REPUBLIC OF SLOVENIA
MINISTRY OF THE ENVIRONMENT, CLIMATE AND ENERGY
SLOVENIAN ENVIRONMENT AGENCY

Slovenia's National Inventory Document 2024

GHG emissions inventories 1986 - 2022

Submission under the United Nations Framework Convention on Climate Change

Ljubljana, December 2024

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PREFACE

Slovenian Environment Agency (SEA) is in accordance with the Slovenian legislation charged with both the overall coordinating of activities that are necessary for the development of emission inventories and with implementing inventories for the purposes of reporting to the United Nations Framework Convention on Climate Change (UNFCCC) and to the European Commission. The Republic of Slovenia is as a party to the convention obligated to make annual GHG emission inventories and to report them.

The National inventory document (NID), as established by decision 18/COP.8 and revised by decision 24/CP.19, is one element of the annual greenhouse gas inventory that is required to be submitted to the UNFCCC by Annex I Parties to the Convention on 15 April each year. According to the EU Regulation 2018/1999 the annual GHG inventory should be submitted to the European Commission by 15 March.

The submission includes the main part of the NID and additional information in five Annexes to the NID:
Annex 1: Key sources
Annex 2: Assessment of Uncertainty
Annex 3: Detailed methodological descriptions for individual source and sink categories:
- A.3. Energy-Road Transport,
- A.3 Energy-Stationary combustion,
- A.3. Agriculture

Annex 4: The national energy balance
Annex 5: Registry

The other elements of this submission include the reporting of GHG emissions by sources and removals by sinks in the common reporting tables (CRT) for the period 1986-2022 and corresponding JSON file.

<u>Specific responsibilities for the 2024 inventory report have been as follows:</u>

Overall responsibility: Tajda Mekinda Majaron - National Inventory Compiler

QA/QC Team: Tajda Mekinda Majaron, Martina Logar D.Sc.,
Boštjan Mali D.Sc., Jože Verbič D.Sc., Matjaž Česen

<u>National inventory document 1986-2022</u>

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<u>CRT Tables</u>

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Executive Summary

An emissions inventory that identifies and quantifies a country's primary anthropogenic sources and sinks of greenhouse gases is essential for addressing climate change. This inventory adheres to both: a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contribution of different emission sources and greenhouse gases to climate change.

In 1992, the Republic of Slovenia signed and in 1995 ratified the UNFCCC. As stated in Article 2 of the UNFCCC, the ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. Parties to the Convention, by ratifying, "shall develop, periodically update, publish and make available…national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies…" The Republic of Slovenia views this document as an opportunity to fulfil these commitments.

This document summarizes the latest information on Slovenian anthropogenic greenhouse gas emission trends from 1986 through 2022. To ensure that the Slovenian emissions inventory is comparable to those of other UNFCCC Parties, the estimates presented here were calculated using methodologies consistent with those recommended in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006. The structure of this document is consistent with the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention. The national greenhouse gas inventory has to be submitted to the UNFCCC Secretariat every year no later than 15 April.

The quality of greenhouse gas (GHG) inventories relies on the integrity of the methodologies used, the completeness of reporting, and the procedures for compilation of data. To this end, the Conference of the Parties (COP) has developed standardized requirements for reporting national inventories.

***A disclaimer:* The greenhouse gas inventory data in this report was compiled using the October 2024 release of the 'CRT reporting tool' provided by the UNFCCC Secretariat. Data provided by this tool may differ from the actual inventory data in some cases due to any remaining technical issues and errors caused by the CRT electronic tool affecting the quality of the GHG inventory".**

1 INTRODUCTION

1.1 Background Information on Greenhouse Gas Inventories and Climate Change

At the Second World Climate Conference in Geneva in October and November 1990, a clear need for standard methodology for monitoring emissions of greenhouse gases was expressed; it was to enable comparing and enhancing inventories in individual countries. Under the auspices of OECD and International Energy Agency and with the support of the United States of America, United Kingdom, and Norway, a draft methodology was set up. That document comprised six direct and indirect greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOCs). The methodology was adopted in Paris in March 1991 at the Fifth Session of the Intergovernmental Panel on Climate Change (IPCC) and it became the starting point for individual states in creating their national inventories of greenhouse gases.

The methodology for the calculation of greenhouse gases has been developing all the time and is a project under development even today. In the IPCC inventory of greenhouse gases for Slovenia, first the 1996 version was applied (Intergovernmental Panel on Climate Change: Greenhouse Gas Inventory - Reference manual, UNEP-OECD-IEA-IPCC, Bracknell 1996), which in some parts also takes into account emissions of direct greenhouse gases that have been encompassed by the Kyoto Protocol (CF_4, C_2F_6, PFCs, HFCs and SF_6). Later the inventory has been permanently improving with implementation of GPG (Intergovernmental Panel on Climate Change: Good practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2000) and the IPCC Good Practice Guidance for Land Use, Land-Use Change, and Forestry (IPCC 2003).

The Subsidiary Body for Scientific and Technological Advice (SBSTA) at its thirtieth session considered the use by Parties of the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines for national greenhouse gas inventories (2006 IPCC Guidelines) starting in 2015. Therefore the emission and removals presented since the submission 2015 have been calculated according to the new guidelines, and since 2023 for some categories calculations are improved using methodology from 2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories (2019 Refinement).

The guidelines for the implementation of the inventory of greenhouse gases contain prescribed methods for calculation of emissions, providing a unified framework for reporting and documenting sources for all inventories. One of the main aims of this method is to ensure comparability of data gathered in individual states and that calls for a definition of at least a minimum scope of equal methods, criteria, and estimating procedures.

The document presents estimates for the following greenhouse gases included in Annex A to the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulphur hexafluoride (SF_6), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NOx), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO_x) and ammonia (NH_3). Nitrogen tri-fluoride (NF_3) emissions do not occur in Slovenia and, therefore, they are not included in this document.

Global warming potential

The global worming potential (GWP) of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas. Direct radiative effects occur when the gas itself is a greenhouse gas. The reference gas used is CO_2 and therefore GWP-weighted emissions are measured in Gg of CO_2 equivalents (Gg CO_2 eq.).

The following table 1.1.1 lists the direct (except for CH_4) 100-year time horizon GWPs relative to CO_2 for all GHGs included in the Slovenian inventory. This table is adapted from table 2.14 of the IPCC Fourth Assessment Report (4AR) which includes most recent GWP values and is available on the IPCC web page:
https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html#table-2-14

Before 2015 the GWPs from the Second assessment report (SAR) have been used for calculation of total GHG emissions in CO_2 equivalents while according to the COP Decision 24/CP.19 the GWPs from AR4 shall be used for all submissions started with 2015. Since 2023 submission GWPs from AR5 are used. For this reason all three sets of GWPs are presented in the table 1.1.1. Only GHGs which are reported in this report are included in this table.

Table 1.1.1: Global Warming Potentials (100 Year Time Horizon) from the IPCC Second, Fourth and Fifth IPCC Assessment Reports.

Gas – common name	Chemical formula	GWP from SAR	GWP from AR4	**GWP from AR5**
Carbon dioxide	CO_2	1	1	**1**
Methane*	CH_4	21	25	**28**
Nitrous oxide	N_2O	310	298	**265**
HFC-32	CH_2F_2	650	675	**677**
HFC-125	CHF_2CF_3	2,800	3,500	**3,170**
HFC-134a	CH_2FCF_3	1,300	1,430	**1,300**
HFC-143a	CH_3CF_3	3,800	4,470	**4,800**
HFC-227ea	CF_3CHFCF_3	2,900	3,220	**3,350**
CF_4	CF_4	6,500	7,390	**6,630**
C_2F_6	C_2F_6	9,200	12,200	**11,100**
SF_6	SF_6	23,900	22,800	**23,500**

** The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapour. The indirect effect due to the production of CO_2 is not included.*

Global warming potentials are not provided for CO, NOx, NMVOCs, SO_2 or aerosols because there is no agreed method to estimate the contribution of gases that are short-lived in the atmosphere, spatially variable, and have only indirect effects on radiative forcing.

1.2 A description of the national inventory arrangements

1.2.1 Institutional, legal and procedural arrangements

In Slovenia, the institution responsible for GHG inventories is the Slovenian Environment Agency (SEA). In accordance with its tasks and obligations to international institutions, the SEA is charged with making inventories of GHG emissions, as well as emissions that are defined in the Convention on Long Range Transboundary Air Pollution within the specified time limit. In making the inventories, the Environmental Agency cooperates with numerous other institutions and administrative bodies which relay the necessary activity data and other necessary data for the inventories.

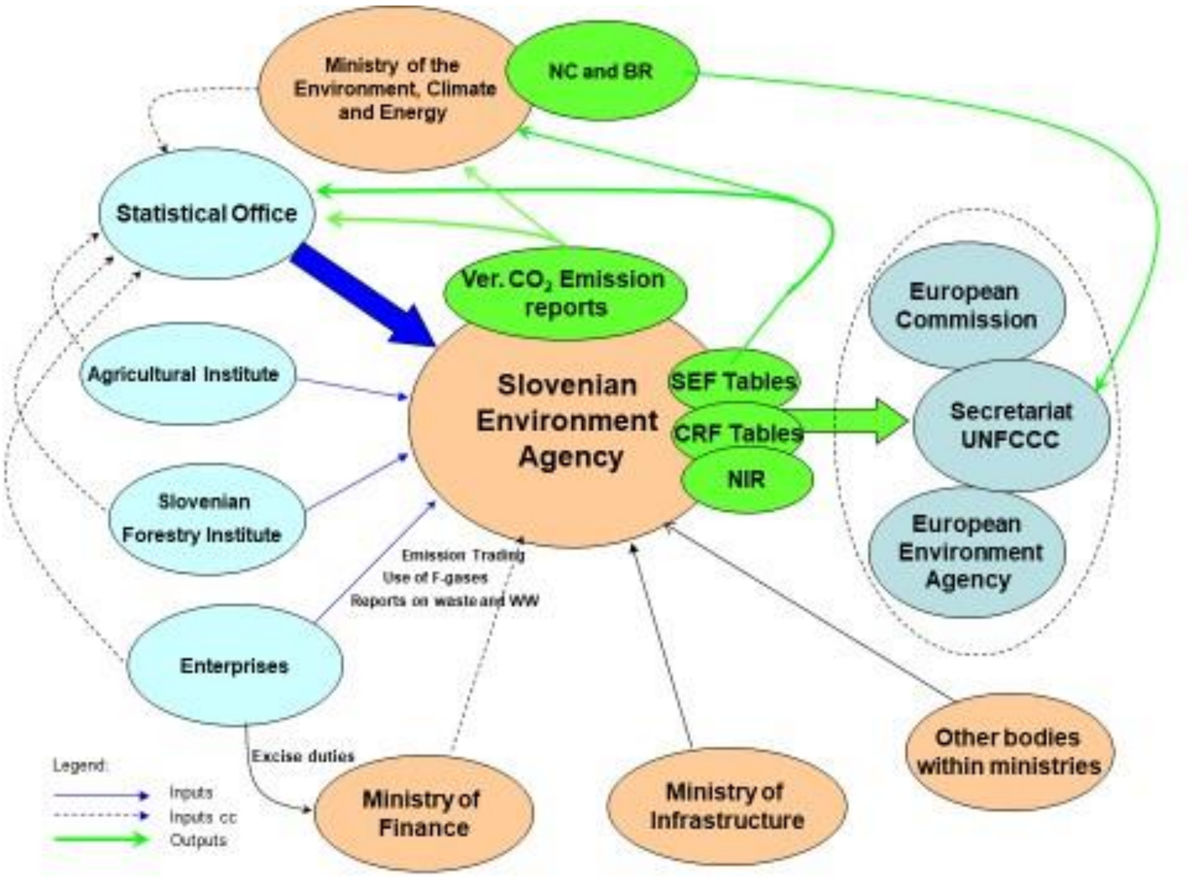


Figure 1.2.1: Data flows in the Slovenian Inventory System

A Memorandum of Understanding has been concluded with the Statistical Office of the Republic of Slovenia (SORS) to submit quality and verified data to the Environmental Agency in due time, because the time limits for inventories and the NID have shortened with the entry of Slovenia into the EU, since inventories and part of the NID for the year before last must be made by 15th of January, and with corrections and final submission of the NID by 15th of March. In view of this, an agreement has been reached with the participating institutions to shorten the time limits for submitting data. For reasons of complexity, attention was mostly focused on the Joint Questionnaires of the SORS, on the basis of which the Statistical Office produces the Energy Balance of the Republic of Slovenia, wherein the most important data on the energy sector are found. All sources of data for GHG inventory are presented in the Table 1.2.1 while the Figure 1.2.1 shows the data flows.

Table 1.2.1: Data Sources

IPCC category	IPCC sub-category	Sources of data
1.A – Energy: Fuel Combustion	1 Energy Industry	• Statistical Office of the Republic of Slovenia: Joint Questionnaires, Energy Balances, annual energy statistics • Slovenian Environment Agency: ETS data
	2 Manufacturing Industries and Construction	• Statistical Office of the Republic of Slovenia: Joint Questionnaires, Energy Balances, annual energy statistics • Slovenian Environment Agency: ETS data
	3 Transport	• Statistical Office of the Republic of Slovenia: Joint Questionnaires, Energy balances • Ministry of Infrastructure • Eurocontrol • Slovenian Maritime Administration • Plinovodi d.o.o.
	4 Other Sectors	• Statistical Office of the Republic of Slovenia • The Fisheries Research Institute of Slovenia
	5 Other	• Slovenian Army and Police
1.B Energy: Fugitive Emissions		• Statistical Office of the Republic of Slovenia: • Slovenian Environment Agency: ETS data • Energy Agency
CRT 2 – Industrial Processes and Product Use	CRT 2A – Mineral Products	• Statistical Office of the Republic of Slovenia: • Slovenian Environment Agency
	CRT 2B – Chemical Industry	• Statistical Office of the Republic of Slovenia:
	CRT 2C – Metal Production	• Statistical Office of the Republic of Slovenia: • Slovenian Environment Agency
	CRT 2D – Non-energy Products	• Statistical Office of the Republic of Slovenia: • Slovenian Environment Agency
	CRT 2F – ODS Substitutes	• Slovenian Environment Agency • Ministry of Finance • Ministry of Environment and Spatial Planning • Statistical Office of the Republic of Slovenia • Health Insurance Institute of Slovenia
	CRT 2G – Other product	• Statistical Office of the Republic of Slovenia • Slovenian Environment Agency
CRT 3 – Agriculture		• Statistical Office of the Republic of Slovenia • Agricultural Institute of Slovenia
CRT 4 – Land Use, Land Use Change, and Forestry		• Slovenian Forestry Institute • Agricultural Institute of Slovenia
CRT 5 – Waste	A. Solid waste disposal	• Slovenian Environment Agency • Statistical Office of the Republic of Slovenia
	B. Biological treatment of solid waste	• Slovenian Environment Agency • Statistical Office of the Republic of Slovenia
	C. Incineration and open burning of waste	• Slovenian Environment Agency
	D. Waste water treatment and discharge	• Slovenian Environment Agency • Statistical Office of the Republic of Slovenia

The year 2003 saw the end of the process of harmonisation of data collection among the Directorate of Energy, Ministry of Agriculture and the Environment, and the Statistical Office of the Republic of Slovenia. An end was put to previous parallel double collecting of data. The competence of collecting data has, by law, passed to the SORS, which checks the data and eliminates potential reporting errors, and submits consolidated data to the Directorate of Energy, which has been publishing data until 2005 in its Energy Yearbook of the Republic of Slovenia. In terms of content, the data were identical to those submitted in the Joint Questionnaires to the IEA.

At the beginning of 2007, the agreement between Statistical Office of the Republic of Slovenia and the Environmental Agency came into force. Accordingly, all statistical data necessary for preparing GHG inventories are available each year by October 30 at the latest. In exchange, ETS data and emission estimates are reported to the Statistical Office within a defined time frame. However, energy statistical data are usually not final due this date and some changes could occurred as long as by the mid-January.

In 2014 the new agreement has been signed which includes more data sets and updated time lines. However with this agreement the access and publication of confidential information has been tightened.

Experts from the Slovenian Forestry Institute and the Agricultural Institute of Slovenia work on GHG inventories according to the standing rules of institutes (ordinance). Financing is assured by governmental institutions according to the yearly work plan. All data from external institutions are submitted to the Slovenian Environmental Agency, where they are archived.

The detailed process from gathering data to emissions calculation and reporting is described in the Manual of Procedures, which was first prepared in 2005 and further updated in 2009. In 2014 a completely new Manual has been prepared, which follows the structure and methodology of the 2006 IPCC GL and includes also the new sources of GHG. In 2020 the LULUCF sector has been included in the Manual for the first time.

1.2.2 Overview of inventory planning, preparation and management

A process of inventory preparation is designed according to the PDCA-cycle (Plan – Do – Check – Act). This is a generally accepted model for pursuing a systematic quality work according to international standards, in order to ensure the maintenance and development of the quality system. This structure is in accordance with structures described in decision 19/CMP.1 and in the 2006 IPCC Guidelines. The system consists of inventory planning, inventory preparation, inventory quality checking and follow-up improvements which are integrated into the annual cycle and preparation as illustrated in the Figure 1.2.2.

Owing to the ever-increasing obligations of Slovenia with regard to reporting, the SEA has decided to implement a unified system of data collection for the purposes of making inventories, as well as secure reliable financing in accordance with the annual program of its work.

For submitting reports to different institutions, various report formats have been devised, since the same data are used to report to the UNFCCC, EEA, EC, and CLRTAP. All external reports of the SEA are prepared in accordance with ISO 9001 via the Agency's reporting service, which keeps inventories of reports. Parallel to this, emissions data are submitted to the SORS, which makes them available in its publications and submits them to EUROSTAT and the IEA.

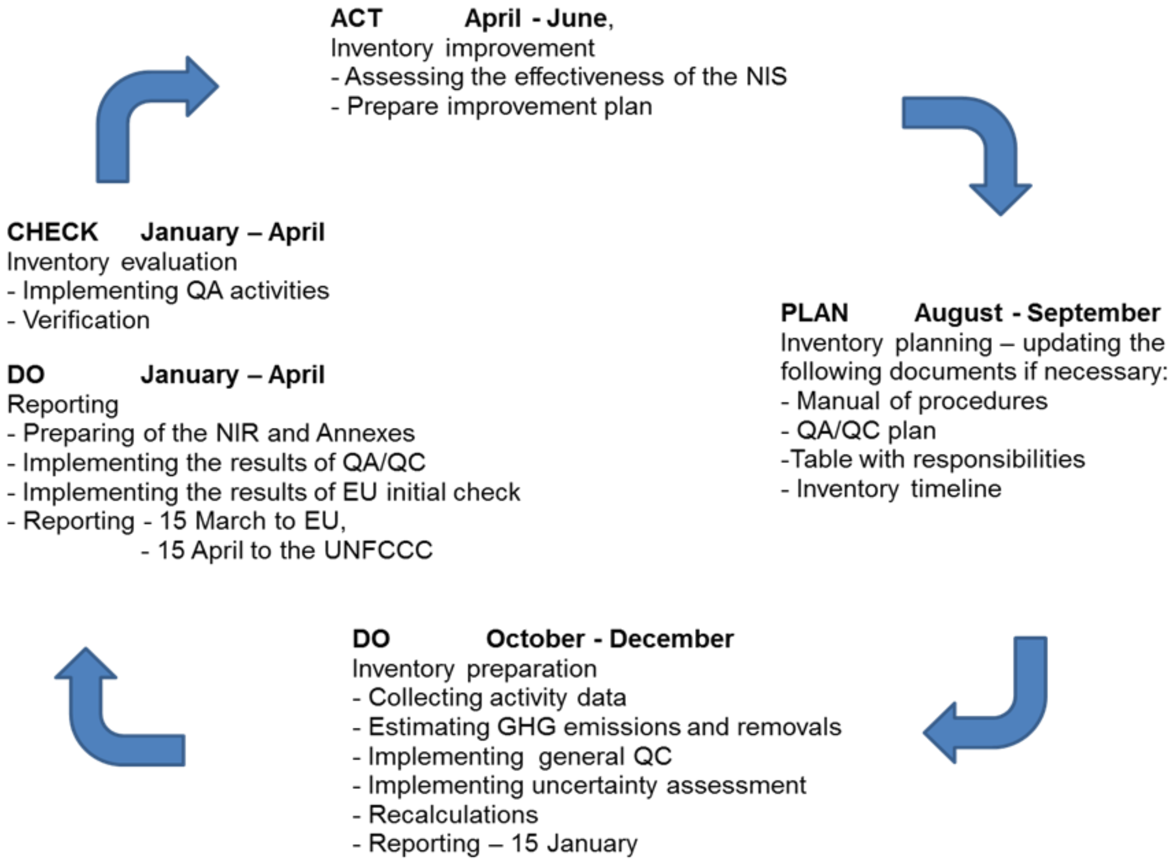


Figure 1.2.2: **The inventory cycle.**

Official Consideration and Approval of the Inventory

Before the inventory is reported to the EU, EEA or UNFCCC Secretariat, it goes through an approval process. The institution designated for approval is the Ministry of the Environment and Spatial Planning. The inventory is usually sent to the Ministry according the following plan:

- draft CRT tables on January 5-7
- final CRT tables and draft NID on March 9-11
- final report on April 9-11

Public Availability of the Inventory

The inventories are publically available on the web at a time of submission. Short after the final submission the estimates are presented in a more simple way with a table similar to Table 2.2.1 from the NID on the web page for Environmental indicators. It is very common that yearly submission of GHG inventory is followed by a press conference, where our last estimates are presented in connection with our emission reduction goals.

Web page address: https://www.gov.si/teme/emisijske-eveidence/

1.2.3 Quality assurance, quality control and verification plan

In 2014, Slovenia developed and implemented a new Quality Assurance and Quality Control Plan as recommended by the IPCC Guidelines (IPCC 2000 and 2006). The QA/QC plan is part of the Manual of Procedures, elaborated in 2005 and updated in 2014. This update was necessary due to the new methodology guidance (IPCC, 2006), which become official guidance for GHG reporting since 2015. The manual is improved and updated regularly.

Quality Control (QC)

Quality Control is a system of routine technical activities to measure and control the quality of the inventory as it is being developed. The QC system is designed to:
- provide routine and consistent checks to ensure data integrity, correctness and completeness;
- identify and address errors and omissions;
- document and archive inventory material and record all QC activities.

The final part of this system was incorporated in an Oracle database (ISEE – "Emission inventory" information system). ISEE enables and ensures that all necessary built-in QA/QC checks have been performed before data and emission estimates are entered in the reporting format tables. It also keeps a record of all changes made to data in the database.

In the beginning emissions from all sectors except LULUCF was included in the ISEE. However, with the development of GHG inventory and the introduction of higher tiers, more and more categories were excluded from ISEE, as the application did not allow for more complex calculations. In addition with development of CRF Reporter importing data in the CRF tables become simple and no longer time consuming, so this ISEE feature has also become unnecessary. However, the ISEE is still used in the stationary fuel combustion for the harmonization of data between pollutants and GHG reporting and for their control.

During development of the database, the following QC was performed:

Check of methodological and data changes resulting in recalculations

- Check for temporal consistency in time series input data for each source category.
- Check for consistency in the algorithm/method used for calculations throughout the time series.

Completeness checks

- Confirm that estimates are reported for all source categories and for all years from the appropriate base year to the period of the current inventory.
- Check that known data gaps resulting in incomplete source category emissions estimates are documented.
- Compare estimates to previous estimates: for each source category, current inventory estimates should be compared to previous estimates. If there are significant changes or deviations from expected trends, recheck estimates and explain any differences.

Check of activity data, emission factors and other parameters

- Cross-check all input data from each source category for transcription errors.
- Check that units are properly labelled in calculation sheets.
- Check that units are correctly carried through from beginning to end in calculations.
- Check that conversion factors are correct.
- Check that temporal and spatial adjustment factors are used correctly.

In 2006, an additional quality control checking point was introduced by forwarding the assessment of verified emission reports from installations included in the National Allocation Plan to the SORS. The role of SORS is to compare data from installations included in EU-ETS with data from their reporting system and to propose corrective measures if necessary. The outcome of data consistency checks is used as preliminary information for the Ministry of Agriculture and the Environment for performing on-site inspections. The use of (EU) ETS data is described in detail in the relevant chapter on Energy and Industrial Processes sectors.

Check of emissions estimates

The main Emissions are calculated in the excel and many years no changes has been made to the formulas or structure of the calculation spreadsheets, so the QA/QC of emissions is focused on the new added categories or in case of stationary combustion in cases of new fuels.

However a regular check like comparison of last year emissions with emissions in the previous year are made on the national level as well as by EU reviewers during initial checks of our January submission. The time series consistency checks of emissions are also part of the CRF Reporter and will be including also in the new ETF tool.

Check of uncertainty estimates

According to the QA/QC plan checks of uncertainty were performed in 2015. The checks consisted of the following:

- Check that the qualifications of individuals providing expert judgement for uncertainty estimates are appropriate.
- Check that qualifications, assumptions and expert judgements are recorded.

- Check that calculated uncertainties are complete and calculated correctly.
- Check that there is detailed internal documentation to support the uncertainty estimates.

While first two QC have been performed, the last two QC showed that detailed documentation is not available for the most of uncertainty estimate which are indicated as expert judgements. For this reason the majority of such uncertainties have been revaluate taking into account data on uncertainties from the 2006 IPCC GL.

Check of NID

- Check that all chapters from annotated NID are included in the NID
- Check that AD, EF and other numerical information mentioned in the text is correct
- Check all AD data is presented in the tables in the NID
- Check all EF and other parameters used in the tables in the NID
- Check all graphs for accuracy and presence in the whole period
- Check all titles for tables and pictures
- Check that all Annexes to the NID are included and updated

Checks of Documentation and archiving

QA/QC checks of documentation and archiving procedures:

- Check that inventory data, supporting data and inventory records are archived and stored to facilitate detailed review.
- Check that all supporting documentation on QA/QC procedures is archived
- Check that results of QC analysis and uncertainty estimates are archived
- Check that there is detailed internal documentation to support the estimates and enable duplication of emissions estimates.
- Check that documentation of the database is adequate and archived.
- Check that bibliographical data references are properly cited in the internal documentation and archived.
- Check that inventory improvements plan is updated ad archived.

Following recommendation from 2013 in country review an instruction have been prepared to determine the form and the names of archived documents.

Quality assurance (QA)

QA generally consists of independent third-party review activities to ensure that the inventory represents the best possible estimates of emissions and removals and to support the effectiveness of the QC program. Since 2008 only one peer review was performed. In 2016, we received many useful comments from the team preparing our fourth National Communication Report. Although the comments were not presented as an official report, we accepted many of the suggestions and corrected a number of errors.

In May 2009, a peer review of the Slovenian inventory was performed for the Energy sector. Since then the Energy sector and Industrial processes sector is regularly checked by experts from Energy efficiency centre (CEU/IJS).

In 2011, the peer review for the Waste sector was performed, no important errors were found.

It is quite difficult to provide a peer review of the Agriculture and LULUCF sector in Slovenia, as experts from the main institutions (Agricultural Institute of Slovenia and Slovenian Forestry Institute) are already involved in the inventory preparation. Nevertheless, to date, the LULUCF sector has been reviewed three times by the external experts, namely in 2012 by the JRC, in 2014 by Zoltan Somogyi in the context of MS technical assistance, and in 2017 by Denitsa Svobodova (independent expert). In 2021 a Slovenian LULUCF sector was reviewed during the voluntary EU review of this sector.

QA/QC procedures performed by other institutions (Agricultural Institute of Slovenia and Slovenian Forestry Institute) are described in the relevant chapters in the NID (Agriculture, LULUCF). Data based on agricultural statistics are mainly from SORS and the Agricultural Institute and data based on forest statistics are produced by the Slovenian Forestry Institute and SORS. All data have been checked.

The Statistical Office of Slovenia (SORS) is our main data provider. In 2005, the European Statistics Code of Practice was adopted, bringing considerable changes to the SORS QA/QC system. The main pillars (factors) of quality are defined and thoroughly described in the Medium-term Programme of Statistical Surveys 2018-2022.
https://www.stat.si/StatWeb/File/DocSysFile/9809/MTPSS%202018-2022-eng.pdf

EU expert review of GHG emissions

According to the Regulation (EU) 525/2015 (MMR) the member states' GHG inventories are subject to the annual review. In the first phase of this review the European commission carry out checks to verify the transparency, accuracy, consistency, comparability and completeness of submitted inventories. In addition the comprehensive review is performed every few years or more often if needed. More details are available in the Commission implementing regulation (EU) 749/2014 in the Chapter III.

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

No changes have been made to the national inventory arrangements since the last submission.

At the beginning of 2023 there was a reorganization of the government, the Ministry of Environment and Spatial Planning became a Ministry of Environment, Climate and Energy, but this has no other effect on the institutional organization

1.3 Inventory preparation, and data collection, processing and storage

The chief source of data is the Statistical Office of the Republic of Slovenia (SORS); however, the Slovenian Environmental Agency obtains much of its data through other activities it performs under the Environmental Protection Act. Emissions from Agriculture are calculated in cooperation with the Slovenian Agriculture Institute (KIS), and emissions and from the LULUCF sector are calculated by the Slovenian Forestry Institute (GIS).

In 2006 we have started to develop a joint database for GHGs and other pollutants: ISEE – Information system for emission inventories. In broad terms the application has been completed and operational since 2011, but it is still necessary to conduct regular maintenance and improvements. The database contains activity data, emission factors and other parameters together with a description of sources from 1980 on for other pollutants, and from 1986 on for GHG emissions. It contains equations necessary for calculation of emissions by simple Tier 1 method.

The main purpose of ISEE was:

- to enable collection and archiving of activity data, emission factors and other parameters including descriptions of sources from 1980 on for other pollutants, and from 1986 on for GHG emissions;
- to calculate GHG and other pollutant emissions;
- to automatically fill in reporting CRF tables.

However in 2015 the UNFCCC Secretariat made available the upgraded CRF Reporter which became operational on April 30. Due to the changes made in the new reporting tool, data have now been imported to the CRF Reporter using excel.

In the last years calculation process for many sources become more and more complicated, therefore only activity data are now included in the ISEE, which is mainly focused now on air pollutants and filling the tables to fulfil NECD and CLRTAP reporting obligation

Documentation and archiving

All inventory data are now stored in a joint database. Supporting data and references are stored in electronic form and/or hard copy form. Inventory submissions are stored mostly in electronic form at various locations and on various media (network server, CD-ROM, computer hard disk). Access to files is limited in accordance with the security policy. Backup copies on the server are made at regular intervals in accordance with the requirements of the information system.

All relevant data from external institutions are also stored at the Environmental Agency in one place. In 2012, all studies have been scanned, transformed to PDF files and stored on network server, CD-ROM and computer hard disk. The studies are available in hard copies and also in electronic format.

1.4 Brief General Description of Methodologies and Data Sources

Inventories of GHG emissions were prepared on the basis of the IPCC methodology as presented in the 2006 IPCC Guidelines for all gases and sectors. Due to the importance of the source and accessibility of activity data, different approaches (tiers) from the IPCC methodology were used (Table 1.4.1).

Table 1.4.1: Summary report for methods and emission factors used from CRT tables

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	EF	Method applied	EF	Method applied	EF
1. Energy	**M,T1, T2,T3**	**CS, D, M, PS**	**M, T1, T2, T3**	**CS, D, M, PS**	**M, T1**	**D, M**
A. Fuel combustion	M,T1, T2,T3	CS, D, M, PS	M, T1, T2	CS, D, M	M, T1	D, M
1. Energy industries	T1, T2	CS, D, PS	T1	D	T1	D
2. Manufacturing ind. and const.	T1, T2, T3	CS, D, PS	T1	D	T1	D
3. Transport	M, T1, T2	CS, D, M	M, T1	D, M	M, T1	D, M
4. Other sectors	T1, T2	CS, D	T1, T2	CS, D	T1	D
5. Other	T1	D	T1	D	T1	D
B. Fugitive emissions from fuels	T1, T3	D, PS	T1, T2, T3	CS, D, PS	T1	D
1. Solid fuels	T1, T3	D, PS	T2, T3	CS, D, PS		
2. Oil and natural gas	T1	D	T1	D	T1	D
2. Industrial Processes	**M, T1, T2, T3**	**CS, D, M, PS**			**D**	**D**
A. Mineral Products	T2, T3	D, PS				
B. Chemical Industry	T2, T3	CS, D				
C. Metal Production	T1, T2, T3	D, PS				
D. Non-Energy Product	M, T1	D, M				
F. Substitutes for ODS						
G. Other product man. and use					D	D
3. Agriculture	**T1**	**D**	**T1, T2**	**CS, D**	**T1, T2**	**CS, D**
A. Enteric Fermentation			T1, T2	CS, D		
B. Manure Management			T1, T2	CS, D	T1, T2	CS, D
D. Agricultural Soils					T1, T2	D
G. Liming	T1	D				
H. Urea application	T1	D				
I. Other C-containing fertilizers	T1	D				
4. LULUCF	**CS,D,T1,T2, T3**	**CS, D**	**D, T1**	**D**	**D, T1**	**D**
A. Forest Land	CS,D,T1,T2,T3	CS, D	D,T1	D	D, T1	D
B. Cropland	CS, D, T1,T2	CS, D			D, T1	D
C. Grassland	D,T1,T2,T3	CS, D			D, T1	D
D. Wetlands	D,T1,T2	CS, D				
E. Settlements	D, T2	CS, D			D, T1	D
F. Other Land	D, T2	CS, D			D, T1	D
G. HWP	D, T1	D			NA	NA
5. Waste	**T1**	**D**	**T1, T2**	**CS, D**	**T1**	**D**
A. Solid Waste Disposal			T2	CS, D		
B. Biological Treatment			T1	D	T1	D
C. Incineration	T1	D	T1	D	T1	D
D. Waste-water Treatment			T1	CS, D	T1	D

	HFCs		PFCs		SF6	
	Method applied	**EF**	**Method applied**	**EF**	**Method applied**	**EF**
2. Industrial Processes	**T1, T2**	**CS, D**	**T3**	**D, PS**	**T1, T2, T3**	**CS, D**
C. Metal Production			T3	D, PS		
F. Substitutes for ODS	T1,T2	CS, D				
G. Other product man. and use					T1, T2, T3	CS, D

In the Energy sector, mainly national/plant specific CO_2 emission factors were used for assessment of emissions from solid fuels, petroleum coke and natural gas (Tier 2/3), while default IPCC emission factors were mainly used for other types of fuels.

The quantities of fuels and consumed fuel energy values were taken from the SORS. Additional data on the energy use of some types of waste (waste tyres, oils and solvents) were acquired from the verified ETS reports. Data on fuel consumption in agriculture and forestry refer to mobile sources only, while the rest of the fuel consumption of these sub-sectors is included in the Institutional and commercial sector. GHG emissions in road transport were determined with the COPERT 5 model using default EFs from the model.

Emission factors for fugitive emissions of CO_2 and CH_4 in mining and post mining activities were determined on the basis of measurements of methane concentrations in ventilation shafts in mines and estimated quantities of released methane and, not very common, also a considerable amount of CO_2. The CH_4 emission factor that was determined in this manner was lower than the default IPCC emission factor. CO_2 emissions in post-mining activities were not assessed, as no estimation method is available. Following 2006 IPCC GL CH_4 emissions from abandoned and closed mines have been also included in the inventory using Tier 2 method and default parameters. Under other CO_2 emissions due to the flue gas desulphurisation are included.

Fugitive emissions from Oil and natural gas have been calculated using EFs from default range from 2006 IPCC Guidance. The old method for calculating CH_4 emissions from the distribution of natural gas, which were estimated according to the length of individual types of transmission or distribution pipelines with regard to the pipe type, material and pressure, applying specific losses per unit of length has been used only for the QA purpose.

Until 1997 emissions from Industrial processes and Product Use were mostly determined on the basis of statistical data on production and consumption of raw materials and by applying country-specific emission factors. After 1997, the SORS partly changed the method of collecting and presenting these data and therefore most of the data were obtained directly from individual companies. These data have also been used for preparing our National Allocation Plan for EU-ETS. Since 2005, data from verified reports have mostly been used while in some cases (aluminium until 2013 and ferroalloy production) the plant data had to be obtained. In determining actual emissions caused by the use of HFCs, data were obtained from companies that have such devices and companies that maintain these devices. Considering SF_6 emissions, the release of this gas from gas-insulated switchgear for electricity is the main source while other sources are also included like a linear particle accelerators and electronic mycroscops.

In Agriculture, methane emissions from enteric fermentation and manure management in bovine animals were determined using Tier 2 approach and the Tier 1 approach was used for other animals that represent a smaller fraction in methane emissions. Input data for N_2O emissions from manure handling and from direct and indirect emissions from fertilisation with animal fertilisers were obtained in the process of estimating methane emissions. For N_2O emissions, CS parameters but default IPCC emission factors were used. A default EF and Tier 1 approach has been used for calculation of CO_2 emissions from liming and application of urea and other C containing fertilizers..

Emissions and removals from the LULUCF sector have been estimated for the six broad land-use categories: Forest land, Cropland, Grassland, Wetlands, Settlements and Other land. The estimation is based on methodologies of the 2006 Guidelines for National Greenhouse Gas Inventories, supplemented by country-specific methods. Estimates of GHG emissions and removals in this sector are calculated from carbon stock changes in the five carbon pools (above-ground biomass, below-ground biomass, dead wood, litter, and soil organic carbon), direct N_2O emissions from N fertilization, N_2O emissions from drainage of soils, N_2O emissions from disturbance associated with land-use conversion to cropland, and non-CO2 emissions from biomass burning. Country-specific emission factors and carbon stock values for forests and partially for cropland and grassland are derived from surveys and measurements. For other land use categories, the IPCC default values or expert judgements are used.

Methane emissions from solid waste handling were determined by the first order decay model from the 2019 Refinement to the 2006 IPCC GL, which takes into account the difference in the time dynamics of methane release from different types of waste. Emissions of CH_4 and N_2O from wastewater and composting, as well as GHG from waste incineration were calculated using the default method.

1.5 Brief Description of Key Categories

The analysis of key categories was performed on the basis of sectoral distribution and use of the approach 1. This approach was used both for the base year and for the year 2022. The level assessment was undertaken for 1986 and 2022, and the trend assessment was performed for 2022. The analyse has been performed at a level of IPCC categories as suggested in Table 4.1 in Volume 1 of 2006 IPCC Guidelines. The results are presented on the Table 1.5.1.

The analyses have been performed with and without LULUCF sector. On the basis of the KCA including LULUCF, 32 categories were selected as keys in 2022 according to the level assessment, and additional 6 were chosen as key categories according to the trend assessment only. As many as 21 categories are key sources according to level and trend KC analysis.

The most of the 38 key categories are from Energy sector (15): 11 categories are CO_2 emissions from fuel combustion, one is CH_4 emissions from biomass and solid fuel combustion in the residential sector, one is N_2O emissions from diesel oil in Road

Transportation, and remaining two are CO_2 and CH_4 fugitive emissions from Coal mining and handling. The second most important sector is LULUCF with 9 key categories, six KCs are in the industrial processes and in the Agriculture sector, where 2 are related to methane emissions and 3 to N_2O emissions, and three KC are in the Waste sector. On the basis of the Tier 1 analysis excluding LULUCF no additional categories were defined to be KC.

Table 1.5.1: IPCC Key Source Categories for 2022, Approach 1

IPCC Category	Gas	with LULUCF	w/o LULUCF additional
1.A.1 Energy Industries, Gaseous Fuels	CO_2	L, T	
1.A.1 Energy Industries, Liquid Fuels	CO_2	L, T	
1.A.1 Energy Industries, Solid Fuels	CO_2	L, T	
1.A.2 Manufacturing Industries and Const., Gaseous Fuels	CO_2	L, T	
1.A.2 Manufacturing Industries and Const., Liquid Fuels	CO_2	L, T	
1.A.2 Manufacturing Industries and Const., Other Fuels	CO_2	L, T	
1.A.2 Manufacturing Industries and Const., Solid Fuels	CO_2	L, T	
1.A.3.b Road Transportation, Diesel Oil	CO_2	L, T	
1.A.3.b Road Transportation, Diesel Oil	N_2O	T	
1.A.3.b Road Transportation, Gasoline	CO_2	L, T	
1.A.4 Other Sectors, Biomass	CH_4	L	
1.A.4 Other Sectors, Gaseous Fuels	CO_2	L, T	
1.A.4 Other Sectors, Liquid Fuels	CO_2	L	
1.B.1.a Fugitive Emissions, Coal Mining and Handling	CH_4	L, T	
1.B.1.a Fugitive Emissions, Coal Mining and Handling	CO_2	T	
2.A.1 Industrial processes, Cement Production	CO_2	L, T	
2.A.2 Industrial processes, Lime Production	CO_2	T	
2.C.3 Industrial processes, Iron and Steel	CO_2	T	
2.C.3 Industrial processes, Aluminium Production	PFC	T	
2.G.3 Industrial processes, N_2O from product use	N_2O	L	
2.F.1 Industrial processes, Refrigeration and Air Conditioning	HFC	L, T	
3.A Agriculture, Enteric Fermentation	CH_4	L, T	
3.B Agriculture, Manure Management	CH_4	L	
3.B Agriculture, Manure Management	N_2O	L	
3.D.1 Agriculture, Direct N2O Emissions from Managed Soils	N_2O	L, T	
3.D.2 Agriculture, Indirect Emissions from Managed Soils	N_2O	L	
4.A.1 LULUCF, Forest Land remaining Forest Land	CO_2	L, T	
4.A.2 LULUCF, Land converted to Forest Land	CO_2	L, T	
4.B.1 LULUCF, Cropland remaining Cropland	CO_2	L	
4.B.2 LULUCF, Land converted to Cropland	CO_2	L, T	
4.C.2 LULUCF, Grassland remaining Grassland	CO_2	L, T	
4.C.2 LULUCF, Land converted to Grassland	CO_2	L, T	
4.E LULUCF, Land converted to Settlements	CO_2	L	
4.E LULUCF, Settlements remaining Settlements	CO_2	L, T	
4.G LULUCF, Harvested wood products	CO_2	L	
5.A.1 Waste, Managed waste disposal sites	CH_4	L	
5.D.1 Waste, Domestic and Commercial Waste Water	CH_4	L	
5.D.2 Waste, Industrial Wastewater	CH_4	T	

In 2010 a Tier 2 key categories analyse has been done for level assessment only and as much as 27 categories have been determined as keys. Mainly due to the large uncertainty, the most KC were in Agriculture sector (9), following by LULUCF (5), Road transport (4), Waste (3), Fuel combustion in Residential sector (2), Fugitive emissions from solid fuels (2), Consumption of HFCs (1) and Electricity and heat production (1).

In addition in 2018, the qualitative approach has been also used to determine key source categories but no additional categories have been found to be keys. For determination the following criteria has been included: mitigation techniques and technologies, high expected emission growth, high uncertainty and unexpected low or high emissions.

Key category analysis as a base for prioritizing improvements in GHG inventory

Key source categories have received special considerations in terms of improvements and QA/QC. On the Table 1.5.2 and 1.5.3 methodologies used to calculate emissions from the key categories are presented.

According to both analyses (Tier 1 and Tier 2), the most important key categories are from LULUCF sector. For 2012 submission the LULUCF sector was highly improved using the newest data from 2012 forest inventory and with additional support from experts from JRC and from EU support project. For the 2017 submission emissions and sinks in LULUCF have been further improved with the introduction of new land transition matrix and inclusion of results from the latest national forest inventory 2017. In 2021 the LULUCF sector has undergo a comprehensive voluntary EU review.

The Energy and Industrial processes sectors have already largely improved with inclusion of big emitters in EU-ETS. The use of default EFs for liquid fuels, mostly fuel oil, represents the main deficiency. Due to the unavailability of resources needed to develop CS EF, the verification of default EFs have been made for the 2014, 2019 and 2022 submission.

The Agriculture sector has improved a lot in the past. Unfortunately, methodologies for calculation of emissions from agricultural soils are not planned for further improvement. It has been assessed that resources (financial and personal) for determination of CS N_2O EFs in this category are unreasonably high for the expected results.

We are improving HFC emissions from Refrigeration and AC with regular updates of the data on stock. In this submission the improved data related to fire protection has been introduced.

In the waste sector two categories are key according to the level and one is key according to the trend (descending). While methane emissions from Managed waste disposal are calculated with the Tier 2 methodology, for methane emissions from Domestic and Commercial WW are calculated with Tier 1 approach. We are intended to use EFs from 2019 Refinement for the 2025 submission and we hope that this will improve the emission estimates from this category.

Table 1.5.2: Methodologies used for key categories according to the level in 2022

IPCC Category	Gas	Methodology	EF and other parameters
1.A.1 Energy Industries, Gaseous Fuels	CO_2	Tier 2	CS
1.A.1 Energy Industries, Solid Fuels	CO_2	Tier 3	PS
1.A.2 Manufacturing Industries and Construction, Gaseous Fuels	CO_2	Tier 2	CS
1.A.2 Manufacturing Industries and Construction, Liquid Fuels	CO_2	Tier 1	D
1.A.2 Manufacturing Industries and Construction, Solid Fuels	CO_2	Tier 3	PS
1.A.2 Manufacturing Industries and Construction, Other Fuels	CO_2	Tier 1, Tier 3	D, PS
1.A.3.b Road Transportation, Diesel Oil	CO_2	Model	Model
1.A.3.b Road Transportation, Gasoline	CO_2	Model	Model
1.A.4 Other Sectors, Gaseous Fuels	CO_2	Tier 2	CS
1.A.4 Other Sectors, Liquid Fuels	CO_2	Tier 1	D
1.A.4 Other Sectors, Biomass	CH_4	Tier 2	CS
1.B.1.a Fugitive Emissions, Coal Mining and Handling	CH_4	Tier 3	PS
1.B.1.c Fugitive Emissions, Other	CO_2	Tier 1	D
2.A.1 Industrial processes, Cement Production	CO_2	Tier 3	PS
2.G.3 Industrial processes, N_2O from product use	N_2O	Tier 1	D
2.F.1 Industrial processes, Refrigeration and AC Equipment	HFC	Tier 2	CS, D
3.A Agriculture, Enteric Fermentation	CH_4	Tier 1, Tier 2	CS, D
3.B Agriculture, Manure Management	CH_4	Tier 1, Tier 2	CS, D
3.B Agriculture, Manure Management	N_2O	Tier 1, Tier 2	CS, D
3.D.1 Agriculture, Direct Soil Emissions	N_2O	Tier 1	D
3.D.1 Agriculture, Indirect Soil Emissions	N_2O	Tier 1	D
4.A.1 LULUCF, Forest Land remaining Forest Land	CO_2	CS, D, Tier 1-3	CS, D
4.A.2 LULUCF, Land converted to Forest Land	CO_2	D, Tier 1-3	CS, D
4.B.1 LULUCF, Cropland remaining Cropland	CO_2	D, Tier 1 - 2	CS, D
4.B.2 LULUCF, Lend converted to Cropland	CO_2	D, Tier 1 - 2	CS, D
4.C.1 LULUCF, Grassland remaining Grassland	CO_2	D, Tier 1 - 3	CS, D
4.C.2 LULUCF, Land converted to Grassland	CO_2	D, Tier 1 - 2	CS, D
4.E.1 LULUCF, Settlements remaining Settlements	CO_2	D, Tier 2	CS, D
4.E.2 LULUCF, Land converted to Settlements	CO_2	D, Tier 2	CS, D
4.G LULUCF, Harvested wood products	CO_2	D	D
5.A.1 Waste, Managed waste disposal sites	CH_4	Tier 2	CS, D
5.D.1 Waste, Domestic and commercial Waste Waters	CH_4	Tier 1	CS, D

Table 1.5.3: Methodologies used for key categories according to the trend only in 2022

IPCC Category	Gas	Methodology	EF and other parameters
1.A.1 Energy Industries, Liquid Fuels	CO_2	Tier 1	D
1.A.3.b Road Transportation, Diesel Oil	N_2O	Model	Model
2.B.6 Industrial processes, Iron and steel	CO2	Tier 3	PS
2.C.3 Industrial processes, Lime production	CO2	Tier 1, Tier 3	D, PS
2.C.3 Industrial processes, Aluminium Production	PFC	Tier 3	PS
5.D.1 Waste, Industrial Wastewaters	CH4	Tier 1	CS.D

1.6 General Uncertainty Evaluation, Including Data on Overall Uncertainty for Inventory Totals

The combined uncertainty was derived from Tier 1 method. The uncertainties of individual activity data and emission factors are based on information available in the 2006 IPCC Guidelines. The total uncertainties have been derived both for Level Uncertainty as well as for Trend Uncertainty. Sectoral uncertainties as well as overall uncertainties for the 1986 base year and for the last reporting year are presented in the table 1.6.1.

Table 1.6.1: Uncertainty in 1986 and 2022 by sectors.

	1986	2022
1A Energy	5.19%	2.28%
1B Fugitive	38.77%	36.85%
2 Industrial Processes/Product use	41.51%	8.93%
3 Agriculture	42.86%	45.28%
4 LULUCF	26.43%	468.40%
5 Waste	55.38%	59.76%
TOTAL COMBINED UNCERTAINTY	**12.07%**	**7.60%**
w/o LULUCF	**6.98%**	**5.54%**

A total trend uncertainty (2022/1986) is 36.97% and without LULUCF it is 2.14% w/o.

Uncertainty in 2022 without LULUCF was lower than in the 1986. The major part to the lower uncertainty was contributed by the Energy and Industrial processes sector due to the more accurate activity data and EFs from EU-ETS. The reason for higher uncertainty in agriculture sector is higher share of soil emissions where the same IPCC default EFs with large uncertainty have been used for the base year and for 2022. The similar reason is in waste sector, where CH_4 emissions from WW treatment plants, with very high uncertainty have a bigger share in 2022 as in 1986.

For 2021 submission uncertainty estimates for LULUCF sector were largely improved and a comprehensive information on all data and assumptions used was included in the NID. In present submission we have continued improvements and updated uncertainties and descriptions in IPPU and Waste sector.

More detailed data on uncertainties are included in the Annex 2 to the April NID and in the excel file SVN_2024_Art12_AnnexX_Uncertainty.

1.7 General Assessment of Completeness

Sources and sinks
All sources of direct GHG gases, included in the IPCC Guidelines, are covered by the inventory.

Gases
All direct GHGs as well as the postulated precursor gases are covered by the Slovenian inventory.

Geographic coverage
The geographic coverage is complete. No territory in Slovenia has been left uncovered by the inventory.

Notation keys

<u>NO (not occurring)</u>
This notation key is used for activities or processes in a particular source or sink category that do not occur within a country. The highest number of source categories marked with NO is found in agriculture and LULUCF sector, but there are some in industrial processes and energy industries as well. In the CRF Reporter we were unable to fill some blank cells with the notation keys. We are waiting on upgrade of CRF Reporter, which will solved this issue. Until then please consider all blank cells in the CRF Tables as they were filled with "NO".

<u>NE (not estimated):</u>
Emissions of CH_4 and N_2O from 5.B.2 Anaerobic Digestion of solid waste at biogas facilities are not estimated, because they are negligible.

<u>IE (included elsewhere):</u>
There are a few categories marked with IE because relevant data are not available on the reporting level and emissions are therefore included in some other categories. These sources are:
- All consumption of liquid fuel in stationary sources in agriculture are reported under Commercial/institutional and biofuel under Residential;
- All N_2O emissions from product use are reported under Medical application
- All GHG emissions from forest fires are reported under Forest land remaining Forest Land.
- CO_2 emissions from dolomite use for Liming are included under Limestone

In addition notation key IE is used also for some categories in the LULUCF sector, when IPCC methodology requires that emissions are reported in the Agriculture sector. These sources are:
- Indirect N_2O emissions from Managed soils (CRT table 4(IV)) are reported in the Agriculture sector under Agriculture Soils – Atmospheric Deposition
- Direct N_2O emissions from M Mineralization/Immobilization from FL and GL converted to CL are reported under relevant category (3.D.1.5) under Agriculture Soils

NA (not applicable):
This notation key is used for activities in a given source/sink category that do not result in emissions or removals of a specific gas. Categories in the CRT for which “NA” is applicable are shaded so they do not need to be filled in.

C (confidential)
The Statistical law considering confidentiality is very strict in Slovenia. All data gathered by three or less reporting units is confidential. It is a good practise in national statistic that this boundary is even higher (five units). As Slovenia is a small country, almost all relevant categories from industrial processes sector and, to a lesser extent, from energy sector are also confidential. The confidentiality problem in activity data has been solved on individual level with each relevant plant. After 2005, verified reports from installations included in ETS have resolved this problem generally for most cases.

However for some small categories we are still depending on data from SORS and for this reason the AD in production of Zinc and production of Lead is marked as confidential.

2 TRENDS IN GREENHOUSE GAS EMISSIONS

2.1 Description and Interpretation of Emission Trends for Aggregated GHG emissions

Total emissions of GHG in 2022, sinks not considered, amounted to 15,615 kt CO_2 eq, which represents a 24.3% decrease of emissions compared to the year 1986. In the period 1986-1991, a reduction of emissions was recorded due to the economic conditions at that time and the fact that the Republic of Slovenia was gaining its independence. In the period 1992-1997, a strong increase of emissions was recorded, which was a consequence of increasing economic growth and revival of industrial production. In the second half of that period, the increased emissions were a consequence of "gasoline tourism" (25% of the total sale of motor fuels in the Republic of Slovenia), since the prices of motor fuels in the Republic of Slovenia were appreciably lower than in the neighbouring countries.

In the period 1998-1999, emission decreased due to the measures undertaken by the neighbouring countries to curb the "gasoline tourism" and due to the increased supply of electrical energy from the Krško Nuclear Power Plant. In the period 2000-2002, the emission kept increasing again due to the renewal of the obligatory export of electrical energy from the Krško Nuclear Power Plant to the Republic of Croatia. After joining the EU in 2004 and after acceptance of Romania and Bulgaria into EU in 2007, emissions from road transport have increased drastically and have prevailed over the decrease in other sectors which has occurred due to the policies and measures in manufacturing industry, agriculture and waste sector.

In 2009, emissions from fuel used and from industrial processes started to decrease due to the global financial crisis. In 2010 and 2011, emissions stayed almost the same as in 2009, while since 2012 a further decrease has been observed. In 2020 a strong decline in emissions happened due to the Covid-19 measures, while in 2022 after increase of emissions in 2021 by 0.8% emissions decrease by 2.9%.

2.1 Description and Interpretation of Emission Trends for by Gas

CO_2 emissions in 2022 represented 81.3% of overall emissions of greenhouse gases. CO_2 emissions excluding LULUCF followed the consumption of energy and with regard to their fraction exerted a major impact on total emissions. Compared to 1986, they decreased by 24.2% in 2022. CH_4 emissions represented 12.2% of total emissions in 2022 and were by 34.8% lower than in 1986. N_2O emissions represented 4.5% of total emissions and were by 3.2% lower than N_2O emissions in 1986. F-gases represented 2.0% of total emissions and some gases (HFCs and SF_6) have shown significant increase since 1995 (base year for F-gases), while PFC decreased drastically in 2008 and has continued to decrease in 2009. Since then a slow increase of emissions was observed until 2016, and since then emissions are decreasing until 2019 and since than emissions of F-gasses are more or less constant.

