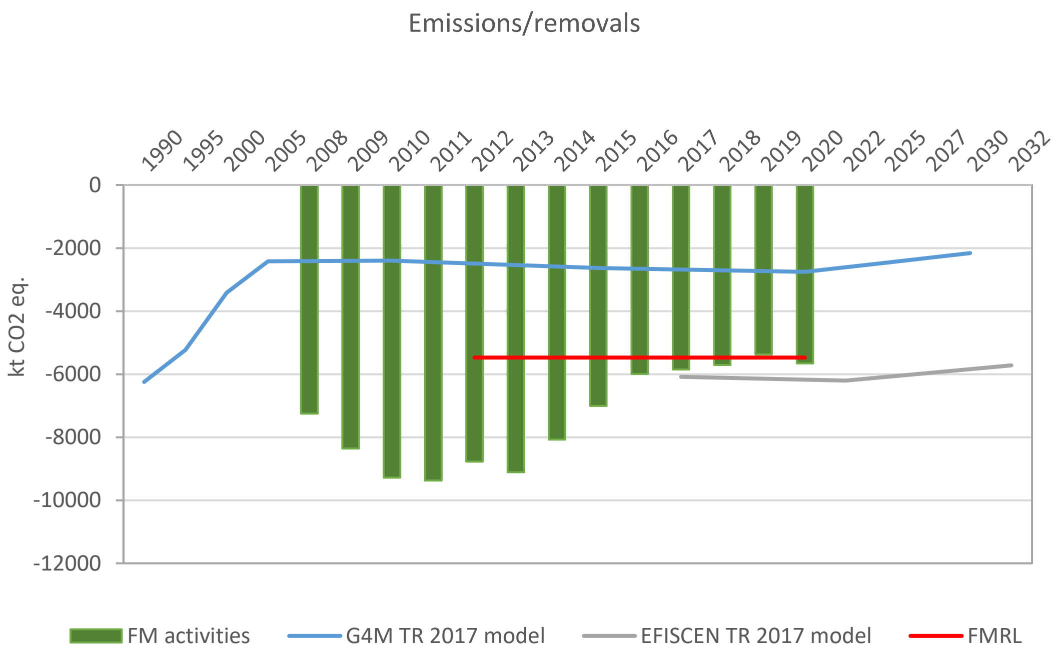


Figure 11-16. Net emissions/removals from Forest Management activities under KP LULUCF, prognosis from G4M and EFISCEN models and Forest Management Reference Level

As it is shown, according to historical FM removals, FM activities under KP LULUCF exceeds removals, prognosed by G4M model, but the latest removal trends since 2016 show decline in absorptions that are below projected EFISCEN TR 2017 removals. This means that EFISCEN model was better suited for showcasing our Forest Management situation and G4M projections were very off – target. FMRL was then calculated as an average from both models with the applied technical correction. FM removals were much higher than FMRL until 2015. This difference between FM removals and FMRL, referred as Accounted Quantity (AQ), was a result of higher biomass increments and age class distribution of pine forests during 2012 – 2015 period (Augustaitis, et al. 2018), and also, due to political reasons in exploitable forests (functional group IV) for preserving protected and other biologically valuable areas, such as Natura 2000, Woodland Key Habitats. Starting from 2016, removals from FM activities were only slightly higher than FMRL, and in 2019, it was below reference level.

11.6 Harvested wood products

11.6.1 Source category description

Harvested Wood Products (HWP) accounting has been identified as mandatory from the beginning of the 2nd CP according to Decision 2/CMP.7 and Decision 2/CMP.8. Annual changes in carbon stocks and associated CO_2 emissions and removals from HWP removed from forests which are accounted for by a Party under Article 3.3 and Article 3.4 has to be accounted using *2013 KP-Supplement* methodology.

Lithuania defines semi-finished commodities relevant for the application of the guidance on estimating the HWP emissions and removals in line with the Decision 2/CMP.7.