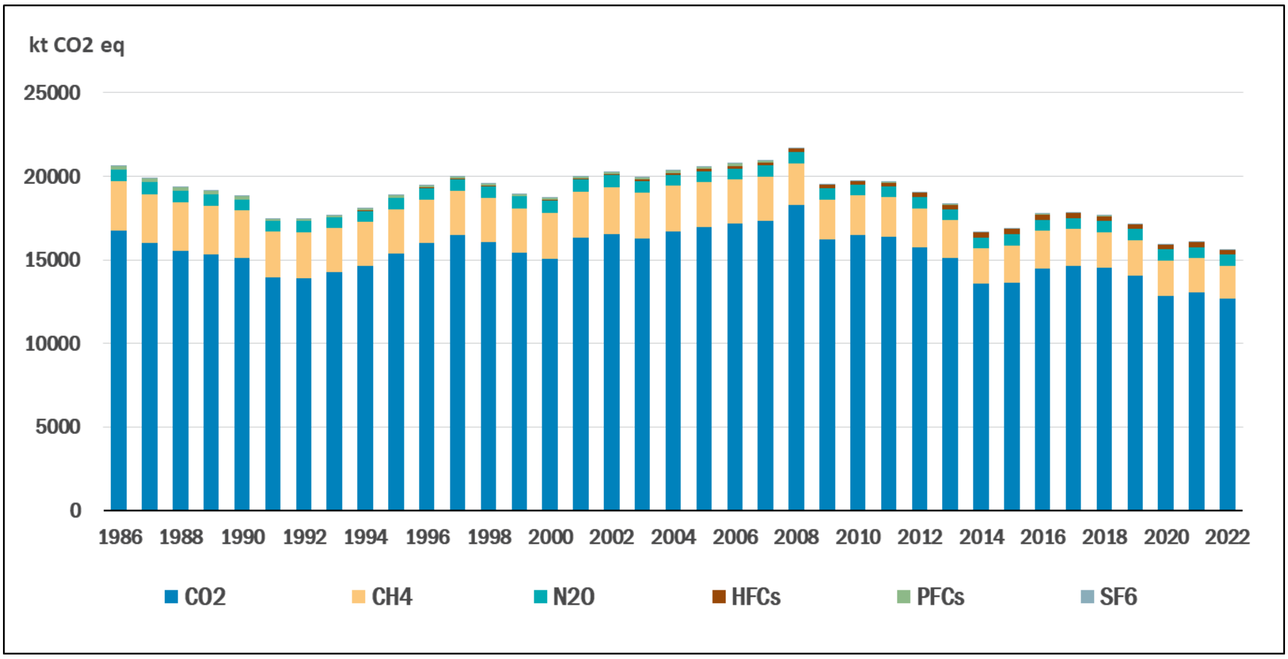


Figure 2.2.1: GHG Emissions in Slovenia by gas.

2.2 Description and Interpretation of Emission Trends by Sector

According to the UNFCCC Reporting Guidelines, emissions estimates are grouped into five IPCC categories: Energy, Industrial Processes and Product Use, Agriculture, Land Use, Land-Use Change and Forestry, and Waste (Figure 2.3.1 and Table 2.2.1).

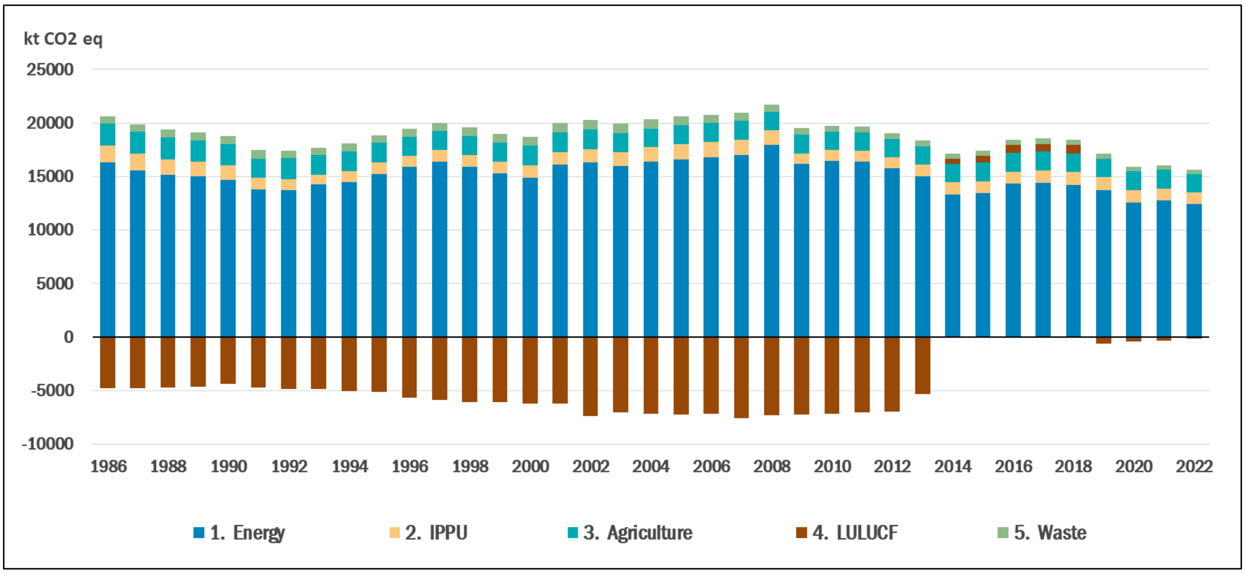


Figure 2.3.1: GHG Emissions in Slovenia by sector

By far the most important sector is Energy, which in 2022 accounted for 79.3% of total GHG emissions. In this sector emissions have decreased by 24.7%, compared to the 1986. Within this sector, in the period 1986–2022, GHG emissions from the Energy Industry, as the biggest sub-sector in the base year, decreased by 50.1%. In the period 1999–2007, steep growth (+27%) has been recorded due to the increased consumption of electrical energy.

Undoubtedly the greatest increase in GHG emissions was observed in the transport sector, by as much as 200% until 2008, due to the increase in road transportation, while emissions from other kinds of traffic slightly declined. In 2009 GHG emissions from transport decreased by 16.3% compared to 2008. Since then emissions fluctuate from year to year but have never reached the 2008 peak. Due to the Covid-19 "lock down" in 2020 emissions in the transport sector decreased by 18.7% compared to the previous year, while in 2021 emissions are almost back on the pre-Covid level and in 2022 emissions increased by 11.3% compared to 2021 and are 182.5% higher as in the base year.

There was an appreciable reduction of GHGs from Manufacturing industry between 1986 and 2001 (-50.3%). After 2001, a stabilisation of emissions was observed until 2008. Due to the global financial crisis, emissions from Manufacturing industry and construction decreased in 2009 by 15.6%. In the following years the emissions have further decreased and altogether in the 2015 due to the economic crises emissions from manufacturing industries and construction were lower by 31.3% from emissions in 2008. Due to the economic recovery in the last years emissions started to increase again until 2018 and since then stabilisation of emissions is observed. However in 2022 emissions decreased by 7.3%. In the period 1986 to 2022 emissions from this sector decreased by 61.1%.

In the CRT category Other sectors, which accounts for 10.4% of emissions, emissions from the households prevails. Mainly due to increasing use of biomass for heating, better insulation of buildings and warmer winters, the GHG emissions from this sector decreased by 51.7% since 1986.

Very small emissions (0.04%) have been reported under "Other" and are related to the military use of fuel. Fugitive emissions in the Republic of Slovenia are also of minor importance thus they represent only 2.5% of emissions in the sector and have decreased by 52.5% compare to emissions in 1986 by 52.5%.

Emissions from Industrial processes and product use (CRT sector 2) in Slovenia account for 7.3% of the total national GHG emissions, excluding LULUCF. They amounted to 1,586 kt CO_2 equivalents in 1986 and 1,139 kt CO_2 equivalents in 2022. The most important GHG of this sector was carbon dioxide, with 64.9% of emissions from this category, followed by HFCs with 24.7%, N_2O with 8.5%, SF_6 with 1.5%, and PFCs with 0.3%. The main source of emissions is mineral industry with 50.4% of emissions, followed by consumption of F-gases (product uses as substitutes for ODS) with 24.7%, and metal industry with 11.6%. Significantly smaller are the contributions from other product manufacture and use (10.0%), metal industry (7.8%), and chemical industry (5.7%), while use of non-energy products from fuels and solvent contributes 1.3% to the total emissions from this sector.

Since 1986, GHG emissions from Industrial Processes at first fell sharply to reach their lowest value in 1993, but then started to rise again and were in 2007 6.0% above 1986 level. Due to the global financial crises and lower industrial production, emissions in 2009 were 28.2% below the 1986 emissions but in the period 2010 – 2019 slowly increased by 24.5% while in 2020 decreased by 4.3% due to the epidemics and continue to decrease also in 2021 by 3.5%. In 2022 the process emissions slightly increased.

In Agriculture as the second most important sector, emissions in 2022 amounted to 1,706 Gg CO_2 eq, which represents 10.9% of all emissions. Agriculture represents the main source of methane and N_2O emissions, namely 64.6% of all methane emissions and 62.2% of all N_2O emissions. In the agricultural sector, CH_4 emissions accounted for 72.5% of emissions and N_2O emissions accounted for 25.6% of emissions, while CO_2 emissions accounted for 1.9% only. GHG emissions from agriculture show small oscillations for individual years, but the general trend is on the decrease. In 2022, emissions were 16.3% below the emissions in the base year.

The most important sub-sector represented emissions from enteric fermentation, which contributed 57.7% of all emissions from agriculture, followed by emissions from agricultural soils, with 21.6%; the rest is contributed by emissions of methane and N_2O from animal manure (18.7%) while CO_2 emissions due to the liming and application of urea and other C-containing fertilizers represented only 1.9% of emissions in this sector (Figure 5.1.1).

In 2022, the LULUCF sector acted as a CO_2 sink of -174 Gg CO_2 eq as total emissions from this sector were higher than total removals. The most important category is forest land, which accounts for 95% of the sector's total net emissions. The LULUCF sector has been a net sink in recent years, largely due to declines in sanitary fellings and mortality rates. In terms of the overall trend of net removals from the LULUCF sector, removals decreased by 35% from 1986 to 2022. Further decreases occurred from grassland and HWP. While net removals from grassland showed a decreasing trend, removals from HWP increased since 2016, due to increased biomass supply following natural disturbances in forests.

In 2022, emissions from the Waste sector amounted to 380 Gg CO2 eq, or 2.4 per cent of the total GHG emissions. Since 1986 emissions decreased by 45.7 per cent. The key driver for the decline of emissions is the decrease of biodegradable part of the municipal waste deposited on the SWD sites and increase of gas recovery on the SWD sites and in the wastewater treatment plants. (Figure 7.1.1).

Methane emissions from the Waste sector are the second largest source of methane and represents 17.1% of the all methane emissions in Slovenia in 2022. The fraction of methane emissions in this sector amounts to 85.8%, while the remaining part represent N_2O (10.5%) and CO2 emissions (3.7%). Solid waste handling contributes 46.4% to the total emissions from this sector, wastewater handling 44.9%, composting 5.0%, and incineration of waste 3.3%.

Emissions from solid waste disposal started to decline in 2005 and since then emissions decreased by 68.4% due to the strong decrease of deposited biodegradable part of municipal waste and gas recovery. Emissions from waste waters were by 48.9% lower than in the base year what is mostly due to recovery of gas in wastewater treatment plants and the decrease in industrial production.

Table 2.2.1: GHG emissions and removals in Slovenia in kt CO_2 eq. by sectors and sub-sectors 1986-2022.

	1986	1990	2000	2005	2010	2015	2020	2021	2022	Change LY to BY (%)	Change LY to PY (%)
1. Energy	16,317	14,705	14,874	16,604	16,454	13,462	12,563	12,754	12,390	-24.1	-2.9
A. Fuel Combustion	15,668	14,144	14,359	16,034	15,891	13,061	12,151	12,395	12,081	-22.9	-2.5
1. Energy Industries	6,840	6,374	5,593	6,449	6,347	4,566	4,515	4,198	3,416	-50.1	-18.6
2. Man. Industries and Construction	4,124	3,095	2,293	2,464	1,932	1,605	1,703	1,733	1,605	-61.1	-7.3
3. Transport	2,051	2,737	3,676	4,401	5,299	5,354	4,576	5,205	5,794	182.5	11.3
4. Other Sectors	2,612	1,906	2,793	2,716	2,309	1,533	1,355	1,254	1,261	-51.7	0.6
5. Other	41	32	3	3	3	4	3	5	5	-88.7	2.1
B. Fugitive Emissions from Fuels	649	561	515	570	563	401	411	359	308	-52.5	-14.0
1. Solid Fuels	602	505	461	511	510	361	367	313	267	-55.6	-14.5
2. Oil and Natural Gas and other…	47	56	54	59	54	40	44	46	41	-13.7	-11.0
2. Industrial Processes	1,586	1,368	1,141	1,395	987	1,109	1,154	1,127	1,139	-28.2	1.0
A. Mineral Industry	744	694	598	636	479	452	560	568	574	-22.8	1.2
B. Chemical Industry	98	88	114	138	90	60	62	65	65	-34.1	-0.6
C. Metal Industry	656	530	321	410	126	207	143	129	89	-86.4	-30.8
D. Non-energy products	8	8	14	25	15	26	31	35	15	84.2	-56.7
E. Electronics industry	NO	NO	NO	NO	NO	NO	NO	NO	NO		
F. Product uses as ODS substitutes	NO	NO	41	130	233	312	281	283	282	100.0	-0.4
G. Other product manufacture and use	80	47	52	56	44	52	77	48	114	42.0	136.5
H. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA		
3. Agriculture	2,038	1,960	1,871	1,769	1,726	1,764	1,773	1,774	1,706	-16.3	-3.8
A. Enteric Fermentation	1,116	1,064	1,050	1,005	989	1,025	1,025	1022	985	-11.7	-3.6
B. Manure Management	448	443	363	348	333	334	336	336	320	-28.6	-4.8
C. Rice Cultivation	NO	NO	NO	NO	NO	NO	NO	NO	NO		
D. Agricultural Soils	418	397	425	388	376	380	382	387	369	-11.8	-4.7
E. Prescribed Burning of Savannahs	NO	NO	NO	NO	NO	NO	NO	NO	NO		
F. Field Burning of Agricultural Residues	NO	NO	NO	NO	NO	NO	NO	NO	NO		
G. Liming	44	44	17	14	13	11	14	15	21	-52.2	38.3
H. Urea applications	9	9	12	12	11	9	12	9	8	-7.7	-11.1
I. Other carbon-containing fertilizers	4	4	4	4	4	5	4	4	3	-18.3	-24.3

	1986	1990	2000	2005	2010	2015	2020	2021	2022	Change LY to BY (%)	Change LY to PY (%)
4. Land Use, Land-Use Change and Forestry	-4,782	-4,386	-6,205	-7,236	-7,172	560	-400	-324	-173	-96.4	-47.2
A. Forest Land	-4,793	-4,818	-6,043	-7,266	-7,145	624	-277	-180	42	-100.9	-123.4
B. Cropland	269	272	138	164	156	191	152	151	152	-43.6	0.2
C. Grassland	-311	-285	-753	-574	-528	-449	-398	-358	-312	-0.3	-12.8
D. Wetlands	42	43	32	30	46	13	42	44	46	7.7	4.2
E. Settlements	454	455	598	579	409	306	219	210	201	-55.8	-4.3
F. Other Land	14	15	8	16	20	4	4	4	4	-71.2	1.0
G. Harvested wood products	-457	-67	-85	-185	-129	-129	-142	-195	-305	-33.3	56.2
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO		
6. Waste	697	769	850	828	574	532	440	419	380	-45.5	-9.2
A. Solid Waste Disposal	327	418	532	546	335	286	219	197	176	-46.1	-10.6
B. Biological treatment of solid waste	NO	NO	NO	3	5	13	20	23	19	100.0	-17.3
C. Incineration and open burning of waste	2	2	3	3	7	27	20	14	14	601.2	0.2
D. Waste water treatment and discharge	368	350	315	276	227	205	182	184	171	-53.6	-7.4
E. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO		
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO		

Memo Items.

International Bunkers	59	49	69	130	133	283	408	310	62	5.2	-80.1
Aviation	59	49	69	61	73	75	26	27	62	5.2	128.4
Navigation	NO,NA	NO,NA	NO,NA	69	60	208	382	283	NO		
Multilateral Operations	NO	NO	1	0	0	1	0	1	1	100.0	1.4
CO_2 Emissions from Biomass	2,763	2,581	2,576	3,315	3,308	3,207	2,933	3,222	2,794	1.1	-13.3
Long term storage of C in waste disposal sites	771	1,084	2,037	2,587	3,063	3,247	3,249	3,249	3,249	321.2	0.0
Total CO_2 Eq. Emissions without LULUCF	20,638	18,802	18,736	20,596	19,741	16,866	15,930	16,074	15,615	-24.3	-2.9
Total CO_2 Eq. Emissions with LULUCF	15,857	14,416	12,532	13,360	12,570	17,426	15,529	15,749	15,442	-2.6	-1.9

2.3 Description and Interpretation of Emission Trends for Indirect GHGs and SO_2

The largest sources of emissions of NOx is transport followed by combustion in energy industries. The road transport sector is the sector contributing the most to the emission of NOx, in 2022 44% of the Slovenian emissions of NOx. The total emissions have decreased by 66% from 1990 to 2022. The largest reduction of emissions has occurred in the road transport sector due to the fitting of three-way catalysts to petrol fuelled vehicles. The reduction has been achieved also due to installation of low-NOx burners and denitrifying units in power plants and district heating plants.

CO emissions have decreased between 1990 and 2022 by 73%. CO is mainly emitted from incomplete combustion. Small combustion is responsible for the dominant share of the total CO emissions from the residential sector. Also transport contributes significantly to the total emission of this pollutant. Emission reduction of CO is mainly a result of introduction of vehicle meeting higher emission standards.

The emissions of NMVOC can be divided into two main groups: incomplete combustion and evaporation. They originate from many different sources. The main contributor of NMVOC in the year 2022 was industrial processes and product use, followed by small combustion. Emissions of NMVOC have decreased from 1990 to 2022 by 56%. The decline in emissions has primarily been due to reductions achieved in the road transport sector due to the introduction of vehicle catalytic converters and carbon canisters on gasoline cars for evaporative emission control. The reductions in NMVOC emissions have been enhanced by the switching from petrol to diesel cars and changes in the solvents and product use sector as a result of the introduction of legislative measures.

The main part of the SO_2 emission originates from combustion of fossil fuels, mainly coal and oil in public power plants and district heating plants. From 1990 to 2022, the total emission decreased by 98%. This enormous reduction is largely due to installation of desulphurisation process in the plant, use of fuels with lower content of sulphur in public power and district heating plants, introduction of liquid fuels with lower content of sulphur and substitution of high-sulphur solid and liquid fuels to low-sulphur fuels such as natural gas.

In the Table 2.3.1, emissions of pollutants reported under Directive 2016/2284 (NECD) are presented. The data are slightly different from the data reported in the CRT tables because emissions from international aviation are not included in the national total in GHG inventory. In addition for the following CRT categories some pollutants cannot be reported: NOx emissions in 2.B.6 TiO_2 production and in 3.B. Manure management; NMVOC emissions in 2.B.10.a Other and SO_2 emissions in 2.C.7 Other (copper production).

Table 2.3.1: Emissions of CO, NOx, NMVOC, and SO_2 (kt) as reported under Directive 2016/2284.

	1990	1995	2000	2005	2010	2015	2020	2022	Change
NOx	75.4	75.2	58.7	55.0	47.7	35.1	25.5	25.6	-66.0
CO	291.2	280.9	204.5	182.0	142.6	121.2	88.6	78.6	-73.0
NMVOC	65.4	62.8	55.1	47.9	39.4	32.3	32.1	28.6	-56.3
SO_2	202.8	124.5	93.1	39.7	10.3	5.6	4.0	3.4	-98.3

3 ENERGY (CRT sector 1)

3.1 Overview over the Sector

The energy sector is the most important sector of GHG emissions in the Republic of Slovenia, since it accounted for 79.3% of overall CO_2 eq. emissions (w/o considering LULUCF) in 2022. Emissions from this sector arise from fuel combustion, accounting for 97.5% emissions from the energy sector, and as fugitive emissions from fuels, accounting for 2.5% of emissions (Figure 3.1.1).

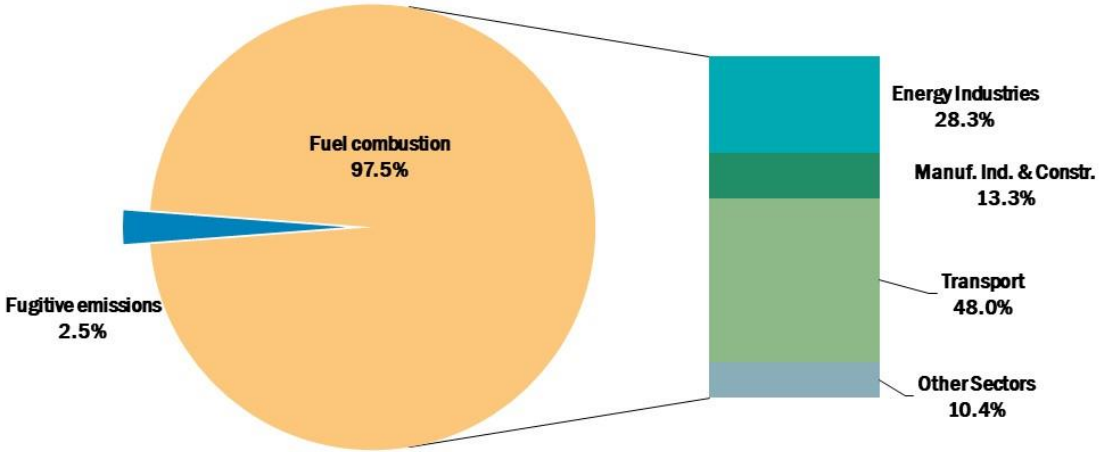


Figure 3.1.1: Emissions of GHG in Energy Sector by categories in 2022

Emissions from Energy sector are presented on the Table 3.1.1. Compared to 2021, GHG emissions decreased by 2.9% in 2022 and were by 24.1% lower than in the 1986 base year.

Until 2014 Energy Industries was the most important sub-sector, while in 2014 a strong decrease of emissions (-23%) was observed. This happened because one thermal power plant was closed in 2014. The most important category in this sector is a production of electricity and heat (IPCC 1.A.1.a). Emissions from this category vary in accordance with the production of electrical energy. It has to be taken into consideration that in the Republic of Slovenia in 2022, 5.3 TWh (i.e. 41.1%) of electrical energy was produced in the Krško Nuclear Power Plant, 3.4 TWh (i.e. 26.1%) in public hydroelectric power plants, 3.5 TWh in thermal power plants (i.e. 27.6%), while the remaining 0.6 TWh (i.e. 5.0%) was produced using solar and wind energy. The structure changes slightly from year to year, depending mostly on the changes in the hydrology of Slovenian rivers. Within this sector, in the period 1986–2022, GHG emissions from the Energy Industry, as the second biggest sub-sector, decreased by 50.1%.

In 2014 with 41.9% share a transport sector became the most important source of fuel combustion emissions and was the most important also in 2022 with share of 48.0%. For traffic, virtually all emissions are accounted for by road traffic and within this category the growth of the fraction of emissions from goods transport is particularly noticeable, since the goods transport in transit through Slovenia has been, annually increasing by more than 10% since 2000. Due to the recession, the emissions in 2009 decreased drastically and since then emissions have fluctuated from year to year but have never reached the 2008 level again. In 2020 due to the Covid-19 measures emissions from transport was by 18.7% lower as in the previous year but as much as 172.6% higher as in 1986. In 2021 emissions from this sector increased by 13.8% and in 2022 they increased further by 11.3%. In the period 1986 to 2022 transport emissions increased by 182.5%.

There was an appreciable reduction of GHGs from Manufacturing industry between 1986 and 2001 (-50.3%). After 2001, a stabilisation of emissions was observed until 2008. Due to the global financial crisis, emissions from Manufacturing industry and construction decreased in 2009 by 15.6%. In the following years the emissions have further decreased and altogether in the 2015 due to the economic crises emissions from manufacturing industries and construction were lower by 31.3% from emissions in 2008. Due to the economic recovery in the last years emissions started to increase again until 2018 and since then stabilisation of emissions is observed. However in 2022 emissions decreased by 7.3%. In the period 1986 to 2022 emissions from this sector decreased by 61.1%.

In the CRT category Other sectors, which accounts for 10.4% of emissions, emissions from the households prevails. Mainly due to increasing use of biomass for heating, better insulation of buildings and warmer winters, the GHG emissions from this sector decreased by 51.7% since 1986.

Very small emissions (0.04%) have been reported under “Other” and are related to the military use of fuel.

Table 3.1.1: Emissions from Energy sector by sources in kt CO_2 eq.

	1986	1990	2000	2005	2010	2015	2020	2021	2022
1. Energy	16,317	14,705	14,874	16,604	16,454	13,462	12,563	12,754	12,390
A. Fuel Combustion	15,668	14,144	14,359	16,034	15,891	13,061	12,151	12,395	12,082
1. Energy Industries	6,840	6,374	5,593	6,449	6,347	4,566	4,515	4,198	3,416
2. Man. Ind. and Const.	4,124	3,095	2,293	2,464	1,932	1,605	1,703	1,733	1,605
3. Transport	2,051	2,737	3,676	4,401	5,299	5,354	4,576	5,206	5,795
4. Other Sectors	2,612	1,906	2,793	2,716	2,309	1,533	1,355	1,254	1,261
5. Other	41	32	3	3	3	4	3	5	5
B. Fugitive Emissions	649	561	515	570	563	401	411	359	308
1. Solid Fuels	602	505	461	511	510	361	367	313	267
2. Oil and Natural Gas	47	56	54	59	54	40	44	46	41

Fugitive emissions in the Republic of Slovenia are of minor importance thus they represent only 2.5% of emissions in the sector and have decreased by 52.5% compare to emissions in 1986. The biggest fraction (73.4%) of GHG emissions from this sector are emissions of carbon dioxide and methane from mining of coal in underground mines, while remaining emissions are emissions of CO_2 due to the SO_2 scrubbing (13.3%) and emissions from oil and natural gas (13.3%). Since the base year emissions constantly diminished due to ever-smaller excavation of coal until 2001, when it stabilized. In the year 2013 emissions decreased due to the closure of one smaller coal mine.

CO_2 emissions from fuel combustion of biomass were calculated, but were not included in the total of CO_2 emissions (they are reported as memo item). However, other two greenhouse gases (CH_4, N_2O) were included in accordance with the IPCC methodology.

3.2 Fuel Combustion (CRT 1A)

In the Fuel Combustion sector, mainly national/plant specific CO_2 emission factors were used for assessment of the majority emissions from solid fuels, petroleum coke, natural gas and some types of waste (Tier 2/3), while default IPCC emission factors were used for other types of fuels. The quantities of fuels and consumed fuel energy values were primary taken from the SORS but since 2005 they were replaced by EU-ETS data when they differ. Additional data on the energy use of some types of waste (waste tyres, oils and solvents) were also acquired from the verified EU-ETS reports.

The European Union Emissions Trading System (EU-ETS) has been established in 2003. It includes heavy energy-consuming installations in power generation and manufacturing. The activities covered are energy activities, the production and processing of ferrous metals, aluminium, the mineral industry and some other production activities. In 2022 EU-ETS is covering 68% of all stationary combustion activities, and 57% of IPPU emissions. As much as 95% of emissions from Energy industries have been included in the EU-ETS in 2022.

Data on fuel consumption in agriculture, forestry, and fishery refer to mobile sources only, while the rest of the fuel consumption of this category is included in the Commercial and Residential sector. GHG emissions from road transport were determined with the COPERT 5 model.

Emissions from the standard liquid fuels are mostly calculated with default CO_2 EFs while in road transport CO_2 EFs from COPERT 5 model are used. We are aware that not using the CS EF for the key categories is not in line with the IPCC methodology. To help many EU countries with the same problem the European Commission has started the project to help MS in developing CS EF. Initially, we expected that this project will resulted in a set of CS EFs used by EU Member States and instructions for their use in the other countries, where CS EFs are not available. However in the end this not happened. The result of the project are the instructions that every MS should determine their own EF. They suggest to analyse carbon content in fuel samples collected under the Fuel Quality Directive (FQD). However this approach is not suitable for us, because samples which are collected under the FQD are not available for further use because they are not archived. The expert from the main company which prepare reports for FQD are of the opinion that fuel should be sampled separately for this purpose. There is also no accredited laboratory in Slovenia to determine C content in the liquid fuels. At this moment we do not yet know exactly how and when we will be able to start with this contract.

In addition we have also a problem because NCVs for standard liquid fuels are not available every year. Since 2005, SORS has been using the same value every year for NCVs for gasoline, gas/diesel oil and LPG. We have discussed with them on this issue but they have no solution how to obtain yearly values for NCVs for the standard liquid fuels. We intended to obtain this data together with C content but the situation due to the Covid-19 postpone this project at least for one year. As these are one-off measurements that will not be performed every year, this will not solve this problem permanently. In addition it is impossible to obtain this data for the years back to 1986.

Country specific CO_2 EF for domestic lignite

With regard to the need to upgrade GHG emissions inventories, national CO_2 emission factors for domestic lignite were developed in 2004. CO_2 emission factors were obtained on the basis of determined carbon contents in the fuel. Data on carbon content in the fuel for the years before 2005 are available only for the biggest pit in Slovenia, the Velenje Lignite Pit. The carbon content of lignite was verified by supplementary chemical analyses of coal samples from this pit in an accredited laboratory in accordance with EN ISO 17025. Additional information is available in the publication from The Milan Vidmar Electric Power Institute, National CO_2 emission factor for lignite from Velenje coalmine; A Review of the Ultimate Analysis of lignite, 2004. Since 2005 the data on carbon content from EU ETS is available what enable the development of country specific and plant specific CO_2 EF for all types of solid fuels.

In the Table 3.2.1 and Figure 3.2.1 the national CO_2 emission factors used for domestic lignite are presented while all other country specific or plant specific CO_2 emission factors for solid fuels are presented under relevant subchapters.

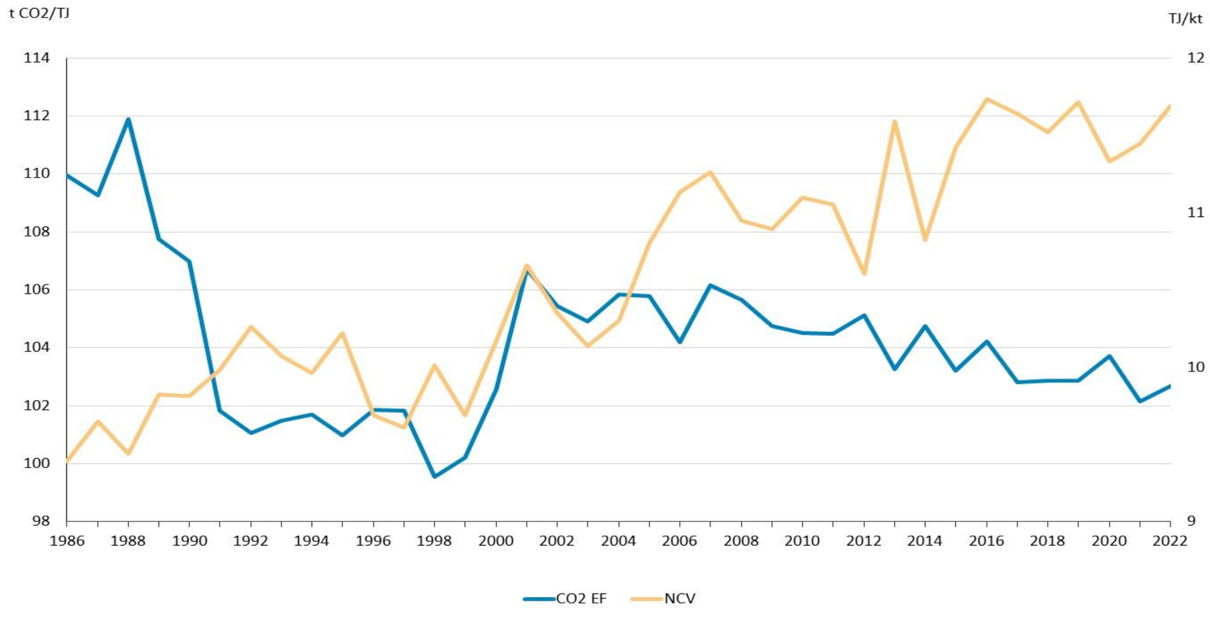


Figure 3.2.1: CO_2 EF and NCV for domestic lignite from Velenje pit for 1986-2022.

Table 3.2.1: National CO_2 EFs for domestic lignite from Velenje pit in t CO_2/TJ.

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
109.95	109.25	111.89	107.76	106.98	101.84	101.06	101.48	101.69	100.99
1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
101.85	101.82	99.54	100.21	102.56	106.71	105.44	104.90	105.85	105.78
2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
104.18	106.16	105.64	104.76	104.52	104.48	105.12	103.26	104.75	103.21
2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
104.18	102.82	102.86	102.87	103.70	102.14	102.67			

Country specific CO_2 EF for natural gas

We are using country specific CO_2 emission factor also for natural gas. It was calculated from the carbon content in the fuel which was determined from the data on chemical composition of natural gas. Methodology used and detailed results for the period 1986-1996 are in the study from 1998, which is available only in Slovene language (Gasperič M, Dornik M.: Določitev emisijskega faktorja CO_2 pri energetski izrabi zemeljskega plina).

Because from this study only yearly values until 1996 are available, in the previous submissions value from 1996 has been used for all years since then.

For the present submission we have obtained data on the chemical composition of natural gas used in Slovenia for the period after 1996. The data are available for the years 2002, 2005, 2009, 2013, and yearly since 2015. Following the methodology described in the study mentioned above CO_2 emission factors have been calculated for these years while the values for the missing years were interpolated. In the Table 3.2.2 a national CO_2 emission factor for natural gas is presented.

Table 3.2.2: National CO_2 EFs for combustion of natural gas in t CO_2/TJ.

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
55.716	55.716	55.716	55.716	55.716	55.716	55.730	55.990	55.695	55.710
1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
55.709	55.291	55.405	55.518	55.631	55.745	55.858	55.938	56.019	56.099
2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
56.117	56.134	56.151	56.169	56.141	56.112	56.084	56.055	56.097	56.139
2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
56.454	56.131	56.148	56.361	56.162	56.301	56.493			

Oxidation factor

Unless otherwise stated we have used default oxidation factors 1 as recommended in the 2006 IPCC Guidelines for all types of fuel. The plant specific oxidation factors which have been used in very limited cases are available since 2010 from EU ETS database and are presented under relevant sub-chapters/categories.

Sources of data

An interesting feature of inventories of greenhouse gases for Slovenia is the fact that the chosen base year 1986 goes back to the time when Slovenia was still a part of Yugoslavia. Notwithstanding this fact, at that time Slovenia already had its own electrical energy statistics and annual reports, which have been published annually without any interruptions ever since 1955. Due to the stable functioning system of data collection and economic conditions (no commercially sensitive data) it is correct to say that the energy statistics in particular was exceptionally good and centralized, and the data reliable and trustworthy.

The number of key reporting units prior to 1992 was exceptionally small, since only one enterprise imported natural gas, two enterprises refined petroleum products, while coal import was transacted within the framework of three thermal power plants.

The main source of data for Fuel consumption for all sectors in the Republic of Slovenia for the period 1986-2001 is LEG – Annual Energy Statistics of the Energy Sector of the Republic of Slovenia. Since 1992 data are available in the digital form as Joint Questionnaires (JQ) and other questionnaires and since 2005 the verified reports from ETS have also been used.

Since 2005 the following files were available to the inventory team every year:

SORS data
E1L-YY-arso – fuel consumption in public power plants
E2L-YY-arso – fuel consumption in auto producers
E2LP-YY-arso – fuel consumption in cogeneration plants
E3L-YY-arso – fuel consumption in public heat
epel_arsoYY_NACE2008.xls – fuel consumption in mining, manufacturing industry and construction
ZBIRNA E8-E12 ARSO YYYY.xls – data on energy balance

Joint questionnaires:
ENERGY_NTGAS_A_SI_YYYY - gaseous fuel
ENERGY_PETRO_A_SI_YYYY - liquid fuel
ENERGY_RENEW_A_SI_YYYY - other fuel
ENERGY_SOLID_A_SI_YYYY - solid fuel

Other data providers
SEA - Individual data and verifying reports from ETS and internal reports from verifiers
Eurocontrol – data on domestic and international flights
Ministry of Infrastructure – fleet composition
Slovenian Maritime Administration – fuel used for domestic navigation
Plinovodi – fuel used for natural gas transport and composition of natural gas
The Fisheries Research Institute of Slovenia – fuel used for fishing
Slovenian Army and Police – consumption of jet kerosene
IJS/CEU – biomass consumption in different types of stoves in residential sector

3.2.1 Comparison of the Sectoral Approach with the Reference Approach

The total difference of CO_2 emissions between the sectoral approach and the reference approach in 2022 amounted to 0.79 per cent related to the energy consumption (Table 3.2.3) and to 0.50 per cent related to the CO_2 emissions (Table 3.2.4).

The large difference is in consumption of other fossil fuels. In the period 1986-1999 SORS did not collect the data on other fuels consumption and for calculation of emissions in the sectoral approach we have obtained relevant data directly from the plants. Since 2000 SORS started to collect the data on waste fuel. In the beginning only waste tyres and waste oils have been included in the EB data. In 2008 one cement plant started to combust other waste, but this data has not been included in the EB until 2010. In the period 2008 to 2010 the other fuel consumption in the SA is therefore larger than in the RA. Since 2011 almost all amount of combusted waste is included in the SORS EB data, however they are not excluded part of biomass fraction in this waste.

Table 3.2.3: Differences in energy consumption, % (Reference approach/National Approach)

Fuels	1986	1990	2000	2005	2010	2015	2020	2021	2022
Liquid	3.16	2.12	2.34	-0.51	0.57	0.15	-0.02	-0.00	1.47
Solid	0.73	0.08	0.01	-1.30	-0.83	-0.03	0.04	0.00	0.03
Gaseous	-4.04	-8.25	0.33	0.62	-0.07	-0.01	0.00	0.00	0.00
Other fossil	-100	-100	-90.91	16.46	-29.33	20.23	-7.54	-9.23	-7.38
Total	**0.88**	**-0.62**	**1.18**	**-0.53**	**-0.18**	**0.25**	**-0.12**	**-0.13**	**0.79**

Table 3.2.4: Differences in CO_2 emissions, % (Reference approach/National Approach)

Fuels	1986	1990	2000	2005	2010	2015	2020	2021	2022
Liquid	1.55	0.96	0.95	-0.97	0.18	-0.21	-0.11	-0.05	-0.29
Solid	0.70	0.06	-0.31	-1.68	-1.47	-0.25	0.81	-0.29	-0.49
Gaseous	-3.98	-8.21	0.42	0.83	0.08	-0.01	-0.01	0.26	- 0.83
Other fossil	-100	-100	-90.91	-3.53	-43.70	5.02	-1.60	1.18	-7.72
Total	**0.47**	**-0.66**	**0.29**	**-1.06**	**-0.78**	**-0.15**	**0.22**	**-0.14**	**0.50**

Note: The values in Table 3.2.3 and 3.2.4 are correct but they from data in the CRT tables in some cases due to the error in the ETF tool.

In the reference approach for the entire period mostly CS NCVs obtained by SORS have been used. The exceptions are crude oil, jet kerosene, lubricants, bitumen, where IPCC default values are used.

Contrary for Carbon content mostly IPCC default values have been used. Exception are petroleum coke, lignite, natural gas and fossil part of waste, where CS values are used. Oxidation value is 1 except for lignite where since 2010 PS oxidation factor is used, because since than all lignite has been combusted in one thermal power plant.

In national statistical publications, “Lignite” is used only for coal excavated in the pit of Velenje. The coal from other pits is entered as „brown coal” in spite of virtually the same net calorific value (NCV). This brown coal is combined with imported coals that have a considerably higher net calorific value and, in terms of methodology, truly belong to brown coals. To avoid erroneous interpretations in international comparisons of inventories, we have decided to combine the entire production of domestic coal in the CRT table 1.A(b) – Sectoral background data for Energy (Reference Approach) on the basis of net calorific value under „Lignite”.

3.2.2 International Bunker Fuels

International navigation

Slovenia has only one international port "Luka Koper", but in the period 1986-2004 no ships were refuelled in that port (mostly the ships were refuelled in the international waters by Italian ships under Panama flags). Since 2005, a small amount of heavy fuel oil has been reported as fuel sold to the international marine bunkers for the first time. Since then the amount of fuel used for this purpose has gradually increased. In 2020 and 2021 emissions decreased due to the Covid-19 pandemic. In 2022 no fuel is used for this purpose.

Method: Tier 1
Source for AD (amount of heavy fuel oil and diesel oil and corresponding NCVs): SORS.
Source for EFs: default values from 2006 IPCC Guidelines, Vol. 2. Table 3.5.2 and 3.5.3

The amount of fuel and the corresponding emissions are presented on the table 3.2.5.

Table 3.2.5: International Navigation Bunkers – fuel used in TJ and GHG emissions in kt CO_2 eq.

	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
fuel in TJ	880	768	2,668	5,122	6,456	9,429	7,974	4,904	3,642	NO
kt CO_2 eq.	69	60	208	400	504	734	619	382	283	NO

International aviation

In the past the entire consumption of jet kerosene was considered aviation bunker fuel since there were no commercial domestic flights in Slovenia. Following recommendation from ERT since 2008, data on jet kerosene used in Slovenian Army and Police have been obtained and corresponding emissions have been excluded from international aviation bunkers and included in 1.A.5.b Other/Mobile. These data are not available for the period 1986-2007. Following the recommendation from ARR 2011, the fuel used in Slovenian army and Police has been estimated using correlation with the number of aircrafts in the Slovenian army. For estimating emissions in the period 1986-1990/91, when Slovenia was still part of Yugoslavia, the fuel used for the international aviation was estimated taking into account a correlation with the number of passengers, and the remaining amount of jet-kerosene was counted as fuel used in the Yugoslavian army over the Slovenian territory.

Table 3.2.6: Consumption of jet kerosene in 2022 in different CRT categories.

Jet kerosene	amount	unit	amount	unit
1A3a Domestic navigation	144	t	6	TJ
1A5b Military use of fuel	1,494	t	65	TJ
Memo – international aviation	19,509	t	849	TJ
Memo – multilateral operation	208	t	9	TJ
Total	**21,355**	**t**	**930**	**TJ**

According to the Eurocontrol data a small amount of jet kerosene has been used since 2006 in domestic aviation. After investigation it was found out that this fuel has been used for reallocation of airplanes between the two largest airports. Corresponding GHG emissions have been reallocated from international aviation to domestic aviation accordingly. Use of jet kerosene in different CRT categories in 2010 is presented in the Table 3.2.6.

Because of negligible quantities of emissions, the entire consumption of aviation gasoline for piston engine aircraft was considered to be used for the domestic aviation, since it was assumed that this was fuel for a small aircrafts, which fly mostly between smaller regional airports in Slovenia.

Method: Tier 1
Source for AD: SORS, Slovenian Army and Police, Eurocontrol
Source for EFs: default values from 2006 IPCC Guidelines, Vol.2, Table 3.6.4 and 3.6.5

In the table 3.2.7 the fuel used in international aviation bunkers and corresponding emissions are presented.

Table 3.2.7: International Aviation Bunkers – fuel used in TJ and GHG emissions in kt CO_2 eq.

	1986	1990	2000	2005	2010	2015	2020	2021	2022
fuel in TJ	812	684	962	852	1017	1037	363	372	858
kt CO_2 eq.	59	49	69	61	73	75	26	27	61

Multilateral operations

The jet kerosene used in Slovenian Army and Police have been excluded from international aviation bunkers and included in 1.A.5.b Other/Mobile. An exception has been the fuel consumption on international missions since 1997 (Kosovo, Afghanistan…), which has been included in 1.C.2 Multilateral operations. Information about Slovenian cooperation in international operations is available on the following web page:
https://www.slovenskavojska.si/en/translate-to-english-v-sluzbi-miru/international-operations-and-missions/

Method: Tier 1
Source for AD: SORS, Slovenian Army and Police
Source for EFs: default values from 2006 IPCC Guidelines. Table 3.6.4 and 3.6.5

In the table 3.2.8 the fuel used in the multilateral operations and corresponding emissions are presented.

Table 3.2.8: Multilateral operations - – fuel used in TJ and GHG emissions in kt CO_2 eq.

	1997	2000	2005	2010	2015	2020	2021	2022
fuel in TJ	3	7	6	5	7	6	9	9
kt CO_2 eq.	0.2	0.5	0.4	0.4	0.5	0.4	0.6	0.7

Other emissions from the Army are included in road transportation (gas-diesel oil), in Institutional sector (heating oil) and in civil aviation (aviation gasoline).

3.2.3 Feedstock and Non-Energy Use of Fuels

Natural gas

Source of activity: all data are from SORS

Figure 3.2.2: Methanol production in Nafta-Petrochem Lendava.

The biggest fraction of non-energy usage of fuels was the consumption of natural gas for the production of methanol, amounting to 89,475 Sm^3 of natural gas in 2010, when this production stopped, and there has been no methanol production in Slovenia since 2011.

Natural gas was entirely used as the row material for transformation into methanol. In every cycle only a fifth of it is transformed to the product, while the remaining natural gas is returned into the process. The schematic diagram of the process is shown in the Figure 3.2.3.

In Slovenia, low-pressure Lurgi technology is used. The methanol is produced from synthesis gas obtained from natural gas and steam in reactor

$CH_4 + H_2O \rightarrow CO + 3\,H_2$

This reaction, commonly called steam-methane reforming or SMR, is endothermic and the heat transfer limitations place limits on the size of the catalytic reactors used. The carbon monoxide and hydrogen then react on a second catalyst to produce methanol.

The exothermal methanol reactor with three main reactions:

$$CO + 2H_2 \rightarrow CH_3OH$$
$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$$
$$CO_2 + H_2 \rightarrow CO + H_2O$$

is operated at high pressure and unconverted gas is recycled.

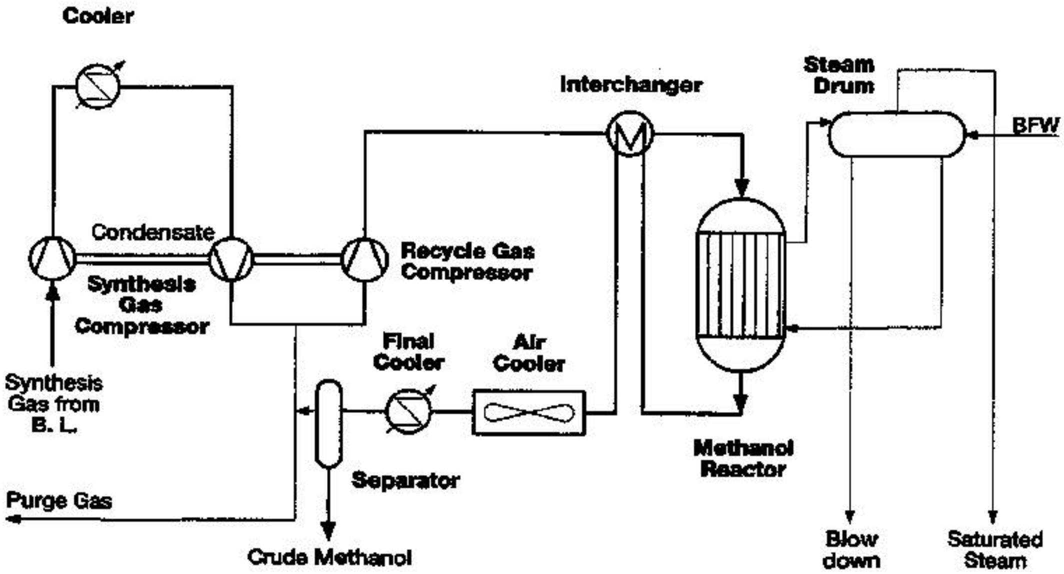


Figure 3.2.3: Schematic diagram of methanol production.

Stored CO_2 has been calculated on the basis of the formula from IPCC guidelines. We have assumed that all methane used for methanol production is stored in the product or in CO in emitted gas. This fact was confirmed also by expert from the company Nafta-Petrochem.

The amount of CO_2 excluded from the energy sector is presented in the table 3.2.9.

Table 3.2.9: Non-energy use of natural gas

	unit	1986	1990	2000	2005	2010	2015	2020	2021	2022
Natural Gas	1000 m^3	67666	69524	136740	164407	97004	6176	6522	7163	6.471
Carbon EF	t C/TJ	15.195	15.195	15.172	15.300	15.311	15.311	15.317	15.355	15.407
Excluded CO_2	kt	125.4	131.2	257.7	292.5	182.8	11.8	12.5	13.7	12.5

The remaining amount of non-energy use of natural gas is used in the chemical industry also as a row material for production of organic and inorganic chemicals and plastics. The detailed data on non-energy use of natural gas are presented in the Table 3.2.10.

Table 3.2.10: Non-energy use of natural gas for different products.

	unit	2005	2010	2015	2020	2021	2022
Methanol prod.	1000 Sm^3	145,903	89,475	0	0	0	0
Other org. chem.	1000 Sm^3	410	0	0	0	0	0
Inorganic chem.	1000 Sm^3	8,314	7,465	5,765	6,521	7,163	6,471

Rubber and Plastics	1000 Sm^3	590	61	0	0	0	0
Other	1000 Sm^3	0	0	411	2	0	0
Total	1000 Sm^3	155,217	97,001	6,176	6,523	7,163	6,471
Total	TJ	5,290	3,306	210	222	244	220

During the UNFCCC review in 2018 the ERT noted, that natural gas used in the chemical industry usually is not stored in the product and should be reported as CO_2 emissions in the IPPU sector. After investigation it was found out that majority of non-energy use of natural gas since 2011 is used for hydrogen production by steam reforming. In the resubmission during the review week we have included CO_2 emission for the period 2011-2016 from hydrogen production under IPPU sector in the category 2B10 Other chemical industry. However, for the 2019 submission we have estimated these emissions also for the period 1986-2010. In addition, we have considered that all amount of non-energy use of natural gas, except for methanol production, have emitted CO_2. Therefore, all excluded CO_2 since 2011 is now reported in the IPPU sector under hydrogen production.

Lubricants

According to the Statistical data all lubricants in Slovenia have been used for non-energy purpose only. Data about different types of use are not available. Likely, the largest applications for lubricants are in the form of motor oil. After the end of use, the lubricants which have been used in the engines are collected and mostly used as a fuel. Lubricants reported in the different sectors are presented in the table 3.2.11.

Table 3.2.11: Oil and Lubricants

	unit	1986	1990	2000	2005	2010	2015	2020	2021	2022
Apparent consumption	kt	6.59	7.20	11.00	28.00	12.00	27.00	37.28	43.82	9.61
Road transport	kt	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.04	0.03
IPPU	kt	6.56	7.17	10.98	27.90	11.98	26.98	37.26	43.78	9.58

In the line with the IPCC methodology emissions from lubricants used in the 2-stroke engines are reported in energy sector under road transport, while other emissions from lubricants are reported in the IPPU sector.

The remaining amount of lubricants which is not combusted or oxidised during use is collected as waste oil. Slovenia has been adhering to the basic system of collection, recovery and disposal of waste oil since 1998. The main foci and provisions regarding the programme of waste oil management are stipulated in our legislation, in particular in the Decree on the disposal of waste oils, which is harmonized with the EU directive on the disposal of waste oils. Producers of waste oil are obliged to deliver the oil to collection services. Each collector must have a collection centre and must ensure either recovery or disposal of waste oils. Recovery is the preferred choice, if technically feasible and if its cost is not unreasonably higher than the cost of disposal. One of the forms of recovery is the utilisation of waste oils for energy – co-incineration in accordance with recovery procedure R1. Records by the SEA show that most waste oils have been used for this purpose. The only evidence of such a use is in the cement production. Emissions are already included in the inventory and are reported in the CRT tables in “1.A.2.g.viii Manufacturing industry and construction/Other industries under other fossil fuels”.

A small portion of collected waste oils has also been incinerated (procedure R9) or reformed and then reused (procedure D10). We reported these emissions in waste sector under waste incineration in submission 2010 for the first time. No other use of lubricants as a fuel has been recorded in Slovenia until now.

The data on import and export as well as data from waste oil combusted in the industry have been obtained from SORS while the data on incineration of waste oils are from SEA.

Stored CO_2 has been calculated on the basis of the formula 6.4 from 2006, IPCC Guidelines, Vol. 2, Ch.6 Reference Approach.

Other types of fuels

Coke and petroleum coke, used in industry as reduction agent or feedstock, have been subtracted from energy sector and emissions from these fuels are presented in industrial processes sector.

Before 1997, amount of coke, used for production of iron and steel, ferroalloys and carbide was reported as fuel consumption in relevant sectors. After 1997, this fuel started to be collected separately, but it took a while that all non-energy used fuel was reported correctly. Energy and non-energy use of fuels in industry have been presented separately in statistical data since 2000.

To avoid double counting we have subtracted all coke used in iron and steel, ferroalloys and carbide production from energy sector except coke in iron production in the base year 1986. In that time, pig iron was still produced and disaggregated into the consumption of fuel as an additive. Thus the consumption of fuel as an energy product was impossible. For consumption of coke, the decision was taken to attribute all coke, which is consumed in the production of iron and steel in this year, to the energy sector as fuel consumption and no emissions from coke used in iron and steel production are presented in industrial processes.

There are also other uses of fuel in chemical processes not emitting any GHGs, therefore no explanation is included in the CRT tables. In 2022, a small amount of fuel oil, LPG, other kerosene, and white spirit was used, mostly for production of lacquers, paintings and other coatings. The same is valid also for bitumen which is used for road paving and for production of roofing material and during this process no GHG emissions are occurring.

3.2.4 Energy industries (CRT 1A1)

3.2.4.1 Category description

This chapter presents the consumption of fuels and emissions of greenhouse gases in:

- Public Electricity and Heat Production (CRT 1A1a)
- Petroleum Refining (CRT 1A1b)
- Manufacture of solid fuels and Other Energy Industries (CRT 1A1c)

Overview of the methods and EFs used as well as an indication whether a category is a key are presented in the Table 3.2.12 below.

Table 3.2.12: Method, EF used, and key categories indications for the year 2021 in Energy industries.

	CO_2			CH_4			N_2O		
Fuel type	**Method**	**EF**	**Key category**	**Method**	**EF**	**Key category**	**Method**	**EF**	**Key category**
solid	T3	PS	L, T	T1	D	-	T1	D	-
liquid	T1	D	T	T1	D	-	T1	D	-
gaseous	T2	CS	L, T	T1	D	-	T1	D	-
biomass	T1	D	-	T1	D	-	T1	D	-
other	T1	D	-	T1	D	-	T1	D	-

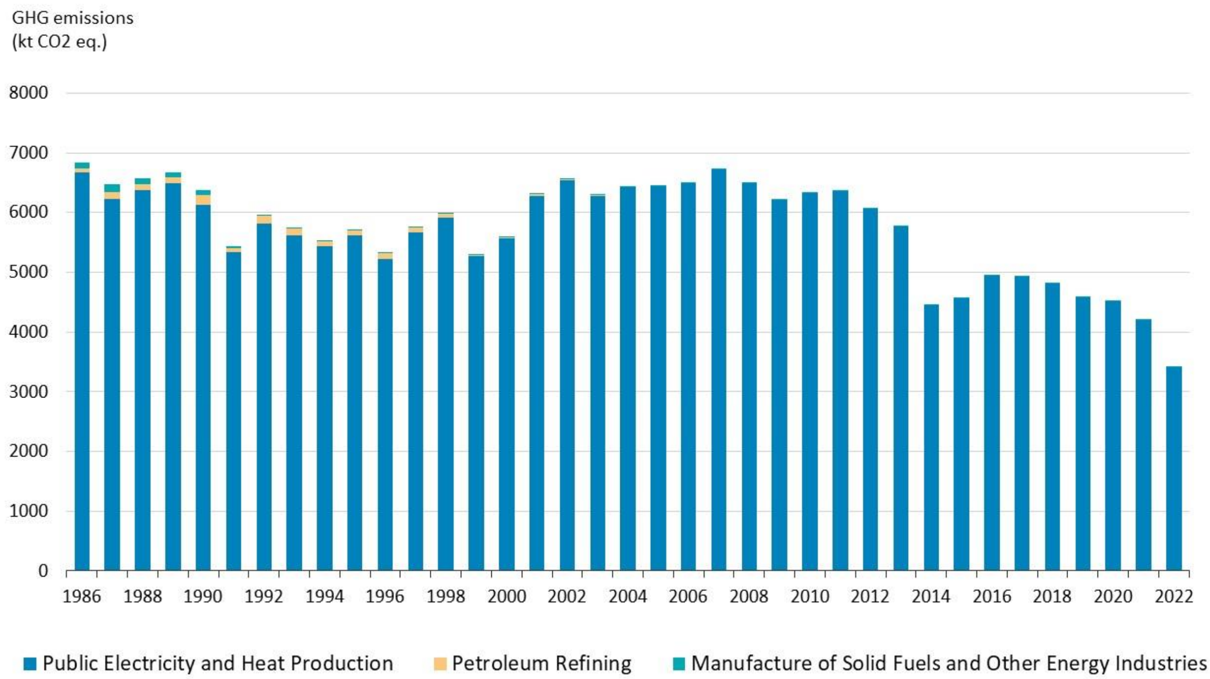


Figure 3.2.4: GHG emissions from Energy Industries in kt CO_2 equivalents.