Sawnwood (Decision 2/CMP.7 refers to this as "sawn wood"): Wood that has been produced from both domestic and imported round wood. either by sawing lengthways or by a profile-chipping process and that exceeds 6 mm in thickness. It includes planks. beams. joists. boards. rafters. scantlings. laths. boxboards and "lumber". etc.. in the following forms: unplanned. planed. end-jointed. etc. It excludes sleepers. wooden flooring. mouldings (sawnwood continuously shaped along any of its edges or faces. like tongued. grooved. rebated. jointed. beaded. moulded. rounded or the like) and sawnwood produced by re-sawing previously sawn pieces. It is reported in cubic metres solid volume.

Wood-based panels (Decision 2/CMP.7 refers to this as "wood panels"): This product category is an aggregate comprising veneer sheets. plywood. particle board. and fibreboard. It is reported in cubic metres solid volume.

Paper and paperboard (Decision 2/CMP.7 refers to this as "paper"): The paper and paperboard category is an aggregate category. In the production and trade statistics. it represents the sum of graphic papers; sanitary and household papers; packaging materials and other paper and paperboard. It excludes manufactured paper products such as boxes. cartons. books and magazines. etc. It is reported in metric tonnes.

More detailed description of the activity data is presented in Chapter 6.8.

11.6.2 Methodological issues

Emissions and removals from HWP removed from forests which are accounted for by Lithuania under Article 3.3 and 3.4 are estimated using stock change method. and only HWP in use are considered. Annual change in carbon stock in HWP in solid waste disposal sites where the wood comes from domestic harvest including HWP exported to other countries are reported in this category.

The worksheet provided in *IPCC 2006* is a tool for estimating annual carbon balance under any of the proposed HWP approaches. The model consists of two elements: solid wood products and paper products. Both variables have different half-life values. GHG accounting for HWP pool in the worksheet is based on first order decay function with default half-life values (Equation 2.8.5. p. 2.120 of *2013 KP-Supplement*):

$$C(i+1) = e^{-k} \cdot C(i) + \left[\frac{(1-e^{-k})}{k}\right] \cdot Inflow(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

where:

i - year;

C(i) - the carbon stock in the particular HWP category at the beginning of year *i*. kt C;

k - decay constant of FOD for each HWP category (HWP_j) given in units yr^{-1} (k = ln(2)/HL. where HL is half-life of the HWP pool in years);

Inflow(i) - the inflow to the particular HWP category (HWP_j) during year *i*. kt C yr^{-1};

ΔC(i) - carbon stock change of the HWP category during year *i*. kt C yr^{-1}.

Annual change in carbon stock in "products in use" where wood came from harvest in the reporting country. including export. was estimated using Equation 12.3 (Ch. 12.2. p. 12.12 of *2006 IPCC Guidelines*).

$$Inflow_{DH} = P \times \left[\frac{IRW_H}{IRW_H + IRW_{IM} - IRW_{EX} + WCH_{IM} - WCH_{EX} + WR_{IM} - WR_{EX}}\right]$$

where:

InflowDH - carbon in annual production of solid wood or paper products that came from wood harvested in the reporting country (that is. from domestic harvest). Gg C yr^{-1};

P - carbon in annual production of solid wood or paper products in the reporting country. Gg C yr^{-1}.

IRW_H - industrial roundwood harvest in the reporting country. Gg C yr^{-1};

IRW_{IM} . IRW_{EX} - industrial roundwood imports and exports. respectively. Gg C yr^{-1};

WCH_{IM}. WCH_{EX} - wood chip imports and exports. respectively. Gg C yr^{-1};

WR_{IM}. WR_{EX} - wood residues from wood products mills imports and exports. respectively Gg C yr^{-1}.

Lithuania uses default half-life values presented in Table 2.8.2 (p. 2.123 of *2013 KP-Supplement*).

Table 11-20. Default half-life values of HWP categories

HWP category	Half-life in years	Fraction loss each year
Sawn wood	35	0.0198
Wood-based panels	25	0.0289
Paper and paperboard	2	0.3466

Default aggregated conversion factors for each HWP category was employed from Table 2.8.1 (p. 2.122 of *2013 KP-Supplement*).