Public electricity and heat production is the most important category in this sub-sector with 97.5% share in the base year and almost 100% share in 2022. Other two categories consist mainly of fuel consumption in one refinery (closed in 2004) and in fuel consumption for coal mining activities and gas extraction. Emissions are presented on Figure 3.2.4 and in the Table 3.2.13.

Table 3.2.13: GHG emissions from Energy Industries in kt CO_2 eq.

	1986	1990	2000	2005	2010	2015	2020	2021	2022
1. Energy Industries	6,840	6,374	5,593	6,449	6,347	4,566	4,515	4,198	3,416
a. Public Electricity and Heat Production	6,670	6,121	5,561	6,448	6,332	4,560	4,515	4,198	3,416
b. Petroleum Refining	63	171	32						
c. Manufacture of Solid Fuels and Oth. Energy Ind.	106	82	0.4	1.6	14	6	0.1	0.3	0.1

3.2.4.2 Methodological issues

To estimate emissions from Energy industries the following methodology has been adopted:

Emissions = Quantity of Fuel Combusted x NCV x EF per energy of Fuel x OF

In the most cases oxidation factor is 1 except in two thermal power plants. (see chapter 3.2.4.2.1 below).

<u>Activity data</u>

The main source of data for all energy industries in the Republic of Slovenia for the period 1986-2004 is LEG – Annual Energy Statistics of the Energy Sector of the Republic of Slovenia. Since 2005 data are obtained from the SORS in the electronic format before they are published. In addition since 2005, the data from the verified reports from ETS have been used.

Data on fuel consumption by type and year are reported in the Annex 3 to the NID.

<u>Net calorific values</u>

Net calorific values have been taken from SORS (Table 3.2.14) except for solid fuels. Since 2005 all three thermal power plants were included into the EU-ETS and very detailed data on NCV became available. The values for solid fuel varies from year to year but for the liquid and gaseous fuel almost the same values have been used for the entire period as these types of fuel don't change a lot from year to year.

Table 3.2.14: NCVs for the fuel used in energy industry.

Year	Lignite (Velenje)	Sub-bituminous Coal - domestic	Sub-bituminous Coal - imported	Bituminous Coal	Gas Oil	Residual Fuel Oil	LPG	Natural Gas	Wood
	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/Mm3	TJ/kt
1986	9.390	11.880			41.820	39.740	46.000	33.500	12.170
1987	9,650	11.820			41.870	39.800	46.000	33,500	12.170
1988	9,440	12.000			41.870	39.800	46.000	34,080	12.170
1989	9,820	12.050			41.870	39.900	46.000	34,100	12.170
1990	9.810	12.760			41.870	39.800	46.000	34.100	12.170
1991	9.980	12.879			41.880	39.800	46.000	34.100	12.170
1992	10.260	12.589			41.900	39.900	46.000	34.100	12.170
1993	10.070	12.050			41.900	39.800	46.000	34.100	12.170
1994	9.960	12.666			41.900	39.860	46.000	34.100	12.170
1995	10.220	11.250	17.410		41.900	40.000	46.000	34.100	12.170
1996	9.690	11.300	17.410		41.900	40.000	46.000	34.100	12.170
1997	9.610	11.300	17.360		41.900	40.000	46.050	34.080	12.170
1998	10.010	11.230	17.760		41.900	40.000	46.050	34.080	12.170
1999	9.690	11.110	17.560		41.900	40.000	46.050	34.080	12.170
2000	10.170	11.230	17.940		41.900	40.000	46.050	34.080	12.170
2001	10.660	10.660	17.940		41.900	40.000	46.050	34.080	12.170
2002	10.350	11.220	18.380		41.900	40.000	46.050	34.080	12.170
2003	10.138	11.560	18.310		41.900	40.000	46.050	34.080	12.170
2004	10.301	11.680	18.676		41.900	40.000	46.050	34.080	12.170
2005	10.803	11.724	18.180		41.900	40.000	46.050	34.080	12.170
2006	11.132	10.880	18.874		42.600	41.420	46.050	34.072	9.764
2007	11.259	11.763	18.275		42.600	41.420	46.050	34.078	9.141
2008	10.949	11.654	17.714		42.600	41.420	46.050	34.096	11.512
2009	10.894	11.094	17.872	28.612	42.600	41.420	46.050	34.074	11.128
2010	11.097	12.815	18.130	28.271	42.600	41.420	46.050	34.080	9.871
2011	11.051	11.935	18.428	28.251	42.600	41.420	46.050	34.087	10.267
2012	10.604	11.778	18.524	26.140	42.600	41.420	46.050	34.093	10.560
2013	11.591	11.946	18.457	25.180	42.600	41.420	46.050	34.079	10.262
2014	10.823	11.727	18.655	26.590	42.600	41.420	46.050	34.083	10.510
2015	11.418	-	18.629	25.800	42.600	-	46.050	34.086	10.474
2016	11.733	-	18.595	25.898	42.600	-	46.050	34.087	10.519
2017	11.640	-	18.230	26.293	42.600	-	46.050	34.085	10.706
2018	11.521	-	18.238	25.800	42.600	-	46.050	34.084	10.583
2019	11.716	-	18.247	25.800	42.600	-	46.050	34.081	10.502
2020	11.329	-	17.929	25.800	42.600	-	46.050	34.087	10.608
2021	11.447	-	17.881	-	42.600	-	46.050	34.086	10.083
2022	11.689	-	18.033	-	42.600	-	46.050	34.085	9.770

Emission factors

For coal and natural gas a country specific/plant specific CO_2 EFs have been used; a more detailed description is in chapter 3.2. Emission factors for all other fuels have been taken from 2006 IPCC Guidelines, Vol. 2 Energy, Table 2.2. On the table 3.2.15 EFs used in the period 1986-2022 are presented.

Table 3.2.15: EFs used for the period 1986-2022

	Unit	Coal	Gas Oil	Residual Fuel Oil	LPG	Natural Gas	Solid Bio-fuels	Gas Biomass	Fossil part of MSW
CO_2 EF	t/TJ	NID, Tables: 3.2.1, 3.2.17-20	74.1	77.4	63.1	NID, Table 3.2.2	112	54.6	91.7
CH_4 EF	t/TJ	0.001	0.003	0.003	0.001	0.001	0.03	0.001	0.03
N_2O EF	t/TJ	0.0015	0.0006	0.0006	0.0001	0.0001	0.004	0.0001	0.004

3.2.4.2.1 Public Electricity and Heat Production (CRT 1A1a)

In this sub-category, there were three big point sources in the Republic of Slovenia, which represent the backbone of electrical energy production from thermal power plants. All three plants use coal for the production of electrical energy (Table 3.2.16). Two of these thermal power plants (the Šoštanj Thermal Power Plant - TEŠ and the Trbovlje Thermal Power Plant - TET) are located beside coal pits. In 2014 the Trbovlje TPP was closed and since then only two plants have remained. Since 2003, CHP Ljubljana – TE-TOL uses exclusively imported coal with high net calorific value and low sulphur contents for the production of electrical energy and heat.

Table 3.2.16: Public electricity and Combined Heat and Power Plants in Slovenia

Power plant	Location	Unit	Period	Power (MW)	Main fuel type
TEŠ	Šoštanj	A/1	1956-2010	30.0	Lignite from Velenje
TEŠ	Šoštanj	A/2	1956-2008	30.0	Lignite from Velenje
TEŠ	Šoštanj	A/3	1960-2014	75.0	Lignite from Velenje
TEŠ	Šoštanj	Unit 4	1972-today	275.0	Lignite from Velenje
TEŠ	Šoštanj	Unit 5	1977-today	345.0	Lignite from Velenje
TEŠ	Šoštanj	Unit 6	2016-today	600.0	Lignite from Velenje
TEŠ	Šoštanj	Gas units	2008-today	2 x 42.0	Natural gas
TE-TOL	Ljubljana	D/1	1966-today	136.0	Imported coal
TE-TOL	Ljubljana	D/2	1967-today	126.0	Imported coal
TE-TOL	Ljubljana	D/3	1984-today	202.0	Imported coal, since 2008 also wood
TET	Trbovlje	F/4	1968-2014	125.0	Coal, mostly domestic brown coal

In addition to these thermal power plants we also have one small plant Brestanica – TEB which uses natural gas and operates mainly as a back-up plant when more electricity is needed or when any other plant is on refit.

Solid fuels

Since 2005 all public power plants are included into ETS and therefore plant specific CO_2 EFs are used.

In the **Šoštanj Thermal Power Plant -TEŠ** considering solid fuel only lignite from Velenje pit had been combusted in this plant and CO_2 EFs from Table 3.2.1 have been used. Until 2011 the oxidation factor was 1, while since then the PS oxidation factors have been determined and they are presented in the table 3.2.17.

Table 3.2.17: Plant specific oxidation factor for coal used in TEŠ.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Oxidation factor	0.997	0.989	0.990	0.991	0.993	0.997	0.995	0.997	0.994	0.995
	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Oxidation factor	0.9974	0.9954								

In **Trbovlje Thermal Power Plant – TET** the low calorific brown coal from Trbovlje-Hrastnik pit was used. Since 2007 also a small amount of imported lignite has been used as well. For calculation of CO_2 emissions before 2005 the default EF from 2006 IPCC Guidelines for lignite (101 t/TJ) has been used while since 2005 plant specific EFs presented in the table 2.3.18 from ETS have been used. Since 2010 the oxidation factor has been determined and is presented in the table 3.2.19. At the end of 2014 the plant has ceased the electricity production and since then is **closed**.

Table 3.2.18: Plant specific CO_2 EFs for domestic brown coal from Trbovlje pit used in TET.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
t CO_2/TJ	101.935	102.890	101.661	101.807	102.707	101.329	101.180	101.186	101.220	103.744

Table 3.2.19: Plant specific oxidation factor for coal used in TET.

	2010	2011	2012	2013	2014
Oxidation factor	0.997	0.976	0.979	0.982	0.983

In **CHP Ljubljana – TE-TOL** since 1995 only imported sub-bituminous coal has been used For calculation CO_2 emission before 2005 the average EF for the period 2005-2013 (99.427 t/TJ) was used while since 2005 plant specific EFs presented in the Table 2.3.20 from ETS have been used. Oxidation factor for the entire period was 1.

Table 3.2.20: Plant specific CO_2 EFs for imported sub-bituminous coal used in TE-TOL.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
t CO_2/TJ	100.407	99.340	100.246	100.877	100.908	100.423	98.837	97.000	97.213	97.085
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
t CO_2/TJ	97.240	96.787	96.796	96.763	96.786	97.286	97.383	96.928		

In the period 2009-2020 sub-bituminous coal and bituminous coal are used in one small heat plant. EFs are available from ETS and are presented in the table 2.3.21, the oxidation factor was 1.

Table 3.2.21: Plant specific CO_2 EFs for imported sub-bituminous and bituminous coal used in one cogeneration heat plant.

Coal type	Unit	2009	2010	2011	2012	2013	2014	2015-2020
Sub-bituminous	t CO_2/TJ	99.047	97.310	98.331	99.407	NO	NO	NO
Bituminous	t CO_2/TJ	92.742	92.829	90.881	92.513	94.022	93.431	94.600

Waste Incineration

Emissions from the category "Other fossil fuels" have arisen from the only Slovenian waste incineration thermal plant which has started to work in 2009. Data on the amount of incinerated waste, NCVs and the split between biogenic and other waste have been obtained directly from the plant.

For the calculation of GHG emissions, the following values from the 2006 IPCC GL, from Table 2.2. for non-biomass fraction of Municipal Waste have been used: CO_2 EF 91.7 t CO_2/TJ (default), CH_4 EF 0.03 t CH_4 /TJ and N_2O EF 0.004 N_2O/TJ.

3.2.4.2.2 Petroleum Refining (CRT 1A1b)

The main representative of this category was the company Nafta Lendava Refinery – Slovenia's only refinery, which stopped oil refining in 2003. According to the statistical methodology in the period 1986-1996, this sector also included quantities of fuels that were consumed for the production of electric energy in this sector.

Activity data

Data on the consumption of fuels in this sector for the period 1986-2004 have been collected in LEG – Annual Energy Statistics of the Energy Sector of the Republic of Slovenia:
for the period 1986-1996 under „Oil Industry"
From 1997 – 2004 under „DF–Production of coke, refined petroleum products and nuclear fuel"
- For the consumption of liquid fuels Table Tg/3 or Table Pg/6 for LPG
- For the consumption of solid fuels Table Pr/6
- For the consumption of gaseous fuels Table Pg/6

After 1996, data on the consumption in this sector have been included in the industrial sector DF – Production of coke, refined petroleum products, and nuclear fuel. With regard to the fact that there is neither production of coke nor nuclear fuel in the Republic of Slovenia, data for the period 1997-2003 are comparable to the data from the period 1986-1996.

In 2003, the only petroleum refinery was closed and no emissions have occurred from this category since 2004. Data on the fuel consumption by type and year are reported in the Annex 3 to the NID.

3.2.4.2.3 Manufacture of Solid Fuels and Other Energy Industries (CRT 1A1c)

This sector covers the consumption of fuels reported in LEG under "Coal-mining" or, since 1997, under CA – Production of energy commodities and DF – Production of fuels.

Activity data

The consumptions according to individual energy products are collected in the LEG tables as follows:
For the period 1986-1996 under „Coal-mining"
From 1997 onwards under „CA–Production of energy commodities"

- For the consumption of liquid fuels	Table Tg/3 or Table Pg/6 for LPG
- For the consumption of solid fuels	Table Pr/6
- For the consumption gaseous fuels	Table Pg/6

Since 2004, data are available in the excel files from SORS (E_PE-M YYYY.xls).
In the period 2004 -2007 according to the old SKD classification the following SKD categories have been included in this CRT category:

CA10	Mining of coal and lignite
CA11	Extraction of crude petroleum and natural gas including support activities
DF	Production of coke, refined petroleum products and nuclear fuel

Since 2008, the new SKD_2008 classification has been used and the following categories have been included in this CRT category:

B05	Mining of coal and lignite
B06	Extraction of crude petroleum and natural gas
B09.1	Support activities for petroleum and natural gas mining
C19.1	Manufacturing of coke oven products - do not exist in Slovenia.
C19.2	Manufacturing of refined petroleum products – do not exist since 2003

Data on the fuel consumption by type and year are reported in the Annex 3 to the NID.

3.2.4.3 Uncertainty and time–series consistency

Uncertainty estimates for energy industry in the base year are based on an expert judgement. To determine the uncertainties of the AD, consultations with experts from SORS were performed, while values from the IPCC Guidelines have also been taken into account for the uncertainties of EF.

The uncertainty of the activity data is a combination of systematic and random errors. The statistical data which are obtained from the obligatory reporting are usually within 3%. In addition, the activity data are subject to the random errors in the data collection. Countries with good data collection systems may keep the random error to about 2-3%. The experts believe that for most developed countries the total uncertainties of the activity data are in the range of 5%. After consultation with SORS and taking into account levels of uncertainties associated with stationary combustion recommended in 2006 IPCC GL, we have used different uncertainties for different types of fuel as presented in the Table 3.2.22.

Table 3.2.22: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year.

	1986				2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF	AD	CO_2 EF	CH_4 EF	N_2O EF
Liquid	5	2	150	150	1	2	150	150
Solid	10	6.4	135	150	1	2.5	135	150
Gaseous	5	2.5	135	135	1	0.5	135	135
Other	NO	NA	NA	NA	7.7	5	150	170
Biomass	10	NA	150	170	10	NA	150	170

In the calculating of emissions from this sector, the plant-specific emission factors, based on coal sampling and ascertaining the carbon contents have been applied for all solid fuel. All analyses have been done in an accredited laboratory in accordance with the EN ISO 17025 (“General requirements for the competence of testing and calibration laboratories”). The public power plants included in ETS have presented their plan of measures to ensure that the fuel consumption will be measured without intermediate storage before the combustion in the installation, applying measuring devices resulting in a maximum permissible uncertainty of less than +/- 2.5% for the measuring process.

3.2.4.4 Category-specific QA/QC and verification

Starting in 2005, all thermal power plants in the Republic of Slovenia have carried out regular coal sampling and determined the carbon content in accordance with the Monitoring guidelines for monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of European Parliament and of the Council and all amending directive, necessary for CO_2 emission trading on the territory of the European Union. For this reason, the plant specific CO_2 EF have been also used for coal from Trbovlje pit in 2006 for the first time.

The monitoring of the fuel in all thermal power plants under EU-ETS is defined in the permit and accompanied monitoring plan. Each fuel is monitored with maximum uncertainty which depends on the total GHG emissions from the plant and typical consumption of a particular fuel. All three plants have to monitor the coal consumption on the higher level of accuracy and determine NCV and C content in the accredited laboratory for every batch of fuel. The fourth plant is using natural gas as a main fuel.

The detailed descriptions of requirements are in the Guidelines for the monitoring and reporting: (COMMISSION REGULATION (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council)
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R0601

Description of the Requests under Particular Tier (Table 3.2.23)

AD

Tier 1: The fuel consumption covering the reporting period shall be determined by the operator or fuel supplier within a maximum uncertainty of less than ±7.5% taking into account the effect of stock changes where applicable.
Tier 2: The fuel consumption covering the reporting period shall be determined by the operator or fuel supplier within a maximum uncertainty of less than ±5.0% taking into account the effect of stock changes where applicable.
Tier 3: The fuel consumption covering the reporting period shall be determined by the operator or fuel supplier within a maximum uncertainty of less than ±2.5% taking into account the effect of stock changes where applicable.
Tier 4: The fuel consumption covering the reporting period shall be determined by the operator or fuel supplier within a maximum uncertainty of less than ±1.5% taking into account the effect of stock changes where applicable.

Table 3.2.23: Levels of pretentiousness (Tiers) for fuels used in TPP in Slovenia in 2005-2022.

	AD	NCV	CO_2 EF
Natural gas	Tier 4	Tier 2a	Tier 2a
Solid fuel	Tier 3	Tier 3	Tier 3
Fuel oil	Tier 1 or 2	Tier 2a	Tier 2a

NCV

Tier 2a: The operator applies country-specific net calorific values for the respective fuel as reported by the respective Member State in its latest national inventory submitted to the Secretariat of the United Nations Framework Convention on Climate Change.
Tier 3: The net calorific value representative for the fuel in an installation is measured by the operator, a contracted laboratory or the fuel supplier in accordance with the provisions of Article 32 to 35 of Commission Regulation 601/2012 on the monitoring and reporting.

EF

Tier 2a: The operator applies country-specific emission factors for the respective fuel as reported by the respective Member State in its latest national inventory submitted to the Secretariat of the United Nations Framework Convention on Climate Change.
Tier 3: Activity-specific emission factors for the fuel are determined by the operator, an external laboratory or the fuel supplier according with the provisions of Article 32 to 35 of Commission Regulation 601/2012 on the monitoring and reporting.

For the thermal power plants the aggregated solid fuel from SORS data are compared with the sum of the fuel used from the verified ETS reports. The NCVs are also checked. In case these numbers are not the same as in ETS, the data from ETS is taken into account and a notification to SORS is made.

Additional QA activity is the reference approach. Before entering data into the database, the sum of each fuel from the disaggregated data is compared with the energy balance data, reported in the Joint Questioner. Until 2017 data in JQ are rounded to 1000 units and the difference should be 500 units or less. If the difference was higher, the reasons for this discrepancy should be found.

3.2.4.5 Category-specific recalculations

No recalculations have occurred in this category.

3.2.4.6 Category-specific planned improvement

No improvement is planned for this category.

3.2.5 Manufacturing Industries and Construction (CRT 1A2)

3.2.5.1 Category description

This chapter presents the consumption of fuels and emissions of greenhouse gases in six specific types of industry, all others are covered by other industry, which includes also fuel for construction industry. An overview of the methods and EFs used as well as an indication whether a category is a key are presented in the Table 3.2.24 below.

Table 3.2.24: Method, EF used and key categories indications for the year 2022.

	CO_2			CH_4			N_2O		
Fuel type	**Method**	**EF**	**Key category**	**Method**	**EF**	**Key category**	**Method**	**EF**	**Key category**
solid	T3	PS	L,T	T1	D	-	T1	D	-
liquid	T1	D	L, T	T1	D	-	T1	D	-
gaseous	T2	CS	L, T	T1	D	-	T1	D	-
biomass	T1	D	-	T1	D	-	T1	D	-
other	T1, T3	D, PS	L, T	T1	D	-	T1	D	-

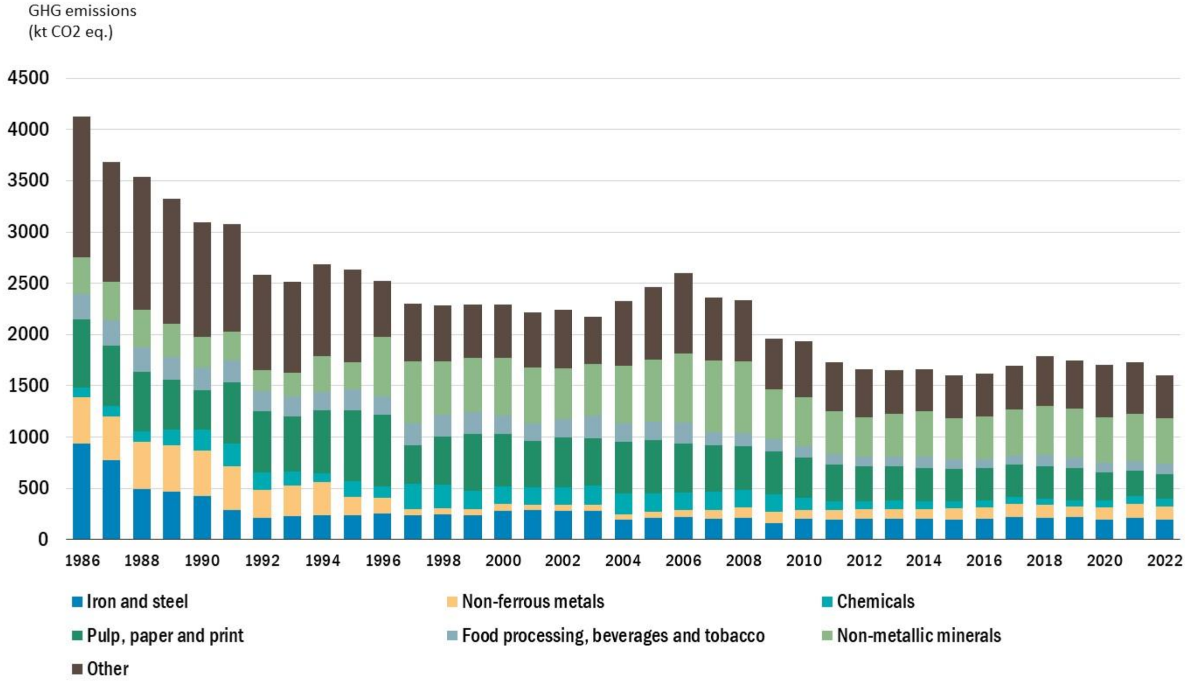


Figure 3.2.5: GHG Emissions from Manufacturing Industries and Construction

There was an appreciable reduction of GHGs from Manufacturing industry between 1986 and 2001 (-50.3%). After 2001, a stabilisation of emissions was observed until 2008. Due to the global financial crisis, emissions from Manufacturing industry and construction decreased in 2009 by 15.6%. In the following years the emissions have further decreased and altogether in the 2015 due to the economic crises emissions from Manufacturing Industries and Const.

were lower by 31.3% from emissions in 2008. Due to the economic recovery in the last years emissions started to increase again until 2018 and since then stabilisation of emissions is observed. However in 2022 emissions decreased by 7.3%. In the period 1986 to 2022 emissions from this sector decreased by 61.1%.

Table 3.2.25: GHG emissions from Manufacturing Industries and Construction in kt CO_2 eq.

	1986	1990	2000	2005	2010	2015	2020	2021	2022
2. Manufacturing Ind. and Constr.	4124	3095	2293	2464	1932	1605	1703	1733	1605
a. Iron and Steel	937	424	284	211	201	196	197	213	192
b. Non-Ferrous Metals	448	441	63	62	90	106	117	139	131
c. Chemicals	100	211	171	173	121	73	67	75	74
d. Pulp, Paper and Print	662	383	509	528	390	317	278	245	242
e. Food Processing, Bev. and Tob.	251	222	183	175	112	90	92	95	105
f. Non-metallic minerals	354	298	561	604	478	405	439	460	443
g. Other - stationary	1213	981	366	564	434	334	411	401	300
g. Other – off road	157	134	157	147	107	84	102	105	119

In the Figure 3.2.6 energy from different types of fuel used in the manufacturing industries and constriction is presented. While the use of liquid and solid fuels is decreasing in the last years, the use of natural gas and biomass stays rather constant. The use of waste fuels (other) is slowly increasing.

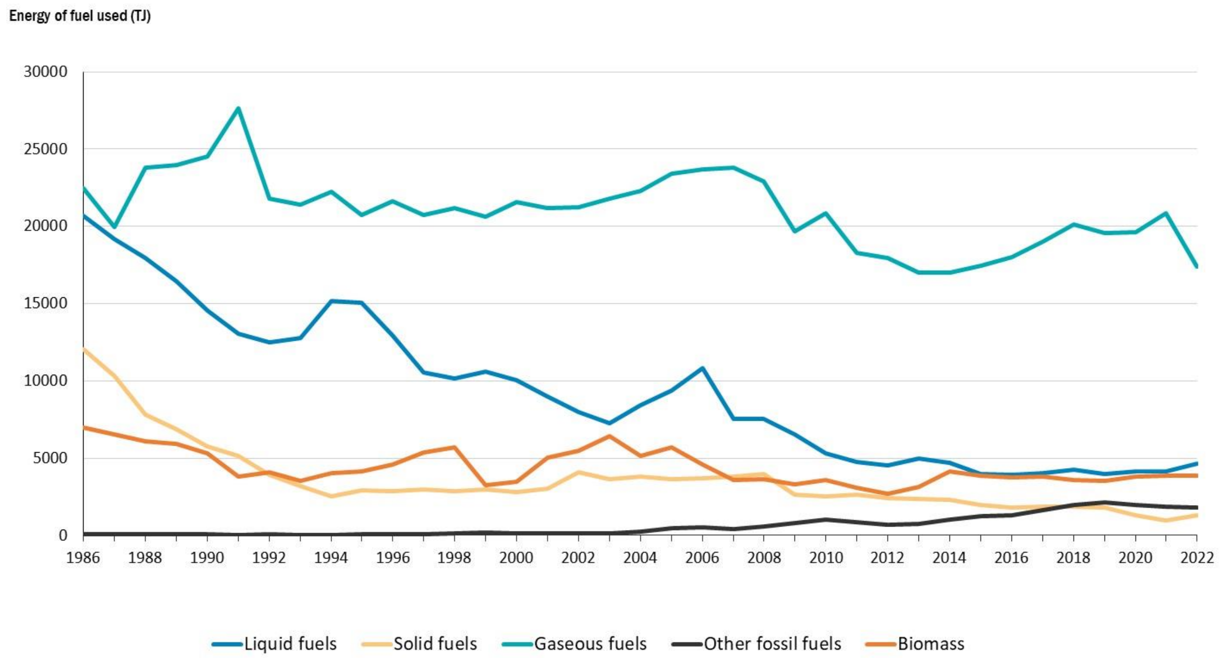


Figure 3.2.6: Energy of fuel used in manufacturing industries and construction in TJ.

3.2.5.2 Methodological issues

The emissions from the combustion in the sector Manufacturing industries and construction were estimated using the Tier 1 methodology described in the 2006 IPCC GL. The following basic formula was used:

Emissions = Quantity of Fuel Combusted x NCV x EF per energy of Fuel x OF

In all cases oxidation factor is 1.

Activity data

The consumption in each category has to be determined in accordance with the classification of activities applied in IPCC guidelines.

PERIOD 1986-1996

Table 3.2.26: Conversion table between national energy statistics (LEG) and CRT

CRT category	LEG Classification (1986-1996)
Iron and Steel	Iron and Steel Production
Non-Ferrous Metals	Non-Ferrous Metals
Chemicals	Chemical Industry
Pulp. Paper and Print	Pulp and Paper Industry, Print Industry
Food Processing. Beverages and Tobacco	Food Processing Industry, Tobacco Industry
Non-metallic minerals	Non-metal industry
Other	Metal Industry Shipbuilding Electrical Industry Construction Timber Industry Textile Industry Leather Industry Rubber Industry Recycling Other Industry

The classification applied in LEG has been taken as the basis and the conversion table between LEG and CRT is presented in the table 3.2.26.

PERIOD 1997-2003

In 1997, LEG began to publish data according to the Standard Classification of Activities, (SCA) which in some categories differs from the classification, which had been used until 1996. Most of the activities are defined in a similar manner, but this is not possible for all activities. The table 3.2.27 shows the distribution of activities in accordance with the IPCC classification.

For the consumption in individual industrial sectors there are detailed (disaggregated) data, the values of which was strongly dependant on the mode of reporting and features of the individual industrial sectors characterized by high concentration (values depending on the consumption in one or two factories) in Slovenia. The data from the basic sources shows some relatively big changes in the consumption of fuels in some sectors.

Table 3.2.27: Conversion table between national energy statistics (LEG) and CRT

CRT category	LEG Classification – SCA category
Iron and Steel	DJ - Production of metals and metal products
Non-Ferrous Metals	
Chemicals	DG - Production of chemicals
Pulp. Paper and Print	DE - Production of fibres, pulp, paper, and cardboard
Food Processing, Beverages and Tobacco	DA – Production of food, beverages, and tobacco products
Non-metallic Minerals	DI - Production of non-metal mineral products
Other	DB - Production of textiles DC - Production of leather and leather goods DD – Wood-processing and woodworking DH - Production of rubber products DK - Production of machines and devices DL - Production of electrical and optical equipment DM – Production of vehicles and vessels DN - Production of furniture. not included elsewhere F - Construction

YEARS 2004 - 2007

Since 2004 very detailed data about the fuel consumption in the industry became available in electronic format. The non-energy and energy use of fuels are reported separately. The data about the fuel consumption and NCV are reported on the lowest level of disaggregation possible. For this reason, from 2004 on the fuel consumption in iron and steel industry and in non-ferrous metals industry can be separated according to the rules presented in the following Table 3.2.28.

Table 3.2.28: Table for disaggregation of fuel in DJ sector (manufacture of basic metals and fabricated metal products)

SCA category	CRT category	Description
DJ 27.1	Iron and Steel	Manufacture of basic iron and steel and of ferrous alloys
DJ 27.2	Iron and Steel	Manufacture of tubes
DJ 27.3	Iron and Steel	Other first processing of iron and steel
DJ 27.4	Non-ferrous Metal	Manufacture of basic precious and non-ferrous metals
DJ 27.510	Iron and Steel	Casting of iron
DJ 27.520	Iron and Steel	Casting of steel
DJ 27.530	Non-ferrous Metal	Casting of light metal
DJ 27.540	Non-ferrous Metal	Casting of other non-ferrous metal
DJ 28	Other industry	Manufacture of fabricated metal products, except machinery and equipment

YEARS since 2008

Table 3.2.29: Conversion table between the CRT categories and The Standard Classification of Activities (SKD).

CRT category	Description
1.A.2.a Iron and Steel	C 24.1 Manufacture of basic iron and steel and of ferrous alloys
	C 24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
	C 24.3 Manufacture of other products of first processing of steel
	C 24.51 Casting of iron
	C 24.52 Casting of steel
1.A.2.b Non-ferrous Metal	C 24.4 Manufacture of basic precious and non-ferrous metals
	C 24.53 Casting of light metal
	C 24.54 Casting of other non-ferrous metal
1.A.2.c Chemicals	C 20 Manufacture of chemicals and chemical products
1.A.2.d Pulp. Paper and Print	C 17 Manufacture of paper and paper products C 18 Printing and reproduction of recorded media
1.A.2.e Food Processing, Beverages and Tobacco	C 10 Manufacture of food products C 11 Manufacture of beverages C 12 Manufacture of tobacco products
1.A.2.f Non-metallic Minerals	C 23 Manufacture of other non-metallic mineral products
1.A.2.g.vii Off road vehicles and other machinery	F Construction (only gasoline and diesel fuel) B and C – only consumption of gasoline and gas/diesel oil
1.A.2.g.viii Other	B07, B08, B09 except B09.1 – Mining and quarrying
	C 13 Manufacture of textiles
	C 14 Manufacture of wearing apparel
	C 15 Manufacture of leather and related products
	C 16 Manufacture of wood and of products of wood and cork, except furniture, manufacture of articles of straw and plaiting materials
	C 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations
	C 22 Manufacture of rubber and plastic products
	C 25 Manufacture of metallic products
	C 26 Production of electrical and optical equipment
	C 27 Production of electrical equipment
	C 28 Production of machines and devices
	C 29 Production of vehicles
	C 30 Production of vessels
	C 31 Production of furniture
	C 32 Other manufacturing
	C 33 Repair and installation of machinery and equipment
	F Construction (all other fuels except diesel and gasoline)

In 2008 the new SCA (Standard Classification of Activities) was applied by SORS which is used until present. The main advantage is that the new classification enables the disaggregation of data on much more detailed level. The conversion table between CRT and the national energy statistics is presented in the Table 3.2.29 on the previous page.

Net calorific values

Table 3.2.30: Average NCVs for solid fuels and petroleum coke used in manufacturing industry

Year	Lignite – domestic (Velenje)	Sub-bituminous Coal - domestic	Lignite - imported	Sub-bituminous Coal - imported	Other Bituminous Coal	Anthracite	Coke	Petroleum coke
	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt
1986	9.390	11.880			27.57	29.25	29.30	31.000
1987	9.650	11.820			27.57	29.25	29.30	31.000
1988	9.440	12.000			27.57	29.25	29.30	31.000
1989	9.820	12.050			27.57	29.25	29.30	31.000
1990	9.810	12.760			27.57	29.25	29.30	31.000
1991	9.980	12.879			25.00	29.25	29.30	31.000
1992	10.260	12.589			25.00	29.25	29.30	31.000
1993	10.070	13.351			25.00	29.25	29.30	31.000
1994	9.960	12.666			25.00	29.25	29.30	31.000
1995	10.220			17.404	25.00	29.31	29.31	31.000
1996	9.690			16.353	25.00	29.31	29.31	31.000
1997	9.610			17.712	25.00	29.31	29.31	31.000
1998	10.010			20.664	25.00	29.31	29.31	31.000
1999	9.690			20.806	25.00	29.31	29.31	31.000
2000	10.170			20.782	25.00	29.31	29.31	31.000
2001	10.660			20.947	25.00	29.31	29.31	31.000
2002	10.350			21.000	25.00	29.31	29.31	31.000
2003	10.138			21.570	25.00	29.31	29.31	31.000
2004	10.301			19.908		29.40	28.49	29.927
2005				20.381	25.15		27.90	29.927
2006				20.108	25.77		29.44	32.223
2007				20.387	24.46		29.37	31.949
2008				18.623	24.31		29.87	31.949
2009			10.078	17.972	23.896		29.67	32.498
2010			9.763	16.325	25.290		29.42	30.644
2011			10.717	15.138	25.422		29.62	31.684
2012			10.159	18.847	25.409		29.41	31.813
2013			10.085	19.224	26.264		29.59	31.721
2014			9.837	19.047	24.915		29.605	31.602
2015			9.885	18.890	25.000		28.859	31.663
2016			9.327	19.194	25.000		29.568	31.236
2017				19.473	25.000		29.609	31.264
2018				18.839	25.000		29.624	31.405
2019				17.085	24.599		30.483	31.348
2020				17.666	24.755		29.328	31.105
2021				17.796	25.001		29.355	31.090
2022				17.818	28.210		29.866	31.136

Table 3.2.31: Average NCVs for all other types of fuel used in manufacturing industry and construction

Year	Gas Oil	Residual Fuel Oil	Diesel	Gasoline	LPG	Natural Gas	Wood
	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/Mm3	TJ/kt
1986	41.82	39.74	42.70	43.18	46.00	33.50	12.17
1987	41,78	39,80	42.70	43.10	46.00	33,50	12.17
1988	41,71	39,80	42.70	43.10	46.00	34,08	12.17
1989	41,85	39,80	42.70	43.10	46.00	34,10	12.17
1990	41.87	39.80	42.70	43.07	46.00	34.10	12.17
1991	41.88	39.80	42.70	43.17	46.00	34.10	12.17
1992	41.90	39.90	42.70	43.10	46.00	34.10	12.17
1993	41.90	39.80	42.70	43.08	46.00	34.10	12.17
1994	41.90	39.86	42.70	43.08	46.00	34.10	12.17
1995	41.90	40.00	42.70	43.08	46.00	34.10	12.17
1996	41.90	40.00	42.70	43.08	46.00	34.10	12.17
1997	41.90	40.00	42.70	43.08	46.05	34.08	12.17
1998	41.90	40.00	42.70	43.08	46.05	34.08	12.17
1999	41.90	40.00	42.70	43.08	46.05	34.08	12.17
2000	41.90	40.00	42.70	43.08	46.05	34.08	12.17
2001	41.90	40.00	42.70	43.08	46.05	34.08	12.17
2002	41.90	40.00	42.70	43.08	46.05	34.08	12.17
2003	41.90	40.00	42.70	43.08	46.05	34.08	12.17
2004	41.90	40.00	42.70	43.08	46.05	34.08	11.91
2005	42.60	41.42	42.70	43.08	46.05	34.08	12.24
2006	42.60	41.42	42.70	43.08	46.05	34.072	12.18
2007	42.60	41.42	42.70	43.08	46.05	34.08	11.44
2008	42.60	41.42	42.70	43.85	46.05	34.096	11.18
2009	42.60	41.42	42.70	43.85	46.05	34.08	10.96
2010	42.60	41.42	42.70	43.85	46.05	34.08	10.77
2011	42.60	41.42	42.60	43.85	46.05	34.087	10.79
2012	42.60	41.42	42.60	43.85	46.05	34.093	10.41
2013	42.60	41.42	42.60	43.85	46.05	34.079	10.58
2014	42.60	41.42	42.60	43.85	46.05	34.083	11.57
2015	42.60	41.42	42.60	43.85	46.05	34.086	11.46
2016	42.60	41.42	42.60	43.85	46.05	34.087	11.10
2017	42.60	41.42	42.60	43.85	46.05	34.085	11.46
2018	42.60		42.60	43.85	46.05	34.084	11.55
2019	42.60		42.60	43.85	46.05	34.081	11.58
2020	42.60		42.60	43.85	46.05	34.087	11.59
2021	42.60		42.60	43.85	46.05	34.086	10.27
2022	42.60		42.60	43.85	46.05	34.085	11.20

Table 3.2.30 presents the net calorific values (NCV) which have been used for solid fuels and petroleum coke combusted in the manufacturing industries. In the past they have been mostly taken from SORS while since 2005 the ETS data are used, if available. The plant specific data for 2022 for solid fuels are presented in the Table 3.2.32. The values for liquid fuels excluding petrol coke and for natural gas and biomass have been taken from SORS for the entire period (Table 3.2.31).

Table 3.2.32: NCVs for the energy use of solid fuels in manufacturing industry and construction in 2022.

Industry	Unit	Sub-bituminous Coal - imported	Other Bituminous Coal	Coke	Petroleum coke
Iron and steel	TJ/kt			29.866	
Non-Ferrous metals	TJ/kt		28.210		
Pulp, Paper and Print	TJ/kt	17.818	26.825		33.178
Non-metallic minerals	TJ/kt			29.866	31.136

Emission factors

The emission factors used in the sector Manufacturing industries and construction are presented in the Table 3.2.33. Until 2005, we had used country specific CO_2 EF for domestic lignite and natural gas, while default values from the 2006 IPCC Guidelines were used for other fuels.

Table 3.2.33: EFs for the fuels used in manufacturing industry and construction.

	Unit	Lignite - domestic (Velenje)	Sub-bituminous Coal - domestic	Lignite – imported	Sub-bituminous Coal - imported	Other Bitumi-nous Coal	Anthra-cite	Coke
CO_2 EF	t/TJ	Table 3.2.1	101*	101*	96.1*	94.6*	98.3*	107.0*
CH_4 EF	t/TJ	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O EF	t/TJ	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015

	Unit	Petroleum coke	Gas Oil	Residual Fuel Oil	Diesel	Gasoline	LPG	Natural Gas
CO_2 EF	t/TJ	97.9*	74.1	77.4	74.1	69.3	63.1	Table 3.2.2
CH_4 EF	t/TJ	0.003	0.003	0.0030	0.00415	0.05	0.001	0.001
N_2O EF	t/TJ	0.0006	0.0006	0.0006	0.0286	0.002	0.0001	0.0001

	Unit	Wood	Gaseous Biomass	Other Biomass	Waste oils	Waste Solvents	Waste tyres	Other Solid Waste
CO_2 EF	t/TJ	112.0	54.6	100.0	73.3	103.2*	85.0	91.7*
CH_4 EF	t/TJ	0.03	0.001	0.03	0.03	0.03	0.03	0.03
N_2O EF	t/TJ	0.004	0.0001	0.004	0.004	0.004	0.004	0.004

**Since 2005, CO_2 EFs for solid fuels and petrol coke have mostly been taken from EU-ETS. CO_2 IEFs which have been used in 2022 and were calculated from plant-specific data are presented in the Table 3.2.34, Table 3.2.37, and 3.2.38.*

Table 3.2.34: Plant-specific CO_2 EF for solid fuel used in manufacturing industry in 2022.

	Unit	Sub-bituminous Coal - imported	Other Bituminous Coal	Petroleum Coke
Pulp, Paper and Print	t/TJ	100.297	96.869	
Non-metallic minerals	t/TJ			95.103

Other fuels

In the industry, particularly in the cement industry, in addition to commonly used fuel, a fraction of waste is also being incinerated, because of the very high temperature in the oven. We have obtained very detailed data on the amount and composition of waste from one cement plant, where the main process of waste incineration in Slovenia occurs. Other data on waste combustion has been obtained from SORS. The amount of waste is presented in the Annex 3 to the NID, while NCVs are presented on the Table 3.2.35. NCV for biogas is not available because AD are available in the energy units (TJ). Since 2005, all waste fuels have been available also from EU-ETS reports.

Table 3.2.35: NCVs for waste incinerated in the manufacturing industries.

	waste industrial oils	waste cooking fat	Waste solvents	waste tyres	other waste	waste biomass	waste cooking oils	Black liquor	Fibrous sludge
	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt
Until 2000	37.00			27.21	11.00			6.4	
2001	37.00	39.20		27.21	11.00			6.4	
2002	37.00	39.20		27.21	11.00			6.4	
2003	37.00	39.20		27.21	11.00			6.4	
2004	41.90	40.41		27.21			40.00	6.4	
2005	34.64	39.20		27.21		15.00		6.43	
2006	34.53	39.20	25.00	27.21		15.00		6.07	
2007	33.76	39.95	25.00	27.21		15.00			
2008	34.48	39.81	25.00	27.21	17.52	16.11			4.48
2009	37.65	39.81	25.00	27.19	26.67	15.14			3.88
2010	36.95	39.20	25.00	27.23	22.34	15.36			3.92
2011	36.25	39.20	25.00	27.26	19.52	13.78			3.86
2012	37.09	39.20	25.00	27.21	20.25	13.50			3.82
2013	37.13	39.20	25.00	27.21	19.44	12.74			3.55
2014	33.03	39.20	25.00	27.20	18.87	11.72			3.47
2015	35.495	39.20	25.00	27.20	19.32	12.14			3.55
2016	36.544	39.20	25.00	27.20	18.19	10.23			3.61
2017	35.342	39.20	25.00	27.20	16.90	12.79			3.48
2018	37.000		25.00	27.20	18.33	8.36			3.52
2019	37.373		25.00	27.20	19.11	15.0			3.56
2020	38.173		25.00	27.20	16.52	15.0			3.24
2021	39.319		25.00	27.20	16.24	15.0			3.34
2022	39.503		25.00	27.20	16.43	15.0			3.28

The EFs used for the estimation emissions from other fuels are mostly taken from 2006 IPCC Guidelines and are presented on Table 3.2.36. The exceptions are the combustion of waste tyres, waste organic solvents and waste oil.

The tyres have been combusted in one cement plant which is included in the EU-ETS and CO_2 EF from the relevant legislation (Commission Regulation (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council, Annex VI) is used. Biodegradable part of tyres was reported under biomass.

Waste organic solvents have been combusted in pharmaceutic industry and CO_2 EF was determined in the accredited laboratory in 2005. Since then the same value has been used.

Table 3.2.36: EFs for waste incinerated in the manufacturing industries

	waste industrial oils	waste solvents	waste tyres	other solid waste	waste cooking fat and oils	other biomass waste
	t/TJ	t/TJ	t/TJ	t/TJ	t/TJ	t/TJ
CO_2 EF	73.3	103.2	85	91.7	100	100
CH_4 EF	0.030	0.030	0.030	0.030	0.030	0.030
N_2O EF	0.004	0.004	0.004	0.004	0.004	0.004

Since 2010 a plant specific CO_2 EFs have been used for calculation of emissions from waste combustion in the cement plant. EFs are obtained from ETS and presented in the Table 3.2.37.

Table 3.2.37: Plant specific CO_2 EFs for solid waste incinerated in the cement plant since 2010

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
t CO_2/TJ	60.43	49.47	49.44	60.74	60.74	58.69	55.99	55.91	53.61	52.79	52.18
	2021	**2022**									
t CO2/TJ	48.97	50.92									

For waste oil which is combusted in the cement plant since 2014 the PS CO_2 EF from EU-ETS have been used. They are presented in the Table 3.2.38.

Table 3.2.38: Plant specific CO_2 EFs for incineration of waste oil in the cement plant since 2014

	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO2 EF	t CO_2/TJ	90.37	84.49	87.36	75.61	74.20	74.20	74.256	75.013	75.196

Inclusion of auto producers into Manufacturing Industries sector

In accordance with IPCC 2006 GL the item Industry reports the consumption of fuels in the group of industrial power plants (auto producers – enterprises that generate electric energy for internal consumption and/or heat for sale) as well as other consumption in industry (except in production processes) .

In the period 1986 -1996, the consumption of fuels by auto producers in LEG was recorded under Electric utilities – Industry, and in the period 1997- 2003 under Conversion – Auto producers.

Period 1986-2000

Because there are no published data on auto producers at the level of industrial branches for the period 1986-2000, on the basis of which it would be possible to assign the consumption of fuel to each individual industrial branch, for each kind of fuel a different (most appropriate) approach was used.

- Lignite

The total consumption is attributed to the pulp and paper industry. The paper mill in Krško uses lignite in its power cogeneration plant. In the documents of the SORS, the total consumption is attributed to the consumption in thermal power plants, while in LEG one half of the consumption is attributed to the consumption in industry, the other half to industrial thermal power plants. In this report, a half is reported as consumption in pulp and paper industry (heat) and the other half as consumption in industrial power plants in pulp and paper industry. The consumption of lignite in other sectors has not been reported.

- Brown Coal

The consumption of brown coal in the industrial power plants in the monitored period was reported only in 1986. Since the quantities are quite small, the consumption is reported in the sector “Other”.

- Residual Fuel Oil

The consumption of residual fuel oil in the industrial power plants in the monitored period was low (from 0 to 10176 t). Since the quantities are quite small, the consumption is reported in sector “Other”.

- Gas Oil and Natural Gas

The majority of industrial thermal power plants use gas oil or natural gas. The total quantities of consumed gas oil and natural gas are disaggregated according to the produced quantities of electric energy in those power plants.

Period 2000-2022

Since 2000 we have commenced to treat auto producers individually, since the SORS, which prepares data for LEG, has completed its database. Now, the aggregated data on the consumption of fuels by auto producers at the level of industrial branches are available, where the sums of the individual fuels correspond to the consumption of auto producers from LEG.

The data on fuel consumption by type of industry, fuel type, and year are reported in the Annex 3 to the NID.

Off road vehicle and other machinery

Following the new CRT categorisation the CRT category 1A2gvii Off road vehicle and other machinery has been introduced. Here all emissions from the combustion of gasoline and diesel from the Manufacturing industries and construction and from the Energy industries are included. EFs used are presented in the Table 3.2.39 and have been taken from the 2006 IPCC Guidelines, Vol 2, Table 3.3.1, Industry. We have assumed that mostly 4-stroke gasoline motors have been used.

Table 3.2.39: Default EFs for gasoline and diesel oil used in the off road machinery.

Year	Diesel	Motor gasoline
	t/TJ	t/TJ
CO_2 EF	74.1	69.3
CH_4 EF	0.00415	0.05
N_2O EF	0.0286	0.002

3.2.5.3 Uncertainty and time –series consistency

The uncertainty estimates for the manufacturing industry in the base year are based on the expert judgement. To determine the uncertainties of the AD, consultations with experts from SORS were performed, while values from the IPCC Guidelines have also been taken into account for the uncertainties of EF.

Table 3.2.40: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year in per cents

	1986				2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF	AD	CO_2 EF	CH_4 EF	N_2O EF
Liquid	5	3	150	150	3	2	150	150
Solid	10	7	135	150	2	2.5	135	150
Gaseous	5	2.5	135	135	2	0.5	135	135
Other	10	25	150	170	7.7	5	150	170
Biomass	10	NA	150	170	10	NA	150	170

The uncertainty of activity data is a combination of systematic and random errors. The statistical data which are obtained from the obligatory reporting are usually within 3% In addition, the activity data are subject to the random errors in the data collection. Countries with good data collection systems may keep the random error to about 2-3%. The experts believe that for most developed countries the total uncertainties of the activity data are in the range of 5%. After consultation with SORS and taking into account levels of uncertainties associated with stationary combustion recommended in 2006 IPCC GL, we have used different uncertainties for different types of fuel as presented in the Table 3.2.40.

During the calculation of the emissions from this sector, the plant specific emission factors based on coal sampling and ascertaining the carbon content, have also been applied for large part of solid fuels, petrol coke and some other fuels. All analyses have been done in an accredited laboratory in accordance with the EN ISO 17025 ("General requirements for the competence of testing and calibration laboratories").

3.2.5.4 Category-specific QA/QC and verification

The source category QA/QC is covered by the general QC procedures described in the chapter 1.2.3. Our main source specific QA/QC activity is comparison of the ETS data with the statistical data.

The aggregated fuel from SORS data is compared with the sum of the fuel used from verified ETS reports and where the connection between both set of data is uniform, the data from Statistical office are substituted with data from the verified reports from installations included in ETS, if necessary. ETS data are also used for different types of waste used as fuel. The list of waste types is not always complete in the SORS data.

Additional QA activity is the reference approach. Before entering data into the database, the sum of each fuel from the disaggregated data is compared with the energy balance data, reported in the Joint Questioner. Until 2017 data in JQ are rounded to 1000 units and the difference should be 500 units or less. If the difference was higher, the reasons for this discrepancy should be found.

3.2.5.5 Category-specific recalculations

1.A.2.b Non-ferrous Metals, Solid Fuels, CO_2, CH_4, N_2O
Emissions for the year 1993 have been slightly changed due to the error in NCV used for domestic brown coal. The calorific value is now in line with domestic brown coal used in the other industrial sectors.

1.A.2.c Chemicals, Liquid Fuels, 1.A.2.d Pulp and Paper, Liquid Fuels, CO_2, CH_4, N_2O
Emissions for the years 2005 and 2007 have been slightly changed due to the error in NCV used for gas diesel oil and residual fuel oil in the previous submission. The calorific value is now in line with other industrial sectors.

3.2.5.6 Category-specific planned improvement

No improvement is planned for these categories.

3.2.6 Transport (CRT 1.A.3)

This chapter presents the consumption of fuels and emissions of greenhouse gases in:

- Domestic Aviation (CRT 1A3a)
- Road Transportation (CRT 1A3b)
- Railways (CRT 1A3c)
- National navigation (CRT 1A3d)
- Other Transportation / Pipeline transport (CRT 1A3e.i)

Table 3.2.41: Method, EFs used for key categories for the year 2022 in the Transport sector.

	CO_2			CH_4			N_2O		
Road transport	**Method**	**EF**	**Key category**	**Method**	**EF**	**Key category**	**Method**	**EF**	**Key category**
Diesel	Model	Model	L,T	Model	Model	-	Model	Model	T
Gasoline	Model	Model	L,T	Model	Model	-	Model	Model	-
Railways – liquid fuels	T1	D	T	T1	D	-	T1	D	-

The only key categories in this sector are from the Road transport where Diesel and Gasoline are key sources according to the level and have a strong increasing trend (Table 3.2.41). The emissions have been calculated with the COPERT 5 model. The emissions from the other categories accounted for less than 1 per cent and have been calculated using Tier 1 approach. GHG emissions from this sector are presented in the Figure 3.2.7 and on the Table 3.2.42.

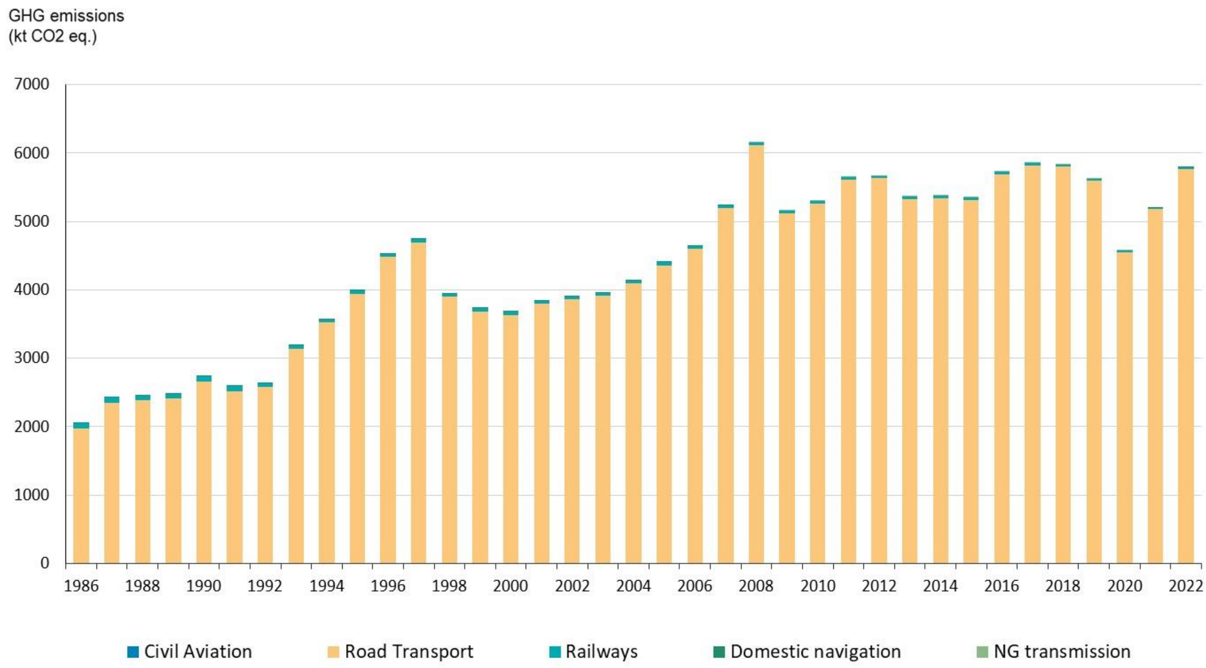


Figure 3.2.7: GHG emissions from Transport.

Undoubtedly the greatest increase in GHG emissions was observed in the transport sector, by as much as 200% until 2008, due to the increase in road transportation, while emissions from other kinds of traffic slightly declined. In 2009 GHG emissions from transport decreased due to the financial crisis by 16.3% compared to 2008. Since then emissions fluctuate from year to year but have never reached the 2008 peak. Due to the Covid-19 “lock down” in 2020 emissions in the transport sector decreased by 18.7% compared to the previous year, while in 2021 emissions are almost back on the pre-Covid level. In 2022 emissions further increased by 11.3%. In the period 1986 to 2022 transport emissions increased by 182.5%.

Table 3.2.42: GHG emissions from Transport in kt CO_2 eq.

	1986	1990	2000	2005	2010	2015	2020	2021	2022
3. Transport	2,051	2,737	3,676	4,401	5,299	5,354	4,576	5,206	5,795
a. Civil Aviation	0.6	1.1	2.8	2.7	2.0	2.0	1.6	1.6	2.0
b. Road Transportation	1,974	2,664	3,631	4,357	5,260	5,308	4,554	5,180	5,769
c. Railways	76	72	42	41	33	41	19	23	23
d. Domestic navigation	0.01	0.01	0.01	0.03	0.04	0.04	0.09	0.07	0.06
e. NG transmission	0	0	0	0	4.4	3.0	0.9	0.9	0.4

3.2.6.1 Road transportation (1.A.3.b)

3.2.6.1.1 Category description

Road traffic is an important source of emissions of greenhouse gases, mostly carbon dioxide and nitrous oxide, and also an important source of emissions that cause problems in terms of air quality, such as sulphur oxides (SO_x), nitrous oxides (NO_x), carbon monoxide (CO), non-volatile organic compounds (NMVOC), particulate matters ($PM_{2.5}$ and PM_{10}) and are, consequently, indirectly responsible for the formation of ozone (O_3) in the lower troposphere.

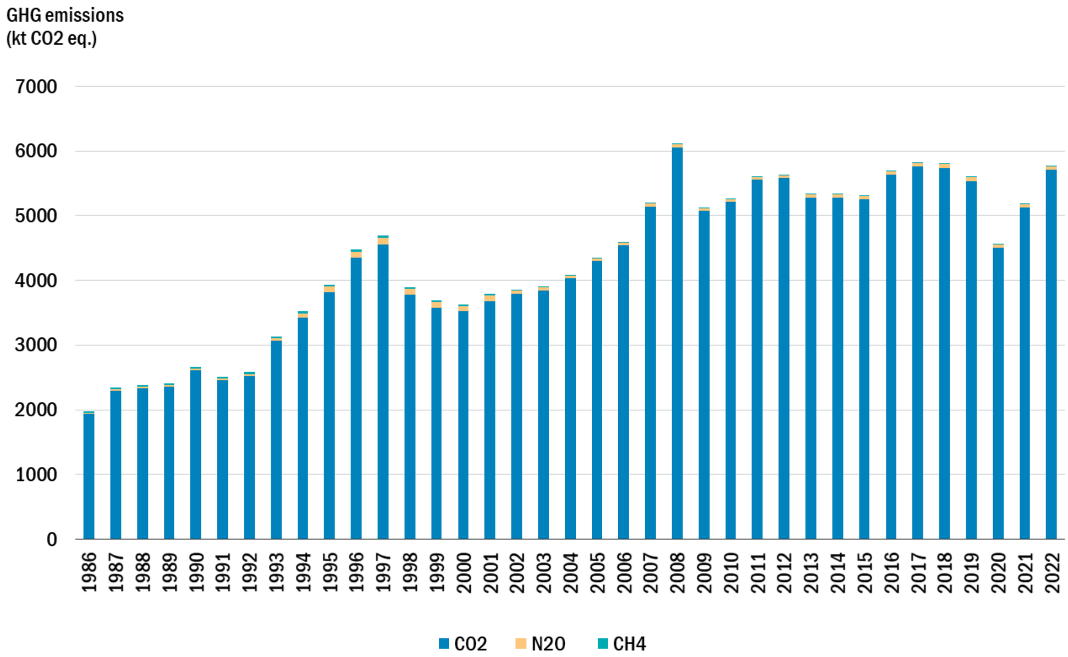


Figure 3.2.8: CO_2, N_2O and CH_4 emissions for road transport 1986–2022.

From 1986 to 2022 the road transport emissions of CO_2 and N_2O increased by 195% and 191%, respectively. Emissions of CH_4 have decreased by 78%. Due to the world economic crises and consecutively smaller fuel consumption emissions of all GHG considerably decreased in 2009. Another huge drop in all GHG emissions occurred in 2020 due to the Covid-19 pandemic crisis. Lockdown measures and reduced mobility caused a drastic decline in emissions. In 2021 the sale of fuel was on the rise again and consequently, emissions increased. The impact of measures for handling the Covid-19 pandemic was just temporary. The same trend was observed in 2022 as well.

Referring to the fifth IPCC assessment report, 1 g CH_4 and 1 g N_2O have the greenhouse effect of 28 and 265 g CO_2, respectively. In spite of the relatively large CH_4 and N_2O global warming potentials, the largest contribution to the total CO_2 emission equivalents for road transport comes from CO_2 (Figure 3.2.8).

Due to the direct dependency of CO_2 emissions on fuel consumption, the total growth in CO_2 emissions reflects the trend of increased fuel consumption till 2008. In 2009 and 2020 significant drops in CO_2 emissions occurred due to the smaller fuel consumption due to the economic crisis and a Covid-19 pandemic crisis. In 2021 a drastic increase in CO_2 emissions is shown due to the release of Covid-19 measures. The same trend was observed also in 2022. As shown in Figures 3.2.9 and 3.2.10, the most important emission source for road transport is passenger cars, followed by heavy duty vehicles and buses, light duty vehicles and mopeds and motorcycles in decreasing order. In 2022, the emission shares were about 65, 25, 10 and below 1 %, respectively.

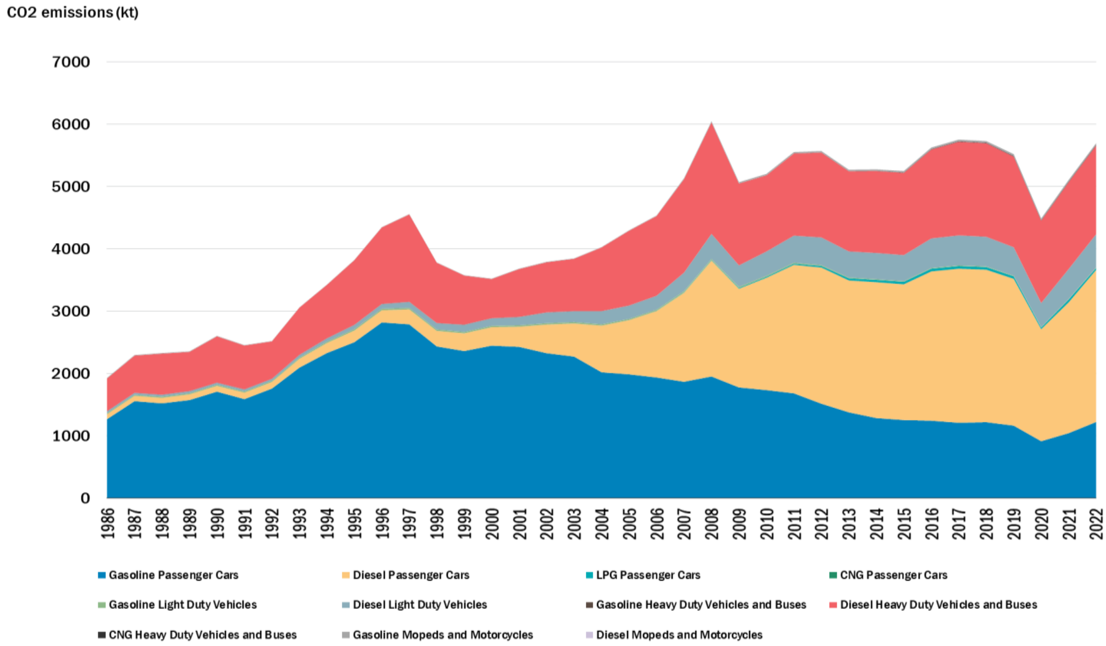


Figure 3.2.9: CO_2 emissions (kt) per vehicle type for road transport 1986−2022.

CO_2 emissions of passenger cars were gradually increasing from 1991 to 1996 mainly due to the fuel being sold to foreigners as a consequence of the lower fuel prices in Slovenia. From 2000 onwards an extensive switch from petrol powered to diesel powered cars could be observed. In 2019 diesel cars prevailed petrol cars. The better energy efficiency of diesel cars and a general improvement in fuel efficiency for all new vehicles diminished a considerable increase in fuel consumption which led to a slower increase of CO_2 emissions in this period.

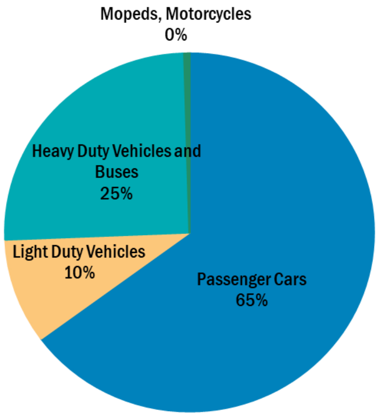


Figure 3.2.10: CO_2 emission share per vehicle type for road transport for 2022.

The road transportation sector also includes CO_2 emissions of lubricant use in two-stroke engines. The emissions from lubricants that are intentionally mixed with fuel and combusted in road vehicles should be captured as mobile source emissions. Those emissions have been reported under 1.A.3.b.iv Motorcycles/ Other Liquid Fuels. In the year 2022 CO_2 emissions from lube oil in two-stroke engines represent only 0.001% of total CO_2 emissions from road transportation.

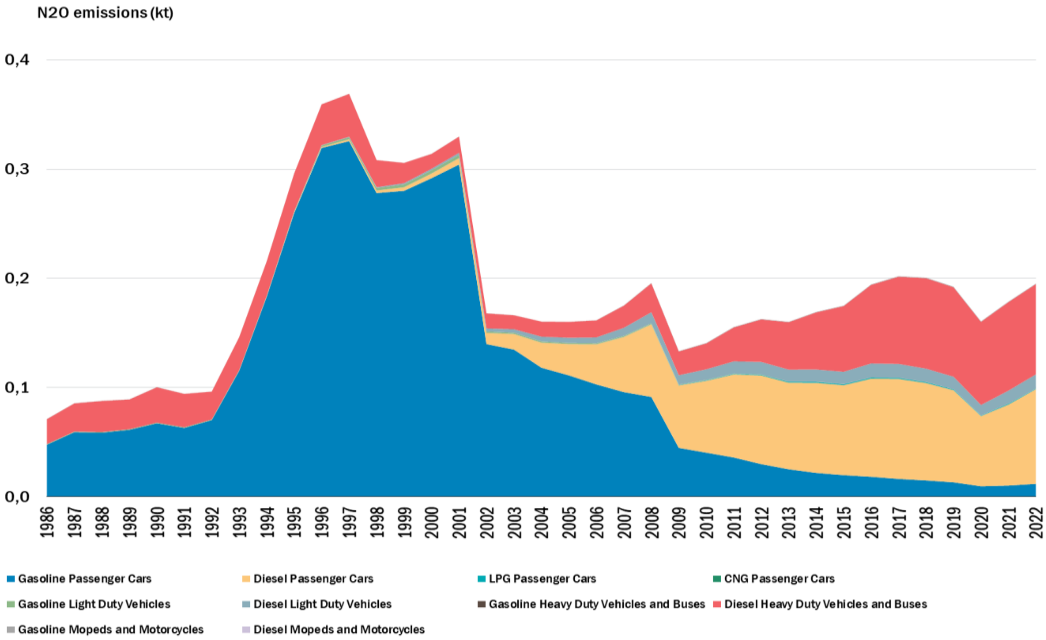


Figure 3.2.11: N_2O emissions (kt) per vehicle type for road transport 1986−2022.

N_2O emissions are not dependent only on fuel consumption, but also on vehicle technology, operating characteristics, fuel characteristics, combustion, and emission control technology.

An undesirable environmental side effect of the introduction of catalyst cars is the increase in the emissions of N_2O. N_2O emissions have increased significantly from 1991 onwards, mostly due to the growing number of passenger cars with catalysts. In 2002, a huge drop in N_2O emissions occurred due to switching to a lower sulphur fuel. The lower sulphur fuel helps improve catalyst performance. The sulphur content in the fuel has an important impact on N_2O emissions. The sulphur content dropped between 2001 and 2002 from 0.05% to 0.015% for gasoline and 0.2% to 0.035% for diesel.

In 2022 emission shares for passenger cars were 50% and heavy duty vehicles and buses 43%. Light duty vehicles contributed 7% to the total road transport N_2O. N_2O emissions from mopeds and motorcycles are negligible (Figures 3.2.11 and 3.2.12).

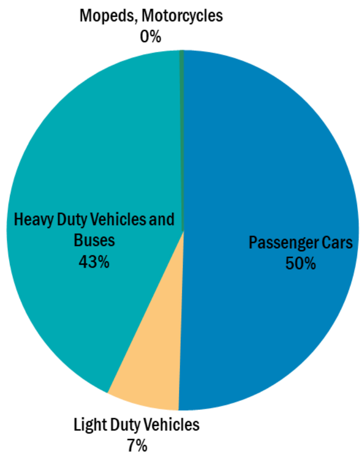


Figure 3.2.12: N_2O emission share per vehicle type for road transport for 2022.

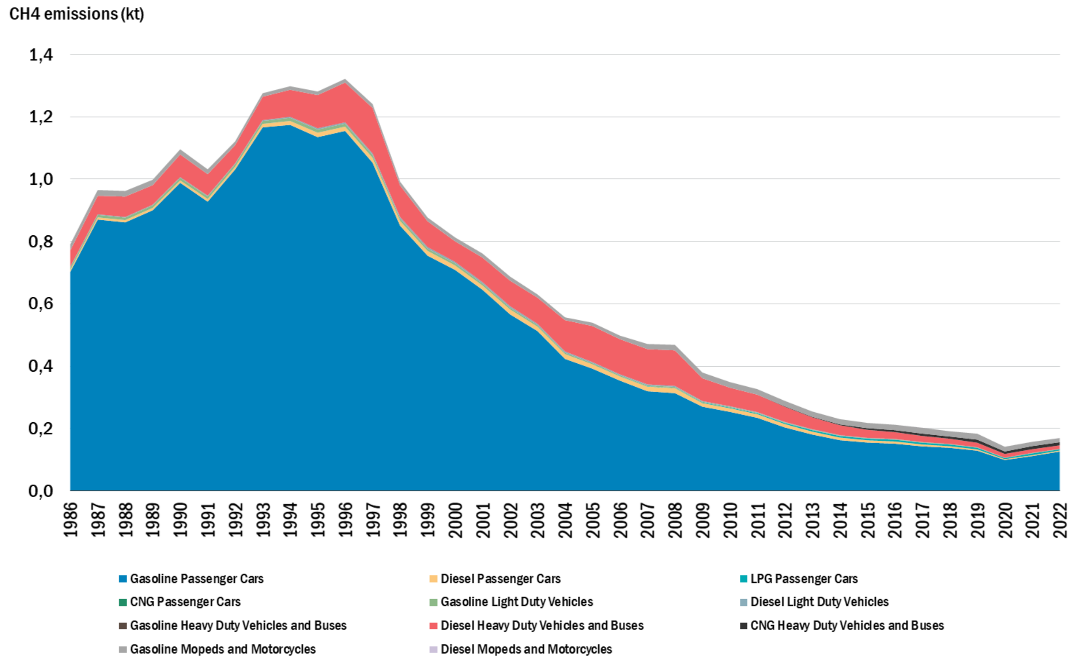


Figure 3.2.13: CH_4 emissions (kt) per vehicle type for road transport 1986−2022.

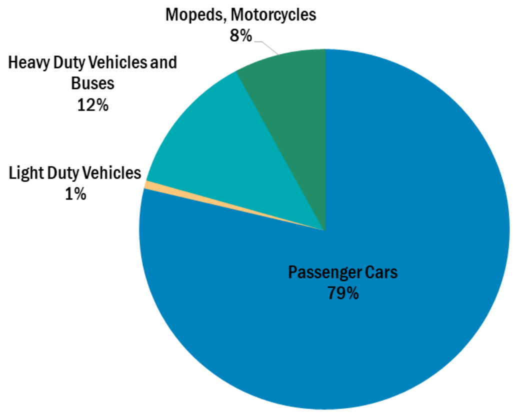


Figure 3.2.14: CH_4 emission share per vehicle type for road transport for 2022.

CH_4 emissions, similarly to N_2O, do not depend only on fuel consumption but also on vehicle technology, operating characteristics, fuel characteristics, combustion, and emission control technology.

The majority of CH_4 emissions from road transport come from gasoline passenger cars. The emission increase in 1991−1996 for this vehicle category is a result of higher fuel consumption. The emission drop from 1997 onwards is explained by the penetration of catalyst cars into the Slovenian fleet. The newer technology stages have lower CH_4 emission factors than conventional gasoline vehicles. The 2022 emission shares for CH_4 were about 79, 12, 8 and 1% for passenger cars, heavy duty vehicles and buses, mopeds and motorcycles and light duty vehicles, respectively (Figures 3.2.13 and 3.2.14).

3.2.6.1.2 Methodological issues

COPERT 5 (version 5.7.2) methodology has been used for the calculation of the national greenhouse gas emissions from road transport for the entire 1986-2022 period. The methodology is fully incorporated in the computer software program COPERT 5 (version 5.7.2) which facilitates its application. The actual calculations have been therefore performed by using this computer software.

COPERT 5 estimates the emissions of all major air pollutants, SO_x NO_x, CO, NMVOC, NH_3 particulate matter ($PM_{2.5}$, PM_{10}, TSP, Black carbon), persistent organic pollutants, heavy metals as well as greenhouse gas emissions (CO_2, N_2O, CH_4) produced by the different vehicle categories (passenger cars, light duty vehicles, heavy duty vehicles and buses, mopeds and motorcycles). The emissions estimated are divided among the three sources: emissions produced during thermally stabilized engine operation (hot emissions), emissions occurring during engine start from ambient temperature (cold-start and warming-up effects) and NMVOC emissions due to a fuel evaporation. The total emissions are calculated as a product of the activity data provided by the user and speed-dependent emission factors calculated by the software.

COPERT 5 also provides CO_2 emission estimates for lubricant use in road transportation. In the case of two-stroke engines, where the lubricant is mixed with another fuel and thus on purpose co-combusted in the engine, the emissions should be estimated and reported as part of the combustion emissions in the Energy Sector/ Road transportation.

The COPERT methodology is in accordance with 2006 IPCC Guidelines for the National Greenhouse Gas Inventories. The COPERT methodology is fully consistent with the Road Transport chapter of the EMEP/EEA air pollutant emission inventory guidebook. The use of a software tool to calculate road transport emissions allows for a transparent and standardized, hence consistent and comparable data collecting and emissions reporting procedure, in accordance with the requirements of international conventions and protocols and the EU legislation.

The applied methodology is fully described in the following literature:

- EMEP/EEA air pollutant emission inventory guidebook 2023 Technical guidance to prepare national emission inventories, Chapters: 1.A.3.b.i-iv Road transport 2023, 1.A.3.b.v Gasoline evaporation 2023, 1.A.3.b.vi-vii Road tyre and brake wear 2023
- https://www.emisia.com/utilities/copert/documentation/
- https://www.emisia.com/utilities/copert/versions/

To calculate the emissions using the COPERT software, at least the following input data are necessary: vehicle fleet data, mileage data per vehicle category and type of roads, speed data, fuel consumption and fuel characteristic, monthly air minimum and maximum temperatures, fuel vapour pressure.

Activity data

Vehicle fleet

The COPERT 5 methodology requires detailed knowledge of the structure of the vehicle fleet composition. The vehicle numbers per all vehicle classes for the period 1986−2022 are shown in Annex 3: Road transport: Fleet data (number of vehicles) 1986−2022.

The fleet composition for the years 1992−2022 was taken from the official database of registered motor and trailer vehicles in the Republic of Slovenia. Until 2009 data were provided by the Ministry of the Interior. Since 2010, those data have been collected by the Ministry of Infrastructure of the Republic of Slovenia. Since no database exists on licensed motor and trailer vehicles in the Republic of Slovenia for the years 1986−1991, an expert estimate has been made on the basis of the annual Statistical Yearbooks, published by the Statistical Office of the Republic of Slovenia (SORS).

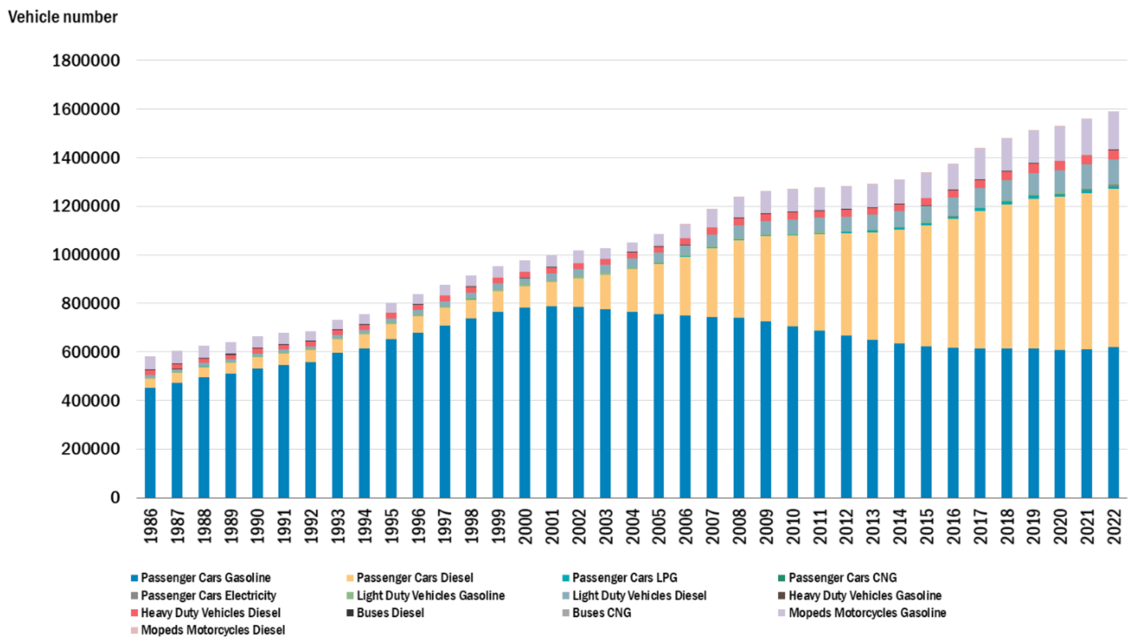


Figure 3.2.15: Vehicle fleet 1986–2022.

The vehicle fleet structure is presented in Figure 3.2.15. The increase in the total number of passenger cars is mostly due to a growth in the number of diesel passenger cars. After the year 2003 a considerable decline in the number of gasoline passenger cars is observed, and at the same time a rise in the number of diesel passenger cars. Liquefied petroleum gas (LPG) and compressed natural gas (CNG) passenger cars represent only a small share of all passenger cars. Mopeds and motorcycles vehicle category correspond to L-Category vehicle classification, which includes 2- and 3-wheel vehicles and quadricycles. In 2024 submission electric passenger cars for the period 2010-2022 were introduced in the national fleet data.

Mileage

Annual mileage (km/year) for each vehicle category for 2015-2022 has been calculated from data on odometer readings from a database on roadworthiness test that has been coupled with a database on registered motor vehicles. The database is administered by the Ministry of Infrastructure of the Republic of Slovenia. For other years the starting point is the same average yearly kilometres per vehicle class as in 2015, corrected to actual fuel consumption. The values used are shown in Annex 3: Road transport: Mileage data 1986−2022.

Speed

Three driving modes are individualized in accordance with COPERT 5 methodology: urban (peek, off peak), rural, and highway. For each specific driving mode, average speeds have to be set by vehicle types whereas vehicle exhaust emissions and fuel consumption are dependent on the speed. Speeds in specific driving modes have been assessed on the basis of the speed data for different types of road assessed from roads counters data. The values used are shown in Annex 3: Road transport: Speed data 1986−2022.

Fuel Consumption

The statistical data on the total volume of the fuel consumed in the Republic of Slovenia has been obtained from SORS. From the total volume of the fuel sold, the consumption in the fields of agriculture, forestry and construction has been excluded.

Figure 3.2.16 shows the total fuel consumption in road transport. Diesel, gasoline, LPG, CNG and electricity have been used as fuels in road transportation. The fuel consumption began to grow markedly during the years 1991–1997 due to fuel being sold to foreigners as a consequence of the lower fuel prices in Slovenia. During the years 2000–2008 an extensive growth in usage of diesel fuel can be observed. The transit of heavy duty trucks has been an important factor for the increase in diesel consumption. In the year 2005, the sale of diesel exceeded the sale of gasoline. In 2009, a significant decline in gasoline and diesel consumption appeared. In comparison with the year 2008, consumption of gasoline dropped by 9% and diesel by 20%. The lower consumption of fuel was due to the world economic crisis. Another huge drop in fuel consumption is seen in 2020. In comparison with the year 2019, consumption of gasoline dropped by 21% and diesel by 18%. Lower fuel consumption was due to reduced mobility as a consequence of the Covid-19 pandemic lockdown measures. In 2021 the sale of fuel was on the rise again due to the release of Covid-19 measures. The same trend was observed in 2022 as well. In 2022, the fuel use shares for diesel and gasoline were about 76% and 23%, respectively. The share of LPG was about 0.6% and CNG only 0.3%. Consumption of LPG was reported for the first time in 2006. It has been used by passenger cars. CNG was reported for the first time in 2012 and has been applied by passenger cars and busses. Electric passenger cars were introduced in 2010.

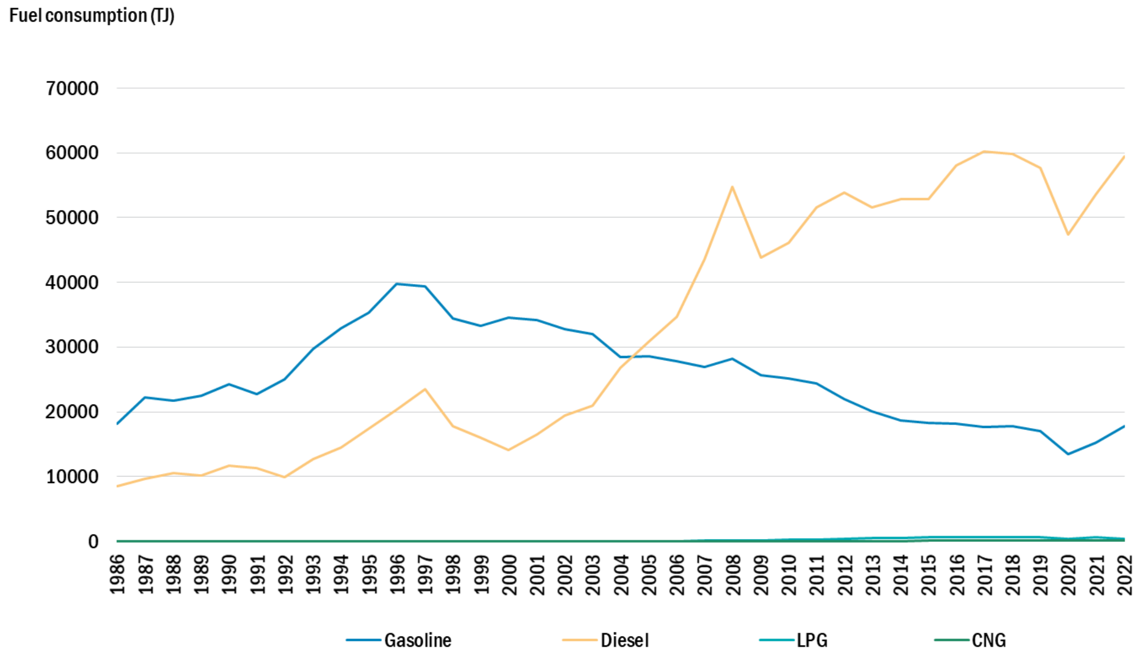


Figure 3.2.16: Fuel consumption in road transport for 1986–2022.

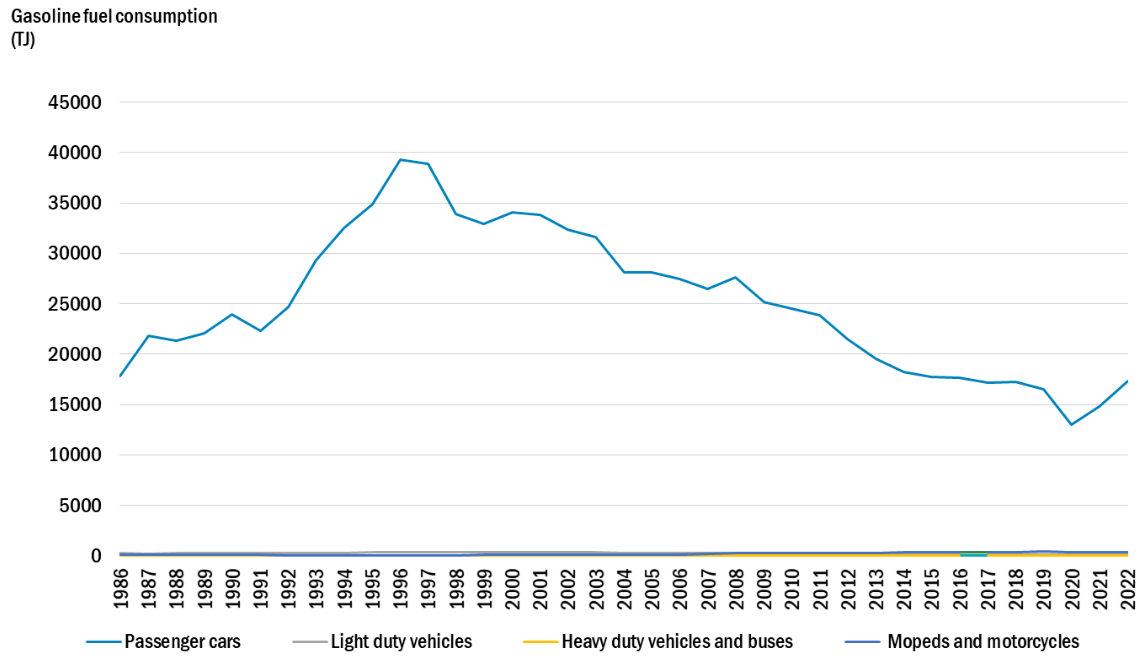


Figure 3.2.17: Gasoline fuel consumption per vehicle type for road transport 1986–2022.

As shown in Figures 3.2.17 and 3.2.18, the passenger cars represent the most fuel-consuming vehicle category, followed by heavy duty vehicles and buses, light duty vehicles, mopeds and motorcycles, in decreasing order. Passenger cars dominate the overall gasoline consumption trend. The development in diesel fuel consumption in recent years is characterised by an increasing fuel use for diesel passenger cars and heavy duty trucks, while the fuel use for light duty vehicles and mopeds and motorcycles is less distinctive. To meet the data quality objective of transparency, the fuel consumption by types of vehicles is shown in Annex 3: Road transport: Fuel Consumption by types of vehicles 1986−2022.

In 2022 the fuel consumption shares for diesel passenger cars, diesel heavy duty vehicles and buses and gasoline passenger cars were about 42, 25 and 22%, respectively (Figure 3.2.19).

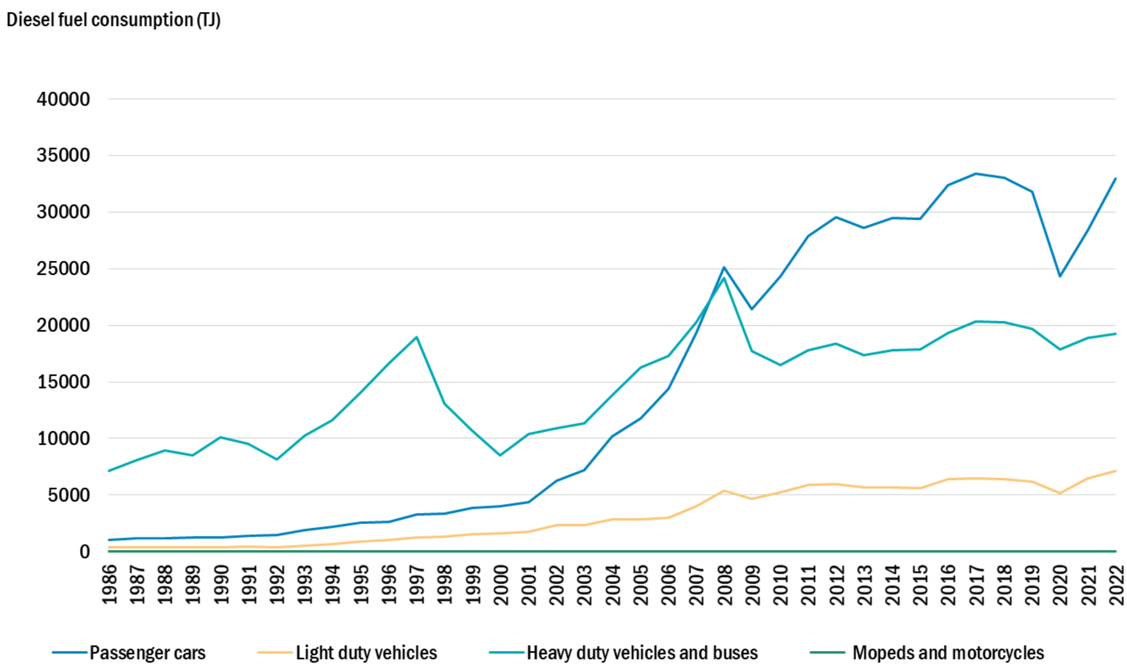


Figure 3.2.18: Diesel fuel consumption per vehicle type for road transport 1986–2022.

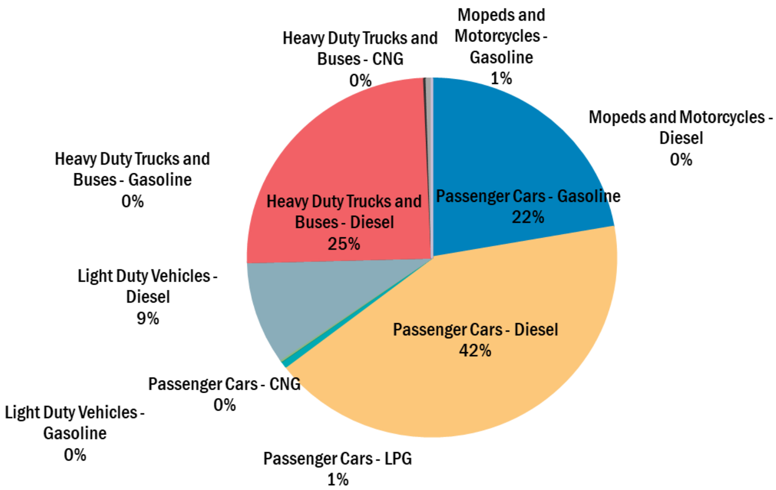


Figure 3.2.19: Fuel consumption share per vehicle type for road transport in 2022.

In addition to fossil fuels biofuels have also been used in road transportation in Slovenia. Biodiesel has been used since 2006 and biogasoline since 2007. Biodiesel in road transportation is mostly blended into fossil diesel, biogasoline into fossil gasoline. The amount of biofuel used in road transport is in steady increase also due to the national legislation on promotion of biofuel use in road transport. The emissions from biofuels have been calculated using the COPERT 5 model as well, based on the total amount of fossil fuels and biofuels used.

Fuel Characteristics

The sulphur and lead content of liquid fuels and the monthly values of the fuel volatility (RVP – Reid Vapour Pressure) were taken from the Slovene national legislation related to the quality of liquid fuels. The leaded gasoline was removed from the market in 2002. All the other physical and chemical data used was proposed as default values by the COPERT 5.

Table 3.2.43: Levels of lead content in gasoline.

Fuel	Period	Lead [g/l]
Gasoline Leaded	1986-1994	0.6
	1995	0.4
	1996-2001	0.15
Gasoline Unleaded	1986-1994	0.026
	1995-2001	0.013
	2002-2022	0.005

Table 3.2.44: Levels of sulphur content in gasoline and diesel fuel.

Fuel	Period	Sulphur [% wt]
Gasoline Leaded	1986-1994	0.1
	1995-2001	0.05
Gasoline Unleaded	1986-1994	0.1
	1995-2001	0.05
	2002-2004	0.015
	2005-2008	0.005
	2009-2022	0.001
Diesel	1986-1994	1
	1995	0.25
	1996-2001	0.20
	2002-2004	0.035
	2005-2008	0.005
	2009-2022	0.001

RVP values used were 70 kPa for the winter period (1 October – 30 April) and 60 kPa for the summer period (1 May – 30 September). The lead and sulphur contents were set as presented in Tables 3.2.43 and 3.2.44.

Monthly minimum and maximum air temperatures

The meteorological data necessary for evaporative emission calculation (annual average minimum temperature and maximum temperature) is obtained from the Slovenian Environment Agency. The data for Ljubljana was taken into consideration with the assumption that they are representative enough for the whole of Slovenia. The data are publicly available on the Slovenian Environment Agency's website.

<u>Other input data</u>

The average trip length (Ltrip) value corresponds to the mean distance covered in trips started with an engine of ambient temperature (cold start). The mean daily trip distance was set at 12 km in accordance with the recommendation of COPERT 5. Ltrip value is introduced for the calculation of the Beta value which represents the fraction of the monthly mileage driven before the engine and any exhaust components have reached their nominal operating temperature. Beta values calculated according to the COPERT 5 methodology were used.

All the other required input data used for the calculation of emissions using COPERT 5 program were default COPERT 5 data.

<u>Emission factors</u>

All emission factors used in the emission inventory for road transport were default emission factors offered by the COPERT 5 (version 5.7.2) program.

3.2.6.1.3 Uncertainties and time-series consistency

The uncertainty based on an expert judgement is 5% for fuel used and 20% for other activity data. The uncertainties of the emission factors are defined by the COPERT 5 program since all emission factors applied were default COPERT 5 emission factors. The uncertainties are presented in the table 3.2.45

Table 3.2.45: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year in per cents.

	1986 and 2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF
Gasoline	5	4	75	75
Diesel Oil	5	1.5	75	75
LPG	5	2	75	75
Lubricants	20	2	NA	NA
CNG	5	12	75	75
Biomass	5	NA	75	75

3.2.6.1.4 Category-Specific QA/QC and Verification

Following the recommendation of the Technical expert review team, a new model was used for GHG emissions calculation. COPERT 5 has been used instead of COPERT 4 model. COPERT 5 model was applied for the first time for 2021 submission. Due to improvements in the performance of COPERT 5 model the newest version of COPERT 5 (version 5.7.2) was used for emissions calculation for 2024 submission.

Since the new model has been applied thorough examination of all input data, the model calculation and the data reported in CRT tables as part of the QA/QC procedure were performed. All emissions distributed among different vehicle categories and fuel types were checked. According to the ERT recommendations improvement of the vehicle fleet was performed. Gasoline heavy duty trucks were introduced into the national fleet for the period 1986-1991.

GHG emissions arising from biofuels were thoroughly examined as well. In contrast with COPERT 4, COPERT 5 enables disaggregation of the emissions from biomass among different vehicle types. CO_2, CH_4 and N_2O emissions reported in the CRT Tables are accurate. CH_4 and N_2O emissions from biofuels have been calculated using the COPERT 5 model as well based on the total amount of fossil fuels and biofuels used.

Following the recommendation of the Technical expert review team, identification and separation of fossil from the biogenic part was performed. The fossil part of the biofuels was estimated and reported under 1A3b Other Fossil Fuels. The fossil part was estimated for biodiesel only. In the case of biogasoline, only the bio part is included in the amount of biogasoline. Emissions from the biogenic part of biodiesel and all biogasoline remain reported under 1A3b Biomass. Disaggregation of the emissions among each vehicle type was performed.

According to the ERT recommendations explanation for the observed variation in the CO_2 IEF for gasoline is included. Fluctuation in IEF for gasoline is due to changes in NCV applied throughout the time series. NCV for gasoline is not of the same value during the whole period. The drop in IEF in the year 2005 was due to an increase in NCV this year. The difference between NCVs in the years 2005 and 2004 is almost 2%. The value of NCV in 2005 was 43.85 TJ/kt, while in 2004 only 43.08 TJ/kt.

A source of NCV used is SORS. Until 2004 SORS collected data from all fuel distributors. Since 2005 SORS has reported an NCV value based on analyses of the biggest fuel distributor in Slovenia and it has used this value since then.

For the 2022 submission we have compare CO_2 EFs from road transport used in Slovenia with the CO_2 EFs from Italy and Austria. To avoid influence of NCVs we have compared IEFs from road transport from fossil diesel and gasoline in g CO_2 / g of fuel for the year 2020. The comparison is in the table 3.2.47. While CO_2 EF for diesel is in between of Austrian and Italian value, the CO2 EF for gasoline is almost 2% lower, but is still larger than IPCC default.

Table 3.2.46: A comparison of CO2 emissions factors for gasoline and diesel.

	gasoline	**diesel**
	g CO2/g fuel	**g CO2/ g fuel**
Italy	3.152	3.150
Austria	3.153	3.153
Slovenia	3.096	3.151
IPCC default	3.070	3.186

During the 2022 UNFCCC review the ERT recommends us to review the information on NCVs for gasoline used in road transportation reported in the most recent annual submissions of Austria and Italy to determine whether NCVs that are appropriate for use by Slovenia can be derived on the basis of the shares of gasoline imported into Slovenia and recalculate the time series using the updated NCVs, if it is determined that they better reflect national circumstances.

However NCVs for gasoline and diesel are not available in the NIDs of Italy and Austria, because they are not used for emission calculation. They are using EFs in g CO2/ g fuel and the same is valid also for Slovenian inventory. NCVs are used only to calculate energy of fuel for CRT reporting. The new NCVs will have no impact on GHG emissions from the road transport, and will not trigger any recalculations.

3.2.6.1.5 Category-specific recalculations

Recalculation of CO_2, CH_4 and N_2O emissions for the whole period 1986-2021 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.7.2) was used for emissions calculation. Improved national fleet data for the period 2010-2021 was used for emissions calculation.

3.2.6.1.6 Category-specific planned improvements

Following the recommendation of the expert review team, we are looking for options to obtain more information on the characterization of the properties of gasoline and diesel used for road transportation.

3.2.6.2 All other types of transportations (CRT cat. 1.A.3.a, c, d, e)

3.2.6.2.1 Category description

This chapter presents emissions of greenhouse gases in:
- Domestic Aviation (CRT 1A3a)
- Railways (CRT 1A3c)
- Domestic Navigation (CRT 1A3d)
- Other Transportation / Pipeline Transport (CRT 1A3e.i)

<u>Domestic aviation</u>

GHG emissions from aviation are included in many CRT categories. The main source of emissions is the consumption of aviation gasoline while the quantity of jet kerosene is much smaller. Slovenia is a small country and there is no need for domestic aviation transport between the cities. All civil domestic flights are for sport or touristic purpose only and have been made by small planes with reciprocating engine using aviation gasoline. For this reason all aviation gasoline sold in Slovenia is considered to be used for domestic aviation and the emissions are reported in this category. However, according to the Eurocontrol data a small amount of jet kerosene has been used since 2005 in domestic aviation. After investigation it was found that this fuel has been used for reallocation of airplanes between the two largest airports (Ljubljana and Maribor).

The remaining emissions from jet kerosene are reported in the category 1.A.5 (Fuel used in the Slovenian army and Police) or in Memo under International Bunkers and Multilateral Operations. The fuel used in TJ and GHG emissions from domestic aviation are presented on the table 3.2.47.

Table 3.2.47: GHG Emissions from domestic aviation in the period 1986-2022.

	1986	1990	2000	2005	2010	2015	2020	2021	2022
Av. gasoline in TJ	9	15	40	24	23	20	19	20	23
Jet kerosene in TJ	NO	NO	NO	15	4	8	3	3	6
Gg CO_2 eq.	0.6	1.1	2.8	2.7	2.0	2.0	1.6	1.6	2.0

<u>Railways</u>

The main source of emissions is the consumption of gas oil. The consumption of brown coal in the railway transportation in the recent years is small as it is used only in one ''archaic'' steam driven locomotive which is almost 100 years old. Since 2020 the steam locomotive has not been used any more. Fuel in TJ and GHG emissions from the railways are presented in table 3.2.48.

There was a strong increase in diesel consumption in 2014. The reason for this increase is a sever ice storm which destroyed electrical infrastructure for the supply of trains on the route Ljubljana - Koper in the February 2014. The repair was going on until the summer 2015. In meantime, the trains on this line were using diesel locomotives what resulted in the higher consumption of diesel oil in 2014 and relatively high consumption in 2015.

Table 3.2.48: GHG Emissions from railways in the period 1986-2022.

	1986	1990	1995	2000	2005	2010	2015	2020	2021	2022
fuel in TJ	931	879	588	514	505	403	498	231	279	286
Gg CO_2 eq.	76	72	48	42	41	33	41	19	23	23

Domestic navigation

For the 2022 submission data on gasoline and diesel oil used in small boats and yachts have been obtained. Fuel consumption in the base year was 0.1 TJ and in recent years around 1TJ and corresponding emissions are very minor. For calculation of emissions the default EF for diesel engine from IPCC GL, Vol 2, Table 3.3.1 have been used. This EFs are suitable for off-road mobile sources and machinery.

As Slovenian coast is short and there is no regular lines between small ports at this coast, all domestic navigation is occurring with a small boats and sailing yacht. For this reason the same EFs have been used for gas/diesel oil as for the other mobile sources with no emission control catalysts installed.

This source category is very minor, fuel consumption in the base year was 0.1 TJ and in recent years it is around 1TJ.

Other transportation

In the category 1.A.3.e Other transportations only emissions from natural gas combusted in the compressor stations have been reported. As data are available since 2008 the notation key IE has been used for the period 2002-2007, and corresponding emissions are included in 1.A.4.a Commercial/Institutional sector. There was no compression station in Slovenia before 2002. Fuel in TJ and GHG emissions are presented in table 3.2.49.

Table 3.2.49: GHG Emissions from compressor station in the period 1986-2022.

	1986 - 2001	2002 - 2007	2010	2015	2020	2021	2022
fuel in TJ	NO	IE	79	53	16	15	8
Gg CO_2 eq.	NO	IE	4.4	2.9	0.9	0.9	0.4

3.2.6.2.2 Methodology issues

To estimate emissions from these categories, the following methodology has been adopted:

Emissions = Quantity of Fuel used x Net Calorific value x EF per energy of Fuel

Activity data and NCV

The data on the fuel consumption as well as NCVs have been obtained from SORS except for AD for 1A3d and 1A3e. Consumption of natural gas in compressor stations has been obtained from the company Plinovodi and consumption of gasoline and gas/diesel oil in domestic navigation has been obtained from Slovenian Maritime Administration. The net calorific values used for the 2022 inventory are presented in table 3.2.50.

Table 3.2.50: NCVs for fuel used in all other transportation in 2022.

	Unit	Aviation Gasoline	Jet kerosene	Gas/Diesel Oil	Coal	Gasoline	Natural gas
NCV	**TJ/kt or TJ/ 10^6 Sm^3**	43.54	43.54	42.6	NO	43.85	34.085

Emission factors

All emission factors have been taken from the 2006 IPCC Guidelines except for CO_2 EF for natural gas which is country specific (Table 3.2.51).

Table 3.2.51: EFs for fuel used in all other transportations in the period 1986-2022.

	Unit	Aviation Gasoline	Jet kerosene	Gas/Diesel Oil	Coal	Gasoline	Natural gas
CO_2 EF	**t/TJ**	69.3	71.5	74.0	101	69.3	Table 3.2.2
CH_4 EF	**t/TJ**	0.0005	0.0005	0.00415	0.002	0.05	0.001
N_2O EF	**t/TJ**	0.002	0.002	0.0286	0.0015	0.002	0.0001
Source	**CO_2**	IPCC, Table 3.6.4	IPCC, Table 3.6.4	IPCC, Table 3.4.1	IPCC, Table 2.2	IPCC, Table 3.6.4	CS
Source	**CH_4, N_2O**	IPCC, Table 3.6.5	IPCC, Table 3.6.5	IPCC, Table 3.4.1 and 3.3.1	IPCC, Table 3.4.1	IPCC, Table 3.3.1	IPCC, Table 2.4

IPCC = 2006 IPCC Guidelines for National GHG Inventories, Vol. 2

According to the information from Railway Company, a very low calorific brown coal with NCVs in the range 10-13 TJ/kt had been used in the “archaic” steam driven locomotive due to the safety reasons, and to preserve this piece of history. For this reason the default EF for lignite has been applied in the calculations. This coal-fired train was only used for tourist purposes and is no longer in service as of 2020.

3.2.6.2.3 Uncertainty and time –series consistency

The uncertainty estimates for the transport sector are mostly based on an expert judgement. To determine the uncertainties of the AD, consultations with experts from SORS were performed, while values from the 2006 IPCC GL have also been taken into account.

Table 3.2.52: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year in per cents.

	1986 and 2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF
Aviation Gasoline	5	2	150	150
Railways/Liquid	5	1.5	150	150
Railways/Solid	10-5	2	135	150
Other/Gaseous	1	2.5-0.5	135	135
Domestic Navigation	20-5	2	150	150

The uncertainty of activity data is a combination of systematic and random errors. The statistical data which are obtained from the obligatory reporting are usually within 3%. In addition, the activity data are subject to the random errors in the data collection. Countries with good data collection systems may keep the random error to about 2-3%. The experts believe that for most developed countries the total uncertainties of activity data are in the range of 5%. After consultation with SORS and taking into account the levels of uncertainties associated with transportation recommended in the 2006 IPCC GL, we have used different uncertainties for different types of fuel as presented in the Table 3.2.52.

3.2.6.2.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3 while QA is applied with the comparison with the energy balance data in RA.

3.2.6.2.5 Category-specific recalculations

No recalculations have been performed for this category.

3.2.6.2.6 Category-specific planned improvements

No improvement is planned for this category.

3.2.7 Other Sectors (CRT 1A4)

This chapter presents the consumption of fuels and emissions of greenhouse gases in:

- Commercial / Institutional sector (CRT 1A4a)
- Residential sector (CRT 1A4b)
- Agriculture / Forestry / Fishing (CRT 1A4c)

Table 3.2.53: Method, EF used and key categories indications for the year 2022 in the Other sectors.

	CO_2			CH_4			N_2O		
Fuels	Method	EF	Key category	Method	EF	Key category	Method	EF	Key category
Gaseous	T2	CS	L,T	T1	D	-	T1	D	-
Liquid	T1	D	L,T	T1	D	-	T1	D	-
Biomass	T1	D	-	T2	CS	L	T1	D	-

In this sector CO_2 emissions due to the use of gaseous and liquid fuel is a key category according to the level and trend, methane emissions from the biomass combustion in residential sector is a key category according to the level. In 2022 a solid fuel has not been used in this sector. The GHG emissions are presented in the Table 3.2.54 and on the Figure 3.2.20.

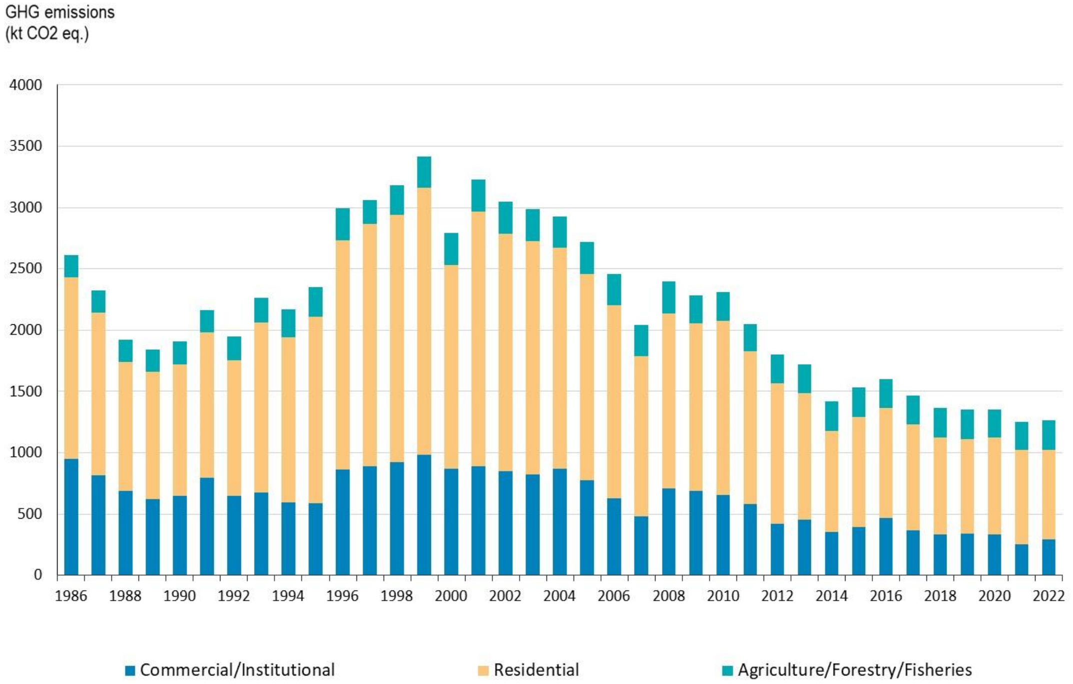


Figure 3.2.20: GHG emissions from Other Sectors.

Table 3.2.54: GHG emissions from Other Sectors in kt CO_2 eq.

	1986	1990	2000	2005	2010	2015	2020	2021	2022
4. Other Sectors	2,612	1,906	2,793	2,716	2,309	1,534	1,355	1,254	1,261
a. Commercial/Institutional	947	648	866	775	654	395	336	251	296
b. Residential	1,486	1,074	1,668	1,685	1,422	898	787	770	729
c. Agriculture/Forestry/Fisheries	179	183	259	257	234	241	232	233	236

3.2.7.1 Commercial / Institutional and Residential Sector (CRT categories 1.A.4.a and 1.A.4.b)

3.2.7.1.1 Category description

Emissions from these two subsectors were in 2022 for 57.9% lower than in 1986 despite that the energy of the fuel used was lower by 29.6% only. The reason for this is the shift in the fuel mix from solid fuels to natural gas and in the last years to biomass. Since 2010 the emissions have decreased also due to the warmer winters and due to an improved thermal insulation of the buildings.

3.2.7.1.2 Methodology issues

To estimate the emissions from these categories, the following methodology has been adopted:

Emissions = Quantity of Fuel used x Net Calorific value x EF per energy of Fuel

Activity data

The data on the fuel used in these two sectors have been obtained from the SORS.

Before 1990 the consumption of fuels in the commercial sector and households has been combined under "Široka potrošnja" in our basic source of data (Statistical Yearbook of Electricity Generating Industries). The disaggregation into these two categories has been done within the framework of the research project done at the end of the year by the Institute of Energy Industries (Gasperič, Dornik 1998). Data from that research project have been corrected in the following points:

- Quantities of fuel oil which have been consumed in the road transport as gas oil and which have been estimated in the research project "Assessment of Emissions of Greenhouse Gases in Road Traffic" (Institute of Transport Technology, 1999) are subtracted from the sector "Široka Potrošnja", namely 80 % from sector Consumption in Households and 20 % from Consumption in Commercial Sector.
- All quantities of residual fuel oil, reported as consumed in Other consumption in LEG, are presented as consumption in the commercial/institutional sector in this report.

Since 1990, the data on the fuel used in commercial and residential sector have been available from Joint questionnaires. In accordance with IPCC 2006 GL (Vol.2, Box 2.1 Autoproducers), emissions from combustion of landfill gas and gas from WW treatment plants which is used for electricity production are included under 1A4a Commercial use and not under 1A1a.

Net calorific values

The net calorific values have been taken from SORS and are presented in the Table 3.2.55.

Table 3.2.55: NCVs for the fuel used in Commercial Sector and Households.