Table 11-21. Default conversion factors for the default HWP categories

HWP categories	Density (oven dry mass over air dry volume) [Mg/m³]	Carbon fraction	C conversion factor (per air dry volume) [MgC/m³]
Sawn wood	0.458	0.5	0.229

Wood-based panels	0.595	0.454	0.269
Paper and paperboard	0.9		0.368

Activity data used for carbon stock changes estimation in harvested wood products pool is presented in Table 11-22. Lithuania is using combined data sources for HWP pool evaluation - The Chronical of Lithuanian forests (LR Aplinkos ministerija. 2003). Statistics Lithuania and. since 1995 - FAO Statistics database. Since Lithuania is using activity data from FAO databases for HWP accounting. therefore data on domestic HWP production. export and import is clearly distinguished (Table 11-22). Carbon stock change in harvested wood products pool and CO_2 emissions/removals are presented in Table 11-23.

Lithuania does not have sufficient activity data on HWP production resulting from deforestation activity. therefore all emissions/removals from HWP originating from forest land were calculated using first order decay function. Lithuania has estimated that emissions from HWP originating from deforestation areas could approximately contribute to only 0.2 percent of total emissions/removals from HWP originating from forest. Estimation was done using the amount of annual wood produced in country. obtained from FAO database. compared with average wood stored in stands per hectare multiplied by the area of deforestation.

Table 11-22. Activity data used for carbon stock changes estimation in harvested wood products

Sawn-wood				Wood-based panels				Paper and Paperboard				Round wood			
Year	**Production, m^3**	**Imports, m^3**	**Export, m^3**	**Year**	**Production, m^3**	**Imports, m^3**	**Export, m^3**	**Year**	**Production, tonnes**	**Imports, tonnes**	**Export, tonnes**	**Year**	**Production, m^3**	**Import, m^3**	**Export, m^3**
1960	885,000.00	140,068.91	0.00	**1960**	39,800.00	3,888.49	14,726.0	**1960**	83,000.00	31,542.65	51,457.0	**1960**	1,740,000.00	968,000.00	29,637.30
1965	1,044,000.00	231,000.00	0.00	**1965**	58,400.00	5,297.40	21,608.00	**1965**	114,000.00	40,925.69	70,675.90	**1965**	2,420,000.00	1,080,000.00	41,219.80
1970	1,313,000.00	317,000.00	0.00	**1970**	91,300.00	8,281.73	33,781.00	**1970**	159,000.00	57,080.57	98,574.30	**1970**	2,814,000.00	1,066,000.00	47,930.70
1975	1,098,000.00	330,000.00	0.00	**1975**	133,900.00	12,145.93	49,543.00	**1975**	240,000.00	86,159.36	148,791.40	**1975**	2,587,000.00	1,161,000.00	44,064.30
1980	855,000.00	361,000.00	0.00	**1980**	165,500.00	15,012.33	61,235.00	**1980**	235,000.00	84,364.37	145,691.60	**1980**	2,472,000.00	699,000.00	45,000.00
1985	934,000.00	361,000.00	0.00	**1985**	168,100.00	15,248.17	62,197.00	**1985**	265,000.00	95,134.29	164,290.50	**1985**	2,648,000.00	693,000.00	44,000.00
1990	775,800.00	200,000.00	0.00	**1990**	197,900.00	17,951.30	73,223.00	**1990**	217,600.00	78,117.82	134,904.20	**1990**	2,667,000.00	456,000.00	74,000.00
1991	664,000.00	100,040.50	0.00	**1991**	185,500.00	16,826.51	68,635.00	**1991**	214,500.00	77,004.92	132,982.30	**1991**	2,908,000.00	228,475.50	179,739.00
1995	940,000.00	23,200.00	767,200.00	**1995**	156,400.00	38,200.00	104,600.00	**1995**	28,900.00	50,600.00	19,400.00	**1995**	5,960,000.00	16,200.00	1,769,900.00
2000	1,300,000.00	279,410.00	823,040.00	**2000**	270,290.00	115,380.00	211,060.00	**2000**	52,630.00	78,250.00	37,100.00	**2000**	5,500,000.00	60,570.00	1,202,850.00
2005	1,445,000.00	658,230.00	912,547.00	**2005**	398,000.00	381,124.00	170,966.00	**2005**	113,000.00	151,752.00	87,140.00	**2005**	6,045,000.00	287,906.00	1,173,919.00
2010	1,272,000.00	291,274.00	555,388.00	**2010**	716,000.00	453,130.00	311,223.00	**2010**	129,229.00	195,261.00	123,233.00	**2010**	7,096,860.00	332,142.00	1,441,955.00
2015	1,248,146.00	605,059.00	818,009.00	**2015**	888,131.00	647,019.00	287,495.00	**2015**	142,322.00	277,278.00	114,613.00	**2015**	6,414,000.00	404,945.00	1,620,910.00
2016	1,406,000.00	750,749.00	931,448.00	**2016**	919,384.00	761,085.00	371,242.00	**2016**	127,377.00	279,332.00	103,607.00	**2016**	6,747,000.00	539,142.00	1,630,716.00
2017	1,406,000.00	750,749.00	931,998.00	**2017**	919,384.00	760,586.00	352,064.00	**2017**	127,377.00	279,332.00	103,607.00	**2017**	6,747,000.00	539,142.00	1,630,716.00
2018	1,330,450.00	1,081,000.00	1,013,000.00	**2018**	852,400.00	862,600.00	149,624.00	**2018**	134,000.00	279,355.00	107,268.00	**2018**	6,683,530.00	277,575.00	1,731,256.00
2019	1,266,000.00	1,247,060.00	1,082,115.00	**2019**	853,800.00	857,440.00	144,039.00	**2019**	159,090.00	291,008.00	96,062.00	**2019**	6,688,000.00	263,156.00	2,109,848.00
2020	1,038,000.00	1,337,495.00	1,212,421.00	**2020**	850,800.00	858,560.00	137,857.00	**2020**	128,400.00	316,642.00	108,318.00	**2020**	6,366,000.00	303,423.00	2,092,365.00