Year	Lignite (Velenje)	Sub-bituminous Coal - domestic	Sub-bituminous Coal - imported	Fuel Oil	Residual Fuel Oil	LPG	Natural Gas	Wood and Other Biomass
	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/kt	TJ/Mm3	TJ/kt
1986	9.390	11.880		41.82	39.74	46.00	33.500	14
1987	9,650	11.820		41,78	39.80	46.00	33.500	14
1988	9,440	12.000		41,71	39.80	46.00	34.080	14
1989	9,820	12,050		41,85	39.90	46.00	34.100	14
1990	9.810	12.760		41.87	39.80	46.00	34.100	14
1991	9.980	12.879		41.88	39.80	46.00	34.100	14
1992	10.260	12.589		41.90	39.90	46.00	34.100	14
1993	10.070	13.351		41.90	39.80	46.00	34.100	14
1994	9.960	12.666		41.90	39.86	46.00	34.100	14
1995	10.220		17.404	41.90	40.00	46.00	34.100	14
1996	9.690		16.353	41.90	40.00	46.00	34.100	14
1997	9.610		18.203	41.90	40.00	46.05	34.080	14
1998	10.010		18.531	41.90	40.00	46.05	34.080	14
1999	9.690		18.563	41.90	40.00	46.05	34.080	14
2000	10.170		17.983	41.90	40.00	46.05	34.080	13.97
2001	10.660		18.834	41.90	40.00	46.05	34.080	13.95
2002	10.350		19.000	41.90	40.00	46.05	34.080	13.95
2003	10.138		19.000	41.90		46.05	34.080	13.98
2004	10.301		19.000	41.90		46.05	34.080	14.02
2005	10.803		17.000	42.60		46.05	34.080	14.05
2006			17.318	41.90		46.05	34.072	14.11
2007			16.863	42.60		46.05	34.076	14.15
2008			16.407	42.60		46.05	34.096	14.19
2009			15.952	42.60		46.05	34.080	14.74
2010			16.155	42.60		46.05	34.080	14,75
2011			15.985	42.60		46.05	34.087	14,77
2012			16.032	42.60		46.05	34.093	14,80
2013			16.457	42.60		46.05	34.079	14.81
2014			15.734	42.60		46.05	34.083	14.81
2015			16.360	42.60		46.05	34.086	14.81
2016			16.575	42.60		46.05	34.087	14.82
2017			16.000	42.60		46.05	34.087	14.82
2018			17.647	42.600		46.050	34.087	14.83
2019			18.282	42.60		46.050	34.081	14.84
2020			18.198	42.60		46.050	34.087	14.84
2021			18.256	42.60		46.050	34.086	14.84
2022			-	42.60		46.050	34.085	14.85

The values for solid fuel varies from year to year but for the liquid and gaseous fuel almost the same values have been used for the entire period, as these types of fuel don't change a lot from year to year.

Emission factors

Emission factors are mainly taken from the 2006 IPCC Guidelines, Vol. 2 Table 2.4 and Table 2.5. with the following exceptions. Country specific CO_2 EFs have been used for domestic lignite and natural gas, and country specific CH4 emissions factor for wood biomass combustion in the residential sector. Emission factors are presented in the Table 3.2.56-58.

Table 3.2.56: EFs for the fuel used in Commercial Sector.

	Unit	Lignite (Velenje)	Sub-bituminous Coal - domestic	Fuel Oil	Residual Fuel Oil	LPG	Natural Gas	Wood and other solid biomass	Gaseous biomass
CO_2 EF	t/TJ	Table 3.2.1	101	74.0	77.1	63.1	Table 3.2.2	112	54.6
CH_4 EF	t/TJ	0.01	0.01	0.01	0.03	0.005	0.005	0.3	0.005
N_2O EF	t/TJ	0.0015	0.0014	0.0006	0.0006	0.0001	0.0001	0.0040	0.0001

Table 3.2.57: EFs for the fuel used in Residential Sector if different from Commercial.

	Unit	Lignite (Velenje)	Sub-bituminous Coal - domestic	Wood biomass
CH_4 EF	t/TJ	0.3	0.3	Table 3.2.56

Table 3.2.58: CS EFs in t CH_4 /TJ for wood biomass combustion in the Residential Sector

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0.2956	0.2956	0.2956	0.2956	0.2956	0.2956	0.2956	0.2956	0.2956	0.2956
1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
0.2965	0.2975	0.2984	0.2994	0.30303	0.3030	0.2947	0.2896	0.2860	0.2926
2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
0.2838	0.2899	0.2872	0.2844	0.2798	0.2811	0.2783	0.2777	0.2692	0.2723
2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
0.2735	0.2718	0.2649	0.2580	0.2467	0.2499	0.2358			

The country specific CH_4 emission factors for biomass combustion in the residential sector have been calculated using EFs from the study made by expert in the Institute Jozef Stefan – Energy Efficiency Centre (Česen, 2020) and are presented on the table 3.2.59.

For this study a literature search on CH_4 emission factors for residential wood combustion installations was made and two publications were selected, one from Sweden (Kindbom, 2017) and one from Italy (Ozgen and Caserini, 2018). Then the formula from Kindbom et al. was used to adapt the emission factors accordingly for all installations except for open fireplaces for which the value from Ozgen and Caserini is used. Finally the CH_4 EFs are compared to EF in GAINS and to CS EF for Austria, Switzerland, and Sweden.

The same Institute also provide us the data on different types of technologies for wood combustion in residential sector for the period 2005 – 2022, while for years before data was estimated taking into account, that in 1986 only conventional boilers and stoves have existed.

Table 3.2.59: CH4 EFs for wood biomass combustion for different combustion technologies.

Device label	Name of the boiler according to the EMEP/EEA GL 2019	CH_4 EF g CH_4/GJ
STD_BOILER	Conventional boilers <50kW	345
STD_BOILER_PEL	Conventional boilers <50kW	4.4
ECOD_BOILER	Advanced eco-labelled stoves and boilers	17.25
ECOD_BOILER_PEL	Pellet stoves and boilers	2.8
ECOD_BOILER_CHIP	Pellet stoves and boilers	28
OPN_FIREP	Open fireplaces	238
H_STOVE	Conventional stoves	98
C_STOVE	Conventional stoves	98
H_STOVE_IMPR	High efficient stoves	108
H_STOVE_ECOD	Advanced eco-labelled stoves and boilers	108

3.2.7.1.3 Uncertainty and time –series consistency

The uncertainty estimates for residential and institutional/commercial sector are mostly based on tan expert judgement. To determine the uncertainties of the AD, consultations with experts from SORS were performed, while values from the 2006 IPCC GL have also been taken into account for the uncertainties of EF.

The uncertainty of the activity data is a combination of systematic and random errors. The statistical data which are obtained from the obligatory reporting are usually within 3%. In addition, the activity data are subject to the random errors in the data collection. Countries with good data collection systems may keep the random error to about 2-3%. The experts believe that for most developed countries the total uncertainties of the activity data are in the range of 5%. After consultation with SORS and taking into account levels of uncertainties associated with stationary combustion recommended in the 2006 IPCC GL, we have used different uncertainties for different types of fuel as presented in the Table 3.2.60.

Table 3.2.60: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year in per cents.

	1986 and 2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF
Liquid	5	2	150	150
Solid	10-5	6.4	135	150
Gaseous	3	0.5	135	135
Biomass	40-20	NA	67-48	170

Uncertainty of EF are mostly taken from 2006 IPCC GL. An exception is CH_4 EF for biomass consumption in the residential sector, which is country specific and is calculated in the study (Česen, 2020). The main source of uncertainties was therefore a main publication which was used in this study from Sweden (Kindbom, 2017).Table 3.2.61: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year in per cents.

3.2.7.1.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3 while QA is applied with the comparison with the energy balance data in RA. In this case the RA is the best verification cross-check as no other data are available for this sector.

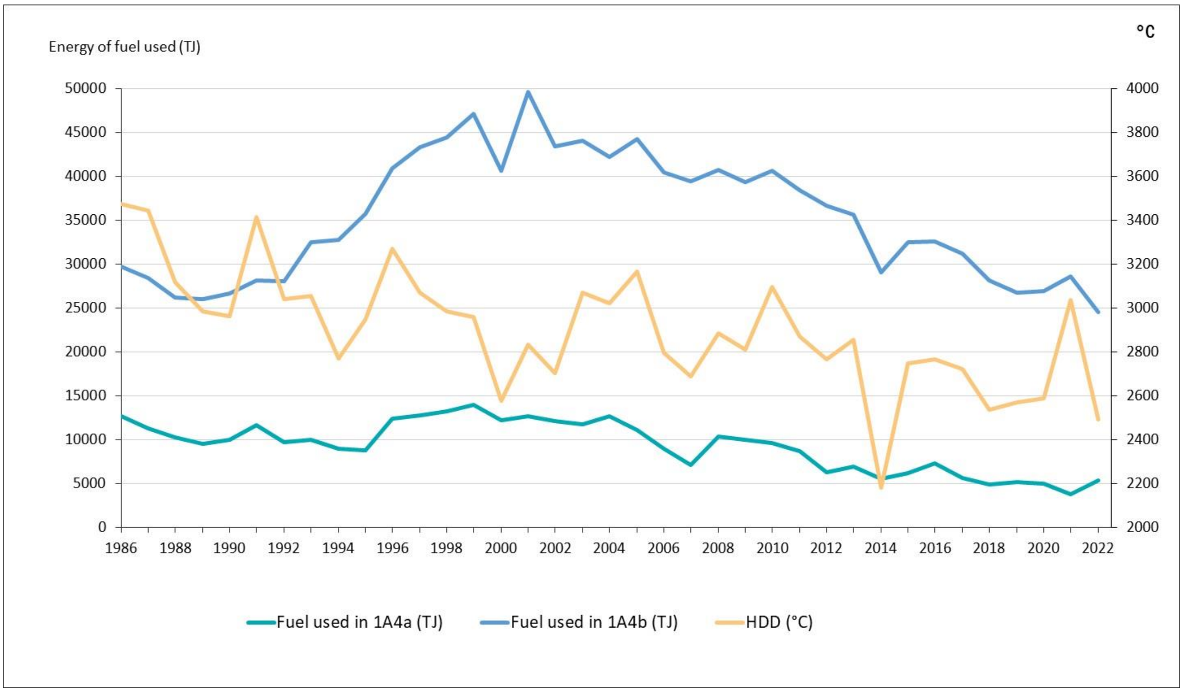


Figure 3.2.21: Heating degree days and energy of fuel used in the commercial/institutional and residential sectors.

In addition every year the energy of fuel consumption in the commercial/institutional and residential sectors is compared with the value of Heating Degree Days (HDD). HDD is a measurement designed to quantify the demand for energy needed to heat a building. The heating requirements for a given building at a specific location are considered to be directly proportional to the number of HDD at that location. By default, the duration is limited to days when the outdoor temperature (threshold) is lower than 12 ° C. For a given place, therefore, we take the average outdoor temperature during the heating season and subtract it from the agreed 20 ° C and multiply it by the number of heating days. This comparison is presented on the Figure 3.2.21.

In the recent years, this correlation is very obvious, while In the past, however, this was not the case, since the heating method at that time was significantly different (lower heating temperature and fewer heated rooms). In recent years insulation of buildings improved what has also a big impact on the energy needed for heating.

3.2.7.1.5 Category-specific recalculations

1.A.4.b Residential, Biomass, CH_4
CS CH4 EF was corrected due to the slightly changed data on share of different types of stove and boilers for combustion of wood and CH_4 emissions have been recalculated accordingly for the period 2010-2021.

3.2.7.1.6 Category-specific planned improvements

No improvements are planned for this category.

3.2.7.2 Agriculture / Forestry / Fishing (CRT category: 1.A.4.c)

3.2.7.2.1 Category description

This chapter should present all consumption of fuel in agriculture, forestry, and fishing. However, only the consumption of fuel for mobile sources in this sector is presented here. Not enough data are available for the consumption of fuel in stationary sources in Slovenia; consequently, these quantities are included in the Commercial / Institutional sector or Residential sector (biomass).

3.2.7.2.2 Methodology issues

To estimate emissions from these categories, the following methodology has been adopted:

Emissions = Quantity of Fuel used x Net Calorific value x EF per energy of Fuel

Activity data

The consumption of fuels until year 2000 has been calculated from the data on fuel consumption in state owned agriculture enterprises and corresponding agriculture land. The same energy intensity have been used to calculate the fuel used on the total agricultural land. Since 2001 data on fuel are available from SORS. The results of the calculation are presented in the Table 3.2.61. Since 2001 data on fuel are available from SORS.

Table 3.2.62: Estimation of the consumption of gasoline and diesel in Agriculture.

	1986	1990	1995	2000
Cultivated Land in State owned Agriculture ent. (1000 ha)	70	77	62	31
Total Cultivated Land (1000 ha)	647	653	634	509
Consumption of Gasoline in State owned Agriculture ent. (1000 t)	1.3	1.1	0.7	0.4
Consumption of Gasoline per ha of Cultivated Land (t/1000 ha)	18.6	14.1	10.5	7.1
Estimated Consumption of Gasoline in Total Agriculture (1000 t)	**12.016**	**9.227**	**6.647**	**3.626**
Consumption of Diesel in State owned Agriculture ent. (1000 t)	11.7	10.1	6.4	3.5
Consumption of Diesel per Hectare of Cultivated Land (t/1000 ha)	167.4	130.6	103.1	123
Estimated consumption of Diesel Fuels in Total Agriculture (1000 t)	**108.326**	**85.255**	**65.353**	**62.596**

The consumption of fuels in the entire forestry until 2000 was estimated on the basis of the consumption of fuel in state-owned logging enterprises. The data used are presented in the Table 3.2.62. Since 2001 data on fuel are available from SORS.

For the state-owned sector, data are available for the consumption of fuel and cut, for the private sector only data on cut are available. Firstly; the consumption per m^3 of cut in the state-owned logging enterprises is estimated. Based on these estimates and the data on the total cut, an estimation of the consumption in the whole of forestry is calculated. There were no separate data on the consumption of gasoline and diesel, only the total consumption. Consequently, the split is done considering the split in agriculture (10 % gasoline, 90 % gas oil), presuming that the same amount of fuels is consumed per m^3 of felled wood in the private forestry as in the state forestry. The data needed for the estimation of the consumption of fuels in Agriculture and Forestry is available for all years and are obtained from the SORS.

Table 3.2.63: The Calculation of the Consumption of Fuels in State Owned Forest

	1986	1990	1995	2000
Consumption of Fuel in State owned Forest (1000 t)	6.902	5.922	3.680	2.808
Cut in State owned Forest (1000 m^3)	1438	1230	862	907
Consumption of Fuel per Cut Quantities (tons per 1000 m^3)	4.8	4.8	4.3	3.1
Total Cut (1000 m^3)	3501	2435	2092	2609
Total Consumption of Fuel in Forestry (1000 t)	16.804	11.720	8.931	8.077
Gasoline (1000 tonnes)	**1.680**	**1,172**	**0.893**	**0.808**
Diesel (1000 tonnes)	**15.124**	**10.548**	**8.038**	**7.272**

Data from fishing on gas-diesel oil since 1995 has been obtained from The Fisheries Research Institute of Slovenia. For the years before 1995 the 1995 value has been used. Consumption of fuel in kt is available in the Table 3.2.63.

Table 3.2.64: Consumption of diesel in Fishing

	1986-1995	2000	2005	2010	2015	2020	2021	2022
Consumption of Diesel in Fishing (kt)	203	270	355	511	202	200	188	200

Net calorific values

We have used value 43.850 TJ/1000t for gasoline and 42.6 TJ/1000t for gas diesel oil as reported by SORS.

Emission factors

For calculation of emissions, the emission factors, recommended in 2006 IPCC Guidelines, Vol 2, Table 3.3.1, Agriculture were used. We have assumed that mostly 4-stroke gasoline motors have been used. EFs are presented in the Table 3.2.64.

Table 3.2.65: Default EFs for gasoline and diesel oil used in the agriculture and forestry.

	Diesel	Motor gasoline
	t/TJ	t/TJ
CO_2 EF	74.1	69.3
CH_4 EF	0.00415	0.08
N_2O EF	0.0286	0.002

3.2.7.2.3 Uncertainty and time –series consistency

The uncertainty estimates for this category are the same as for residential and commercial/sector, because the same estimates have been used for whole “Other Sectors” (Table 3.2.65).

Table 3.2.66: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year in per cents.

	1986 and 2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF
Liquid	5	2	150	150

3.2.7.2.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3 while QA is applied with the comparison with the energy balance data in RA.

3.2.7.2.5 Category-specific recalculations

No recalculations have been performed for this category.

3.2.7.2.6 Category-specific planned improvements

No improvement is planned for this category.

3.2.8 Other (CRT 1A5)

3.2.8.1.1 Category description

This chapter presents the consumption of fuels and emissions of greenhouse gases in:

- Other mobile (CRT 1A5b)

The emissions from jet kerosene in Slovenian Army and Police have been included in this category. The fuel used (TJ) and GHG emissions are presented in the Table 3.2.66.

Table 3.2.67: GHG Emissions in the period 1986-2022.

	1986	1990	1995	2000	2005	2010	2015	2020	2021	2022
fuel in TJ	575	444	19	43	46	40	51	44	64	65
Gg CO_2 eq.	41	32	1.4	3.1	3.3	2.9	3.7	3.2	4.6	4.7

3.2.8.1.2 Methodology issues

To estimate the emissions from these categories, the following methodology has been adopted:

Emissions = Quantity of Fuel used x Net Calorific value x EF per energy of Fuel

Activity data

Since 2008, the consumption of jet kerosene in Slovenian army and police has been obtained. These data are not available for the period 1986-2007. Following the recommendation from ARR 2011, the fuel used in Slovenian army and Police has been estimated using correlation with the number of aircrafts in the Slovenian army. To estimate emissions in the period 1986-1990/91, when Slovenia was still part of Yugoslavia, the fuel used for the international aviation has been estimated taking into account the correlation with the number of passengers on commercial flights and the remaining amount of jet-kerosene was counted as fuel used in the Yugoslavian army on Slovenian territory.

Net calorific values

We have used value 43.54 TJ/1000t for jet kerosene. This value was obtained from SORS.

Emission factors

For the calculation of emissions and individual gases, the emission factors from 2006 IPCC Guidelines, Vol 2, Table 3.6.4 and 3.6.5 for jet kerosene were used as presented on the Table 3.2.67.

Table 3.2.68: Default EFs for jet kerosene used in the Slovenian Army and Police.

	Jet kerosene
	t/TJ
CO_2 EF	71.5
CH_4 EF	0.0005
N_2O EF	0.002

3.2.8.1.3 Uncertainty and time –series consistency

The high uncertainty of the AD for the base year is due to the unavailability of data. The uncertainties of the EFs are from the 2006 IPCC GL (Table 3.2.68).

Table 3.2.69: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year in per cents.

	1986				2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF	AD	CO_2 EF	CH_4 EF	N_2O EF
liquid	30	3	150	150	10	3	150	150

3.2.8.1.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3 while QA is applied with the comparison with the energy balance data in RA.

3.2.8.1.5 Category-specific recalculations

No recalculations have been performed in this sector.

3.2.8.1.6 Category-specific planned improvements

No improvement is planned for this category.

3.3 Fugitive emissions from solid fuels, oil, natural gas and other emissions from energy production, (CRT 1.B)

This chapter presents the fugitive emissions of greenhouse gases from:

- Solid fuels (CRT 1.B.1)
- Oil and natural gas (CRT 1.B.2)

Coal mining and handling is a key category and the emissions have been calculated using Tier 3 methodology with EFs specific for each mine. For the methane emissions from abandoned and close coal mines we have used Tier 2 approach.

Emissions of CO_2 due to the flue-gas desulfurization in coal power plants have been also reported in this category under 1.B.1.c Other. They were calculated using Tier 3 methodology and PS data.

Fugitive emissions from oil and natural gas are not a key category and have been calculated using Tier 1 approach and default EFs as indicated on the Table 3.3.1 below.

Table 3.3.1: Method, EF used and key categories indications for the year 2022 in the Fugitive emissions sectors.

	CO_2			CH_4			N_2O		
Fuels	**Method**	**EF**	**Key category**	**Method**	**EF**	**Key category**	**Method**	**EF**	**Key category**
Coal Mining and Handling	T3	PS	-	T2, T3	D, PS	L,T	NO	NO	NA
SO2 scrubbing	T3	PS	L_{sub}, T	NO	NO	NA	NO	NO	NA
Oil and Natural Gas	T1	D	-	T1	D	-	T1	D	-

GHG emissions in kt of CO_2 equivalent for each category are presented in the table 3.3.2 and on the Figure 3.3.1.

Table 3.3.2: Fugitive emissions of GHGs in kt CO_2 eq.

in kt CO2 eq.	1986	1990	2000	2005	2010	2015	2020	2021	2022
Total	**649**	**561**	**515**	**570**	**563**	**401**	**411**	**359**	**308**
Solid Fuels	602	505	461	511	510	361	367	313	267
Oil and Natural gas	47	56	54	59	54	40	44	46	41

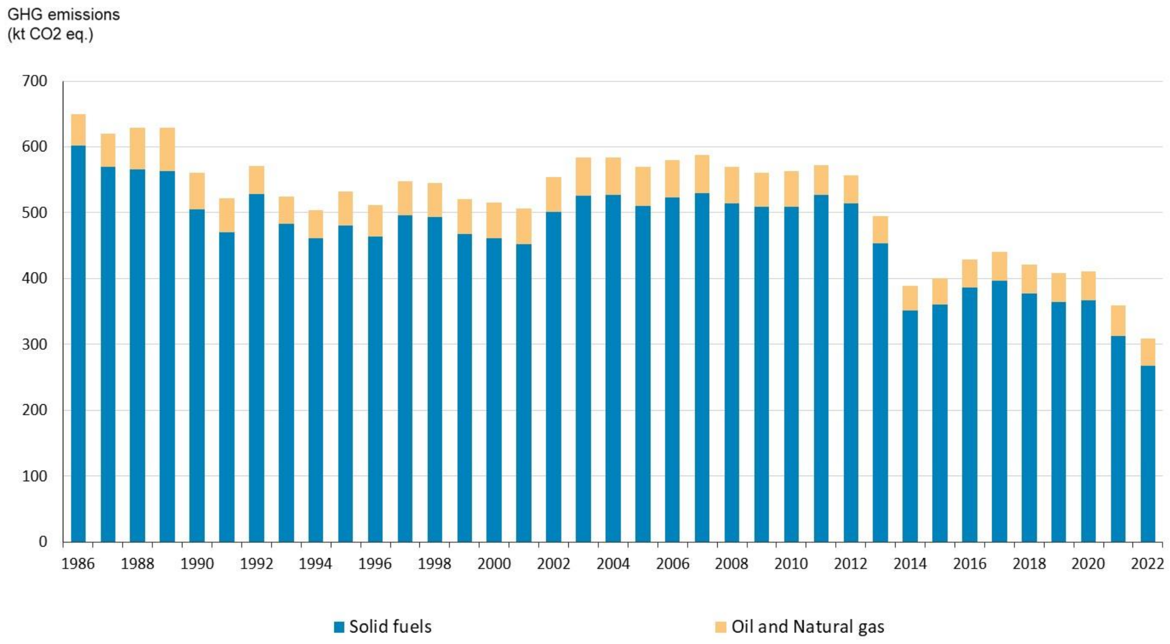


Figure 3.3.1: Fugitive emissions in kt CO_2 eq.

Fugitive emissions from fuel represent only 2.5% of emissions in the Energy sector and have decreased by 52.5% compared to the emissions in 1986. The decrease of emissions is mainly due to the gradual closure of coal mines. Emissions from Solid fuels represent 86.7% of fugitive GHG emissions and remaining 13.3% are from Oil and natural gas.

3.3.1 Solid Fuels (CRT 1.B.1)

3.3.1.1 Category description

This sub-chapter presents the fugitive emissions of greenhouse gases from:

- 1.B.1.a.i Coal mining and handling / Underground mines
  - Mining activities
  - Post-mining activities
  - Abandoned underground mines
- 1.B.1.c Other
  - SO_2 scrubbing

This chapter encompasses emissions arising from underground coal mines due to the production, processing, and storage of coal. The most important component of those emissions are CH_4 emissions that arise during mining and post-mining activities although CO_2 emissions occur as well. In 2015 submission CH_4 emissions from abandoned coal mines have been estimated for the first time following methodology described in 2006 IPCC GL. The emissions due to the flu-gases desulphurization have been also included to the energy sector as recommended in the 2006 ICC GL and reported under 1.B.1.c Other. The emissions from these categories are presented in the Table 3.3.3 and Table 3.3.4.

Table 3.3.3: Emissions from Coal mining and handling 1986 – 2022 in kt CO_2 eq.

	1986	1990	2000	2005	2010	2015	2020	2021	2022
Mining (CH_4)	116	59	224	233	234	178	179	147	133
Mining (CO_2)	123	101	81	83	82	61	62	51	46
Post-Mining (CH_4)	363	344	112	107	99	59	60	49	44
Abandoned coal mines (CH_4)	0.2	0.4	8	4	3	7	4	4	4
Total	602	505	424	428	418	306	304	251	226

Table 3.3.4: Emission of CO_2 from SO_2 scrubbing 1986 – 2022 in kt CO_2.

	1986-1991	1995	2000	2005	2010	2015	2020	2021	2022
SO_2 scrubbing	NO	30.0	36.7	82.3	91.5	55.3	63.4	62.1	41.0

3.3.1.2 Methodology issues

Mining and post mining

*Methane emissions (t) = (EF_1+ EF_2) * excavated coal (t) * 0.67(kg/m^3)*

*CO_2 emissions (t) = EF_3 (m^3 CO_2/t) * excavated coal (t)* 1.84(kg/m^3)*

EF_1 = Methane emission factor in coal excavation (m^3 CH_4/t)
EF_2 = Methane emission factors in post-mining activities for coal (m^3 CH_4/t)
EF_3 = CO2 emission factor in coal excavation (m^3 CO_2/t)

The methodology follows Tier 3 approach as the EFs in the equation above are specific for each mine.

Activity data

The data on excavated quantities of coal according to the individual coalmines are taken from SORS and are presented in the Table 3.3.5.8

Table 3.3.5: Excavation of Coal in Slovenia 1986 – 2022

Pit	1986	1990	1995	2000	2005	2010	2015	2020	2022	Closed in
Velenje	5,001	4,210	3,917	3,743	3,945	4,011	3,168	3,175	2,358	
Trbovlje - Hrastnik	1,242	905	812	737	594	419				2013
Zagorje	315	244	75							1997
Senovo	120	108	45							1996
Kanižarica	126	94	35							1996
Laško	25									1990
Total Coal Excavation (Gg)	**6,828**	**5,561**	**4,883**	**4,480**	**4,540**	**4,430**	**3,168**	**3,175**	**2,358**	

Emission factors

The estimates of the emission factors for the individual coalmines in Slovenia were done at the Ecological Research Institute (Zapušek A., Orešnik K., Avberšek F: Assessment of methane emission factors in coal excavation in 1986 and in the period 1990-1996, Velenje: ERICO - Ecological Research Institute, 1999).

Since 1997, the emission factors recommended in the study have been assumed.

Details from the ERICO study:

The data on the amount of exhaust air used for ventilation of the mines and methane content in the outlet air was obtained from the technical services in each mine. For the coal mines with more ventilation stations, the data from each ventilation station was considered. The chemical analysis of all samples was done in Chemical-technological laboratory in the coal mine Trbovlje-Hrastnik. Air sampling at the exit valves was held once a month in the middle of the month and in the middle of the working week, when the CH_4 concentrations are generally the highest. The air flow was measured with congestive pressure (Pittot Prandt tube). The proportions of CH_4 were determined on the basis of IR detection. The range of the uncertainties of EFs for mining was from 8 to 100%, it depended on the amount of methane in the air.

From the measurement of methane de-sorption in samples it was found that, after long enough period, all methane is released. It was assumed that the total EF for the type of coal or for the coal from the particular mine was constant. The total EF was determined as EF from mining plus EF from post-mining activities. For Velenje and Trbovlje coal mine the total EF was determined to be 4 m^3/t coal. Methane emission factors for mining and post-mining activities for each particular coal mine are presented in the Table 3.3.6 and 3.3.7, respectively.

In 1994, the new method of excavation has been introduced in the Velenje Coal mine which affected EFs from mining activities. Due to the new technology of mining, the coal is broken into smaller pieces what causes more methane to be released from the coal during mining and, consequently, less methane is available for the emissions during post-mining activities. This excavation methodology in the Velenje coal mine has been applied until now, while no major changes of mining practice have occurred in the Trbovlje-Hrastnik coal mine in the reporting period.

In the same study, the CO_2 EFs for mining activities have been determined using the same sampling method. Due to a large variation between years, the average value for 1986-1996 has been used for all reporting years (Table 3.3.8)

Table 3.3.6: Emission Factors for CH_4 in Coal Excavation 1986 – 2022 (m^3 CH_4/t coal)

Pit	1986	1990	1995	1997-2022
Velenje	0.95	0.33	3,56	3.00
Trbovlje - Hrastnik	0.62	0.88	0,46	1.00 (Closed since 2013)
Zagorje	1.39	3.59	11.30	Closed since 1997
Senovo	0.57	0.63	1.53	Closed since 1996
Kanižarica	0.33	0.45	1.21	Closed since 1996
Laško	3.82	Closed since 1990		

Table 3.3.7: Emission Factors for CH_4 in Post Mining Activities 1986 – 2022 (m^3 CH_4/t coal)

Pit	1986	1990	1995	1997-2022
Velenje	3.05	3.67	0.44	1.00
Trbovlje - Hrastnik	2.38	2.12	2.54	3.00 (Closed since 2013)
Zagorje	1.61	2.00	2.00	Closed since 1997
Senovo	2.43	2.37	1.47	Closed since 1996
Kanižarica	2.67	2.52	1.79	Closed since 1996
Laško	0.18	Closed since 1990		

Table 3.3.8: Emission Factors for CO_2 in Coal Excavation 1986 – 2022 (m^3 CO_2/t coal)

Pit	1986-2022
Velenje	10.54
Trbovlje - Hrastnik	6.03
Zagorje	9.51
Senovo	16.16
Kanižarica	8.21
Laško	30.80

<u>Abandoned underground mines</u>

The data on abandoned and close mines have been obtained from the study made by Geological Institute of Slovenia in 2004 for coordination with activities of the European Union (Budkovič, 2005). This study contained register of 44 opened, closed and abandoned coal mines in Slovenia. From this list we have chosen 7 closed gassy coal mines which are not fully flooded. For 4 closed mines data on measured emissions on the last year of operation are available, while for other 3 these emissions have been estimated with correlation with the data on probable coal reserve. All data from this registry are available in the Table 3.3.9.

Table 3.3.9: Closed and abandoned coal mines – data from the registry.

Coal mine	type of coal	Opened in the year	Closed in the year	Maximal yearly production in tonnes	in the year	Average probable reserves in million tones	Measured emissions on the last year of operation in kt CH_4
Trbovlje-Hrastnik	brown	1804	2013	1,000,000	1929	35	0.22
Zagorje	brown	1736	1997	685,000	1960	18.5	0.39
Senovo	brown	1819	1995	250,000	1943	4.65	0.07
Kanižarica	brown	1854	1995	143,000	1969	4.35	0.04
Laško	brown	1800	1989	132,000	1962	1.2	0.01
Šega	brown	1863	1963	18,000	1957	0.8	0.01
Krmelj	brown	1809	1962	11,.000	1950	3.6	0.043
Leše	brown	1824	1936	4,.000	1850	0.5	0.006

Table 3.3.10: EFs used for calculating emissions from Closed and abandoned coal mines in 2022.

Coal mine	type of coal	Measured emissions on the last year of operation in kt CH_4	T (years since abandonment)	EF
Trbovlje-Hrastnik	brown	0.22	9	0.292
Zagorje	brown	0.39	25	0.129
Senovo	brown	0.07	25	0.121
Kanižarica	brown	0.04	27	0.121
Laško	brown	0.01	33	0.101
Šega	brown	0.01	59	0.059
Krmelj	brown	0.043	60	0.058
Leše	brown	0.006	86	0.041

The emissions are calculated using Tier 2 equation 4.1.12 from 2006 IPCC GL, and coefficients have been taken from the Table 4.1.9 from 2006 IPCC GL. All mines were sub-bituminous coal mines (A = 0.27, b = -1)

$$CH_4 \text{ emissions} = CH_4 \text{ emissions prior to abandonment} * EF$$

$$EF = (1 + a * T)^b$$

a and b are constants determining the declining curve
T = years elapsed since abandonment and inventory year

T and EFs calculated from equation above for 2022 are presented in the Table 3.3.10.

SO_2 scrubbing

Using a technology for reduction of SO_2 emissions in the process of consumption of coal is causing the emissions of CO_2. CO_2 emissions from the SO_2 scrubbing have been calculated from consumption of limestone and the appropriate emission factor.

The activity data on $CaCO_3$ consumption for the period 1995-2004 have been taken from the documents of Milan Vidmar Electro-institute. Prior to 1995, there were no wet flue gas desulphurisation units installed for reducing emission of SO_2 in Slovenia. The data on $CaCO_3$ and $MgCO_3$ for the period 2005–2022 have been obtained from the verified ETS reports. The default emission factors, 439.71 kg CO_2/ton limestone and 521.97 kg CO_2/ton magnesium carbonate, have been applied for the whole period.

3.3.1.3 Uncertainty and time – series consistency

The uncertainties have been taken from 2006 IPCC Guidelines, while for other the other sources (SO_2 scrubbing) are based on the uncertainty of data in the ETS. They are presented in the Table 3.3.11. following the suggestions from the 2006 IPCC GL.

Table 3.3.11: Uncertainties of activity data and emission factors as used in the 2024 submission for the base year and the last reporting year.

	1986				2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF	AD	CO_2 EF	CH_4 EF	N_2O EF
Coal Mining and Handling	10	150	30	NA	10	150	30	NA
Other – SO_2 scrubbing	NO	NO	NA	NA	5	2	NA	NA

3.3.1.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

In addition, for 1B1 Mining activity methane emissions for the only operational coal mine in Velenje as reported to the E-PRTR have been compared to emissions from GHG inventory. The results are presented on the Figure 3.3.2. EFs calculated from emissions reported to E-PRTR fluctuates a lot, but the average methane EFs is almost the same as EF used in the inventory, 1.95 and 2.01 t/kt respectively. As the total methane emissions from mining activity are calculated in the way that the total emissions (mining + post-mining emissions) per excavated kt of coal are constant, data from E-PRTR will not change the final CH_4 emissions from this category.

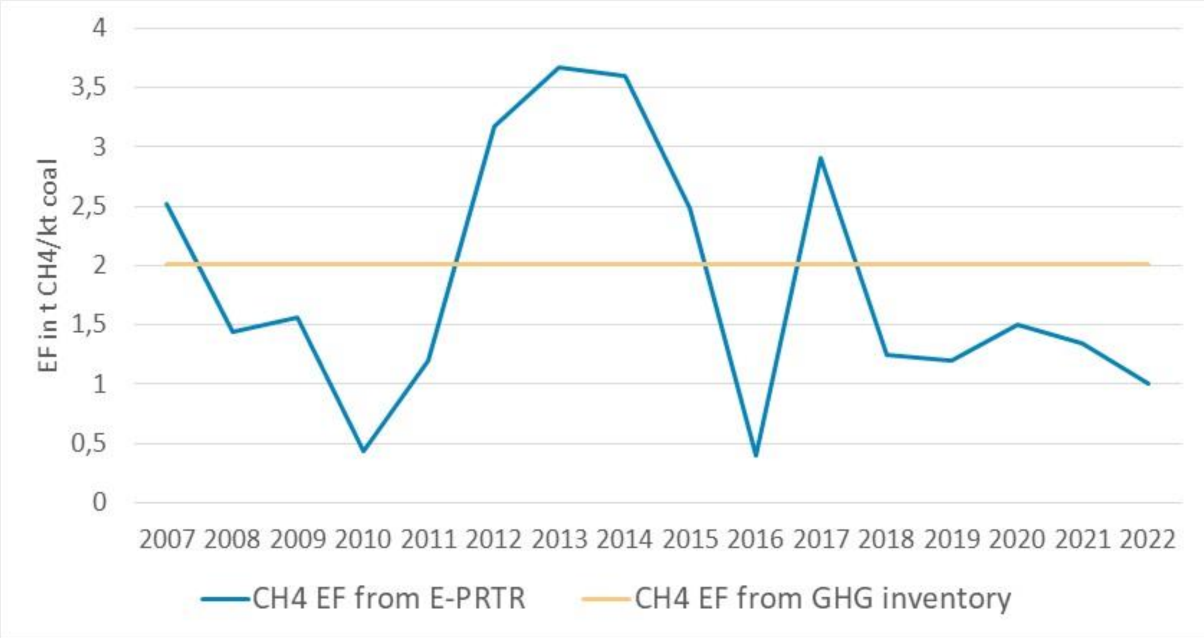


Figure 3.3.2: CH_4 EF in t CH_4 / kt of excavated coal from Velenje coal mine as calculate from emissions reported to E-PRTR and EF used in GHG inventory.

CO_2 emissions from 1B1c Other / SO_2 scrubbing were a key category many years until 2021, but in 2022 was not KC any more. Due to the fact, that AD are obtained from the verified ETS reports, additional QA is not necessary. We have compared the final CO_2 emissions from ETS report and from GHG inventory and the difference in 2022 was 0.06%. The reason is a different EFs used: in ETS the EF factors are rounded and are 440 instead of 439.71 kg CO_2/t $CaCO_3$ and 522 instead of 521.97 kg CO_2/t $MgCO_3$.

3.3.1.5 Category-specific recalculations

No recalculations have been performed for this category.

3.3.1.6 Category-specific planned improvements

No improvement is planned for this category.

3.3.2 Oil and natural gas (CRT 1.B.2)

3.3.2.1 Category description

Fugitive emissions of GHG from Oil and Natural Gas in the period 1986-2022 are presented in the Table 3.3.12. Methane emissions from the production of crude oil and refined petroleum products were insignificant in the period 1986-2002 and have not occurred since 2003. There was also one oil refinery in Slovenia which was closed in 2002. Since then no oil is refined in the country. According to the 2006 IPCC GL fugitive CH_4 emissions due to transport of LPG have been also reported under this category.

Table 3.3.12: Fugitive emissions of GHG from Oil and Natural gas in 1986 – 2022 (kt CO_2 eq.)

		1986	1990	2000	2005	2010	2015	2020	2022
OIL	Production	0.00005	0.00005	0.00001	0.00001	0.00000	0.00001	0.00000	0,00000
	Transport	0.032	0.025	0.059	0.065	0.062	0.060	0.061	0,059
	Refining	0.382	0.382	0.104	NO	NO	NO	NO	NO
	Venting	0.073	0.071	0.016	NO	NO	NO	NO	NO
	Flaring	0.150	0.146	0.033	NO	NO	NO	NO	NO
NATURAL GAS	Production	2.517	8.068	1.084	0.159	0.251	0.113	0.201	0,162
	Transmission	11.177	11.989	12.656	14.172	12.519	8.676	9.460	8.740
	Distribution	25.655	27.519	31.283	35.201	32.681	25.174	27.872	26.164
	Venting	7.454	7.995	8.440	9.451	8.349	5.786	6.309	5.829
	Flaring	0.011	0.034	0.010	0.005	0.008	0.004	0.007	0,005
TOTAL		47,449	56.229	53.685	59.053	53.870	39.813	43.910	40.960

Natural gas transmission and distribution is the main source of emissions in this category while fugitive emissions from natural gas production are less important. The gasification of Slovenia began in the early 1970s and in 1978 the newly constructed pipeline system enabled the transportation of Russian natural gas for Croatia and delivered gas to the first two consumers in Slovenia. Today, the total length of the gas pipeline transport network in Slovenia is 1,177 km and slowly growing**.**

Besides Russia, in 1992, natural gas deliveries from the second source, namely, from Algeria, started, which essentially increased the reliability of the supply and enabled the growth of natural gas consumption also in households and for commercial use. Since 2001, natural gas from a third source, Austria, has been delivered.

There is no processing of natural gas in Slovenia. A very small amount, which is produced, is transported directly without processing to the chemical plant located nearby in Hungary.

3.3.2.2 Methodology issues

GHG emissions in this category include:

- $emissions_1$: venting, flaring and fugitive GHG emissions from crude oil production,
- $emissions_2$: fugitive CO_2 and CH_4 emissions from crude oil refining,
- $emissions_3$: CO_2 emissions from the transport of LPG
- $emissions_4$: flaring and fugitive GHG emissions from natural gas production,
- $emissions_5$: venting and fugitive CO_2 and CH_4 emissions from NG transmission,
- $emissions_6$: fugitive CO_2 and CH_4 emissions from NG distribution.

The emissions have been calculated using Tier 1 approach as describe in 2006 IPCC GL with the equations below:

$emissions_1$= crude oil produced (ton) x density (t/1000 m^3) x EFs (Gg/1000 m^3)
$emissions_2$= oil refined (ton) x density (t/1000 m^3) x EFs (Gg/1000 m^3)
$emissions_3$= LPG consumed (ton) x density (t/1000 m^3) x EFs (Gg/1000 m^3)
$emissions_4$= natural gas production (1000 m^3) x EFs (Gg/10^6 m^3)
$emissions_5$= marketable gas (1000 m^3) x EFs (Gg/10^6 m^3)
$emissions_6$= natural gas utility sale (1000 m^3) x EFs (Gg/10^6 m^3)

Activity data

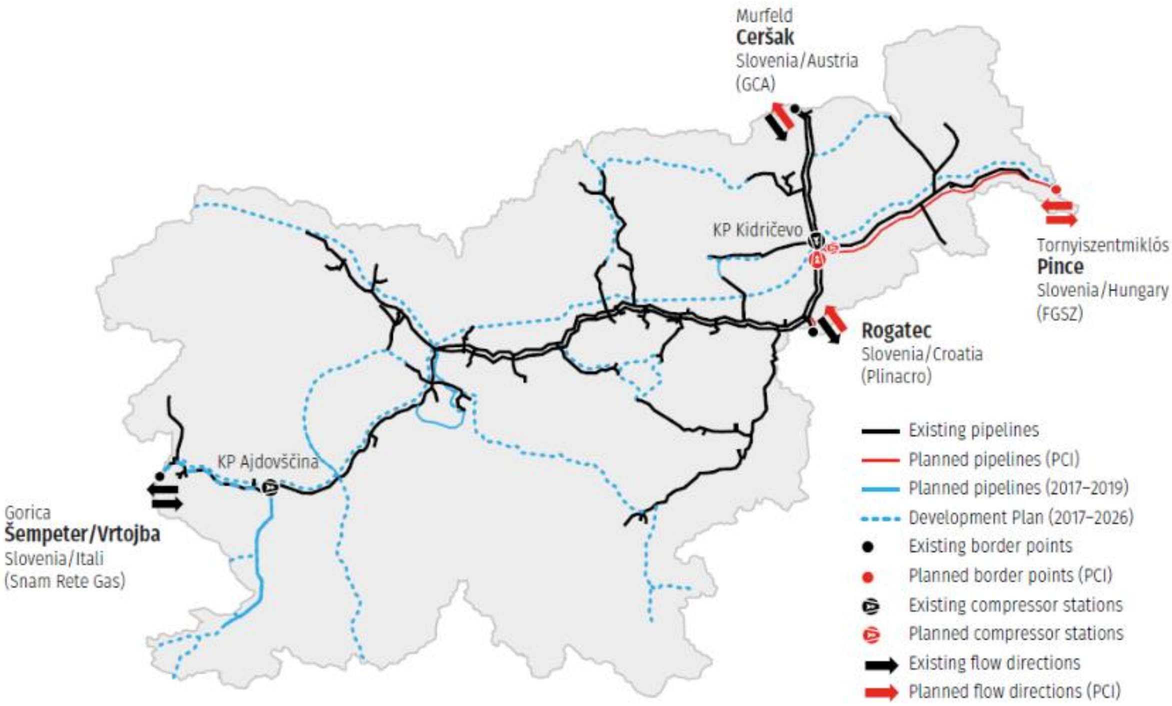
The data on the amount of crude oil produced and refined and LPG consumed have been obtained from SORS. As all data are available in tonnes the following densities have been used to transform ton to m^3: crude oil: 0.85 t/m^3 and LPG: 0.58 t/m^3.

The data on the natural gas production and amount of marketable gas / utility sale are also from SORS and are available in the standard m^3. In Slovenia the amount of marketable gas is the same as utility sale, because no export of natural gas has occurred in the reporting period and there is no storage facility.

For the better estimation of EFs used we have also used the yearly data on length of transmission and distribution pipelines. From 1986 to 1996 the data on the length of transmission pipelines have been taken from the research project of the Institute of Energy Industries (Gasperič M., Dornik M.: Determining the CO_2 Emission Factor in Energy Use and CH_4 Emission Factor in Transport and Distribution of Natural Gas, Ljubljana: Institute of Energy Industries, 1998). For the period 1997 - 2007, the data have been obtained directly from the company Geoplin Plinovodi, and since 2008 from the Energy Agency. The data are presented in Table 3.3.13 and the transmission network is presented on Figure 3.3.2.

Table 3.3.13: Length of transport pipelines in km and share with regard to the year of construction.

	1986	1990	2000	2005	2010	2015	2020	2022
Length (km)	740	784	948	960	1,018	1,155	1,177	1,200
Built before 1992	100%	100%	83%	82%	78%	68%	67%	66%
Built between 1992 and 2004			17%	18%	17%	15%	14%	14%
Built since 2005					6%	17%	18%	20%



Source: Plinovodi

Figure 3.3.3: Network of pipes for transportation of natural gas.

In 2022, a company Plinovodi d.o.o. operates and owns 1200 kilometres of the Slovenian gas transmission network which is a part of the European gas network. The network is composed of longitudinally welded steel pipes, which are protected with anticorrosive isolative material and dug in the ground approximately 1.5 m deep. It has a nominal pressure between 50 and 67 bar. As the demand for natural gas is increasing, the compressor station in Kidričevo began to work in 2002 and in 2010 the other one in Ajdovščina. GHG emissions from natural gas used on these two compressor stations are reported under the Fuel consumption sector under category 1.A.3.e Other transportation.

Table 3.3.14: Distribution pipelines in km and share with regard to the year of construction.

	1986	1990	2000	2005	2010	2015	2020	2022
Length (km)	401	514	2,079	3,413	4,246	4,633	4,953	5,082
Built before 1992	100%	100%	26%	16%	13%	12%	11%	11%
Built between 1992 and 2004			74%	75%	60%	55%	52%	51%
Built since 2005				9%	27%	33%	37%	38%

The activity data for the period 1986 to 2005 for the distribution of natural gas have been taken from the research project, prepared by the Economic Interest Association of Natural Gas Distributors. Since 2008 the data on distribution pipelines are available from the Energy Agency, while for 2006 and 2007 this data have been interpolated (Table 3.3.14).

Emission factors

The emission factors have been taken from 2006 IPCC GL, Vol. 2, Chapter 4, partly from the Table 4.2.4 which is relevant for developed countries and partly from the Table 4.2.5 which is appropriate for the countries with the economy in transition.

For the calculation of fugitive emissions from oil production and refining as well as corresponding emissions from venting and flaring the default values for counties with the economy in transition have been used. In case the range was available, the average values have been taken into account. As these emissions are not occurring any more since 2002 the EFs used seem appropriate. For the fugitive emissions from LPG transport the same default value is available for developed country and as for counties with the economy in transition, thus there was no dilemma which EF should be chosen. EFs used are presented in the Table 3.3.15.

Table 3.3.15: EFs used in Fugitive emissions from oil in g/m^3.

		CO_2 EF	CH_4 EF	N_2O EF	Source, 2006 IPCC GL
Oil Production	Fugitives	0.043	0.59		Table 4.2.5
	Venting	112.50	855		Table 4.2.5, average
	Flaring	48,500	29.50	0.76	Table 4.2.5, average
Oil Refining	Fugitives		21.80		Table 4.2.4
LPG Transport	All	430		(0.0022)*	Table 4.2.4

**N_2O emissions from transport of LPG have not been reported because CRT tables do not enable to import N_2O emissions under relevant category 1.B.2.a.iii.3 Transport.*

To better estimate the fugitive emissions from natural gas 3 different periods have been introduced:

1986 – 1991: Slovenia is part of Yugoslavia
1992 – 2004: independent Slovenia, before joining EU
Since 2005: Slovenia is part of EU

The first period covers the time when Slovenia was still part of Yugoslavia. Slovenia was always the most developed and west oriented Yugoslav republic but despite this fact the system of control wasn’t as rigorous as it is nowadays. After the separation we have started to change the Slovenian legislation to be in line with the EU. For this time period an important fact is that the consciousness of the people, involved in the building and maintenance of the pipelines was on a higher level in independent Slovenia than it was in the past. Since 2005 in Slovenia all legislation and relevant standards are the same as in other EU countries, additionally the system of control is on the highest level possible.

For the calculation of fugitive emissions from natural gas, except for natural gas production EFs for developed countries have been used. Despite the fact that we were not developed country in the past, the complete natural gas network has been build according to the West European standards. Before 1974, the companies used different standards. The material for pipelines was made according to the JUS (Yugoslav standard), which was transferred from DIN (West Germany standard) to a high degree. In some domains also East German standard TGL (Technische Güte und Lieferbedingungen) was used. In 1974, all companies together with body of inspectors made an agreement to use west German standards (DVGW, DIN, VDI), because more than 90% gas devices were made according to these standards, particularly DVGW standard (Deutsche Vereinigung des Gas und Wasserfaches e.V.). Until 2002, when a new regulation was passed, DVGW had been the main directive for planning, construction, operation and maintenance of the pipeline system. Today standard SIST EN 12007, completely in line with CEN (standard of European Committee for Standardization), is used in Slovenia.

On the following tables EFs used for the calculation of fugitive emissions, and emissions due to the venting and flaring from natural gas are presented. For the natural gas production the average value for countries with economy in transition was used for the first period and average value for developed countries for the last period, while EFs in between have been interpolated following linear decreasing trend (Table 3.3.16).

Table 3.3.16: EFs used for emissions from Natural gas production in g/m^3.

		gas	1986-1991	1992-2004	2005-2022
Gas production	Fugitives	CO_2	0.097	interpolation	0.048
	Flaring	CO_2	1.4	interpolation	1.2
Gas production	Fugitives	CH_4	12.19	interpolation	1.34
	Flaring	CH_4	0.00088	interpolation	0.00076
Gas production	Fugitives	N_2O	NO	NO	NO
	Flaring	N_2O	0.000025	interpolation	0.000021
Source		2006 IPCC Guidelines	Table 4.2.5, average		Table 4.2.4, average

Table 3.3.17: EFs used for emissions from Natural gas transmission and distribution in g/m^3.

		gas	Built before 1992	Built between 1992 and 2004	Built since 2005
Transmission	Fugitives	CO_2	0.00088	0.00088	0.00088
	Venting	CO_2	0.0031	0.0031	0.0031
Transmission	Fugitives	CH_4	0.48	0.273	0.066
	Venting	CH_4	0.32	0.182	0.044
Distribution	All	CO_2	0.051	0.051	0.051
	All	CH_4	1.1	1.1	1.1
Source		2006 IPCC Guidelines	Table 4.2.4, the highest value	Table 4.2.4, average	Table 4.2.4, the lowest value

For the natural gas transmission and distribution the default values from 2006 IPCC GL, Table 4.2.4 for developed countries have been used, except for calculation of CH_4 emissions from natural gas transmission, for which a range of Tier 1 EF is available. For this cases it has been taken into account the length of transmission pipelines built in the each period (see Table 3.3.13). For the pipelines, which were built in the first period the highest values from the range of EFs has been taking into account, for the pipelines which were built in the last period the lowest EFs has been used, while for the time in-between the average value from the range has been used. EFs used are presented in the table 3.3.17 above.

3.3.2.3 Uncertainty and time – series consistency

The uncertainty are based on an expert judgements taking into account suggested values from 2006 IPCC GL for default values. They are presented on the Table 3.3.18.

Table 3.3.18: Uncertainties of activity data and emission factors used in the 2024 submission for the base year and the last reporting year in per cents.

	1986 and 2022			
	AD	CO_2 EF	CH_4 EF	N_2O EF
Oil	5	100	100	NA
Natural gas	2	200	200	NA
Venting and Flaring	3.5	50	50	50

3.3.2.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3. In addition the verification of the fugitive emissions (including venting and flaring) from natural gas have been performed and the results are presented in the Table 3.3.19 below. In these calculations the low emission factors from the 2006 IPCC GL from Table 4.2.8 have been used to calculate the emissions from the production and transmission and use of natural gas. The CH_4 emissions for 2018 from GHG inventory are 40% higher than the total emissions calculated by this simplified method using low EFs.

Table 3.3.19: Data used for verification of fugitive emissions from natural gas.

	AD	unit	EF	unit	CH_4 (1000 m^3)
production	16,027	1000 m^3	0.05	% of net prod.	8
transmission	1,175	km	200	m3/km	235
Compressor stations	19.5	MW	6000	m3/MW	117
MRS	254	stations	1000	m3/station	254
distribution	4,827	km	100	m3/km	483
gas use	269,284	appliances	2	m3/appliance	539
TOTAL					**1,639**
TOTAL CH_4 emissions in 2018 from NID (1.5563 kt CH_4, density: 0.6788 t/1000m^3)					**2,293**

It is important to know that the Slovenian distribution network is very new. More than two thirds of the network has been built in the last 20 years and all old steel and cast iron pipes were replaced with the new PE or PVC pipes with very low leakages. In addition, the reasons for low emissions is also the strict EU legislation in this field which requires good maintenance and, last but not least, the high price of natural gas, which is almost entirely imported.

3.3.2.5 Category-specific recalculations

No recalculations have been performed for this category.

3.3.2.6 Category-specific planned improvements

No improvement is planned for this category.

3.4 CO_2 capture from flue gases and subsequent CO_2 storage

There are no plants for recovery and storage of CO_2 in Slovenia.

4 INDUSTRIAL PROCESSES AND PRODUCT USE (CRT sector 2)

4.1 Overview of Sector

This chapter presents the processes emissions of greenhouse gases in:

- Mineral industry (CRT 2.A) ,
- Chemical industry (CRT 2.B),
- And Metal Industry (CRT 2.C),

and emissions due to the product use:

- Non-energy products from fuels and solvent use (CRT 2.D),
- Product uses as substitutes for ODS (CRT 2.F),
- and Other product manufacture and use (CRT 2.G).

The processes emissions from electronic industry have not occurred in the country.

Industrial activities unrelated to energy produce various GHG emissions. The emission sources are the industrial production processes in which raw materials are chemically or physically transformed. In this transformation, many different GHGs can be released, such as CO_2, CH_4, N_2O, and PFCs. Some industrial sources also produce NO_x, NMVOCs, CO, and SO_2.

Some fluorinated compounds (Hydro-fluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur Hexafluoride (SF_6)) are consumed in industrial processes or used in different applications as substitutes for ozone depleting substances (ODS). They have also been considered in the inventory.

Further, this sector comprises emissions from other product manufacture and use. An evaporative emissions of nitrous oxide (N_2O) can arise from various types of product use. Medical applications and use as a propellant in aerosol products, primarily in food industry are likely to be dominant sources.

Due to the intertwined nature of procedures in the industry and the characteristics of the individual reported units, it is in some cases difficult to distinguish if certain emissions originate from the consumption of fuels for energy purposes or from the consumption of raw materials in the industrial processes. The main criterion is the purpose for which a raw material or fuel is used.

An overview of the methods and EFs used as well as an indication whether a category is a key are presented in the Table 4.1.1.

Table 4.1.1: Method, EF used and key categories indications for the year 2022 in the IPPU sector.

		CO_2		
		Method	EF	Key category
A. Mineral industry	1. Cement production	T3	PS	L, T
	2. Lime production	T3	PS	T
	3. Glass production	T3	D	-
	4. Other process uses of carbonates	T2	D	-
B. Chemical industry	6. Titanium dioxide production	T3	D	T_{sub}
	10. Hydrogen production	T2	CS	-
C. Metal industry	1. Iron and steel production	T2	PS	-
	3. Aluminium production	T2	D, PS	L_{sub}
	5. Lead production	T1	D	-
	6. Zinc production	T1	D	-
	7. Other	T2	D	-
D. Non-energy products from fuels…	1. Lubricant use	M	M	-
	2. Paraffin wax use	T1	D	-
	3. Other	M	M	-
		N_2O		
		Method	EF	Key category
G. Other product manufacture and use	3. N2O from product use	D	D	L
		HFC		
		Method	EF	Key category
F. Product uses as substitutes for ODS	1. Refrigeration and AC	T2	CS,D	L, T
	2. Foam blowing agents	T2	CS,D	-
	3. Fire protection	T2	CS,D	-
	4. Aerosols	T1	D	-
		PFC		
		Method	EF	Key category
C. Metal industry	3. Aluminium production	T3	D, PS	T
		SF6		
		Method	EF	Key category
G. Other product manufacture and use	1. Electrical equipment	T2	CS	-

Emissions from Industrial processes and product use (CRT sector 2) in Slovenia account for 7.3% of the total national GHG emissions, excluding LULUCF. They amounted to 1,586 kt CO_2 equivalents in 1986 and 1,139 kt CO_2 equivalents in 2022. The most important GHG of this sector was carbon dioxide, with 64.9% of emissions from this category, followed by HFCs with 24.7%, N_2O with 8.5%, SF_6 with 1.5%, and PFCs with 0.3%. The main source of emissions is mineral industry with 50.4% of emissions, followed by consumption of F-gases (product uses as substitutes for ODS) with 24.7%, and metal industry with 11.6%.