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Table 11-23. Annual change in carbon stock of HWP in use produced from domestic harvest

Year	ΔC HWP IU DH	ΔC HWP IU DH	ΔC HWP IU DH	ΔC HWP IU DH	kt CO_2
	Wood-Based Panels. kt C	**Sawnwood kt C**	**Paper & Paperboard kt C**	**Total. kt C**	
1990	27.72	36.95	-1.97	62.70	-229.91
1995	20.52	95.67	-13.95	102.24	-374.88
2000	45.26	159.99	-1.09	204.15	-748.56
2005	66.42	163.21	-0.55	229.07	-839.92
2010	133.66	114.08	-2.54	245.20	-899.07
2011	157.75	110.32	1.93	270.00	-990.01
2012	152.49	82.98	-3.55	231.92	-850.38
2013	151.05	69.36	1.07	221.47	-812.07
2014	156.98	115.78	-0.38	272.38	-998.71
2015	150.71	92.72	1.18	244.61	-896.92
2016	148.33	116.15	-0.13	264.34	-969.26
2017	145.36	115.29	-0.08	260.56	-955.40
2018	121.83	92.87	0.39	215.09	-788.66
2019	125.95	87.14	5.36	218.45	-800.99
2020	122.72	39.03	-2.38	159.38	-584.38

11.7 Other information

11.7.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Key category analysis for KP-LULUCF was developed according to section *2013 Revised Supplement* Table 3 (p. 2A.10).

Categories under Articles 3.3 and 3.4 were considered as key if their contribution was greater than the smallest category considered key in the UNFCCC inventory (including LULUCF). The results are presented in Table 11-24.

Table 11-24. Key categories in Article 3.3 and 3.4 activities

Key categories	**Gas**	**Criteria used for key category identification**		
Specify key categories according to the national level of disaggregation		**Associated category in UNFCCC inventory is key**	**Category contribution is greater than the smallest category considered key in the UNFCCC inventory (including LULUCF)**	**Comments**
Forest Management	CO_2	Forest land remaining forest land	Yes	L1.L2.T1.T2
Forest Management	CH_4	Forest land remaining forest land	No	
Forest Management	N_2O	Forest land remaining forest land	No	
Afforestation and Reforestation	CH_4	Conversion to forest land	No	
Afforestation and Reforestation	CO_2	Conversion to forest land	Yes	L1.L2.T1.T2

Afforestation and Reforestation	N_2O	Conversion to forest land	No	
Deforestation	CH_4	Conversion to cropland. settlements and other land	No	
Deforestation	CO_2	Conversion to cropland. settlements and other land	Yes	L1.L2.T1.T2
Deforestation	N_2O	Conversion to cropland. settlements and other land	No	
Harvested Wood Products	CO_2	Harvested Wood Products	Yes	L1.L2.T1.T2

12 INFORMATION ON ACCOUNTING OF KYOTO UNITS

12.1 Background information

In accordance with Decision 15/CMP.1 Section E and adhering to the standard electronic format (SEF) guidelines, Parties included in Annex I are required to report from its national registry the information on holdings and transactions of Kyoto units.

This data is reported in the SEF tables – an agreed format, embodied in a special report, for reporting on Kyoto units.

Lithuania's SEF reports for the first commitment period (CP1) and the second commitment period (CP2) were submitted to the UNFCCC Secretariat in an electronic .xml and .xlsx.

Information related to transfers, CDM notifications, accounting of Kyoto units and publicly available information is presented in the following paragraphs of this chapter, whereas information on significant changes to the National Registry of Lithuania is available in Chapter 14.

12.2 Summary of information reported in the SEF tables

Annual Submission Item	Reported for 2021
15/CMP.1. annex I.E paragraph 11 Standard electronic format (SEF)	The SEF tables for CP1 ('RREG1_LT_2021_1_2.xlsx'; 'RREG1_LT_2021_1_2.xml') and CP2 ('RREG1_LT_2021_2_1.xlsx'; RREG1_LT_2021_2_1.xml') were generated with the data from the Union Registry with the help of the SEF report tool 3.8.3. These SEF tables include summarized information on assigned amount units (AAUs), emission reduction units (ERUs), certified emission reductions (CERs), temporary certified emission reductions (t-CERs), long-term certified emission reductions (l-CERs), removal units (RMUs) in the National Registry of Lithuania at 31.12.2021 as well as information on acquisitions, holdings, transfers, cancellations, retirements, carry-overs during the reported year.

First commitment period (CP2)

Although reporting for CP1 is no longer mandatory, for the purpose of completeness and transparency the information on CP1 is made available and can be viewed at the submitted SEF table for CP1.

Second commitment period (CP2)

At the end of 2021, the holdings in the National Registry of Lithuania per unit type were as follows:

- a total of **113 600 821 AAUs** (all amount in the Party holding accounts);
- a total of **797 085 ERUs** (633 399 in the Party holding accounts, 140 754 in the Entity holding accounts and 22 932 in the Voluntary cancellation account);
- a total of **246 966 CERs** (229 828 in the Party holding accounts, 659 in the Entity holding accounts and 16 479 in the Voluntary cancellation account).

Additionally, a total of 229 915 ERUs were externally transferred.

No cancellations, replacements or retirements took place in the National Registry of Lithuania during the reported year.

Full details of the accounting of Kyoto units can be found in the SEF tables for CP2.

12.3 Discrepancies and notifications

With regards to the respective paragraphs of the annex I.E to Decision 15/CMP.1, relevant information on discrepancies and notifications (if any) identified in the National Registry of Lithuania is reported in the following Table 12.3.

Table 12-3. Discrepancies and notifications

Annual Submission Item	Reported for 2020
15/CMP.1. annex I.E paragraph 12 List of discrepant transactions	No discrepant transactions occurred in 2021. Thus, no report R-2 is submitted.
15/CMP.1. annex I.E paragraph 13 and 14 List of CDM notifications	No CDM notifications were received by the National registry during the reported period. Thus, no report R-3 is submitted.
15/CMP.1. annex I.E paragraph 15 List of non-replacements	No non-replacements occurred in 2021. Thus, no report R-4 is submitted.
15/CMP.1. annex I.E paragraph 16 List of invalid units	No invalid units existed as at 31st December 2021. Thus, no report R-5 is submitted.
15/CMP.1. annex I.E paragraph 17 Actions and changes to address discrepancies	No actions were taken, or changes made to address discrepancies in 2021, since there were no problems to correct.