Significantly smaller are the contributions from other product manufacture and use (10.0%), metal industry (7.8%), and chemical industry (5.7%), while use of non-energy products from fuels and solvent contributes 1.3% to the total emissions from this sector.

Since 1986, GHG emissions from Industrial Processes at first fell sharply to reach their lowest value in 1993, but then started to rise again and were in 2007 6.0% above 1986 level. Due to the global financial crises and lower industrial production, emissions in 2009 were 28.2% below the 1986 emissions but in the period 2010 – 2019 slowly increased by 24.5% while in 2020 decreased by 4.3% due to the epidemics and continue to decrease also in 2021 by 3.5%. In 2022 the process emissions slightly increased. Emissions of GHG (in kt CO_2 eq.) for 1986-2022 are shown in Figure 4.1.1.

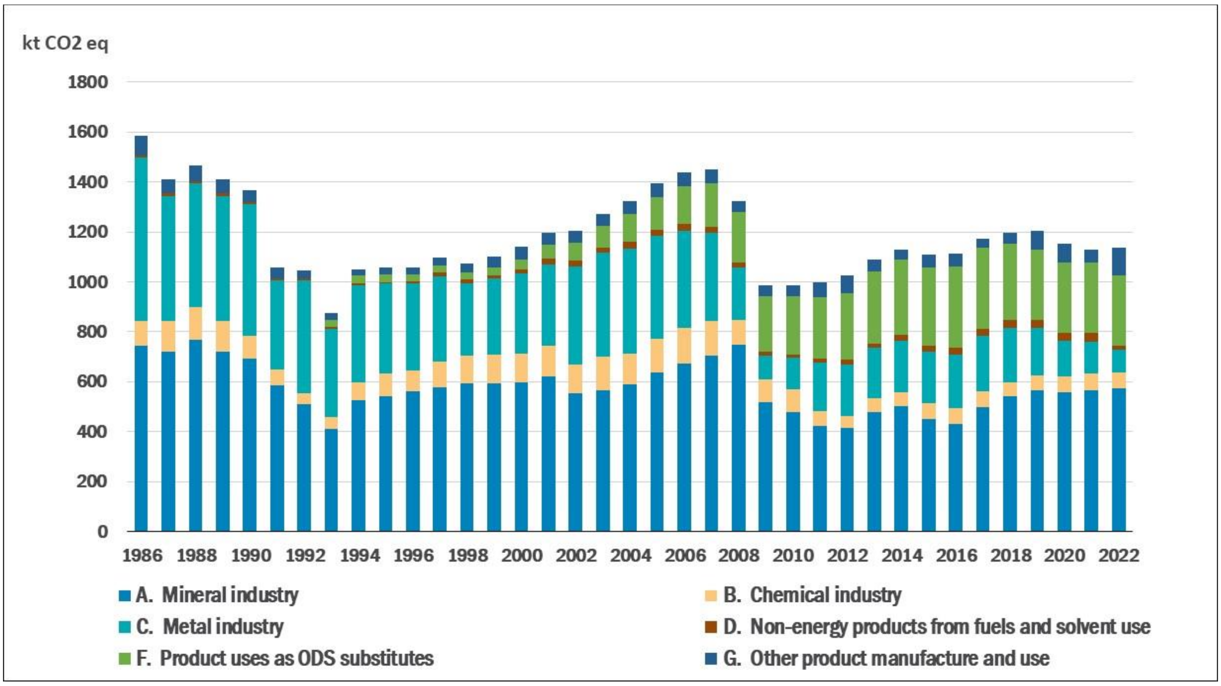


Figure 4.1.1: Process emissions of GHG from different types of industries and product use.

4.2 MINERAL INDUSTRY (CRT 2.A)

4.2.1 Cement Production (CRT 2.A.1)

4.2.1.1 Category descriptions

Carbon dioxide emissions arising in the production of cement are a major industrial process source of emissions of greenhouse gases.

The basic raw material for the production of cement is marl, which is a homogeneous mixture of limestone and clay and which was formed in the past geological periods through sedimentation. As there is no longer enough natural marl for mass production, a cement production mix, which must contain 75-78% of calcium carbonate ($CaCO_3$), is prepared by mixing limestone and clay components: from such with 35% of $CaCO_3$ to limestone with more than 95% of $CaCO_3$. The limestone, which is a source of CaO, normally has an admixture of dolomite, which introduces MgO into the system. The clay components are bearers of SiO_2, Al_2O_3 and Fe_2O_3. Blast furnace slag, silica sand, bauxite, and gypsum are added to the homogenized mix during grinding.

Raw meal powder is fed into the cement kiln through a heat exchange unit. Natural gas, fuel oil, petroleum coke, coal dust, waste oils, and tyres are used as fuels in the clinker calcination process.

Carbon dioxide emissions from cement production result from the conversion of $CaCO_3$, the main constituent of limestone, to lime (CaO), while CO_2 as a by-product is let out into the atmosphere.

4.2.1.2 Methodological issues

CARBON DIOXIDE EMISSIONS

Separate emissions are estimated from carbon originally present in the fuel and carbon present in the raw materials, although they are in fact emitted at the same place and are inseparable in concept. CO_2 from carbon in the fuel has been estimated from the fuel consumption for each fuel type. Emissions of this kind have already been included in the sector Manufacturing Industries and Construction (CRT code: 1A2).

CO_2 emissions from carbon present in the raw materials are reported under the category Cement Production (CRT code: 2A1) and described in the following paragraph. In Slovenia, there have been two cement producers until 2015. In the year 2022 only one cement plant has been in operation. The activity data are data on the annual amount of clinker produced. The clinker production data have been obtained from the Statistical Office of the Republic of Slovenia (SORS) for the period 1986–1998, and directly from the two plants producing cement for the period 1999–2004. The activity data on clinker produced in the period 2005-2022 have been obtained from these cement plants in the scope of GHG Emission Trading System (ETS) delivered in verified reports.

For national allocation plan purposes linked to the ETS more detailed data have been obtained for the period 1999–2004. The data on the fraction of CaO and MgO in clinker from both cement plants for the period 1999–2004 enabled us to determine our own emission factor. The average implied emission factor for the period 1999–2004 is 528 kg CO_2/t of clinker. As the location of quarries is the same as in the base year, we have applied this emission factor for calculating emissions from the base year 1986 to 1998. For calculating emissions for the years 1999–2004, we have used year-specific EFs obtained from these two plants. For the period 2005–2022 we have obtained plants data on CaO and MgO composition of clinker and EFs from verified ETS reports. Country specific EFs from these reports have been used to calculate CO_2 emissions using IPCC methodology. In the year 2022 only one plant has been in operation.

EFs from both periods before and after 2005 are based on plant specific production conditions. There have been two producers of cement in Slovenia and the data for both periods were obtained from these two cement plants. The same sources of raw material and methodology were used for the calculation of EFs both before and after 2005. Detailed data on EFs are presented in Table 4.2.1. Inter-annual variations of EFs are due to a different annual ratio of CaO and MgO in clinker.

Table 4.2.1: Emission factors used for calculation emissions from cement production.

Year	Implied emission factor (t CO_2/t of clinker)		
	Producer 1	Producer 2	TOTAL
1986 - 1998			0.528
1999	0.520	0.544	0.528
2000	0.518	0.544	0.528
2001	0.518	0.544	0.528
2002	0.518	0.544	0.527
2003	0.519	0.544	0.529
2004	0.517	0.541	0.527
2005	0.518	0.542	0.528
2006	0.517	0.539	0.526
2007	0.517	0.545	0.528
2008	0.518	0.545	0.527
2009	0.517	0.549	0.526
2010	0.516	0.549	0.526
2011	0.517	0.531	0.519
2012	0.520	0.547	0.522
2013	0.518	0.547	0.526
2014	0.512	0.546	0.518
2015	0.514	0.547	0.515
2016	0.515	-	0.515
2017	0.515	-	0.515
2018	0.515	-	0.515
2019	0.515	-	0.515
2020	0.514	-	0.514
2021	0.512	-	0.512
2022	0.514	-	0.514

Cement kiln dust (CKD) was not included in the emission calculation for the period 1986-2018 as in both cement plants CKD is returned into the process. A group of experts had visited both cement plants in the process of acquisition of the permits for greenhouse gas emissions and accompanied monitoring plans. Together with experts from the plants they defined a method for the calculation of CO_2 emissions. It is in accordance with methods from Guidelines for the monitoring and reporting. For both plants it was confirmed that CKD was 100% returned to the process. This is also evident from plant specific monitoring plan which has been issued by the competent authority. In 2019 a producer reported emissions from CKD for the first time. CO_2 emissions from CKD for the period 2019 - 2022 are included in the emission calculation for cement production and reported under the category Cement Production (CRT code: 2A1). CO_2 emissions from CKD for the period 2019 - 2022 are included in the emission inventory due to the change in fuel type used in cement production in that period. A cement factory increased the amount of waste used as fuel. Due to the application of alternative fuels, flue-gas cleaning has been needed. A bypass system has been used to reduce the content of chloride and sulphur oxides.

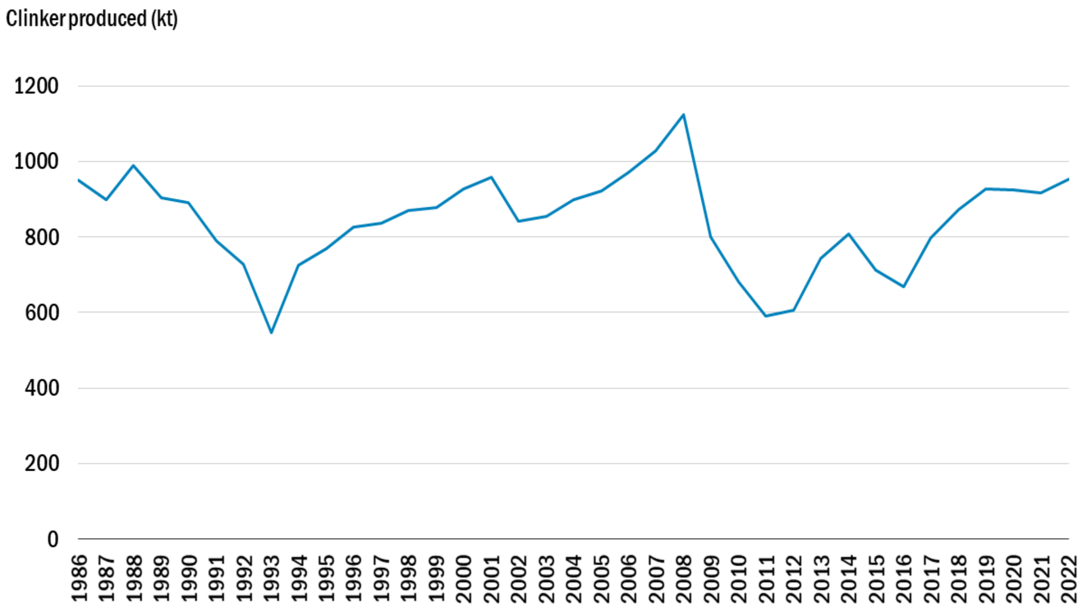


Figure 4.2.1: Clinker production in kilotons/year.

To calculate emissions from cement production after 2005 we have been using data obtained by ETS. The data on clinker production and plant specific emission factors for both cement factories have been annually verified by independent verifiers. The expert review team (ERT) recommended showing that the estimated CO_2 process emissions from cement production are comparable and consistent with the emissions reported under the ETS. ETS reports cannot be publicly revealed due to the sensitivity of the information. All documentation is available for internal communication with ERT only. However, the total emissions from cement production, that is a sum of process emissions and emissions from fuel combustion, reported under the ETS, are publicly available on the web site of the Slovenian Environment Agency.

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The annual amount of clinker produced and CO_2 emissions arising from cement production are shown in Figures 4.2.1 and 4.2.2.

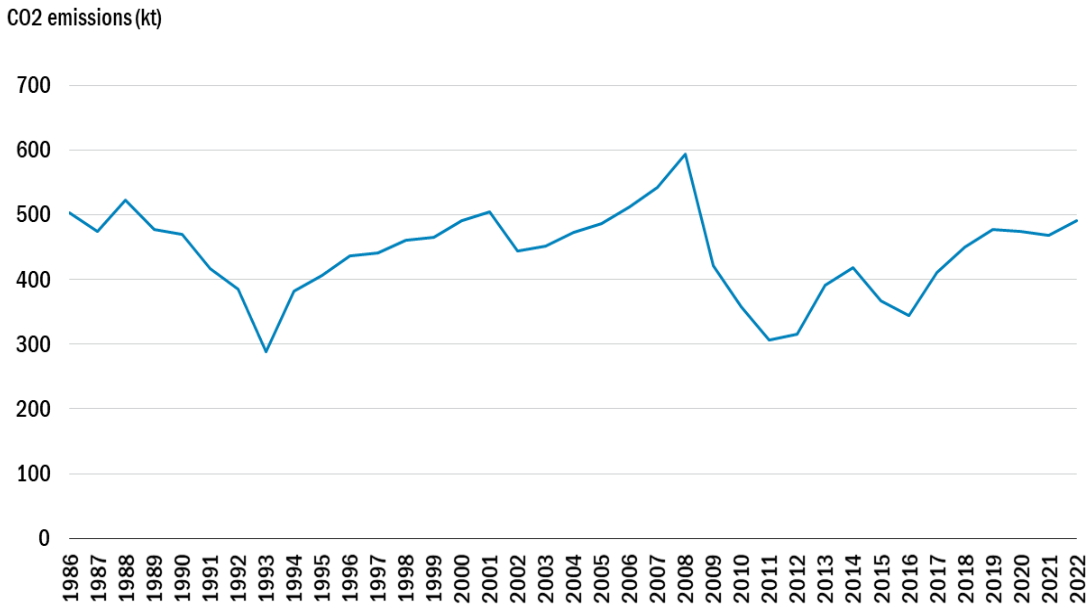

Figure 4.2.2: CO_2 emissions from cement production.

4.2.1.3 Uncertainties and time-series consistency

The uncertainty estimates in the 1986 base year are based on an expert judgement following instructions from the 2006 IPCC GL. The uncertainty of the activity data which are plant production data amounts to 10% and the same relatively high uncertainty was used also for EF, because average implied emission factor for the period 1999–2004 has been used also for the base year.

To determine uncertainty of emissions in 2022 the data on uncertainties from verification process in the EU-ETS has been used and uncertainty of emissions in this year was 1.39%.

4.2.1.4 Category-specific QA/QC and verification

QC procedures for the two plants data collected under the ETS have been performed. In the year 2022 only one cement factory has been in operation. The amount of clinker produced, the composition of clinker and calculated EFs for the whole period have been thoroughly examined. The activity data on clinker production obtained from verified ETS reports were cross checked through direct communication with plant representatives. We also compared data on cement production and clinker production. The clinker production does not entirely track cement production due to additional clinker imports. Cement has been produced not only from domestically produced clinker but also from imported clinker.

4.2.1.5 Category-specific recalculations

No recalculations have been performed since the last submission.

4.2.1.6 Category-specific improvements

No improvements are planned for the next submission.

4.2.2 Lime Production (CRT 2.A.2)

4.2.2.1 Category descriptions

CO_2 emissions from the production of lime are reported under Lime Production (CRT Code: 2A2). In Slovenia, there have been three lime producers until 2013. One of the lime plants had been closed down at the end of 2012. In the year 2022 therefore only two lime plants have been in operation.

Lime is generated by heating the input raw material (limestone and dolomite) to a high temperature (900°C-1200°C). During this process, limestone is converted into CaO and emits CO_2.

4.2.2.2 Methodological issues

CARBON DIOXIDE EMISSIONS

The estimation of CO_2 emissions for the period 2005-2022 has been based on the data provided by the lime plants in the scope of ETS scheme delivered in verified ETS reports.

The amount of CaO and MgO in the lime produced or the amount of carbonates from the raw material were used as activity data for the emission calculations. The emission factors used for emission calculation are based on the stoichiometric ratio of CO_2 and CaO, CO_2 and MgO or CO_2 and $CaCO_3$.

An annual implied emission factor was then calculated from the total CO_2 emissions for all plants, and the total amount of lime produced in these plants. A detailed description of the emissions calculation is presented in the following paragraph. The data used for the emission calculations are shown in Tables 4.2.2-4.2.5. One of the lime plants (producer 3) had been closed down at the end of 2012 (Table 4.2.4).

Table 4.2.2: Lime production emissions from producer 1.

Year	CaO (t)	MgO (t)	EF (t CO_2/t CaO)	EF (t CO_2/t MgO)	Emissions CO_2 (t)
2005	87142	1597	0.785	1.092	70150
2006	105200	1885	0.785	1.092	84641
2007	94178	1291	0.785	1.092	75340
2008	90633	1393	0.785	1.092	72668
2009	65411	1257	0.785	1.092	52721
2010	87423	1463	0.785	1.092	70225
2011	80298	6471	0.785	1.092	70101
2012	55425	5456	0.785	1.092	49467
2013	53670	4065	0.785	1.092	46570
2014	52889	3063	0.785	1.092	44863
2015	52419	5201	0.785	1.092	46828
2016	51421	4318	0.785	1.092	45081
2017	51539	4175	0.785	1.092	45017
2018	51714	4345	0.785	1.092	45340
2019	51780	3302	0.785	1.092	44254
2020	55536	2394	0.785	1.092	46210
2021	76896	660	0.785	1.092	61084
2022	63990	549	0.785	1.092	50832

Table 4.2.3: Lime production emissions from producer 2.

Year	CaO (t)	MgO (t)	EF (t CO_2/t CaO)	EF (t CO_2/t MgO)	Emissions CO_2 (t)
2005	13869	249	0.785	1.092	11159
2006	13788	228	0.785	1.092	11072
2007	17222	332	0.785	1.092	13882
2008	9256	215	0.785	1.092	7500
2009	8733	213	0.785	1.092	7089
2010	11504	333	0.785	1.092	9394
2011	12230	291	0.785	1.092	9918
2012	15737	343	0.785	1.092	12729
2013	14781	322	0.785	1.092	11955
2014	14073	316	0.785	1.092	11393
2015	16281	360	0.785	1.092	13173
2016	19167	425	0.785	1.092	15509
2017	16558	367	0.785	1.092	13398
2018	19610	433	0.785	1.092	15867
2019	15410	341	0.785	1.092	12469
2020	12749	308	0.785	1.092	10344
2021	7219	147	0.758	1.092	5828
2022	609	11	0.758	1.092	490

Table 4.2.4: Lime production emissions from producer 3.

Year	$CaCO_3$ (t)	EF (t CO_2/t $CaCO_3$)	Emissions CO_2 (t)
2005	90993	0.43971	40037
2006	88068	0.43971	38750
2007	77738	0.43971	34205
2008	67816	0.43971	29839
2009	25432	0.43971	11190
2010	24156	0.43971	10629
2011	24355	0.43971	10716
2012	26831	0.43971	11806

The monitoring and reporting guidelines for EU ETS installations were adopted in the Commission decision 2004/156/EC. Activity-specific guidelines for installations for the production of lime are in Annex VIII.
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32004D0156

On installation level, calcination CO_2 can be calculated in two ways:
(1) based on the amount of carbonates from the raw material (mainly limestone, dolomite) converted in the process (calculation method A),
(2) based on the amount of alkali oxides in the lime produced (calculation method B). The two approaches are considered to be equivalent.

Producer 1 and producer 2 have chosen the calculation method B, while producer 3 had chosen calculation method A. The annual implied emission factor (IEF) was then derived from the total emissions from all plants and the activity data on the annual production of quicklime in these lime plants (Table 4.2.5).

Table 4.2.5: Total CO_2 emissions of all three producers, total lime production and calculated implied emission factor for the last few years.

Year	2005	2010	2015	2018	2019	2020	2021	2022
Lime Produced (t)	165125	125117	79507	81214	75777	75638	88862	68224
Total emissions CO_2 (t)	121346	90248	60001	61207	56723	56554	66911	51322
Implied emission factor (kg CO_2/t of lime)	735	721	755	754	749	748	753	752

CO_2 emissions for the period 1986-2004 have been calculated using the average implied emission factor for the period 2005–2012 and data on annual production of lime obtained from SORS. The average emission factor for the period 2005–2012 is 728 kg CO_2 /t of lime. Data on implied emissions factors are presented in Table 4.2.6.

Table 4.2.6: Emission factors used for calculation emissions from lime production.

Year	Implied emission factor ($t\ CO_2$/t of lime)
1986-2004	0.728
2005	0.735
2006	0.726
2007	0.724
2008	0.723
2009	0.725
2010	0.721
2011	0.730
2012	0.743
2013	0.736
2014	0.740
2015	0.755
2016	0.757
2017	0.753
2018	0.754
2019	0.749
2020	0.748
2021	0.753
2022	0.752

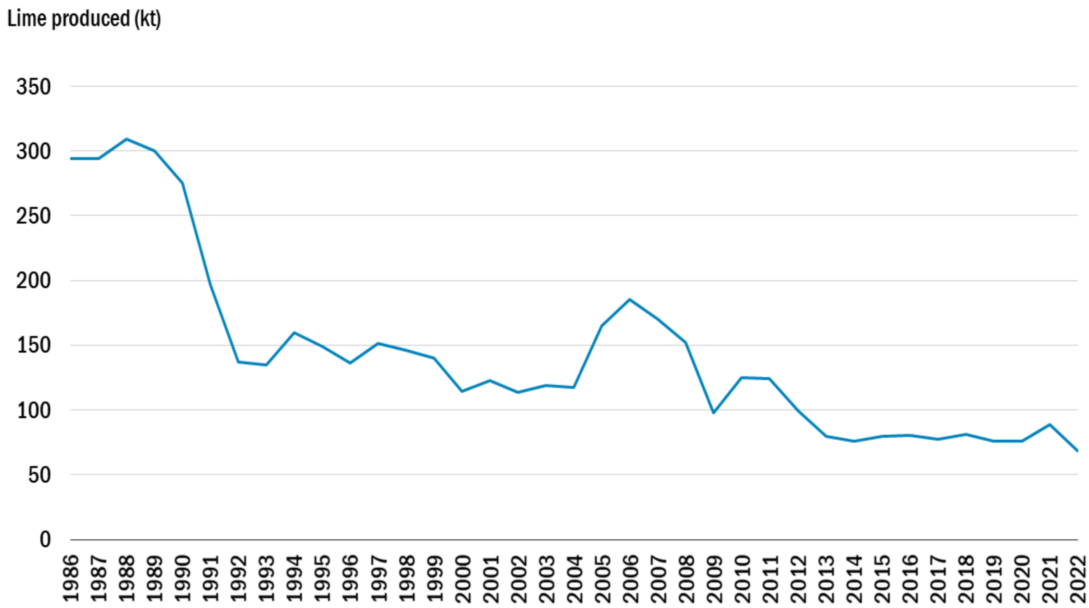

Figure 4.2.3: Lime production in kilotons/year.

The limestone used for lime production contains mostly $CaCO_3$. In the limestone there is also a small amount of dolomite, which, in addition to $CaCO_3$, consists also of $MgCO_3$. A high-calcium lime is the main type of lime. Quicklime and hydrated lime are the main types of lime produced in Slovenia. The lime kiln dust (LKD) is included in the final amount of the lime produced and therefore included in the calculation of the CO_2 emissions.

The annual amount of lime produced and CO_2 emissions arising from the lime production are shown in Figures 4.2.3 and 4.2.4.

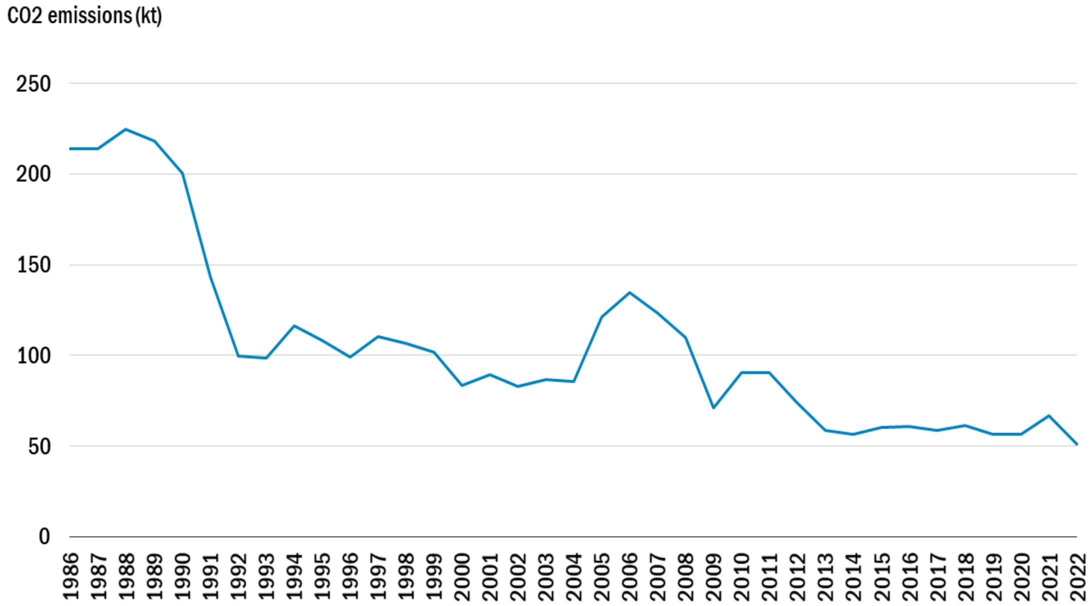

Figure 4.2.4: CO_2 emissions from lime production.

4.2.2.3 Uncertainties and time-series consistency

The uncertainty estimates in the 1986 are based on an expert judgement following instructions from the 2006 IPCC GL. The uncertainty of the activity data amounted to 15% and of EF to 5%

To determine uncertainty of emissions in 2022 the data on uncertainties from the ETS has been used in combination of uncertainties from 2006 IPPC GL. For the biggest company which emitted almost 80% of emissions this uncertainty was 1,5%, while for the rest the uncertainty of AD and EF was 2% each. Total combined uncertainty of emissions from lime in 2022 was therefore 1.74%.

4.2.2.4 Category-specific QA/QC and verification

QC procedures for the three lime plants data collected under the ETS have been performed. In the year 2022 therefore only two lime plants have been in operation. The amount of lime produced and the composition of lime and the raw material have been thoroughly examined. The methodology of emission calculation was checked. To calculate emissions from lime production after 2005 we have been using the data obtained by ETS. These data have been annually verified by independent verifiers.

A thorough examination of the activity data and emission factors were performed also for the data before entering the ETS scheme. Time series consistency was assured since the same lime plants with the same raw material were taken into account in both periods. To ensure the completeness of activity data by including also emissions from other industries we have performed a thorough examination of all potential sources. We checked all data collected by SORS. We also performed personal communication with persons involved in environmental permit issues. No other lime production activity was identified.

4.2.2.5 Category-specific recalculations

No recalculations have been performed since the last submission.

4.2.2.6 Category-specific planned improvements

No improvements are planned for the next submission.

4.2.3 Glass Production (CRT 2.A.3)

4.2.3.1 Category description

This chapter comprises CO_2 emissions from glass manufacturing and from the production of glass wool, where the production process is similar to glassmaking. The emissions are reported under Glass Production (CRT Code: 2A3). There are four glass and glass wool producers in Slovenia.

CO_2 is emitted during the melting process of glass raw materials. The calcination of carbonates at high temperatures yields CO_2. Major raw materials in glass production which emit CO_2 during the melting process are limestone, dolomite and soda ash.

4.2.3.2 Methodological issues

CO_2 emissions from glass production for the period 1999-2022 have been calculated taking into account the consumption of all carbonates in the glass production. The data on the carbonate use in the glass production have been obtained from glass producers. The amount of all carbonates used in glass production is included in this sector. Those carbonates are limestone ($CaCO_3$), magnesium carbonate ($MgCO_3$), soda ash (Na_2CO_3), potash (K_2CO_3) and barium carbonate ($BaCO_3$).

Default 2006 IPCC emission factors have been used for the calculation of CO_2 emissions from calcium carbonate, magnesium carbonate and sodium carbonate (Chapter 2: Mineral Industry Emissions, Table 2.1, pg. 2.7). They are 0.43971 t CO_2/t calcium carbonate, 0.52197 t CO_2/t magnesium carbonate and 0.41492 t CO_2/t sodium carbonate.

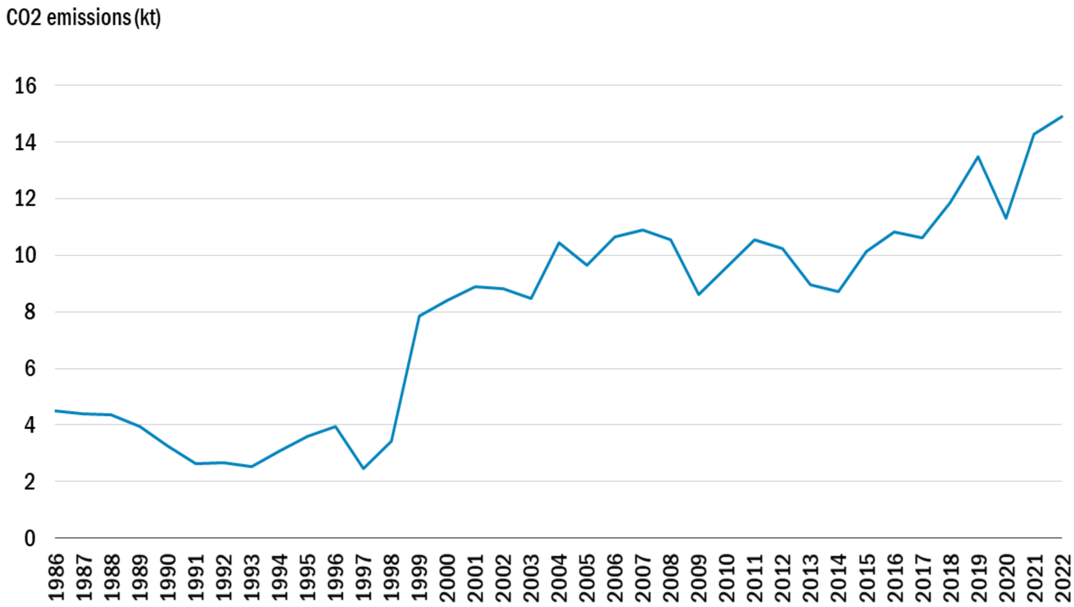

Figure 4.2.5: CO_2 emissions from glass production.

The emission factors for potassium carbonate and barium carbonate are based on the stoichiometric ratio of CO_2 and K_2CO_3 and CO_2 and $BaCO_3$. They are 0.318 t CO_2/t potassium carbonate and 0.223 t CO_2/t barium carbonate.

The calculation of CO_2 emissions from the glass production for the period 1986-1998 has been performed in another way due to a lack of data on carbonate consumption. The average implied emission factor for the years 1999-2013 has been multiplied with the annual glass production data. The data on glass production has been obtained from glass producers.

CO_2 emissions arising from glass production for the whole period are shown in Figure 4.2.5.

4.2.3.3 Uncertainties and time-series consistency

Although glass producers are included in the EU-ETS uncertainty estimates are not exactly calculated by verifiers so we have used emissions uncertainty from the ETS permits, which is 5%. The lover uncertainty is calculated using mid value of AD, EF and OF uncertainties from 2006 IPCC GL (2%, 2%, and 1%, respectively) and the combined uncertainty is 3% what is used in the inventory.

In 1986 emissions are calculate with Tier 2 methodology from amount of glass produced and with average EF from the later period. We have follow the IPCC GL where the uncertainty of the activity data is 5% and of EF is 10%.

4.2.3.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.2.3.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.2.3.6 Category-specific planned improvements

No improvements are planned for the next submission.

4.2.4 Other Process Uses of Carbonates

4.2.4.1 Category description

Carbonates are used in many industries. During heating to a high temperature, carbonates convert to oxides, emitting CO_2. Most limestone and dolomite are thus consumed in the production of cement and lime, as described above. Along with other carbonates, they are also used in the other production of mineral products.

This sector comprises the use of carbonates in Ceramics (CRT code: 2A4a), Other Uses of Soda Ash (CRT Code: 2A4b) and Other (CRT Code: 2A4d). CRT Code: 2A4d, Other comprises emissions from mineral wool production. Figure 4.2.6 shows CO_2 emissions from ceramics, other uses of soda ash and mineral wool production.

4.2.4.2 Methodological issues

<u>Ceramics</u>
Ceramics include the production of bricks and roof tiles, household ceramics, sanitary ware and technical ceramics. Process related CO_2 emissions from ceramics result from the calcination of carbonates in the clay, as well as the addition of carbonate additives.

CO_2 emissions for the period 2005-2022 have been calculated from the use of $CaCO_3$, $MgCO_3$ and $BaCO_3$ in ceramics production. The data on carbonates used have been obtained from verified ETS reports. Default 2006 IPCC emission factors have been used for the calculation of CO_2 emissions from calcium carbonate and magnesium carbonate. They are 0.43971 t CO_2/t calcium carbonate and 0.52197 t CO_2/t magnesium carbonate. The emission factor for barium carbonate is based on the stoichiometric ratio of CO_2 and $BaCO_3$. It is 0.223 t CO_2/t barium carbonate.

CO_2 emissions for the period 1995-2004 have been estimated in another way due to a lack of data on carbonate consumption. There are no detailed data on the use of carbonates before entering the ETS scheme. An estimation of emissions based on the parameter “Gross value added - glass, pottery and buildings materials industry, Bio Euro (EC95)” obtained from SORS. The data for 2005 were used as a reference year. CO_2 emissions for the period 1986-1994 have been estimated with extrapolation method.

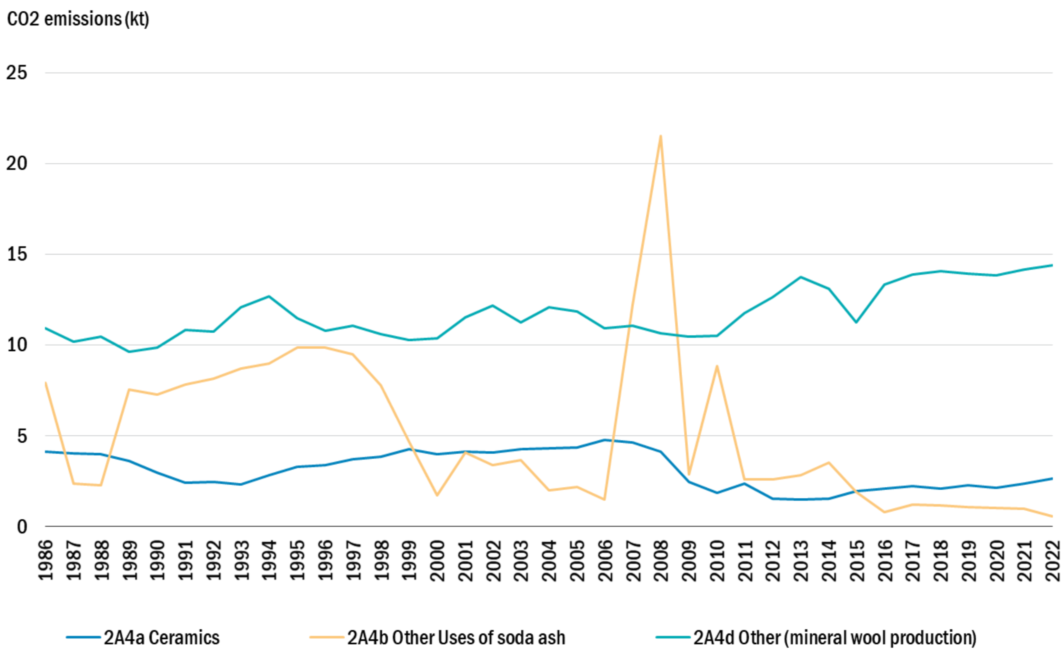

Figure 4.2.6: CO_2 emissions from other process uses of carbonates.

<u>Other Uses of Soda Ash</u>

Soda ash is used as a raw material in numerous industrial processes: production of glass, soap and detergent, production of paper, chemicals and other common consumer products. This sector comprises all uses of soda ash except use in glass production. The use of soda ash in glass production is reported in the sector Glass Production (CRT Code: 2A3).

CO_2 emissions for the period 1986-2022 have been calculated from the difference in the amount of total soda ash consumed and soda ash consumed in the glass production. The data on the total consumption of soda ash for the period 1986-1997 was obtained from SORS. Later on those data were not available anymore. The consumption of the total soda ash for the period 1998-2022 was calculated from the data on import and export published by SORS as well. The use of soda ash in glass production has been subtracted. The default emission factor from 2006 IPCC GL has been used for the calculation of CO_2 emissions for the whole period (0.41492 t CO_2/t Na_2CO_3).

<u>Other</u>

This sector comprises CO_2 emissions arising from mineral wool production. Dolomite is used as a raw material in mineral wool production. The activity data for the period 1986-2012 have been obtained from the producer of mineral wool used for insulation purposes. The default 2006 IPCC emission factor 0.47732 t CO_2/t dolomite has been used for the period 1986-2012. For the period 2013-2022 ETS data on the consumption of individual carbonates have been available. The default 2006 IPCC emission factors 0.43971 t CO_2/t calcium carbonate and 0.52197 t CO_2/t magnesium carbonate have been used for the period 2013-2022.

4.2.4.3 Uncertainties and time-series consistency

The uncertainty estimates in the 1986 are based on an expert judgement. The uncertainty of the activity data amounted to 15% and of EF to 5%. The reason of high uncertainties of AD is in the fact that all uses of carbonates are maybe not properly allocated to the different uses (categories).

To determine uncertainty of emissions in 2022 the data on uncertainties from the ETS has been used in combination of uncertainties from 2006 IPPC GL. For the biggest company which emitted more than 82% of emissions this uncertainty was 1,41 %, while for the rest of emissions the uncertainty of AD was 5% and EF was 1%. Total combined uncertainty of emissions from other uses of carbonates was 2.05%.

4.2.4.4 Category-specific QA/QC and verification

We carried out surveys to determine that all carbonate use in the country was accounted for. We approached the Tax administration of the Republic of Slovenia and The Agency of the Republic of Slovenia for Public Legal Records and Related Services to examine other potential carbonate users. No new sources were found. Completeness in emission estimation was confirmed. Following the UNFCCC ERT recommendation the timing and frequency of the surveys conducted are included. The surveys were carried out in the years 2014 and 2019, and there is a plan to conduct a survey every five years. All new applications for environmental permits and the data obtained from SORS are examined on an annual basis to check for any new sources of carbonate used. For the 2024 submission, no new sources of carbonate use were found.

4.2.4.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.2.4.6 Category-specific planned improvements

No improvements are planned for the next submission.

4.3 CHEMICAL INDUSTRY (CRT 2.B)

4.3.1 Nitric Acid Production (CRT 2.B.2)

4.3.1.1 Category description

The production of nitric acid (HNO_3) generates nitrous oxide (N_2O) as a by-product of the high temperature catalytic oxidation of ammonia (NH_3). N_2O emissions from nitric acid production are reported under Nitric Acid Production (CRT code: 2B2).

4.3.1.2 Methodological issues

Nitric acid production existed in Slovenia in the period 1997-2005. Since 2006 there is no production of nitric acid in Slovenia. No emissions of N_2O have originated from this sector since 2006. N_2O emissions have been calculated from the amount of nitric acid produced. Nitric acid production data was obtained from SORS. Following the ERT recommendations, an examination of the emission factor used was performed. We used the 2006 IPCC emission factor for the emission calculations. The emission factor of 7 kg N_2O/ton nitric acid was used since the production based on medium pressure combustion process.

4.3.1.3 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.3.1.4 Uncertainties and time-series consistency

The uncertainty estimates in 1986 are based on an expert judgement and IPCC GL.
The uncertainty of the activity data amounts to 10%.
The uncertainty of the emission factor amounts to 20%.

4.3.1.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.3.1.6 Category-specific planned improvements

No improvement is planned for this category.

4.3.2 Carbide Production (CRT 2.B.5)

4.3.2.1 Category description

The greenhouse gas emissions are associated with the production of silicon carbide (SiC) and calcium carbide (CaC_2). The production of carbide can result in emissions of carbon dioxide (CO_2) and methane (CH_4). Silicon carbide is a significant artificial abrasive. It is produced from silica sand or quartz and petroleum coke. Calcium carbide is made from two carbon-containing raw materials: calcium carbonate and petroleum coke. It is mostly used as a reductant in electric arc steel furnaces.

There had been only one carbide producer in Slovenia. This factory was closed down in the first quarter of 2008. The production of calcium carbide was discontinued in 2008, while the production of silicon carbide had been discontinued as early as 1995. CO_2 and CH_4 emissions from carbide production are reported under Carbide Production (CRT code: 2B5).

4.3.2.2 Methodological issues

Silicon carbide production

Silicon carbide (SiC) is produced from silicon dioxide and petroleum coke. Petroleum coke is used as a source of carbon. CO_2 is released as a by-product. CO_2 emissions had been estimated for the period 1986-1994. From 1995 onwards there has been no production of silicon carbide in Slovenia. CO_2 emissions had been calculated from the amount of petroleum coke consumed. The data on the consumption of petrol coke was provided by the factory. The 2006 IPCC emission factor of 2.3 t CO_2/t petroleum coke had been used for the CO_2 emission calculations.

The petroleum coke used in the process may contain volatile compounds which will form methane. CH_4 emissions had been calculated from the amount of petroleum coke consumed obtained from the producer. The 2006 IPCC emission factor of 10.2 kg CH_4/t petroleum coke had been used for the CH_4 emission calculations.

Calcium carbide production

Calcium carbide (CaC_2) is produced by heating calcium carbonate and subsequently reducing CaO with carbon (petroleum coke). Both steps lead to emissions of CO_2. In Slovenia, calcium carbide was not produced from limestone but from lime, hence CO_2 emissions arose only in the reduction with carbon.

CO_2 emissions had been estimated for the period 1986-2008. Since the only carbide factory had been closed down in 2008, there was no production of calcium carbide from this year onwards. CO_2 emissions had been calculated from the amount of calcium carbide produced. The data on CaC_2 production was obtained from the carbide producer. The 2006 IPCC emission factor of 1.09 t CO_2/t calcium carbide produced had been used for the CO_2 emission calculations.

To avoid double counting of CO_2 emissions all the quantities of petroleum coke used in calcium carbide production were subtracted from the energy sector.

4.3.2.3 Uncertainties and time-series consistency

The uncertainty estimates in 1986 are based on an expert judgement and IPCC GL.
The uncertainty of the activity data amounts to 5%.
The uncertainty of the emission factors amounts to 10%.

4.3.2.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.3.2.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.3.2.6 Category-specific planned improvements

No improvements are planned for this category.

4.3.3 Titanium dioxide production (CRT 2.B.6)

4.3.3.1 Category description

Titanium dioxide (TiO_2) is one of the most commonly used white pigments. The main use is in paint manufacture followed by paper, plastics, rubber, ceramics, fabrics, floor covering, printing ink, and other miscellaneous uses. In Slovenia there is one producer of TiO_2. The production of TiO_2 is based on the sulphate route process. The CO_2 emissions from titanium dioxide production are reported under Titanium Dioxide Production (CRT code: 2B6).

4.3.3.2 Methodological issues

According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories sulphate route process does not give rise to the process of greenhouse gas emissions. But in the manufacturing of TiO_2 limestone has been used for the neutralization of sulphuric acid used in sulphate process. The use of limestone is a source of CO_2 emissions.

CO_2 emissions have been estimated for the period 1986-2022. The CO_2 emissions have been calculated from the amount of calcium carbonate consumed. The data on the consumption of $CaCO_3$ has been provided by the producer. The 2006 IPCC emission factor of 0.43971 t CO_2/t of calcium carbonate has been used for the CO_2 emission calculations for the whole period (Figure 4.3.1).

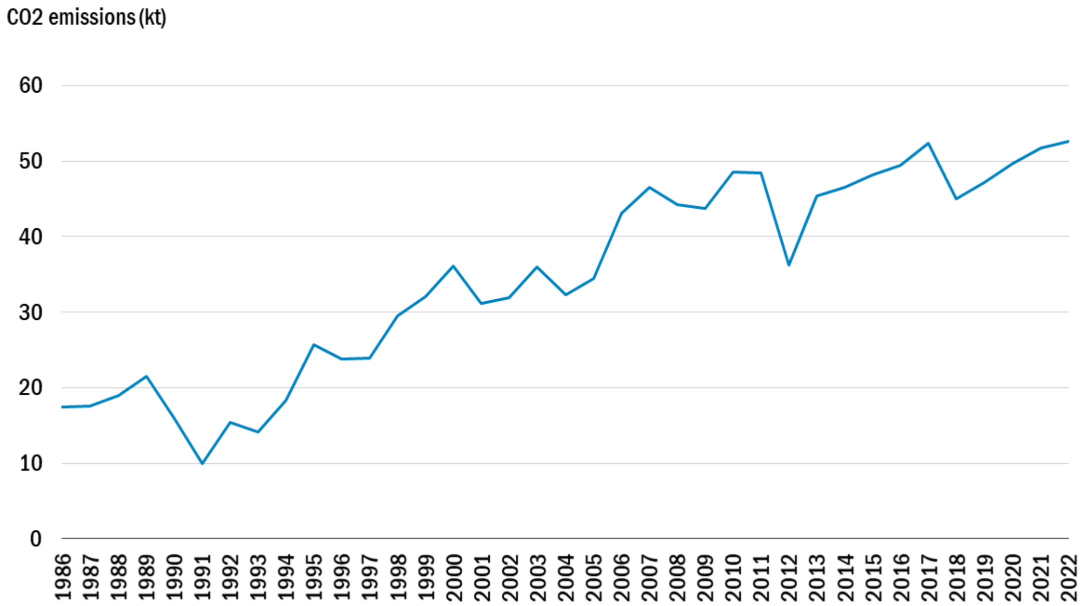

Figure 4.3.1: CO_2 emissions from titanium dioxide production.

4.3.3.3 Uncertainties and time-series consistency

The uncertainty estimates are based on information from the plant and an expert judgement. The uncertainty of the activity data amounts to 10% in 1986 and 5% in the recent years. The uncertainty of the emission factor amounts to 1%.

4.3.3.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.3.3.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.3.3.6 Category-specific planned improvements

No improvements are planned for this category.

4.3.4 Petrochemical and carbon black production (CRT 2.B.8)

4.3.4.1 Category description

This category includes emissions arising from the production of petrochemicals (methanol, ethylene and propylene, ethylene dichloride, ethylene oxide, acrylonitrile). The petrochemical industry uses fossil fuels (e.g., natural gas) or petroleum refinery products (e.g., naphtha) as feedstock. In Slovenia, there was the only production of methanol. There is no other production of other petrochemicals in the country. CH_4 and CO_2 emissions from methanol production are reported under the subcategory Methanol (CRT code: 2B8a).

4.3.4.2 Methodological issues

CH_4 and CO_2 emissions had been estimated for the period 1986-1991 and 1994-2010. For the years 1992, 1993 and from 2010 onwards there was no production of methanol in Slovenia. CH_4 and CO_2 emissions had been calculated from the amount of methanol produced. The production data of methanol had been obtained from SORS. The 2006 IPCC emission factors of 2.3 kg CH_4/t methanol produced and 0.267 t CO_2/t methanol produced had been used for the emissions calculations.

4.3.4.3 Uncertainties and time-series consistency

The uncertainty estimates in 1986 are based on an expert judgement and IPCC GL.
The uncertainty of the activity data amounts to 20%.
The uncertainty of the emission factors amounts to 10%.

4.3.4.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.3.4.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.3.4.6 Category-specific planned improvements

No improvements are planned for this category.

4.3.5 Other - Hydrogen production (CRT 2.B.10)

4.3.5.1 Category description

This category includes emissions arising from the production of hydrogen by the steam reforming of natural gas. During this process, CO_2 is produced and capture with 70% efficiency and then sold to the other users. However, this CO_2 is considered to be released somewhere else within the country in the same year and therefore it is included in the inventory.

4.3.5.2 Methodological issues

Activity data on non-energy use of natural gas have been obtained from SORS. In addition to the amount used for hydrogen production, a very small amount was also used for the production of organic chemicals and some other products. Due to completeness reasons emissions from these sources have also been included in this category.

Due to the unavailability of methodology in the 2006 IPCC GL, CO_2 emissions are calculated using the same approach as for combustion emission using the same country specific NCV and CO_2 EF as for the energy sector, energy industry. The NCV and CO_2 EFs for natural gas were reported in the NID (Tables 3.2.14 and 3.2.2 respectively).

4.3.5.3 Uncertainties and time-series consistency

Uncertainties are the same as uncertainties for natural gas in manufacturing industries.
The uncertainty of the activity data amounts to 5% in 1986 and 2% in recent years.
The uncertainty of the CO_2 emission factor amounts to 2.5% in 1986 and 0.5 in 2022.

4.3.5.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.
A methodology for the determination of CO_2 emissions given in the 2019 Refinement to the 2006 IPCC Guidelines was examined. It was confirmed that the methodology currently applied is correct.

4.3.5.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.3.5.6 Category-specific planned improvements

No improvements are planned for this category.

4.4 METAL PRODUCTION (CRT 2.C)

4.4.1 Iron and Steel Production (CRT 2.C.1)

4.4.1.1 Category description

Iron is produced through the reduction of iron oxide (ore) using metallurgical coke as the reducing agent in a blast furnace. Steel is subsequently made from iron and scrap in other furnaces.

In the production of iron CO_2 emissions are associated with the use of carbon to convert iron ore to iron. Carbon is supplied to the blast furnace mainly in the form of coke. Carbon serves a dual purpose in the iron making process, primarily as a reducing agent to convert iron oxides to iron, but also as an energy source to provide heat when carbon and oxygen react exothermically. The process emissions of carbon dioxide in the production of iron take place as a result of coke oxidation.

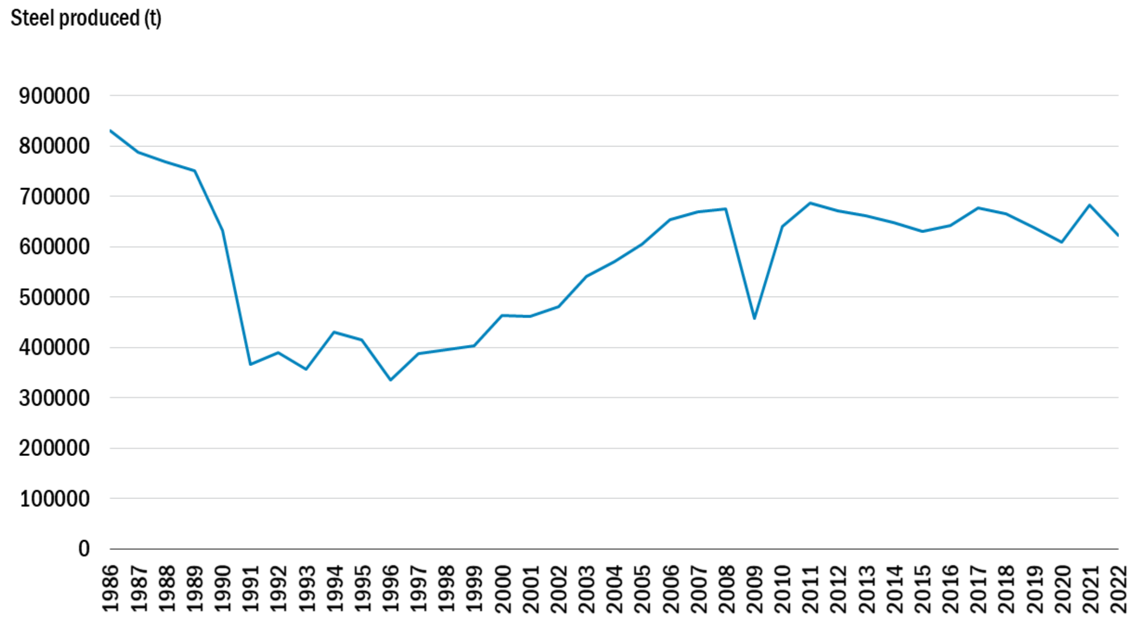

Figure 4.4.1: Production of steel in ton/year.

The production of steel is a multiphase process and some phases give rise to emissions of CO_2. Most emissions occur in smelting iron scrap in an electric arc furnace (EAF). The furnace is first filled with steel scrap then limestone and/or dolomite are added to allow the slag to form. The furnace utilizes electric heating through graphite electrodes. For increased productivity in the initial phase of melting, oxygen lances and a carbon injection system are used. From a metallurgical point of view, oxygen is used to reduce the carbon content in the molten metal and for removing other undesired elements. Decarburising is performed also in secondary phases in a ladle furnace. During steel production, the CO_2 emissions take place as a result of graphite electrode consumption in the EAF. CO_2 emissions originate also in the consumption of limestone and dolomite and carbon containing additives. In Slovenia, there are three steel production plants.

Following the UNFCCC ERT recommendation description of the production process of pig iron produced from iron ore was added. Primary production of iron from ore existed only in 1986 and 1987. Pig iron was produced in blast furnaces directly from iron ore and coke. No other production steps were included in pig iron production process. Pig iron (hot metal) was produced from pre-treated ore in an ordinary blast furnace. Coke was the only reducing agent. Blast furnace cowpers provided a hot blast for the blast furnace operation. Iron ore was transported from other parts of our former common state Yugoslavia. Also coke used for the reduction of ore was delivered from former Yugoslavian republics in that period. CH_4 emissions from pig iron production were not calculated since 2006 IPCC Guidelines do not provide CH_4 emission factor for this type of production process.

CO_2 emissions from iron and steel production are reported under Iron and Steel Production (CRT code: 2C1). The annual amount of steel produced is shown in Figure 4.4.1.

4.4.1.2 Methodological issues

CO_2 emissions from iron production were calculated for the years 1986 and 1987. According to the UNFCCC ERT recommendation emissions of CO_2 from pig iron production have been recalculated for the years 1986 and 1987. CO_2 emissions had been calculated from the amount of pig iron produced. The production data were obtained from the producers. The emission factor used for emission calculation was obtained from the 2006 IPCC Guidelines, Volume 3: Industrial Processes and Product Use, Table 4.1, pg 4.25. The emission factor applied was 1.35 t CO_2/t pig iron produced.

The CO_2 emissions from steel production for the period 2005-2022 have been calculated from the amount and carbon content of input and output materials. In our case, the input materials were mostly graphite electrodes, coke, carburizing agents, scrap iron and steel, metal and non-metal additions, limestone and dolomite. The output material is the amount of steel produced. An individual data for all three steel producers have been obtained from the verified ETS reports. Figure 4.4.2 shows CO_2 emissions contributed by the different input materials and steel produced for 2005-2022.

The calculation of CO_2 emissions from steel production for the period 1988-2004 has been performed in another way due to a lack of precise data on the amount and carbon content of the input materials. We calculated an average implied emission factor for the years 2005-2013. This emission factor was then multiplied with the annual steel production data. This emission factor was not appropriate for the base year because of a different type of steel production (from ore). The data on steel production has been obtained from the producers.

In the period 1986–1987 production of pig iron from ore still occurred. The disaggregation into the consumption of fuel as an additive and the consumption of fuel as an energy product was impossible. Consequently, for these two years a decision was made to attribute all coke, which is consumed in the production of iron and steel, to the energy sector as fuel consumption. When this production was discontinued and a new electric arc furnace started production in 1988, the only source of process emissions in this category was the production of steel from scrap iron in the EAF. We assumed that the energy source in this type of industry is only electricity and the emissions from coke and other materials are all process emissions. The consequence is that all coke consumption for the years 1986–1987 is allocated to the energy sector, whereas for the period 1988 - 2022 all coke consumption is included in the industrial processes sector. The CO_2 emissions from steel production for the years 1986 and 1987 were therefore calculated from the amount of electrodes consumed only. Coke was not taken into account for the process emissions calculation for that period. The emission factor used for the emission calculation was calculated from carbon content data obtained from the 2006 IPCC Guidelines. The emission factor applied was 3.006 t CO_2/t carbon electrodes.