12.4 Publicly accessible information

All non-confidential information as described at paragraphs 44-48 of the annex to Decision 13/CMP.l is publicly available both on the website of the Environmental Project Management Agency under the Ministry of Environment of the Republic of Lithuania:

In English: https://www.apva.lt/en/national-investments/public-information-eu-greenhouse-gas-registry/

In Lithuanian: https://www.apva.lt/sajungos-siltnamio-efekta-sukelianciu-duju-registras/viesai-prieinama-sajungos-siltnamio-efekta-sukelianciu-duju-registro-informacija/

and via the homepage of Lithuania's domain of the Union Registry: https://unionregistry.ec.europa.eu/euregistry/LT/public/reports/publicReports.xhtml

Public information is updated on a monthly basis.

Further information on unit holdings and transactions as well as information on Article 6 projects and accounts is presented in the following Table 12.4.

Table 12-4. Publicly accessible information

Annual Submission Item	Reported for 2021
13/CMP.1 Annex paragraph 45 Account information	The most up-to-date account information may be accessed via links indicated in the introductory part of this section. The Environmental Project Management Agency under the Ministry of Environment of the Republic of Lithuania complies with the requirements stipulated in the EU legislation.

13/CMP.1 Annex paragraph 46 Joint implementation project information	No Joint Implementation (hereinafter – JI) project is reported as conversion to an ERU under an Article 6 project because there are no approved JI projects in Lithuania for the reported year. However, the complete documentation of the JI projects and ERUS issued as a result of the Article 6 project is presented and available in the following URL: https://www.apva.lt/en/public-information-eu-greenhouse-gas-registry/
13/CMP.1 Annex paragraph 47 Unit holding and transaction information **paragraph 47 (a), (d), (f), (l)**	The most up-to-date account information may be accessed via links indicated in the introductory part of this section. Holding and transaction information is provided on an account type level, due to more detailed information being declared confidential by article 80 of Commission Delegate Regulation (EU) 2019/1122. In relation to paragraphs 47 (d) and (f), only the details of transferring and/or acquiring registry ID can be viewed.
paragraph 47 (b)	In total 227 306 177 AAUs were issued during the previous commitment period (CP1).
paragraph 47 (c)	Since no JI projects were hosted, no ERUs were issued.
paragraph 47 (e)	Since no LULUCF activities were performed, no RMUs were issued.
paragraph 47 (g)	No ERUs, CERs, AAUs and RMUs were cancelled based on activities under Article 3, paragraphs 3 and 4 to date.
paragraph 47 (h)	No ERUs, CERs, AAUs and RMUs were cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1.
paragraph 47 (i)	No ERUs, CERs, AAUs and RMUs were cancelled for the CP2.
paragraph 47 (j)	No ERUs, CERs, AAUs and RMUs were retired for the CP2.
paragraph 47 (k)	A total of 2 327 000 ERUs and 246 966 CERs were carried over from the CP1 to CP2.
13/CMP.1 Annex paragraph 48 Authorized legal entities information	The most up-to-date account information may be accessed via links indicated in the introductory part of this section. In line with the data protection requirements of Regulation (EC) No 2018/1725 and Regulation (EU) 2016/679 and in accordance with Article 80 of Commission Delegate Regulation (EU) 2019/1122, the legal entity contact information (required by paragraph 48) is considered confidential.

Additional up-to-date and publicly available information can be found on the European Union Transaction Log (EUTL) website: http://ec.europa.eu/environment/ets/

Previous Annual Review Recommendations

The previous assessment report included no recommendations for Lithuania.

12.5 Calculation of the commitment period reserve (CPR)

Each Party included in Annex I shall maintain, in its national registry, a commitment period reserve which should not drop below 90 per cent of the Party's assigned amount calculated pursuant to Article 3, paragraphs 7bis, 8 and 8bis, of the Kyoto Protocol, or 100 per cent of eight times its most recently reviewed inventory, whichever is lowest:

- 100 per cent of eight times most recently reviewed inventory (2020)

20,182,554 x 8 = 161,460,429 tonnes CO_2 eq.

- 90 per cent of Lithuania's assigned amount:

113,600,821 x 90 % = 102,240,739 tonnes CO_2 eq.

In the case of Lithuania, the relevant size of the **Commitment Period Reserve is 90 per cent of the Lithuania's assigned amount (102,240,739 tonnes CO_2 eq.)**

12.6 KP-LULUCF accounting

Not relevant for this submission.

13 INFORMATION ON CHANGES IN NATIONAL SYSTEM

No changes in national system had occurred during preparation of NIR for the period 1990-2020.

14 INFORMATION ON CHANGES IN NATIONAL REGISTRY

The following changes to the national registry of Lithuania have occurred in 2020. Note that the 2020 SIAR confirms that previous recommendations have been implemented and included in the annual report.

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 reported period.
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.
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. The publicly available information is updated on a monthly basis, the confidential information is marked as confidential. The relevant information is present both: In English: https://www.apva.lt/en/national-investments/public-information-eu-greenhouse-gas-registry/ In Lithuanian:

	https://www.apva.lt/sajungos-siltnamio-efekta-sukelianciu-duju-registras/viesai-prieinama-sajungos-siltnamio-efekta-sukelianciu-duju-registro-informacija/
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	The internet address of the Lithuanian registry has not changed during the reported period. The URL: https://unionregistry.ec.europa.eu/euregistry/LT/index.xhtml
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.
Annual Review Report Previous Expert Review Team recommendations	The last available report FCCC/ARR/2019/LTU of 4 February 2020 does not contain recommendations related to the national registry.
1/CMP.8 paragraph 23 PPSR account	The opening of the PPSR account is linked to the entry into force of the Doha Amendment. Since the Doha Amendment entered into force for the European Union only on 31 December 2020, the Lithuania's PPSR account was not opened during the reported year.

15 INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

Lithuania continues to finance various projects which minimize the adverse social, environmental and economic impacts of the developing countries.

From 2014 the Ministry of Environment supports bilateral development cooperation projects in the field of climate change according to the Law on Development Cooperation and Humanitarian Assistance (approved by the Parliament) and Directions for the Policy of Development Cooperation in 2019-2021 (approved by the Government).

In 2021, the Minister of Environment has allocated a total amount of 1,94 mil. Euros to 6 new climate related projects in developing countries. In 2021 private and public investments for developing countries was 3,1 mil. Euros.

Selected projects will be implemented in 3 countries – Sakartvelo (Georgia), Armenia and Moldova.

2 projects will be implemented in Sakartvelo. Long-term Lithuania's partner country will be continuing to install solar power plants in public spaces/buildings – schools, local training centres etc. Lithuania's public and private investments for Georgia will account about 1,12 mil. Euros.

Two projects will be financed in Moldova with approx. of 1,3 mil. of Euros investments in solar power plants. Also 2 projects will be implemented in Armenia – total projects value is approx. 670 thous. Euros.

In 2021 Lithuania continued to support projects that have been started to be implemented in 2019 and 2020. The solar power plant projects were implemented in Africa Mali (finished in 2021), Nigeria. Also, other projects are continued in Eastern Partnership countries, especially Sakartvelo, Armenia and Moldova.

In 2021 Lithuania has contributed 100 thous. EUR to the EIB's Eastern Partnership TA Trust Fund, which directs a large part of its funds towards the Climate Action (approx. 60% of the fund are directed for climate-related purposes).

The table below summarizes the data on international climate finance provided by Lithuania in 2021:

Thous. EUR	Type of support	Recipient of support	Provider of support
1940*	bilateral	Development cooperation projects	Ministry of Environment
100	multilateral	EPTATF - Eastern Partnership Technical Assistance Trust Fund, administered by the European Investment Bank	Ministry of Finance

* total subsidy amount

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