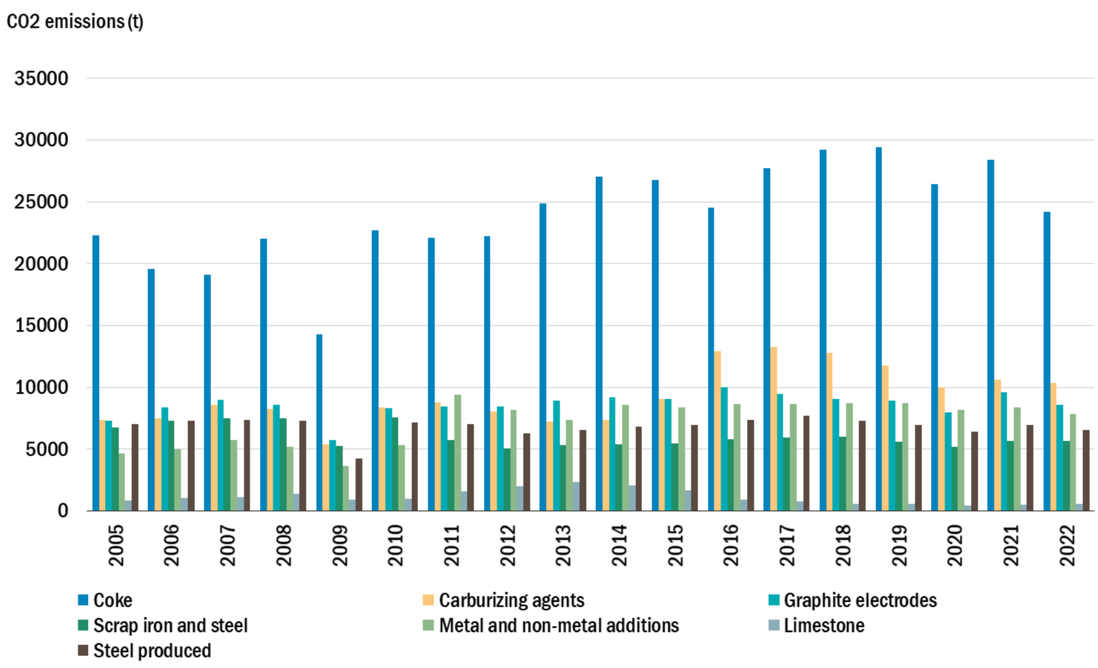

Figure 4.4.2: CO_2 emissions contributed by different input material in steel production.

4.4.1.3 Uncertainties and time-series consistency

The uncertainty estimates in 1986 are based on an expert judgement and IPCC GL. The uncertainty of the activity data amounts to 10% and of the emission factor amounts to 25%.

All three steel producer are included in the EU-ETS and uncertainties for AD and EF in the permits are 5%. The same uncertainty is recommended also in the 2006 IPCC GL when using Tier 3 methodology. As no more information on uncertainties are available in the reports of verifiers we have used 5% for AD and for EF uncertainty in the inventory in recent years.

4.4.1.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.4.1.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.4.1.6 Category-specific planned improvements

No improvements are planned for this category.

4.4.2 Ferroalloys Production (CRT 2.C.2)

4.4.2.1 Category description

Ferroalloys are concentrated alloys of iron and one or more metals such as silicon, manganese, chromium, molybdenum, vanadium and tungsten. These alloys are used for deoxidising and altering material properties of steel. Ferroalloy production involves a metallurgical reduction process which results in significant carbon dioxide emissions.

In ferroalloy production, raw ores, coke and slagging materials are smelted together under a high temperature. Usually, alloy formation occurs in electric arc furnaces, where heating is accomplished by passing current through graphite electrodes. A carbon reduction of metallic oxides occurs as both coke and graphite electrodes are consumed. The carbon captures oxygen from metal oxides to form carbon monoxide, while ores are reduced to molten base metals. The component metals then combine in the solution. The carbon monoxide is then converted to carbon dioxide.

There had been only one ferroalloy producer in Slovenia. This factory was closed down in the first quarter of 2008 and consequently the production of ferroalloys was discontinued in 2008 as well. No ferroalloys were produced since 2008. This subsector contributed no emissions from 2009 onwards. CO_2 and CH_4 emissions from ferroalloy production are reported under Ferroalloys Production (CRT code: 2C2).

4.4.2.2 Methodological issues

CO_2 emissions had been estimated for the period 1986-2008. From 2009 onwards there was no production of ferroalloys in Slovenia. The CO_2 emissions have been calculated from the amount of reducing agents used. Coke, petroleum coke and graphite electrodes were used as reducing agents in the production of ferroalloys. The data on the consumption of reducing agents was provided by the factory. The 2006 IPCC emission factors had been used for the CO_2 emission calculations. These were 3.3 t CO_2/t coke, 3.5 t CO_2/t petroleum coke and 3.4 t CO_2/t electrodes.

CH_4 emissions had been estimated for the period 1986-2008 as well. The CH_4 emissions have been calculated from the amount of ferroalloys produced. The data on the production of ferroalloys was provided by the factory. The 2006 IPCC emission factors had been used for the CH_4 emission calculations. These were 1.2 kg CH_4/t Si-metal and 1.1 kg CH_4/t FeSi 65-75.

The trend in the CO_2 implied emission factor had not been stable due to different annual shares of fuels split between the energy sector (coal and natural gas) and the process emission sector (coke, petroleum coke and graphite electrodes). The emissions from the consumption of coal and natural gas have been reported in the Energy Sector/Manufacturing industry and Construction/Iron and Steel (CRT sector 1A2a), and the emissions from coke and graphite electrodes have been reported in the process emission sector. Changing levels of the annual consumption of coke and electrodes over time and the different amounts and types of annual ferroalloys produced have also caused variation in the implied emission factors. Different ferroalloys have different CO_2 emissions factors.

4.4.2.3 Uncertainties and time-series consistency

The uncertainty estimates in 1986 are based on the 2006 IPCC GL
The uncertainty of the activity data amounts to 5%.
The uncertainty of the emission factor amounts to 10%.

4.4.2.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

In addition, quality control was performed in the estimation of CO_2 emissions. The CO_2 emissions were calculated by using two different methods. According to the first method the consumption of reducing agents was used as activity data. The second method was used for comparison. It applied the amount of ferroalloys as activity data. Both methods yielded very similar results.

4.4.2.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.4.2.6 Category-specific planned improvements

No improvements are planned for this category.

4.4.3 Aluminium Production (CRT 2.C.3)

4.4.3.1 Category description

Aluminium is produced in two phases. In the first phase alumina (Al_2O_3) is extracted from bauxite ore. Aluminium is then produced in the second phase in an electrochemical process in electrolysis cells, where alumina disintegrates into its components: aluminium and oxygen. Molten aluminium gathers on the cathode while oxygen reacts with carbon in the anode and carbon dioxide is released. This causes the consumption of anodes, which have to be replaced.

In addition to CO_2, perfluorocarbons (PFCs) also arise in the production of aluminium. This occurs during anode effect when the alumina content of the electrolyte falls below 1-2% and a gas film is formed in the anode. This stops the production of the metal and increases the cell voltage. The factors that affect the generation of PFCs are frequency and duration of anode effects and operating current of the cell.

The most significant process emissions are therefore:

- carbon dioxide emissions from the consumption of carbon anodes in the reaction to convert aluminium oxide to aluminium metal;
- perfluorocarbons emissions of tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) during anode effects.

In Slovenia, there is only one aluminium producer. Since the base year, the production of aluminium has undergone numerous modernisations, resulting in reduced GHG emissions from this source in spite of increased production. Exact information on technological changes and improved operating conditions in the aluminium production process is presented.

The technology used in the production of aluminium since Slovenian aluminium plant has been established:
1954 start of electrolysis unit A,
1963 start of electrolysis unit B,
1988 start of electrolysis unit C and technological reconstruction in electrolysis unit B,
1991 discontinuance of electrolysis unit A,
2002 start of operation of doubled electrolysis unit C,
2007 (21st Dec) discontinuance of electrolysis unit B,
2010 reduction of production in electrolysis unit C due to economic crisis.

In 1986, the aluminium producer had two electrolysis units, A and B, both using Søderberg Horizontal Stud anode reduction cells. The annual production of aluminium in electrolysis unit A amounted to 17000 t, in electrolysis unit B to 27400 t, the total annual production amounted to 44400 t of aluminium. In 1986, the production of aluminium included production of alumina. This production was discontinued in 1991 due to economic and ecological reasons, and ever since then alumina has been purchased on foreign markets. In 1991, the production in electrolysis unit A was discontinued as well.

In 1988, a new electrolysis unit C with an annual production capacity of about 40000 t of aluminium was built and its electrolysis technology was taken from Aluminium Pechiney. Simultaneously, the reduction cells in electrolysis unit B were reconstructed to use prebaked anodes.

In 2002, upgrading the aluminium production that includes the construction of the second half of the electrolysis unit C with an annual production capacity of 40000 t of aluminium was carried out. Due to high costs for electricity used, the plant had to wind up the production in pot B in the end of 2007. Since 2008, only doubled electrolysis unit C with technologically improved point feeding prebaked anode Pechiney has been in operation. The annual production of aluminium in 2009 and 2010 were halved compared to 2008. A significant drop in aluminium production occurred due to the world economic crisis. In the period 2020-2022, the production of aluminium decreased considerably due to a global pandemic and energy crisis and unstable political situation in Europe and worldwide.

The emissions of CO_2, CF_4 and C_2F_6 from aluminium production are reported under Aluminium Production (CRT code: 2C3).

4.4.3.2 Methodological issues

Carbon dioxide emissions

The data on the amount of primary aluminium produced, consumption of anodes, sulphur and ash content and CO_2 emissions are submitted to the Slovenian Environment Agency by producer expert service on a regular basis.

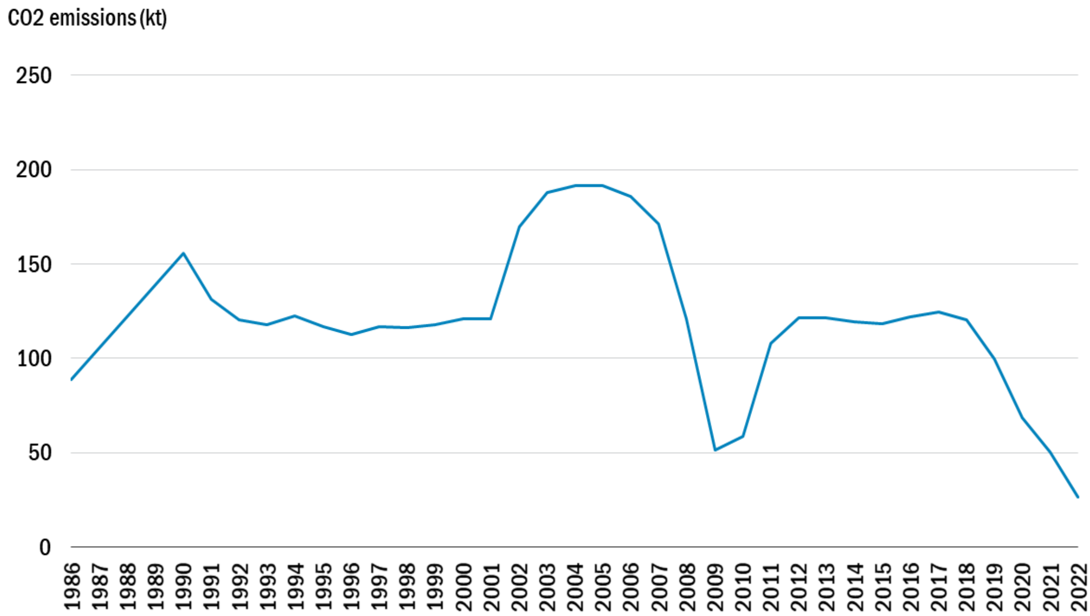

Figure 4.4.3: CO_2 emissions from aluminium production.

CO_2 emissions from primary aluminium production are most precisely estimated from the consumption of anodes. The consumption of anodes in 2022 amounted to 0.378 t/ton aluminium. The emission factor was 3.63 t CO_2/ton anodes. The significant decline of CO_2 emissions in 2009 occurred due to lower aluminium production. In 2012, the production of aluminium increased considerably and CO_2 emissions reached pre-crises values. The same trend is observed for the following years. In the period 2020-2022, the CO_2 emissions decreased considerably due to smaller aluminium production as a result of the unstable situation on markets due to the global pandemic and energy crisis and unstable political situation in Europe and worldwide (Figure 4.4.3).

In 2022, electrolysis unit C with point feeding prebaked anode Pechiney technology was in operation.

The 2006 IPCC methodology is used for the CO_2 emission calculation.

ECO_2 = (MP*NAC*(100 - S - Ash)/100)*44/12

ECO_2 = CO_2 emissions from prebaked anode consumption (t CO_2)
MP = aluminium production (t)
NAC = net prebaked anode consumption per tonne of aluminium (t C/t aluminium)
S = sulphur content in baked anodes (wt %)
Ash = ash content in baked anodes (wt %)
44/12 = CO_2 molecular mass/ carbon atomic mass ratio

This chapter comprises also CO_2 emissions arising from anode burn-off in the process of anode production. In accordance with 2018 UNFCCC ERT recommendation emissions from anode burn-off have been moved into category 2.C.3. Those emissions were previously reported under Other (CRT code: 2C7).

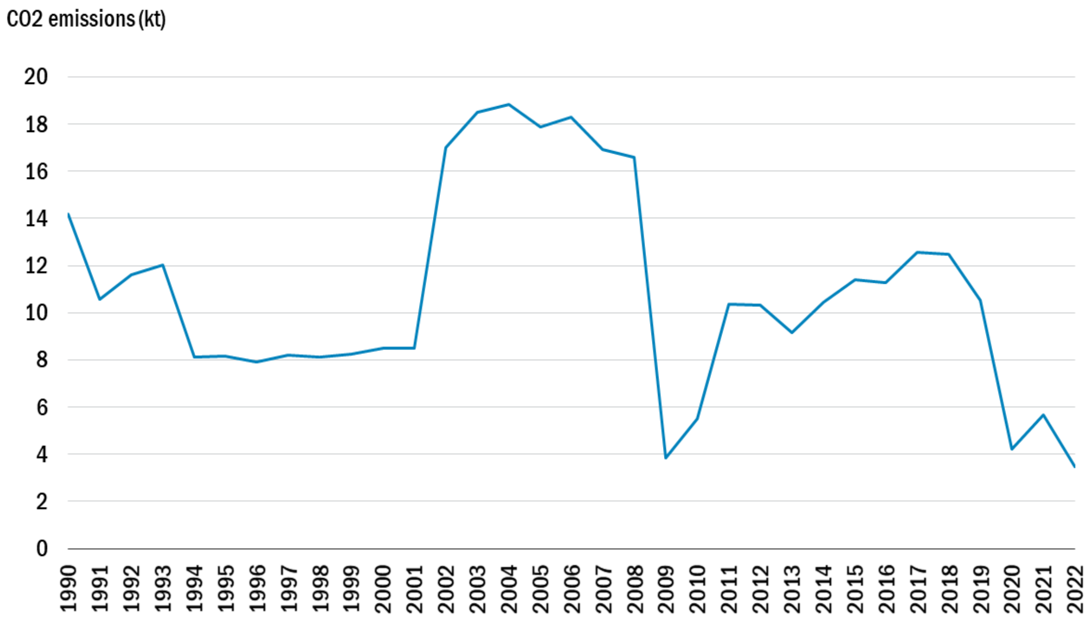

Figure 4.4.4: CO_2 emissions in the process of anode production.

Two sources of CO_2 emissions are associated with anode baking furnaces: combustion of volatile matter released during the baking operation and the combustion of baking furnace packing material. Anodes are used in potline cells - pots for the production of aluminium. The CO_2 emissions generated in the process of green anodes baking arise from oxidation of volatile substances from a tar pitch and burning-off the covering material (petroleum coke). The emission factor for anode burn-off is a plant specific. Data on the amount of anodes, operational parameters and emissions of CO_2 are provided by the producer expert service. The CO_2 implied emission factor for 2022 is 3.34 t CO_2/t anode burn-off. Figure 4.4.4 shows CO_2 emissions arising from anode burn-off in the process of anode production.

PFC emission

Data on emission calculations of tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) have been obtained directly from the aluminium producer. The technological changes and improved operating conditions in the aluminium production process are the reason for the decrease of CF_4 and C_2F_6 emission factors from 1995 to 2022. The CF_4 emission factor has decreased from the base year 1995 till now from 0.2 kg CF_4/ton Al to 0.02 kg CF_4/ton Al and C_2F_6 emission factor from 0.02 kg C_2F_6/ton Al in the base year to 0.003 kg C_2F_6/ton Al in 2022.

In the scope of establishing a scheme for greenhouse gas emission allowance trading for the third trading period after 2012 thorough examination of data was performed. A higher method (Tier 3) was used for calculating PFC emissions in electrolysis unit C for the period 2005 - 2022. Annually determined emission factors have been used for the emission calculation. The Pechiney overvoltage method has been used for the emissions calculation for both gases. All data has been obtained from the producer’s electronically recorded anode-effect inventory. The emissions of CF_4 and C_2F_6 in aluminium production are shown in Figure 4.4.5.

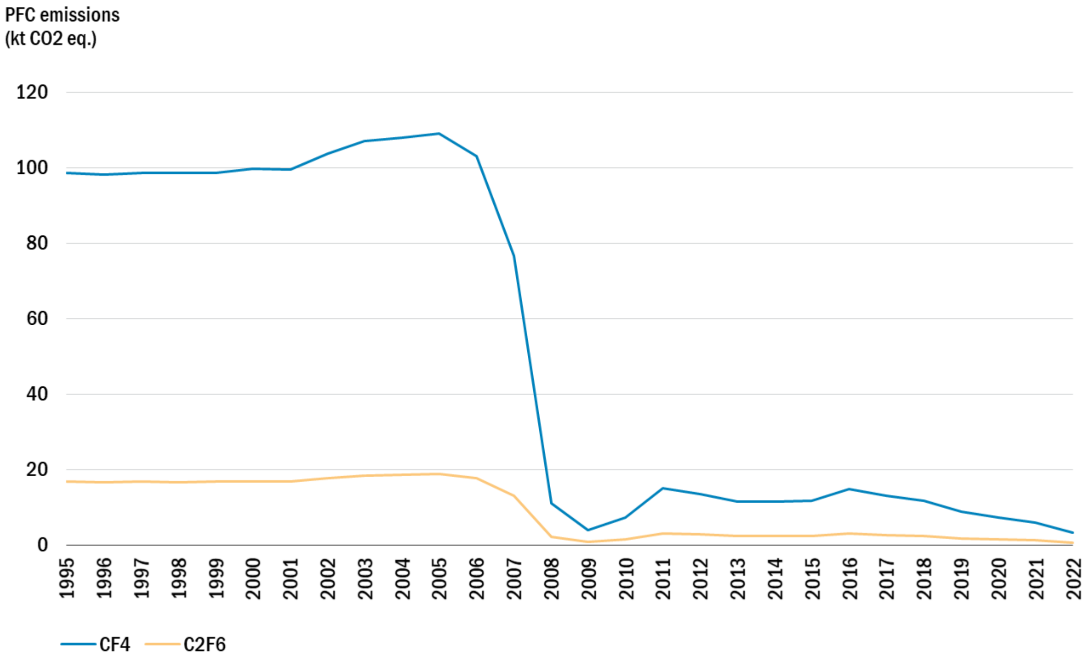

Figure 4.4.5: CF_4 and C_2F_6 emissions in aluminium production.

In 2022, electrolysis unit C with point feeding prebaked anode Pechiney technology has been in operation.

Referring to the fifth IPCC assessment report, 1 g CF_4 and 1 g C_2F_6 have the greenhouse effect of 6630 and 11100 g CO_2, respectively.

The 2006 IPCC methodology is used for CF_4 and C_2F_6 emission calculation.

ECF_4 = MP*OVC *AEO/CE
$EC_2F_6 = E_{CF4} \bullet F_{C2F6/CF4}$

ECF_4 = emissions of CF_4 from aluminium production (kg CF_4)
EC_2F_6 = emissions of C_2F_6 from aluminium production (kg C_2F_6)
OVC = Overvoltage coefficient for CF_4 ((kg CF_4/tonne Al)/mV)
AEO = anode effect overvoltage (mV)
CE = aluminium production process current efficiency expressed (%)
MP = aluminium production (t)
$F_{C2F6/CF4}$ = weight fraction of C_2F_6/CF_4, kg C_2F_6/kg CF_4

The PFC emissions for the period 1995 – 2004 were calculated from the annual production of aluminium in each electrolysis unit and the corresponding emission factor is stated in Table 4.4.1.

Table 4.4.1: Technology used in the aluminium production and corresponding CF_4 and C_2F_6 emission factors.

Technology	Unit	Emission factors
Electrolysis unit A, Soderberg, HSS	kg CF_4/t	0.61
	kg C_2F_6/t	0.061
Electrolysis unit B, Soderberg, HSS, until 1987	kg CF_4/t	0.61
	kg C_2F_6/t	0.061
Electrolysis unit B, reconstruction to PB, 1988	kg CF_4/t	0.40
	kg C_2F_6/t	0.04
Electrolysis unit C, Pechiney, PFPB, until 2004	kg CF_4/t	0.022
	kg C_2F_6/t	0.003

PF - Point Feeding, PB - PreBaked anode, HSS - Horizontal Stud Soderberg

4.4.3.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgement following the recommendations from the 2006 IPCC GL. There is very little uncertainty in the data for the annual production of aluminium, less than 1 percent. The uncertainty in recording carbon consumption as baked anode consumption is estimated to be only slightly higher than for aluminium production, less than 2 percent.

CO_2 emission factor is more uncertain. For Tier 1 EF, which was used in the base year uncertainty is 10%, while in the recent years CO_2 emissions are calculated using PS EF and suggested uncertainty from IPCC GL is 5%.

PFC EF is even more uncertain – in 1986 it was 380% (Tier 1), while with the improved technology uncertainty decreased. Since 2005 emissions are calculated very precise with PS parameters and uncertainty of EF is calculated to be 7%.

4.4.3.4 Category-specific QA/QC and verification

The data obtained from the aluminium producer was thoroughly examined and CO_2 and PFC emissions are compared with the verified emissions from ETS. Possible inconsistencies were consulted with the producer´s expert team. We also visited the factory and observed a production operation and data acquiring in person.

4.4.3.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.4.3.6 Category-specific planned improvements

No improvements are planned for the next submission.

4.4.4 Lead Production (CRT 2.C.5)

4.4.4.1 Category description

The category comprises primary and secondary lead production. In the direct primary smelting process, the sintering step is skipped, and the lead concentrates and other materials are entered directly into a furnace in which they are melted and oxidized. The secondary production of refined lead amounts to the processing of recycled lead to prepare it for reuse. The vast majority of this recycled lead comes from scrapped lead acid batteries. The CO_2 emissions from lead production are reported under Lead Production (CRT code: 2C5).

4.4.4.2 Methodological issues

CO_2 emissions have been estimated for the period 1986-2022. The CO_2 emissions have been calculated from the annual amount of lead produced. The data on the lead production for the period 1986-2016 was obtained from SORS. Data for 2017-2022 were obtained from the producer. Primary production of lead existed in Slovenia in the period 1986-1988. After 1988 only secondary lead production has been taken place in the country. The 2006 IPCC emission factors have been used for the CO_2 emission calculations. These were 0.25 t CO_2/t lead produced for primary production (1986-1988) and 0.2 t CO_2/t lead produced for secondary lead production (1989-2022).

4.4.4.3 Uncertainties and time-series consistency

The uncertainty estimates are based on information on uncertainty from the 2006 IPCC GL

The uncertainty of the activity data amounts to 10%.
The uncertainty of the emission factors amounts to 50%.

4.4.4.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.4.4.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.4.4.6 Category-specific planned improvements

No improvements are planned for the next submission.

4.4.5 Zinc Production (CRT 2.C.6)

4.4.5.1 Category description

Zinc is produced from various primary and secondary raw materials. The primary processes use sulphidic and oxidic concentrates, while in secondary processes recycled oxidised and metallic products mostly from other metallurgical operations are employed. CO_2 emissions from zinc production are reported under Zinc Production (CRT code: 2C6).

4.4.5.2 Methodological issues

CO_2 emissions have been estimated for the period 1986-2022. The CO_2 emissions have been calculated from the annual amount of zinc produced. The data on the zinc production for the period 1986-2016 was obtained from SORS. Data for 2017-2022 were obtained from the producer. The 2006 IPCC emission factor of 1.72 t CO_2/t zinc produced has been used for the CO_2 emission calculations.

4.4.5.3 Uncertainties and time-series consistency

The uncertainty estimates are based on information on uncertainty from the 2006 IPCC GL
The uncertainty of the activity data amounts to 10%.
The uncertainty of the emission factors amounts to 50%.

4.4.5.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.4.5.5 Category-specific recalculations

No recalculations were performed since the last submission.

4.4.5.6 Category-specific planned improvements

No improvements are planned for the next submission.

4.5 NON-ENERGY PRODUTS FROM FUELS AND SOLVENT USE (CRT 2.D)

4.5.1 Lubricant use (CRT 2.D.1)

4.5.1.1 Category description

Lubricants are mostly used in industrial and transportation applications. The lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. They can be divided into motor and industrial oils and greases. The CO_2 emissions from lubricant use are reported under Lubricant Use (CRT code: 2D1).

4.5.1.2 Methodological issues

CO_2 emissions have been estimated for the period 1986-2022. The 2006 IPCC methodology was used for emission calculation (Vol. 3 IPPU, Chapter 5: Non-Energy Products from Fuels and Solvent Use, Equation 5.2). Activity data is the difference between the total amount of lubricant consumption and lubricant used in two-stroke engines. The lubricant used in two-stroke engines was subtracted from the total consumption of lubricant. The data on the total lubricant use for the whole period was obtained from SORS. Tier 1 values for the carbon content of lubricant (20 t/TJ) and oxidised during use factor (0.2) were used for the emission calculation. COPERT 5 (version 5.7.2) model has been used as a source of lubricant used in two-stroke engines. COPERT 5 is a model for the estimation of emissions in the road transportation sector.

4.5.1.3 Uncertainties and time-series consistency

The uncertainty estimates are based on information on uncertainty from the 2006 IPCC GL.
The uncertainty of the activity data amounts to 10%.
The uncertainty of the emission factors (ODU) amounts to 50%.

4.5.1.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.5.1.5 Category-specific recalculations

Recalculation of CO_2 emissions for the whole period 1986-2021 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.7.2) was used for emissions calculation. An amount of lubricant used in two-stroke engines was obtained by a new COPERT 5 model. That amount was subtracted from the total consumption of lubricant. Changes in the total consumption of lubricant led to a recalculation of CO_2 emissions in 2.D.1 sector.

4.5.1.6 Category-specific planned improvements

No improvements are planned for this category.

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

4.5.2.1 Category description

Paraffin waxes are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffin are combusted during use (e.g., candles). The paraffin waxes are separated from crude oil during the production of light (distillate) lubricating oils. The paraffin waxes are categorised by oil content and the amount of refinement. The CO_2 emissions from paraffin wax use are reported under Paraffin Wax Use (CRT code: 2D2).

4.5.2.2 Methodological issues

CO_2 emissions for the period 2000-2022 have been calculated from the consumption of paraffin wax. Data on the amount of paraffin wax used have been obtained from SORS. Default 2006 IPCC parameters have been used for the calculation of the CO_2 emissions. It can be assumed that 20% of paraffin waxes are used in a manner leading to emissions, mainly through the burning of candles, leading to a default ODU factor of 0.2. The carbon content in paraffin wax of 20.0 kg C/GJ has been used for the emission calculation.

CO_2 emissions for the period 1995 -1999 have been estimated in another way due to a lack of data on paraffin wax consumption. The estimation of emissions was performed from Gross domestic product (GDP) data. The CO_2 emissions for 2000 were used as a reference year.

Estimated emission for 1995 was applied for the period 1986 - 1994 due to a lack of data on paraffin wax consumption and information on BDP.

4.5.2.3 Uncertainties and time-series consistency

The uncertainty estimates are based on information on uncertainty from the 2006 IPCC GL.
The uncertainty of the activity data amounts to 10%.
The uncertainty of the emission factors (ODU) amounts to 100%.

4.5.2.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.5.2.5 Category-specific recalculations

No recalculation was performed since the last submission.

4.5.2.6 Category-specific planned improvements

No improvements are planned for this category.

4.5.3 Other (CRT 2.D.3)

4.5.3.1 Category description

This sector comprises emissions of non-methane volatile organic compounds (NMVOC) from road paving with asphalt, asphalt roofing and solvent use, and CO_2 emissions from the use of urea-based additives in catalytic converters. The emissions from these sources are reported under the category Other (CRT code: 2D3).

Asphalt paving consists of a mix of aggregate, sand, filler, bitumen and occasionally a number of additives. Asphalt road surfaces and pavements are composed of compacted aggregate and an asphalt binder. The asphalt binder may consist of heated asphalt cement (hot mix) or liquefied asphalts (cutback or emulsified). Hot Mix Asphalt is by far the most widely used, generally over 80%, and produces very few emissions. Cutback asphalts are liquefied by blending with petroleum solvents (diluents such as heavy residual oils, kerosene or naphtha solvents) and therefore show a relatively high level of emissions of NMVOC due to the evaporation of the diluent. Therefore most emissions from road paving will arise from the use of cutback asphalts. This section covers emissions from asphalt paving operations as well as subsequent releases from the paved surfaces.

The asphalt roofing industry produces saturated felt, roofing and siding shingles, roll roofing and sidings: asphalt shingles, smooth surfaced organic and asbestos felt roll roofing, mineral surfaced organic and asbestos felt roll roofing and sidings, asphalt saturated organic and asbestos felts, asphalt saturated and/or coated sheeting and asphalt compound. Most of these products are used in roofing and other building applications. Asphalt felt, roofing and shingle manufacture involves the saturation or coating of felt. Key steps in the total process include asphalt storage, asphalt blowing, felt saturation, coating and mineral surfacing. The direct greenhouse gas emissions from asphalt roofing products are negligible compared to NMVOC emissions.

The use of solvents manufactured using fossil fuels as feedstocks can lead to evaporative emissions of various NMVOCs, which are subsequently further oxidised in the atmosphere. Fossil fuels used as solvent are notably white spirit and kerosene. White spirit is used as an extraction solvent, as a cleaning solvent, as a degreasing solvent and as a solvent in aerosols, paints, wood preservatives, lacquers, varnishes and asphalt products. White spirit is the most widely used solvent in the paint industry.

Urea-based catalyst is used in Selective Catalytic Reduction (SCR). SCR is an advanced active emissions control technology system that injects a liquid-reductant agent through a special catalyst into the exhaust stream of a diesel engine. The reductant source is usually automotive-grade urea, which sets off a chemical reaction that converts nitrogen oxides into nitrogen, water and tiny amounts of carbon dioxide, which is then expelled through the vehicle tailpipe. CO_2 emissions from the use of urea-based additives in catalytic converters are non-combustive emissions. Urea consumption for catalytic converters in vehicles is directly related to vehicle fuel consumption and technology.

4.5.3.2 Methodological issues

NMVOC emissions

EMEP/EEA air pollutant emission inventory guidebook, 2019 was applied for estimating NMVOC emissions from road paving with asphalt, asphalt roofing and solvent use. NMVOC emissions have been calculated for the period 1990-2022. Detailed information about the methodologies used is described in the Slovenian Informative Inventory Report 2023 submitted under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) and Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants (NEC Directive).
Slovenia CLRTAP Report 2023: Informative inventory report (IIR 2023) (europa.eu)

CO_2 emissions

This chapter comprises CO_2 emissions from the use of urea-based additives in catalytic converters in road transport. After treatment systems used to reduce NO_x emissions utilize an aqueous solution of urea as a reducing agent. Urea is injected upstream of a hydrolysis catalyst in the exhaust line. Ammonia and CO_2 are formed by the reaction. The CO_2 emissions have been calculated for the period 2006-2022. The CO_2 emissions have been estimated with COPERT 5 methodology. The methodology is fully incorporated in the computer software program COPERT 5 (version 5.7.2) which facilitates its application. The actual calculations have been therefore performed by using this computer software. Urea consumption for catalytic converters in vehicles is directly related to vehicle fuel consumption and technology. Vehicle fleet and fuel consumption used for the emission calculation is presented in the chapter, describing emissions from Road transport. The consumption factors and other data used for the emission calculation are default values offered by COPERT 5 program.

4.5.3.3 Uncertainties and time-series consistency

The uncertainty estimates are based on COPERT uncertainties.
The uncertainty of the activity data amounts to 20%.
The uncertainty of the emission factors amounts to 2%.

4.5.3.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.5.3.5 Category-specific recalculations

Recalculation of CO_2 emissions for the period 2013-2021 was performed due to changes in CO_2 emissions from urea-based additives used in catalytic converters in road transport. Emissions from urea-based catalysts were calculated with a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.7.2) was used for emissions calculation. Application of a new version of COPERT 5 for emissions calculation in road transportation led to a recalculation of CO_2 emissions in 2.D.3 sector.

4.5.3.6 Category-specific planned improvements

No improvements are planned for this category.

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

4.6.1 Category description

This category includes HFC emissions, only. The emission sources, the time period and the gases included in the GHG inventory are presented in the Table 4.6.1. The gases have been used in the pure form and most often in the following blends: R-402a, R-404a, R-407a, R-407c, R-410a, R-417a and R-507a. For the purpose of the GHG inventory all blends have been transformed to the pure F-gases using the data from the Table 7.8 from 2006 IPCC GL, Vol 3.

Table 4.6.1: Emission sources of F-gases with the time period.

	period	gases
Refrigeration and AC equipment		
- domestic refrigeration	Since 1993	HFC-134a
- commercial refrigeration	Since 1993	HFC-32, HFC-125, HFC-134a, HFC-143a
- industrial refrigeration	Since 1997	HFC-32, HFC-125, HFC-134a, HFC-143a
- transport refrigeration	Since 1993	HFC-125, HFC-134a, HFC-143a
- stationary air conditioning and HP	Since 1995	HFC-32, HFC-125, HFC-134a, HFC-143a
- mobile air conditioning - production	1993-2016	HFC-134a
- mobile air conditioning - use	Since 1993	HFC-134a
Foam blowing		
- hard foam - production	1995-2005	HFC-134a
- hard foam - use	Since 1995	HFC-134a
- soft foam	1995-1998	HFC-134a
Fire extinguishers	Since 1997	HFC-227ea
Aerosols and meter dose inhalers	Since 2001	HFC-134a

HFCs began to be used in Slovenia in 1993 as a substitute for CFCs, which are ozone-depleting substances. They asserted themselves in particular in those fields where no other, more appropriate alternatives (e.g. hydrocarbons, CO_2 etc.) were available.

Slovenian chemical industry does not produce HFCs and therefore these substances are imported. Major users generally import them on their own, minor users buy them from distributors. In the first years only HFC-134a was used, while since 1998 also the other F-gases like R-125 and R-143a and HFC mixtures like R-402a, R-404a, R-407a, R-407c, R-410a, R-417a and R-507a have been used. In the fire extinguishers R-227ea have been used since 1997.

Emissions of HFC are presented on the Figure 4.6.1. The most important source of HFC emissions in 2022 was Commercial refrigeration with contribution of 31.3%. Mobile Air-Conditioning was the second most important source in 2022, 28.3% of all HFC emissions arose from the MAC. The production and sales of cars with air conditioning has risen sharply in recent years, but due to the EU directive from 2011, the increase use of the refrigerant with lower GWP (R-1234yf) was observed. In addition the sealing of AC system in the new vehicles is much better than in the old one. The consequence is that emissions from this source in 2022 was by 14.1% lower than in 2016, when the highest emissions from this source have occurred.

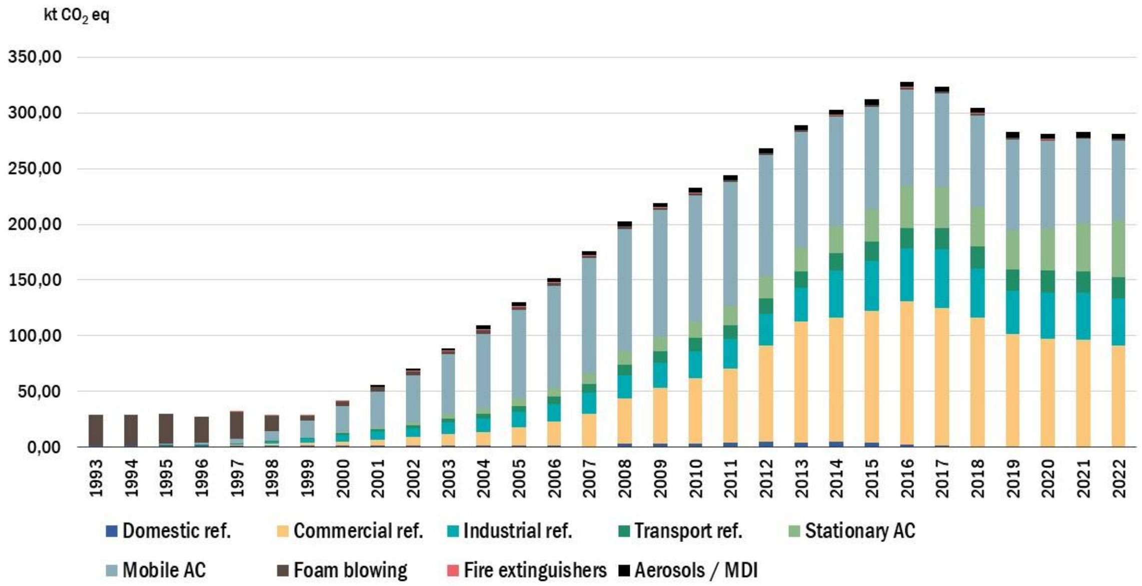

Figure 4.6.1: HFC emissions from different sources.

The first data on HFC consumption for the period 1995-1997 was obtained by a research project carried out by the Chamber of Commerce and Industry of Slovenia in 1999. In this study the potential emissions and the actual emissions according to Tier 2 method have been calculated.

Due to the increase use of F-gases for the refrigeration and air-conditioning and to fulfil the requirements from the related EU legislations the establishment of different data collection system has begun. The first system has focused on collection of data on the first fillings in the equipment in the manufacturing industry, but was then expanded to collect data on all devices in the country with 3 kg of F-gases or more. In 2011 the database of these reports has been established; which includes information on the amount and type of F-gases, year of installation and purpose of the device (AC, industrial refrigeration…). These data have been used to estimate the amount of F-gases for stationary conditioning, industrial refrigeration and partly also for commercial refrigeration.

The second source of data are reports from the service companies which are authorized to perform the 1st filling and to maintain the equipment which is filled with ODS and F-gases in the stationary sources. In these reports, the total amount of each F-gas or blend, used for maintenance in one year, is available, but no disaggregation according to the type of maintained equipment was available until 2013 when for the first time data were collected and reported separately for four types of use (commercial, industrial, stationary AC, and fire protection).

There was one more source of data on F-gases in Slovenia. In 2008, Slovenia adopted a regulation on an environmental tax on the use of fluorinated greenhouse gases, which entered into force on 1 January 2009. This tax was calculated on the basis of pollution units referring to CO_2 equivalents. When introducing the tax on the use of F-gases, the Slovenian government anticipated a transition period during which the tax burden has gradually increased until 2013, when the full price per pollution unit has been reached. The level of the tax depends on the purpose of F-gases use: The first fill of pre-charged equipment and stationary equipment was taxed 5%, while F-gas quantities used for servicing and maintenance of equipment was taxed 100%.

In the beginning data on F-gas quantities which based on the tax revenues give a good estimate of the level of HFC used in the country, but after few years the tax revenues started to decrease due to the fact, that taxes were not applied in the neighbouring countries within the EU and outside of the EU and that it was possible for companies to buy F-gases there at lower prices. Furthermore, tax rebates for recovered F-gases for reclamation and destruction were not part of the scheme. For these reasons the tax has been abolished in 2017.

4.6.2 Methodological issues

Actual emissions of HFC have been calculated using Tier 2a approach and the following equation (2006 IPCC GL, Vol 3, chapter 7.1.2.1, eq. 7.4)

$E_t = E_{assembly.\ t} + E_{operation.\ t} + E_{disposal.\ t}$

where:

$E_{assembly,\ t} = E_{charge,\ t} * (k/100)$

$E_{assembly,\ t}$	=	Emissions during system manufacture/assembly in year t
$E_{charge,\ t}$	=	The amount of F-gas charged into new systems in year t
k	=	Production/assembly losses (%)

$E_{operation.\ t} = E_{stock.\ t} * (x/100)$

$E_{operation.\ t}$	=	Amount of F-gas emitted during system operation in year t
$E_{stock.\ t}$	=	Amount of F-gas stocked in existing systems in year t
x	=	Annual leakage rate (in per cent of total F-gas charge in the stock)

$E_{disposal,\ t} = E_{consumption\ (t-n)} * (y/100)$

$E_{disposal,\ t}$	=	Amount of F-gas emitted at disposal in year t
$E_{consumption\ (t-n)}$	=	Amount of F-gas used for production in year (t-n)
n	=	product lifetime (in years)
y	=	Share of F-gas in products to be disposed of in % of the amount used for their production

2.F.1 Refrigeration and Air Conditioning Equipment

The following chapters describe types of refrigeration and air-conditioning equipment considered in individual sub-categories, refrigerants used in the respective applications and method used for the calculation of emissions in Slovenia.

Domestic refrigeration:

The use of HFC-134a as a refrigerant began towards the end of 1993 only to become partly replaced by isobuthane already in 1995. Appliances with R-134a are produced exclusively for export to the USA and to other non-European countries.

Since 1996, all household refrigerators produced in Slovenia for Slovenian market have been filled in with R-600 (isobuthane). The amount of HFC-134a in imported refrigerators was estimated in the study (Chamber of commerce, 1999). Afterwards, the amount in new appliances decreased until 2006, when according to the information from experts there were no imported household refrigerators with HFC-134a. No other F-gases have been used. Since 2020 there was no F-gases in the operating systems any more.

The emission factors are presented in the Table 4.6.2. Product lifetime is considered to be 15 years and emissions from disposal have been calculated since 2008.

Commercial and industrial refrigeration:

In Slovenia there is one producer of small commercial refrigerators with HFC-134a, while all other commercial and industrial refrigerators are imported. They are usually filled with refrigerant during installation.

The amount of refrigerant used was estimated in the study (Chamber of commerce, 1999) and we have used projections from this study to determine the amount for Standalone commercial appliances, while the amount in Medium and large commercial and Industrial refrigerators have been taken from the database. In addition to HFC-134a, the following blends have been used: R-402a, R-404a, R-407a, R-407c, and R-410a.

Since 2015 emissions data on amount filled in the new product and amount refilled during maintenance have been obtained from the reports from service companies. Emissions have been calculated with the EFs as presented in the Table 4.6.2. The exceptions are emissions from the use of medium and large commercial refrigerators and industrial refrigerators. Since 2015 emissions from these categories have been estimated to be equal to the total amount of refrigerant which was used during regular maintenance.

The disposal emissions from commercial refrigeration have been calculated since 2007 as product lifetime is considered to be 12 years for small and 15 years for medium and large appliances. Product lifetime for industrial refrigerators is 25 years, hence in 2022 the disposal emissions occurred for the first time.

Transport refrigeration

To determine the amount of refrigerant used in this category the data from the official database of registered vehicles have been used. The trucks and trailers with the cooling unit has been divided into 3 groups according to the size: small – less than 3.5 t, medium – between 3.5 and 10 t, and large – more than 10 t. The amount of refrigerant in each type of vehicle has been taken from the 2006 IPCC Guidelines, Vol. 3, Table 7.9. For small trucks and trailers the lower value from the range 3 kg has been used, for large the highest value 8 kg and for middle the average value 5.5 kg of refrigerant. The operation emissions have been calculated using emission factor of 30%. In Slovenia in the transport refrigerators only HFC 134a and HFC 404a have been used. No data are available on share of each F-gas, therefore it has been assumed that half of the amount is R134a and half is R404a. We also don't know how fast the ODS have been replaced with F-gases.

For the inventory purpose we have assumed that no F-gases were in these vehicles in the years before 1995.

According to the database on registered vehicles 80 to 200 trucks and trailers with the cooling unit have been yearly deleted from the database in the recent period. According to the evidence on disposed vehicles, these vehicles have not been disposed in Slovenia. In Slovenia there is no centre for decommissioning of spent trucks and buses therefore no transport refrigerators can be legally disposed in the country.

To avoid illegal disposal of old vehicles and to encourage the owners of the deregistered vehicle to dismantle the vehicle in accordance with environmental protection regulations in April 2018 the new legislation come into force. According to this legislation the owners of the nonregistered vehicles have to pay the duty for a deregistered vehicle. This obligations ends when the vehicle is decommissioned or when the vehicle is re-registered. The obligation also ceases if the owner deregisters the vehicle from registration submits to the competent authority:
a) certificate of destruction of the vehicle in accordance with regulations on environmental protection,
b) a police report showing that the vehicle was stolen,
c) proof that the vehicle is registered in another country,
d) export customs declaration confirming the exit of the vehicle from the EU customs area

This duty is not valid for heavy duty trucks, however it looks that all old trucks are exported to the other countries. In some cases for the decommission, but more often to be further used in the countries with less strict environmental standards. For 2021 we have obtained the data on the export of used trucks and trailers and the main findings are:

- the number of exported used trucks and trailers was 7390 (in the same time an import of such vehicles was 2046)
- about 75% of spent trucks and trailers were exported to the Former Yugoslav republics, which are not part of EU, as much as 62% to Serbia)
- the remaining was exported to the EU (21%), Africa (2%) and other countries 2%.

Taking into consideration that in 2021 about 2.9% of truck/trailers has an ATP unit, the number of exported transport refrigerators is more than 200 what is almost the same as the number of such vehicles deleted from the database on registered vehicles in this year.

Emissions from transport equipment accidents are not included in the inventory because exact data on the amount of refrigerant which is lost during accident is not available. We have estimate this amount based on the total number of truck/trailers which were involved in the accident in the period 2015 – 2021. We have assume the same proportion of trucks/trailers with the cooling unit to be involved in the accident and that during every accident the total amount of refrigerant is lost, what is an overestimation. Emissions due to the accidents have been estimated to be between 1.2 and 1.9 kt CO_2 eq. what is below the threshold of significance. These emissions from accidents are not included in the inventory.

Stationary A/C and heat pump

There is almost no production of air conditioners in Slovenia; their sale on Slovenian market is almost equal to their import. For a long time, only HCFC-22 was used. The import of air conditioners with HFC began in 2000.

The amount of refrigerant in A/C has been taken from the F-gases database. Although some AC equipment is already filled with refrigerants when imported, many of them are filled during installation. For this reason we have assumed that all amounts of F-gases have been filled in Slovenia. We have also included estimates on the amount of F-gases in small home AC appliances. In addition to HFC-134a, the following blends have been used: R-404a, R-407a, R-407c, R-410a, R-417a, and R-507a.

For the 2020 submission emissions from the heat pumps have been included in the inventory for the first time. Data have been obtained from the Energy Efficiency Centre from IJS.

The emission factors are presented in the Table 4.6.2. Product lifetime is considered to be 15 years and emissions from disposal have been calculated since 2011.

Mobile AC

Air conditioning systems in motor vehicles are filled with refrigerant at the moment of their installation into a vehicle. Car air conditioners are usually installed during vehicle assembly, although retrofitting is possible. HFC-134a began to be used in Slovenia in 1994, but some imported vehicles have been equipped with such air conditioners already since 1993.

There is one car producer in Slovenia and data on the amount filled in the new cars have been obtained from a personal contact with the producer. Since 2017 HFC-134a was replaced with HFC-1234yf.

Annual data on HFC stock in MAC has been estimated from data on number of registered vehicles by year of manufacture. It was assumed that in 1993 only 1% of new vehicles were equipped with MAC. Since then the share of MAC increased and since 2008 it was assumed that all vehicles are air-conditioned. Until 2000 we have assume a constant charge over time at an average 0.8 kg, which is typical to medium-sized passenger cars, which was more often equipped with AC in this period then small cars. For the recent period the charge have been estimated from data on amount of refrigerant in 20 most selling car models in the county.

According to the European legislation on F-gases in the period 2013-2016 the use of new refrigerant HFC -1234yf was obligatory in the new models of cars, only. According to the list of such models we have estimated that around 10% of MAC in the new vehicles have used R1234yf, while all others are still using R134a. Since 2017 all new cars have to use the new refrigerant. However in 2017 only around one third of the new registered vehicles was also manufactured in 2017 and therefore equipped with the MAC using R1234yr. Around one third of new cars were made in 2016 (therefore only 10% are using R1234yf) and the last third of the first registered vehicles were imported used vehicles. For this reason the new refrigerant was used only by 7.5% of all registered vehicles in 2017. In 2020 the situation was similar and the new refrigerant was used by 19.3% of all registered vehicles in the country.

Product life factor (EF) was estimated in accordance with directive 2006/40/EC of the European parliament and of the council relating to emissions from air-conditioning systems in motor vehicles. The directive states that MAC value of 20% is appropriate for countries with no recovery and recycling program, and 10% for the countries with such program. Slovenia started to implement that directive in 2006. 20% for MAC system emission rate was applied until 2006 due to the absence of such program. After implementation of the directive, gradually a recovery and recycling program have been introduced. We assumed 1 per cent point lower emissions in 2006 and the same decrease for every year afterwards. We assumed that a certain adaptation period is needed for the total implementation of recycling program. An annual decrease of 1 per cent point in the EF is our conservative assumption, since we have been informed that mechanical workshops intensively carry out that recycling program. The directive is available on the link:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:161:0012:0018:EN:PDF

Disposal emissions are calculated from the official number of disposed vehicles and with the assumption that a product lifetime is 15 years.

At the beginning of disposal in 2008 we have used disposal factor 85% as suggested from the expert who is familiar with the situation at a car recycling facilities. This factor has slowly decreased and since 2015 the middle value of the default range is used.

The disposal factor of 85%, which was used at the start of decommissioning, was recommended by experts from the Ministry of the Environment, which supervised the implementation of the legislation in practice and had a good overview of used vehicle centres. This factor was very high because the end-of-life vehicle recovery facilities were only gradually adapting to the new legislation, which required that the collection of HFCs from air conditioners be carried out only by certified personnel and with appropriate equipment. Fortunately, there were very few used cars with air conditioning back then.

Until 2011, the system of end-of-life vehicles management was provided by public utility services. One essential measure for the functioning of the system was the introduction of the “dismantling certificate”. Upon deregistration of a vehicle, the last owner of a vehicle qualifying as an end-of-life vehicle pursuant to regulations governing environmental protection and end-of-life vehicle management was obliged to present a certificate of vehicle destruction. The service of dismantling is free of charge for the last owner of a vehicle.

According to the most recent estimates, at least 30,000 end-of-life vehicles are generated in Slovenia each year. The actual number of dismantled ELVs differed considerably from these estimates largely due to abuse of the instrument of deregistration of vehicles. Vehicle location statements were being abused in such a way that the last owners were using them to deregister vehicles that were later being illegally dismantled. In view of the large number of vehicle location statements that were issued in Slovenia (approximately 15,000 annually), it was impossible to efficiently carry out control of vehicles that were deregistered in this way.

With the adoption of a new regulation in 2011 introducing extended producer responsibility, end-of-life vehicle management has become more transparent. In Slovenia there are currently 51 collection points for end-of-life vehicles that collect ELVs under the authorisation of three dismantling facilities operating within the framework of the extended producer responsibility system Evidenca-nacrtov-ravnanja-z-izrabljenimi-vozili.pdf (gov.si) . In addition, 24 independent facilities for ELV dismantling operate. (Samostojni-obrati-za-razstavljanje-izrabljenih-vozil-in-pripadajoca-zbiralna-mesta.pdf (gov.si) . For the last owner, recovery of an end-of-life vehicle is free of charge. Upon handing over an end-of-life vehicle for dismantling, the owner is issued a certificate of destruction.

In 2018 the additional regulation was adopted. Owners of vehicles, who deregister the vehicle become liable for the payment of duty on deregistered vehicles. The duty for deregistered vehicles must be paid every year by the owners of a certain category of vehicles, namely for passenger vehicles, light duty trucks (below 3.5 t) and three-wheeled mopeds.

Owners of these vehicles can avoid paying the fee in cases where it is clear from the records of registered vehicles that the vehicle was decommissioned in accordance with environmental protection regulations or if they provide proof that the vehicle was registered in another country. With this new legislation, the inspection of used vehicles will be improved. For now, there is no official data on where these vehicles if they are not disposed in the county, end up.

Emission factors used

On the table 4.6.2 comparison of EFs and other parameters used in the inventory (upper line) with the range from 2006 IPCC Guidelines is presented. At the beginning the emission factors have been taken from a research made by The Chamber of commerce and industry, while for the recent period EF used based on the actual data or on the expert judgements taking into account information available in the 2006 IPCC Guidelines.

Table 4.6.2: **HFC emissions in 2022, emission factors and other parameters used in refrigeration and air conditioning appliances and comparison with EF from 2006 Guideline (Table 7.9).**

	EF Production (%)	EF Use (%)	Lifetimes (years)	Recovery (%)	Charge (%)	HFC emissions (Gg CO_2 eq)
Domestic refrigeration Range from 2006 IPCC GL	1 0.2 - 1	0.5 0.1 – 0.5	15 12 - 20	70 0 - 70	85 0 - 80	0.01
Commercial refrigeration Stand alone Range from 2006 IPCC GL Medium and large Range from 2006 IPCC GL	 3 0.5 – 3 3 0.5 – 3	 8 1 – 15 25* 10 - 35	 12 10 – 15 15 7 – 15	 70 0 – 70 70 0 - 70	 40 0 – 80 75 50 - 100	90.9
Industrial refrigeration Range from 2006 IPCC GL	3 0.5 – 3	12* 7 - 25	25 15 - 30	NO 0 - 90	NO 50 - 100	42.6
Transport refrigeration Range from 2006 IPCC GL	NO 0.1 - 1	30 15 - 50	NA 6 - 9	NO 0 - 70	NO 0 - 50	19.3
Stationary Air Conditioning Range from 2006 IPCC GL	0.6 0.2 - 1	1 – 10* 1 – 10	15 10 - 20	80 0 - 80	40 0 - 80	50.2
Mobile Air Conditioning Range from 2006 IPCC GL	0.5 0.5	10 10 - 20	15 9 - 16	50 0 - 50	25 0 - 50	72.3

*Note: Since 2015 EFs indicated with * are not used for calculation any more*

<u>Recovery</u>

Recovery of F-refrigerants is mandatory under the EU F-gas Regulation No. 517/2014 and there are measures in place to increase recovery; however data on recovered amounts are not available by subcategories. For this reason we have used an approach which was agreed among EU members (default approach) and is presented with the following equation:

Recovery = amounts remaining in products at decommissioning – disposal emissions

2.F.2 Foam Blowing

<u>Hard Foam</u>

There is very few information about the use of F-gases in the past. For production of insulating foams for refrigerators only one plant had used HFC-134a until 1996, when it was replaced by cyclopentane. Emissions of HFC in the manufacturing of insulating foam for household refrigerating/freezing appliances amount to 3 to 5 %, for the calculations we have used an average value of 4%. Data about HFC in hard foam from the period 1993-1995 are available and default value of 4.5 % has been used to determine annual losses, as suggested from the 2006 IPCC GL, Vol. 3, Table 7.5.

In Slovenia many plants had produced one-component PU foam in the past but all products with HFC were exported. Emissions during the production of polyurethane assembly foams amounted to 1%. HFC performed the function of propellant and blowing agent. Part of HFC was emitted during application of the product, for instance during installation of windows or doors, within a year, but a part of HFC remained in the foam and has been slowly released during the following 20-25 years. Considering the fact that this product was entirely destined for export, there are no emissions from application of the product on the domestic market and emissions have arisen in the importing countries.

Since 2007, the use of F-gases for PU OCF has been prohibited by the EU legislation. There is no other evidence that F-gases have been used for hard foam blowing in Slovenia. For production of PU, XPS and EPS hard foams, CO_2 and pentane have been used as blowing agents, while flammable hydrocarbons (propane, butane…) have been used for PU OCF.

<u>Soft Foam</u>

In the production of soft foam the total amount of HFC is emitted during the production (EF is 100%) and therefore no emissions occur during their use and disposal. The only production of soft foam with HFC in Slovenia was the production of polyurethane (PU) shoe soles and until 1998 HFC-134a was used for this purpose.

2.F.3 Fire protection

The company's database of installed fire protection equipment is not complete. Because we are aware of this, we are not using the data from this database for the calculation, so for this reason, the emissions are not underestimated.

First data about HFC used as a replacement for CFC was collected for the research made in 1999 (Chamber of Commerce, 1999). In this research it was assumed that 400 kg of HFC would be used per year. According to information from The operational plan of the Republic of Slovenia for management of Halon, 5800 kg of CFC still existed in fire extinguishers in 2002. It was assumed that the total amount was replaced with substitutes until the end of 2005. Due to the lack of detailed data we have assumed that all CFC was replaced with HFC, which is probably an overestimation.

For the 2021submission actual data on use of HFC in the fire extinguishers since 1999 were obtained from service companies. In Slovenia, only use of HFC-227ea has been detected. Since 2012 all new installations are filled with Novec 1230 and all HFC-227 which is filled in the systems since then is used for a replacement of gas which is released during the firefighting. For this reason, amount filled in the installations in particular year is the same as emitted amount from the use.

Reference for EF 5% for the first filling is the Operational plan on replacement of Halons with HFC. There the EF of 5% which were used for Halons is recommended, to be used also for HFC. We have used this value for the period 1996-1999. Since 2012, only one service company (Zarja) fills HFC-227ea into fire protection systems in Slovenia. Based on their experience, they suggested using an EF of 0.5%. We are using this value since 2012, while the EFs for years in between are interpolated

In calculating emissions of HFC, IPCC methodology and the therein-stated assumption that emissions amount to 5% of the quantities used in new stationary systems were applied. This assumption is derived from experience with the use of Halon systems and is supposed to be appropriate also for estimating HFC emissions. Reference for EF 5% for the first filling is the Operational plan on replacement of Halons with HFC. There the EF of 5% which were used for Halons is recommended, to be used also for HFC. We have used this value for the period 1996-1999. Since 2012, only one service company (Zarja) fills HFC-227ea into fire protection systems in Slovenia. Based on their experience, they suggested using an EF of 0.5%. We are using this value since 2012, while the EFs for years in between are interpolated. The EF from the 1st filling has decreased from 5% as it was estimated in 1997 to 0.5% in 2012 due to the rigorous legislation and high prices of F-gases and settled on this value since then.

To estimate emissions from the use since 2012 emissions data from the service companies has been used. All emissions from the use are released during the fire accident. In the period 2012-2019 this amount was between 0.44% and 1.07% of installed capacity for this reason for the years before emission factor of 1% has been applied.

Reference for EF 5% for the first filling is the Operational plan on replacement of Halons with HFC. There the EF of 5% which were used for Halons is recommended, to be used also for HFC. We have used this value for the period 1996-1999. Since 2012, only one service company (Zarja) fills HFC-227ea into fire protection systems in Slovenia. Based on their experience, they suggested using an EF of 0.5%. We are using this value since 2012, while the EFs for years in between are interpolated.

Slovenia is the member of EU since 2004 and therefore all relevant EU regulations are directly applicable in the country. The legislation is therefore available on:
https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases_en

In addition the Slovenian legislation is a Decree on the use of fluorinated greenhouse gases and ozone-depleting substances. This regulation defines:
- the competent authorities, supervision and sanctions for violations.
- determines the rules for training and issuing certificates to the person who carries out leak detection, capture, installation, maintenance, repair or dismantling of equipment containing F-gases and rules for the selection of training providers.
- determines the obligation to register equipment containing F-gases and the reporting obligation of the operator, maintainer and authorized company in relation to the use, collection and delivery of waste F-gases.

2.F.4 Aerosols/Metered Dose inhalers

In this category only emissions from metered dose inhalers is considered. Slovenia began to use HFC-134a in the MDI in 2001 as replacement for the CFC.

Data on MDI have been obtained from the Slovenian Heath Insurance Institute. For calculation of emissions we have assume that all amount of HFC-134a from medical equipment which is sold in one year is release in the same year. EF is therefore equal to 100%. There is no production of this type of medicine in Slovenia.

4.6.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgement and presented in the table 4.6.3 below.

Table 4.6.3: **Uncertainties in %.**

Category	**AD**	**EF**	**Combined uncertainty**
1. Refrigeration and Air Conditioning Equipment	20	30	36.1
2. Foam Blowing	10	50	51.0
3. Fire Extinguishers	10	20	22.4
4. Aerosols/MDI	50	0	50

4.6.4 Source-specific QA/QC and verification

After applying the standard QC procedure data, EFs and emissions have been undergoing the following QA/QC procedures:

- all EFs have been compared with the EFs from 2006 IPCC Guidance;
- values of stock have been compared with the data from neighbouring countries;
- emissions from every CRT category have been compared with the emissions from neighbouring countries

For the purpose of verifying the F gases, data from the reports in accordance with the Regulation 517/2014 have been used.

By 31 March 2015 and every year thereafter, each producer, importer and exporter that produced, imported or exported one metric tonne or 100 tonnes of CO_2 equivalent or more of fluorinated greenhouse gases and gases listed in Annex II during the preceding calendar year shall report to the Commission the data specified in Annex VII on each of those substances for that calendar year.

By 31 March 2015 and every year thereafter, each undertaking that used 1 000 tonnes of CO_2 equivalent or more of fluorinated greenhouse gases as feedstock during the preceding calendar year shall report to the Commission the data specified in Annex VII on each of those substances for that calendar year.

By 31 March 2015 and every year thereafter, each undertaking that placed 500 tonnes of CO_2 equivalent or more of fluorinated greenhouse gases and gases listed in Annex II contained in products or equipment on the market during the preceding calendar year shall report to the Commission the data specified in Annex VII on each of those substances for that calendar year.

Each importer of equipment that place on the market pre-charged equipment where hydrofluorocarbons contained in this equipment have not been placed on the market prior to the charging of the equipment shall submit to the Commission a verification document issued pursuant to Article 14(2).

Although we have some difficulties in understanding this report, we note that the data from these reports is quite different from what we report. Basically, the amounts of F gases in the reports are too small, especially HFC 134a, which is used to fill car air conditioners. The reason may be that smaller utilities do not need to report and may not buy this gas in Slovenia.

4.6.5 Category-specific recalculations

2.F.1 Refrigeration and Air conditioning, , HFCs

Emissions of HFC for the period 2019-2021 were recalculated due to the change of product lifetime for medium and large commercial refrigerators from 10 to 15 years.

4.6.6 Source-specific planned improvements

Slovenian F-gases database has not been completed yet. Every year, new devices are included and the amount of F-gases in stock is increasing. For this reason, data on stock will be updated regularly and, if needed, and recalculation of emissions will be performed. This can be regarded as an ongoing process and will probably lead to an improvement of the inventory.

4.7 Other Product Manufacture and Use (CRT 2.G)

4.7.1 Electrical equipment (CRT 2.G.1)

4.7.1.1 Category description

SF_6 is mostly used as an insulating agent and fire-extinguishing agent in electrical installations, in middle voltage and high voltage (110 kV and 400 kV) gas insulated switchgear and circuit breakers (HV equipment). SF_6 insulated switchgear and circuit breakers were first used in Slovenia in 1976. A general increasing trend can be observed, and particularly since 1993, the use of equipment with SF_6 as insulating gas has increased strongly (Table 4.7.1). This type of equipment is not produced in Slovenia and there is no export of SF_6 in equipment.

Table 4.7.1: **SF_6 emissions from a high-voltage equipment.**

Emissions from	Units	1986	1990	1995	2000	2005	2010	2015	2020	2022
manufacturing	kg	0.1	0.0	0.9	1.4	2.6	2.3	1.2	0.5	0.0
stock	kg	428.4	431.1	481.2	657.1	786.7	751.2	730.1	699.2	699.2
disposal	kg	-	-	-	-	-	-	0.4	-	-
Total SF_6	**kg**	**428.5**	**431.1**	**482.1**	**658.5**	**789.3**	**753.5**	**731.7**	**700.0**	**699.2**
Total SF_6	**Gg CO_2 eq**	**10.1**	**10.1**	**11.3**	**15.5**	**18.5**	**17.7**	**17.2**	**16.4**	**16.4**

4.7.1.2 Methodological issues

In 2006, a research covering all high-voltage equipment in Slovenia was done by The Milan Vidmar Electric Power Institute, Ljubljana. Estimation of SF_6 emissions for the period 1986-2005 was performed. In this study, emissions have been calculated according to the Tier 3 methodology, with the equation:

Emissions have been calculated according to Tier 3 methodology form 2006 IPCC GL, where Total $E_{emissions} = \sum E_{manufacturing,t} + \sum E_{installation,t} + \sum E_{use,t} + \sum E_{recycling,t}$

Manufacturing emissions do not existed in Slovenia.

The equipment installation emissions have been estimated by subtracting the nameplate capacity of all new equipment filled from the actual amount of SF_6 used to fill the new equipment.

The emissions due to the use of the equipment are determined by the amount of SF_6 used to maintain the equipment. SF_6 which has been recovered from equipment before maintaining and returned after maintaining is not included in the estimate.

Since 2009 the activity data has been taken from the F-gases database (see chapter 4.6.1). To determine emissions from installation EF of 0.15 has been used. Emissions from use depends on the type of equipment: for MV Block and switchgear EF is 0.1 while for HV circular breakers EF of 0.5 was assumed. These factors are based on the technical specifications of equipment. Emissions for the years 2006-2008 were interpolated.

The amount of SF_6 in the disposed equipment is determined by multiplying the nameplate capacity of disposed equipment by fraction of charge remaining at retirement. The default fraction for Europe has been taken from 2006 IPPC Guidance, Vol. 3, Ch. 8, from the Table 8.2. for MV switchgear (0.93) and from the Table 8.3. for HV switchgear (0.95). These factors are based on the technical specifications. According to the expert judgement the SF_6 is fully recovered from the retiring equipment and it is their estimate that a leakage is less than 0.15%. Experts justify such a low factor with an extremely high gas price.

At the end of life, all SF_6 equipment, including hermetically sealed-pressure switchgear, is properly decommissioned to avoid emissions. Any remaining gas is fully extracted using recovery systems that achieve acceptable blank-off pressure (i.e., vacuum generated during the recovery process to levels of 0.05 bars and lower). Used SF_6 is purified either on-site or off-site. A gas that is non-reusable is collected in the original cylinders in which the SF_6 gas was supplied and is sent to specialized incineration plants to other countries (e.g. France) for destruction. There is not such plant in Slovenia. The value 0.15% was obtained in the personal communication with the experts from the largest users of SF_6 . We have contacted more of them and majority assured that there is no leakages at all. There is no reason that in our case the leakages are higher from leakages during the installation for which value 0.15% is used.

When calculating SF6 emissions from electrical equipment we rely entirely on data from the database of this equipment, which we keep at SEA. Operators of electrical equipment with SF_6 must notify SEA of any changes to this equipment, the correctness of this information is checked by environmental inspectors. A disposal of the equipment does not occur every year. When in a given year there was no information that any equipment was replaced or removed, we use the notation key NO for disposal emissions.

4.7.1.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgement.
The uncertainty of the activity data amounts to 20%.
The uncertainty of the emission factor amounts to 10%.

4.7.1.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.7.1.5 Category-specific recalculations

No recalculations have been performed for this category.

4.7.1.6 Source-specific planned improvements

No improvements are planned for the next submission.

4.7.2 SF_6 and PFCs from other product use (CRT 2.G.2)

4.7.2.1 Category description

The other uses of SF_6 in Slovenia, which are included in the GHG inventory are:
- SF_6 used in research particle accelerators (since 1997);
- SF_6 used in electronic microscopes (since 2002);
- SF_6 used in equipment in medical particle accelerators (since 1986);
- SF_6 used in equipment in industrial particle accelerators (since 2017);
- SF_6 used in sound-proof windows (1995-1997);

4.7.2.2 Methodological issues

<u>Research particle accelerator</u>

SF_6 is used in university and research operated particle accelerators as an insulating gas. Typically, high voltage equipment is contained and operated within a vessel filled with SF_6 at a pressure exceeding atmospheric pressure.

There is only one research accelerator in Slovenia, it is in MIC - Microanalytical Centre at IJS. Accelerator “Tandetron” started to operate in December 1997. Acceleration of ions takes place electrostatically in a DC electric field provided by a rectifier with a voltage of up to 2 MV (two million volts). The accelerator is among the most technologically advanced electrostatic accelerators, as high voltage is created in the rectifier without mechanically moving parts with semiconductor diodes. The rectifier is very stable, because at an output voltage of 2 million volts, the voltage instability is only about 100 V.

The nameplate capacity of SF_6 is 350 kg. The largest leakages occurred at installation in 1997 and during maintenance (around 5 kg). The first maintenance was in 2011, and the following was in 2015 and 2020. According to the information from IJS they lost only 100 kg of SF_6 in 25-years of operation what includes also leakages during installation and maintenance.

For inventory purpose we are therefore using Tier 3 methodology with PS EF to be 1% in normal year and 2.4% in the year of maintenance. The IPCC 2006 GL suggests that annual losses range between 5% and 7% of vessel capacity. These values are very high and in no way suitable for our situation. The losses generally depend on the vessel opening frequency plus the efficiency of the recovery and transfer equipment. On Table 4.7.2 emissions from a research particle accelerator are presented

Table 4.7.2: **SF_6 emissions from a research particle accelerator**

	1997- installation	2011, 2015, 2020	Other years 1998-2022
Number of accelerators	1	1	1
Capacity (kg)	350	350	350
Leakages in kg at installation or maintenance	5	5	-
Leakages in kg due to the use	-	3.5	3.5
Total kg SF_6	**5**	**8.5**	**3.55**
Total kt CO_2 eq	**0.118**	**0.200**	**0.107**

<u>Electron microscopes</u>

Electron Microscopes are divided into scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

The accelerating voltage of a SEM is variable, usually in the range 0.5 to 30 kV and they don't use SF_6 as a high voltage insulator. In SEM, SF_6 is typically used as a gas that is introduced into the chamber to enhance the imaging of the sample surface by producing secondary electrons from the sample. No such use of SF_6 was detected in Slovenia.

Table 4.7.3: **SF_6 emissions from electron microscopes.**

	2002-2006	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	2017-2018	2019-2022
Number of microscope	2	3	4	5	6	7	8	9
Capacity (kg)	10	10	10	10	10	10	10	10
Total amount in kg	20	30	40	50	60	70	80	90
EF in %	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Total kg SF_6	**0.52**	**0.78**	**1.04**	**1.30**	**1.56**	**1.82**	**2.08**	**2.34**
Total kt CO_2 eq	**0.012**	**0.018**	**0.024**	**0.031**	**0.037**	**0.043**	**0.049**	**0.055**

It is different situation with a TEM which are using high voltage up to 200 kV. They are all using SF_6, there was 2 such electronic microscope in Slovenia in 2002 and the number gradually increased to 9 in 2019. A typical nameplate capacity is 10 kg. These components are sealed and there are almost no emissions during operation. The microscopes are in the special room equipped with sensors which will detect any leakages. Possibly emissions are only during the yearly maintenance. Emissions are calculated with Tier 1 approach and default EF 2.6%. from IPCC 2006 GL, Vol 3, Table 8.3 and are presented in table 4.7.3.

Medical particle accelerators

There were 2 medical particle accelerators in 1986 and since 2010 there are 8 medical particle accelerators in Slovenia. They are all located at Institute for Oncology in Ljubljana and used for radiation therapy for patients with a cancer. No detailed data about this accelerators is available to the inventory team, therefore emissions are calculated using Tier 1 approach and default values from the IPCC 2006 GL, Vol 3, Table 8.9. The amount of SF_6 used is 0.5 kg/accelerator and leakages are 2%.

Emissions are presented on the Table 4.7.4.

Table 4.7.4: **SF_6 emissions from medical particle accelerators.**

	1986-1989	1990-1994	1995-2000	2001-2005	2006-2008	2009	2010-2022
Number of medical PA	2	3	4	5	6	7	8
Capacity (kg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total amount in kg SF_6	1	1.5	2	2.5	3	3.5	4
EF (kg/kg)	2	2	2	2	2	2	2
Total kg SF_6	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Total kt CO_2 eq	**0.047**	**0.071**	**0.094**	**0.118**	**0.141**	**0.165**	**0.188**

Industrial accelerators

It is not easy to get information about the use of linear particle accelerators (LPAs) in the industry because they do not publish this information online, as do medical or research institutions. That's why we turned to the Nuclear Safety Administration of the Republic of Slovenia for help, since in accordance with the legislation (Regulation on Radiation Activities), it keeps records of LPAs, which are radiation facilities of minor importance.

There are two facilities of this type in Slovenia - one is used for scanning trucks in the port of Koper, and the other for sterilizing new medical equipment. The nameplate capacity of the first one is 4 kg and the second one 1.55 kg SF_6.

Emissions from the first company are calculated with the IPCC default EF from IPCC 2006 GL, Vol 3, Table 8.2. which is suitable for Europe.

Emissions in the second companies was very high in the past, because they had a lot of breakdowns, which require repairs several times a year. During this repairs, all SF6 was released, and the supply pipes were also purged with SF6. They will no longer do this in the future, they have also acquired their own device for gas cleaning, which will enable that after cleaning the SF_6 is returned to the system. In calculation of emissions from this company their estimate of yearly leakages are included (Tier 3)

Emissions from this source are in the Table 4.7.5 below.

Table 4.7.5: **SF_6 emissions from industrial accelerators.**

	2017	2018	2019	2000	2021	2022
Number of companies	1	1	1	2	2	2
Amount in kg	1.55	1.55	1.55	5.55	5.55	5.55
Total kg SF_6	**45**	**36**	**31**	**10.3**	**3.3**	**2.8**
Total kt CO_2 eq	**1.058**	**0.846**	**0.728**	**0.242**	**0.077**	**0.065**

Sound-proof windows

In the period 1995-1997 the production of double-glazed sound-proof windows had occurred in Slovenia. All windows had been exported, thus no emissions from stock occurred. Since 1997 there has been no use of SF_6 for production of the soundproof windows in Slovenia. According to the Regulation on certain fluorinated greenhouse gasses, placing of double glazed windows filled with SF_6 on the market has also been prohibited in EU countries since 4 July 2007. (Regulation (EC) No 842/2006, Article 9 and Annex II.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:161:0001:0011:EN:PDF

The amount of SF_6 in the sound-proof windows have been estimated by the research project carried out by the Chamber of Commerce and Industry of Slovenia in 1999. For the calculation of emissions from manufacturing the EF of 10% has been used.

4.7.2.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgement.
The uncertainty of the activity data amounts to 20%.
The uncertainty of the emission factor amounts to 10%.

4.7.2.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.7.2.5 Category-specific recalculations

Emissions of SF_6 were recalculated for the entire period 1986-2021 due to inclusion of emissions of SF_6 from other uses like particle accelerators used in medicine, research and industry and electron microscopes. This emissions were calculated and included in the inventory for the first time. Due to the problems with adding the relevant child node in CRT Reporter, these emissions are included in the CRT category 2.G.2 Soundproofed Windows. We will report these emissions in the separate category when ETF Reporting Tools will be operational.

4.7.2.6 Source-specific planned improvements

No improvements are planned for the next submission.

4.7.3 N_2O from Product Uses (CRT 2.G.3)

4.7.3.1 Category description

Evaporative emissions of nitrous oxide (N_2O) can arise from various types of product use. Medical applications and use as a propellant in aerosol products, primarily in the food industry are likely to be dominant sources. All emissions from this category are reported under CRT code 2G3a: N_2O from Medical Applications, since the largest application of N_2O in Slovenia arising from the use in health service.

N_2O emissions from CRT code 2G3b: Other are reported as IE. CRT code 2G3b covers the use of N_2O as a propellant in aerosol products in the food industry. The emissions from that category are included under CRT code 2G3a.

4.7.3.2 Methodological issues

N_2O emissions have been estimated for the period 1986-2022. N_2O emissions have been calculated from the amount of nitrous oxide used. Data on N_2O consumption for the period 1999-2022 have been obtained from SORS. Activity data for the year 1986 and the period 1993-1998 have been provided in the scope of the research project done by the Chamber of Commerce and Industry of Slovenia. Activity data for the period 1987-1992 was estimated by nearest-neighbour interpolation method. 2006 IPCC emission factor of 1.0 t N_2O /t have been used for the emission calculations. Figure 4.7.1 shows N_2O emissions arising product uses.

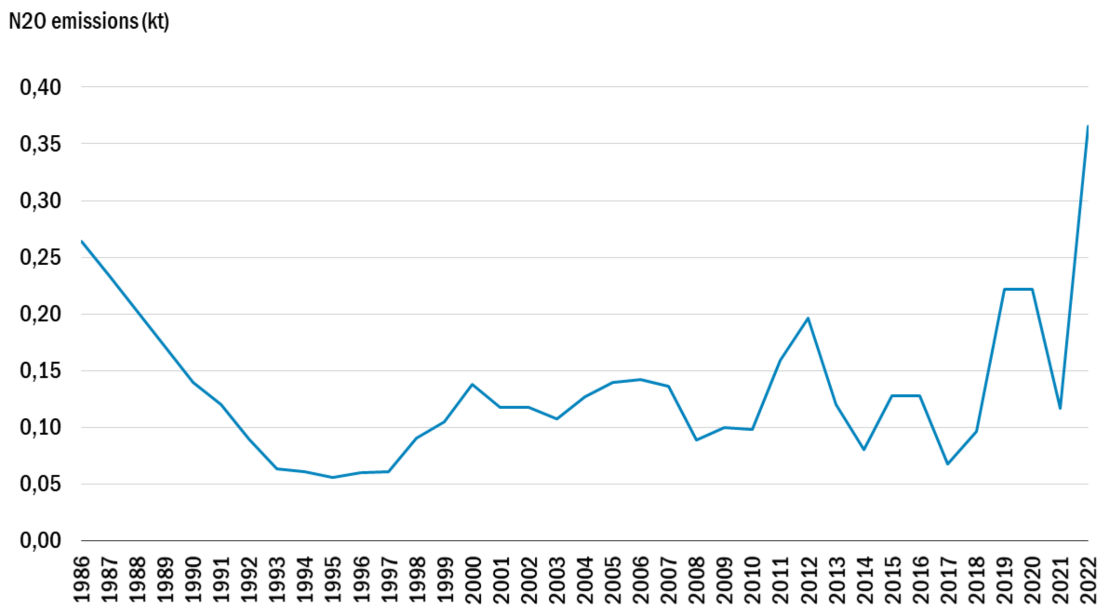

Figure 4.7.1: N_2O emissions from product uses.

4.7.3.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgement.
The uncertainty of the activity data amounts to 20%.

4.7.3.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

4.7.3.5 Category-specific recalculations

No recalculation was performed since the last submission.

4.7.3.6 Category-specific planned improvements

No improvements are planned for this category.

5 AGRICULTURE (CRT sector 3)

5.1 Overview of sector

In agricultural activities, emissions of GHGs are generated from a variety of different sources. This section includes the quantification of CH_4 emissions from livestock and manure management, N_2O emissions from manure management (direct and indirect emissions) and from managed agricultural soils (direct and indirect emissions) as well as CO_2 emissions from limestone and urea application.

Burning crop residues is not practiced in Slovenia and is prohibited by a law since 2005, therefore emissions of greenhouse gases from this source have not been considered in this report. There are no ecosystems in Slovenia that are considered natural savannahs or rice fields; consequently, no greenhouse gas emissions exist for these subcategories.

Identification of the Key categories as well as methods and EFs used are in the Table 5.1.1.

Table 5.1.1: Methods, EFs used and key categories indications for the year 2022 in the Agriculture sector.

	CO_2			CH_4			N_2O		
	Method	**EF**	**Key cat.**	**Method**	**EF**	**Key cat**	**Method**	**EF**	**Key cat**
3.A Enteric Fermentation	NA	NA	NA	T1, T2	CS, D	L, T	NA	NA	NA
3.B Manure Management	NA	NA	NA	T1, T2	CS, D	L,	T1, T2	CS, D	L
3.D.1 Direct Emissions	NA	NA	NA	NA	NA	NA	T1	D	L, T
3.D.2 Indirect Emissions	NA	NA	NA	NA	NA	NA	T1	D	L
3.G Liming	T1	D	-	NA	NA	NA	NA	NA	NA
3.H Urea application	T1	D	-	NA	NA	NA	NA	NA	NA
3.I Other C-cont. fertilizers	T1	D	-	NA	NA	NA	NA	NA	NA

In Agriculture as the second most important sector, emissions in 2022 amounted to 1,706 Gg CO_2 eq, which represents 10.9% of all emissions. Agriculture represents the main source of methane and N_2O emissions, namely 64.6% of all methane emissions and 62.2% of all N_2O emissions. In the agricultural sector, CH_4 emissions accounted for 72.5% of emissions and N_2O emissions accounted for 25.6% of emissions, while CO_2 emissions accounted for 1.9% only. GHG emissions from agriculture show small oscillations for individual years, but the general trend is on the decrease. In 2022, emissions were 16.3% below the emissions in the base year.

The most important sub-sector represented emissions from enteric fermentation, which contributed 57.7% of all emissions from agriculture, followed by emissions from agricultural soils, with 21.6%; the rest is contributed by emissions of methane and N_2O from animal manure (18.7%) while CO_2 emissions due to the liming and application of urea and other C-containing fertilizers represented only 1.9% of emissions in this sector (Figure 5.1.1).

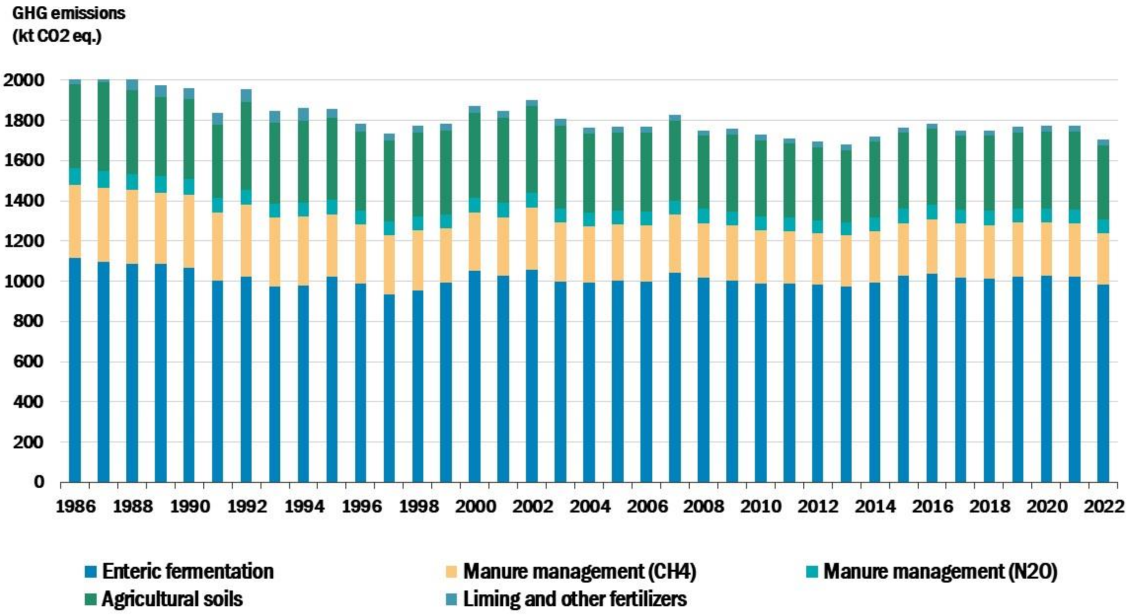

Figure 5.1.1: GHG emissions from agriculture activities in Gg CO_2 eq.

5.2 Enteric Fermentation (CRT 3.A)

5.2.1 Category description

CH_4 emissions from enteric fermentation in animals result from methane being produced as a by-product of microbial fermentation in the digestive system. This process occurs especially in the rumen of ruminant animals, but also in smaller quantities in monogastric animals (swine, horses…) where feedstuffs ferment in the large intestine. The estimates in this inventory comprise only emissions in farm animals. Emissions from wild animals and semi-domesticated game are not quantified and neither are emissions from humans or pet animals.

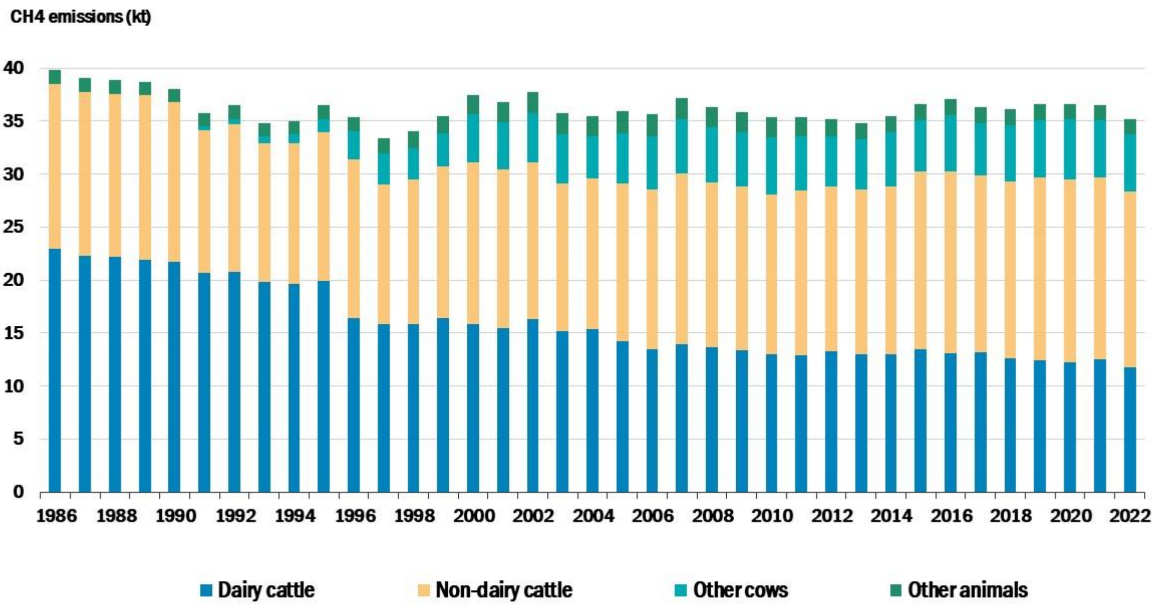

Figure 5.2.1: CH_4 emissions from enteric fermentation in Gg.

CH_4 emission from enteric fermentation is a key source, both by level and trend. Dairy cows and non-dairy cattle (including other cows) are significant sources: dairy cows represent 34.9% of total CH_4 emissions from enteric fermentation, other cows 15.9%, while non-dairy cattle represent about 49.2% of total CH_4 from enteric fermentation. Jointly, cattle are responsible for 95.9% of total CH_4 emissions from enteric fermentation in 2022 (Figure 5.2.1).

The contribution of all other animals to methane emissions from enteric fermentation, e.g. sheep, horses, swine, goats and rabbits, listed here according to the importance of their contributions, is around 4%. No methodology for calculating CH_4 emission from poultry is available in IPCC guidelines, for this reason emissions are not calculated and notation key NE is used.

5.2.2 Methodological issues

The methodology suggested by IPCC (2019) was used to assess the of CH_4 emissions from enteric fermentation.

The majority of activity data were obtained from the Statistical Office of the Republic of Slovenia (SORS). They are also available on the web page: http://www.stat.si/eng/index.asp

The agriculture statistics is on the SI-STAT data portal, under Environment and natural resources: http://pxweb.stat.si/pxweb/Database/Environment/Environment.asp

Some pieces of information, such as number of calves per cow and year, concentration of fat in milk for the period before the year 2000 and average daily gains in fattening cattle, were obtained from Central database CATTLE, managed by Agricultural Institute of Slovenia (most recent reports by Sadar et al., 2023 and Žabjek et al., 2023 or calculated on request).

Table 5.2.1: The correspondence between statistical and IPCC categories

IPCC	SORS
Dairy cattle	**Dairy cows over 2 years**
Other cows (suckler-cows)	**Other cows over 2 years**
Non-dairy cattle	**All other cattle**
Non-dairy cattle	**YOUNG CATTLE – under 1 year** calves for slaughter- young bulls calves for slaughter - young heifers calves for fattening - young bulls calves for fattening - young heifers **YOUNG CATTLE – 1 -2 years** breeding heifers in calf other breeding heifers heifers for fattening bulls, oxen **CATTLE – over 2 years** breeding heifers in calf other breeding heifers heifers for fattening bulls for breeding bulls and oxen for fattening

In the category dairy cattle, only dairy cows have been included. Other cows (suckler cows) were treated differently due to the production of milk for calf. Non-dairy cattle consists of all other cattle groups. The correspondence between statistical and IPCC categories are evident from the Table 5.2.1 above.

Before 1997, SORS collected data on the number of livestock by ownership and as of December 31. Data on livestock in agricultural enterprises were collected and reported in the Annual Report on Livestock Production, while data on livestock on family farms were collected in the Sample Survey on the Number of Livestock. Data on the number of livestock on family farms as of December 31, 1991 were estimated on the basis of the 1991 Census of Population, Households, Housing, and Agricultural Holdings. Some data on the number of livestock were taken from other administrative sources (Secretariat for Agriculture, Forestry and Food).

In 1997, SORS started collecting data on the number of livestock several times a year: data on the number of pigs were collected three times a year (April 1, August 1, and December 1), data on cattle twice a year (June 1 and December 1) and data on sheep and goats once a year (December 1). Data on family farms and agricultural enterprises were collected by mail, separately for cattle, pigs, sheep, and goats. All agricultural enterprises were covered, but only those family farms that were selected in the sample. In 1997, the date of monitoring the number of animals changed: because of the harmonisation with EU standards, we no longer collect these data as of December 31, but as of December 1. Data on animal output up to 1997 are therefore not entirely comparable with data since 1997.

Since 2000, SORS has been collecting data on the number of livestock twice a year (June 1 and December 1) for cattle and pigs, and once a year (December 1) for sheep and goats, and poultry. To facilitate presentation of data on the structure of agricultural holdings, the number of animals is shown by where they are stabled and not by ownership as was the case until 2000. In the December 2002 survey, the data on the number of animals were collected with fieldwork and not by mail; this accounts for some differences between the individual periods.

In 2003, SORS published revised data on livestock numbers and production for the period 1991-2002. These data were published in Rapid Reports No. 256. The main purpose of this revision was the methodological harmonisation of data and methods of estimating data for the mentioned period. This methodology is harmonised with recommendations of the Statistical Office of the European Communities. Corrections refer to livestock number and production, while the data on total number of animals did not change. Not all published data were revised. Some remained the same. Explanations of corrections are therefore valid only for the revised data. Data were revised on the basis of the 2000 Census of Agriculture.

The explanations of corrections were divided into two parts: number of livestock and livestock production. Data on cattle, pigs, poultry, sheep and goats were mostly revised in the same way. Differences appear due to particularities of the individual species, the previous method of data collection for individual species of domestic animals and the quality of collected data.

In all monitored years, data on the total number of animals were obtained with statistical surveys and have not been corrected, but changes have been made to the year that the data refer to. Before 1997, each year data about animal population were collected on December 31 and in the past they were applied for the next year, but now SORS considers these data to be valid for the current year. Because SORS did this only for data from 1991 (the year Slovenia became an independent state), we have to change all data prior to 1991 in the same way by ourselves.

But discrepancies with FAO data still exist. In the FAO database, livestock numbers have been grouped in 12-month periods, ending on September 30 of the year stated in the tables. SORS collects data on animal population in December and reports them in the current year. In the FAO database, these data are applied for the next year. Considering this explanation, all data on animals in the FAO database and in our statistical database are the same. The only difference is in the number of poultry, where our entire poultry population is shown in the FAO database as chicken population.

2019 IPCC methodology provides two different methods for estimating the quantity of methane from enteric fermentation. A more detailed method (Tier 2) for calculating emissions is used for cattle because of the comparatively large population and considerable emission per head and the default methodology (Tier 1) is used for other animals.

5.2.2.1 Cattle (CRT 3.A.1)

Dairy cattle

The method for estimation of emissions due to enteric fermentation is based on data on dairy cow population (Figure 5.2.2) and their performance expressed in terms of milk production per year (Figure 5.2.3), milk composition, pregnancy rate and activity (grazing). IPCC (2019) methodology was used taking into account the local production practices.

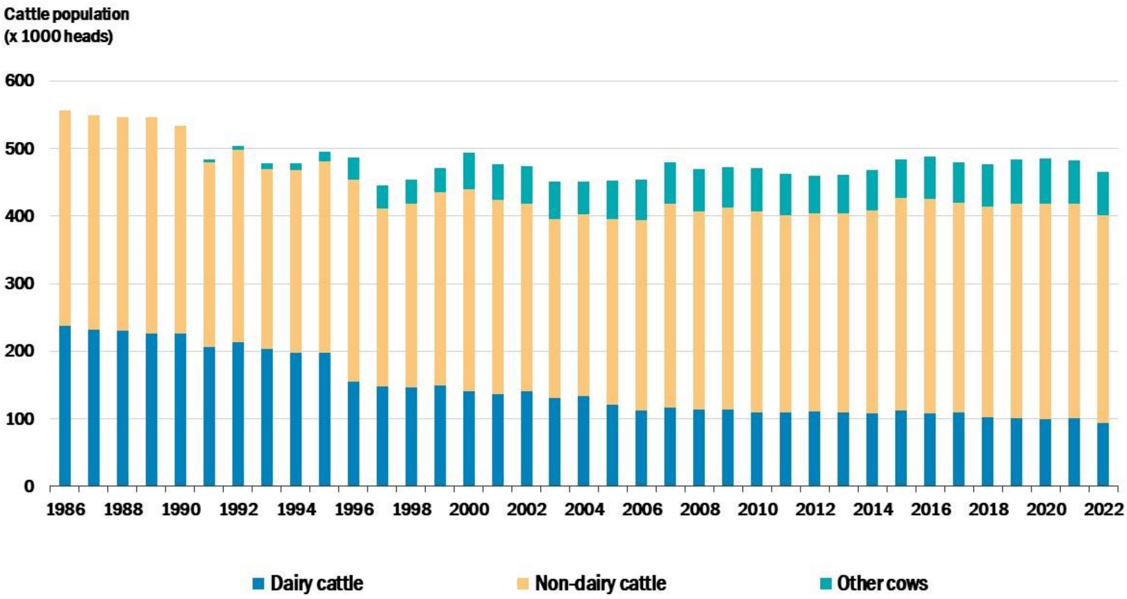

Figure 5.2.2: Number of cattle, dairy, non-dairy, and other cows in thousands.

In the first step, net energy requirements for the maintenance (NE_m), activity (NE_a), milk production (NE_l) and pregnancy (NE_p) were estimated. Maintenance requirements were calculated on the basis of animal weight. It was supposed that animals producing more milk were heavier than those producing less milk. The relationship W = 418.8 + 0.0313 × M was used to estimate body weight (W, in kg). M in the equation is the milk production in standard lactation (kg in 305 days). The equation was first proposed in 2009. It is based on expert estimates. In 2023, the equation was tested on the basis of data from slaughterhouses. The equation was found to be appropriate and it was therefore decided not to make any changes. In case of grazing, additional energy required for animals to obtain their food was added up (NE_a, 17 % of maintenance requirements). Coefficient which was used to calculate the net energy required for maintenance was increased by 20% in case of cows in lactation (i.e. 0.386 MJ d^{-1} kg^{-1}, IPCC, 2019). Requirements for milk production were estimated on the basis of milk production and milk fat content. Requirements for pregnancy were calculated on the basis of cow weight and constant (10 % of maintenance requirements) according to IPCC (2019). In order to express the requirements for pregnancy on a yearly basis (365 days) the obtained values were multiplied by the number of calves per cow and year. In Slovenia, cattle are not used for work. Therefore, no requirements for this kind of activity were taken into account.

In the second step, the gross energy intake was estimated on the basis of net energy requirements that were estimated during the first step. To do this, the information on the concentration of net energy for lactation in diets is needed. It is the most critical point of the whole procedure. Overestimation of the net energy concentration in the diet would result in underestimation of gross energy intake and vice versa. It may considerably affect the final result. The concentration of the net energy for lactation depends mainly on its concentration in the basal diet and on the proportion of concentrates in the diet. The latter depends largely on daily milk production and intake capacity of a dairy cow. Therefore, it was decided to use country-specific data at this stage. Based on data from milk recording (the monitoring service performs monthly measurements of the milk yield of every individual cow) a total of 705.860 lactation curves were calculated for the period between January 1, 2000 and June 1, 2009. On the basis of the results, typical lactation curves for the range between 3500 and 12000 kg of milk in standard lactation were calculated for the intervals of 500 kg. Expected daily milk yields (for each individual day in lactation) were calculated for all these classes.

Based on daily milk yields and assumed concentrations of net energy for lactation in basal diet, the required proportions of concentrates in diets were estimated roughly. The equation for total mixed ratios presented by Spiekers (2004) was used. The rough estimates of the amount of concentrates in the diets enabled the use of more precise equation for prediction of dry matter intake (Gruber et al., 2006). Various parameters, such as breed, day of lactation, body weight, daily milk production in dependence on day of lactation, amount of concentrates, and concentration of net energy for lactation in the basal diet were used to predict dry matter intake for each individual day within each individual production class.

On the basis of forage quality in Slovenia it was estimated that with the increasing milk yield from 3500 to 8000 kg per standard lactation the concentration of net energy for lactation in the basal diet increased from 5.4 to 6.4 MJ per kg dry matter and remained on the same level at higher milk yields. It was also assumed that with increasing milk yields the concentrations of net energy for lactation in concentrates increased from 7.6 to 8.2 MJ per kg of dry matter. The concentration of net energy for lactation in the diet was calculated as a quotient between the animal requirements for maintenance, milk production and pregnancy on the one hand and potential dry matter intake on another. National feeding standards (Verbič and Babnik, 1999) were used to assess the requirements. The average concentration of net energy for lactation in the diet was obtained by averaging the daily values over the whole lactation and dry period. Information on the concentration of net energy for lactation was then transformed to organic matter digestibility (dOM) by the use of equation

$$dOM = 24.12 + net\ energy\ for\ lactation \times 7.9.$$

The equation was derived on the basis of wide range of forages, cereals and oil seed meals presented in DLG Feeding Tables (DLG, 1997). Energy digestibility (DE%) was estimated as

$$DE\% = dOM - 3.1.$$

The relation was obtained on the basis of equations presented by INRA (1989) taking into account that diets are composed of grassland forages, maize silage and cereals. Finally, the gross energy intake (GE) was calculated as:

$$GE = \frac{\frac{NE_m + NE_a + NE_l + NE_p}{REM}}{\frac{DE\%}{100}}.$$

The ratio of net energy available for maintenance to digestible energy (REM) was calculated as suggested by IPCC (2019).

The emission factor was calculated from the data on gross energy intake (GE) and the methane conversion rate (Y_m, %) according to IPCC (2019):

Emissions (kg/animal/year) = (GE (MJ/year) × Y_m (%) ÷ 55.65 MJ/ kg methane)/100

The methane conversion rates (Y_m) were linked to productivity (milk yield) using the following equation:

Y_m = 7.2309 – 0.000142857 × milk yield (kg/animal/year)

The equation was derived from the data in IPCC (2019). It resulted in the same values as in the manual (6.5 for 5000 kg and 6.0 for 8500 kg milk per year). The EFs and milk yields are shown in Table 5.2.2 and Figure 5.2.3.

Table 5.2.2: Milk yield and EFs for dairy cattle in kg/head/year.

	1986	1987	1988	1989	1990	1991	1992	1993	1994
Milk yield	2818	2763	2770	2796	2774	3252	2836	2800	3015
EF	96.8	96.3	96.4	96.6	96.5	100.5	97.4	97.4	99.4
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Milk yield	3168	3833	3975	4092	4252	4625	4807	5198	5063
EF	100.9	106.2	107.4	108.4	109.8	112.7	114.1	116.8	115.9
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Milk yield	4855	5479	5709	5727	5763	5530	5519	5515	5592
EF	114.6	118.7	119.6	119.9	120.3	118.7	118.7	118.8	119.4
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Milk yield	5435	5716	5598	6024	5954	6123	6178	6356	6341
EF	118.6	120.2	119.1	121.7	121.5	122.6	122.8	123.8	124.0
	2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Milk yield	6706								
EF	126.4								

Emission factor for methane released from enteric fermentation depends mainly on the level of milk production. By the increase of annual milk production from 3000 to 6000 kg of milk per cow, the emissions increase from about 101 to 122 kg of methane per year. Average milk production per cow was more than doubled during the period 1986 – 2022. The increase was due to transition to open market economy and was accompanied by specialization of dairy sector. The proportion of concentrates in the diets for dairy cows increased and dual purpose Simmental and Brown Swiss cows were in part replaced by cows of specialized Holstein-

Frisian breed. The increase in milk yield was also affected by the public agricultural advisory service and by the results of breeding programmes.

The increase in IEF for dairy cattle is due to the increase in the milk yield. In 2022, the CS EF (126.4 kg/head/year) was comparable to the updated EF for dairy cattle for Western Europe from IPCC 2019 Refinement (126 kg/head/year) and considerably higher than updated default EF for Eastern Europe (93 kg/head/year) from the same source. Since agriculture sector in Slovenia is more similar to the systems in the countries from West Europe, the CS EF seems reasonable.

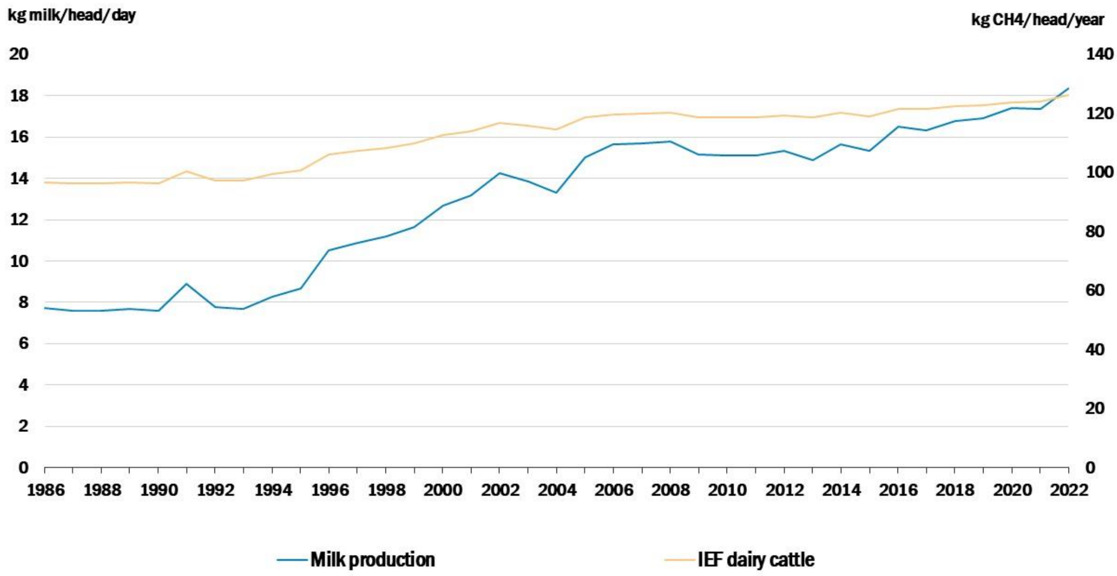

Figure 5.2.3: Milk production per cow in kg milk/head/day and IEF in kg CH_4/head/year.

Other cows

This category appeared after 1990. SORS differentiates between dairy cows and suckler-cows from the year 1996; the figure for the year 1995 is based on the number of premiums paid for suckler-cows and for the years 1991-1994 the numbers were estimated by an expert (Volk, personal communication). Data on pregnancy rate was obtained from Agricultural Institute of Slovenia (CATTLE database). For suckler-cows it was considered that the amount of emitted methane was equal to the amount attributed to dairy cows with 3000 kg of milk per lactation. Due to variation in pregnancy rate CS EF varied from 83.5 to 84.1 kg per cow per year (Table 5.2.3).

Non-dairy cattle

This group comprises young cattle (cattle for fattening, heifers) and sires (breeding bulls). Data on the number of heads of non-dairy cattle according to different categories are reported by the SORS.

The method for estimation of emissions due to enteric fermentation is based on data on population and their performance expressed in terms of growth rate, pregnancy rate and activity (grazing). IPCC (2019) methodology was used taking into account the local production practices.

Young cattle (cattle for fattening, heifers)

Since in younger animals the rumen does not function normally yet, calves up to the age of 3 months were not considered. In calculating methane emissions, only ¾ of young bovine animals up to 1 year were considered.

In the first step, net energy requirements for the maintenance (NE_m), activity (NE_a), growth (NE_g) and pregnancy (NE_p) were estimated. Maintenance requirements were calculated on the basis of the average animal weight. For heifers it was supposed that the final weight is 90 % of the weight which characteristic for dairy cows (see 5.2.2.1). For the fattening cattle the final weight of 650 kg was supposed. Average weight was calculated on the basis of expected final weight and expected weight at the age of 3 months. In case of grazing, additional energy required for animals to obtain their food was added up (NE_a, 17 % of maintenance requirements). Coefficient which was used to calculate the net energy required for maintenance of heifers was 0.322 MJ d^{-1} kg^{-1} (IPCC, 2019). It was increased by 15% in case of intact males (i.e. 0.335 MJ d^{-1} kg^{-1}, IPCC, 2019). Requirements for growth were estimated on the basis of information on growth rate, average body weight and specific body weight of adult female. For the heifers the growth rate was calculated by dividing the difference between final and birth weight by the expected age at first calving (in days). For fattening cattle no exact data on daily gains existed for the period before 2005. There was official information (Statistical Yearbook) on total weight gain (country level) and number of various cattle categories for the year 1986. It has been assumed that the weight gain of growing heifers from their sixth month of age to first mating amounts to 600 g per day, and of pregnant heifers to 500 g per day. The remaining weight gain (according to the Statistical Yearbook) has been equally distributed across other growing categories of cattle and thus the average daily weight gain for young bovine animals for fattening has been assessed as 740 g per day. Since 2005, more precise average daily gains for young bovine animals for fattening have been obtained. For the period 2005-2009, they were calculated based on slaughter date and slaughter weight data from slaughterhouses and on the birth dates of individual animals recorded in the Central database CATTLE (Verbič and Jeretina, 2009, unpublished). This is a large database to which public access cannot be granted. Since 2010, data on daily gains have been published regularly by the Agricultural Institute of Slovenia (most recent report by Žabjek et al., 2023). Average daily gains between 1986 and 2005 were estimated by interpolation. For the period 2005-2022, average daily gains on a yearly basis were used for calculations. Requirements for growth were calculated according to equation given by IPCC (2019), taken into account a specific coefficient C= 0.8 for females and C=1.2 for males. In heifers, the requirements for pregnancy were calculated on the basis of adult cow weight and a constant value of 10% of its maintenance requirements (IPCC, 2019). In order to express the requirements for pregnancy on a yearly basis (365 days) the obtained values were multiplied by the factor (365/age at first calving).

In the second step, the gross energy intake was estimated on the basis of net energy requirements that were estimated during the first step. To transform net energy requirements into gross energy, the estimated energy digestibility was needed. Equations to predict the energy digestibility for individual categories were estimated on the basis of national feeding standards (Verbič and Babnik, 1999) and the expected feed intake was estimated according to Kirchgeßner et al. (2008). In the first step the required concentrations of the metabolisable energy were assessed. In the second step they were converted into organic matter digestibility (dOM) by the use of equation:

$$dOM = 13.95 + \text{concentration of metabolisable energy} \times 5.74.$$

The equation was derived on the basis of wide range of forages, cereals and oil seed meals presented in DLG Feeding Tables (DLG, 1997). Then it was converted into energy digestibility (DE%) using the same conversion factor as described for dairy cattle. The following equations for predicting average energy digestibility (DE%) were derived on the basis of the above mentioned procedure:

Cattle for fattening $DE\% = 57.2 + 13.72 \times \text{daily weight gain (g)}$

Breeding heifers $DE\% = 54.9 + 16.28 \times \text{daily weight gain (g)}$

Finally, the gross energy intake (GE) was calculated as:

$$GE = \frac{\frac{NE_m + NE_a + NE_p}{REM} + \frac{NE_g}{REG}}{\frac{DE\%}{100}}$$

The ratio of net energy available for maintenance to digestible energy (REM) and the ratio of net energy available for growth to digestible energy (REG) were calculated as suggested by IPCC (2019).

Emission factor was calculated from data on gross energy intake (GE) and methane conversion rate (Y_m, %) according to IPCC (2019):

Emissions (kg/animal/year) = (GE (MJ/year) × Y_m (%) ÷ 55.65 MJ/ kg of methane)/100

For methane conversion rate (Y_m) the value of 6.3% was used, as recommended by IPCC (2019).

Table 5.2.3: EFs for non-dairy cattle and other cows in kg/head/year

	1986	1987	1988	1989	1990	1991	1992	1993	1994
Other cows	84.1	84.0	84.0	84.0	84.0	84.1	84.0	84.1	84.0
Heifers	48.0	47.9	47.9	48.0	47.9	48.8	48.1	48.0	48.5
Cattle for fattening	55.4	55.6	55.7	55.8	55.9	56.1	56.2	56.3	56.5
Breeding bulls	69.8	69.8	69.8	69.8	69.8	69.9	69.9	70.0	70.1
Other cattle	48.7	48.7	48.7	48.8	48.8	49.3	49.1	49.1	49.4
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Other cows	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	83.9
Heifers	48.7	49.9	50.2	50.4	50.7	51.3	51.7	52.4	52.2
Cattle for fattening	56.6	56.8	56.9	57.1	57.2	57.4	57.5	57.6	57.7
Breeding bulls	70.1	70.2	70.2	70.3	70.4	70.4	70.4	70.4	70.5
Other cattle	49.6	49.8	50.0	50.1	50.3	51.1	51.9	53.0	52.8
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**

Other cows	83.9	83.8	83.8	83.8	83.8	83.7	83.7	83.7	83.7
Heifers	51.9	53.0	53.4	53.5	53.5	53.2	53.1	53.2	53.2
Cattle for fattening	57.8	58.0	58.0	58.1	57.9	57.8	57.8	57.9	57.9
Breeding bulls	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5
Other cattle	52.7	53.8	53.6	53.2	52.9	51.5	50.9	53.1	53.2
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Other cows	83.7	83.5	83.5	83.5	83.6	83.5	83.5	83.5	83.5
Heifers	53.0	53.5	53.2	53.9	53.7	53.9	54.0	54.4	54.3
Cattle for fattening	57.9	57.8	57.9	57.9	57.9	58.3	58.2	58.2	58.2
Breeding bulls	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6
Other cattle	52.8	53.0	53.6	53.9	53.4	53.8	54.5	54.1	54.0
	2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Other cows	83.6								
Heifers	54.8								
Cattle for fattening	58.3								
Breeding bulls	70.6								
Other cattle	53.9								

Breeding bulls

Emissions for breeding bulls were estimated by the use of same principles as for young cattle. The body weight of 700 kg and no daily gain were taken into account. It was estimated that energy digestibility of the diet has to be 60.6%. The value was derived on the basis of requirements and expected dry matter intake as summarized by Kirchgeßner et al. (2008).

The country specific CH_4 EFs are presented on the Table 5.2.3. Emission factors for non-dairy cattle are affected not only by differences in emission factors for individual categories, but also by the ratios in their abundance. Thus, for 2009 and 2010, non-dairy cattle were characterized by very low emission factors. It can be explained by a significant increase in the proportion of calves for slaughter (by 83 and 106% compared to the 2004-2008 average). Since in younger animals the rumen does not function normally yet, calves are not considered to be a source of methane from enteric fermentation. The reason for the increase in the extent of slaughter of calves in 2009 and 2010 is in very poor economic situation. In 2009, milk prices decreased by more than 20% compared to 2008. In 2010, milk prices increased slightly again (+ 2.1% compared to 2009), but nevertheless remained significantly lower than in the previous period. The year 2011 was again more optimistic for the cattle sector (milk prices increased by 13.8%). It resulted in reduction of slaughter of calves and also their number decreased to a similar level as before.

All other data, which are not presented in the NID, are available in the Annex 3 to the NID and in the CRT tables.

5.2.2.2 Swine (CRT 3.A.3)

The number of swine (Figure 5.2.4) has been taken from the Statistical Yearbook.

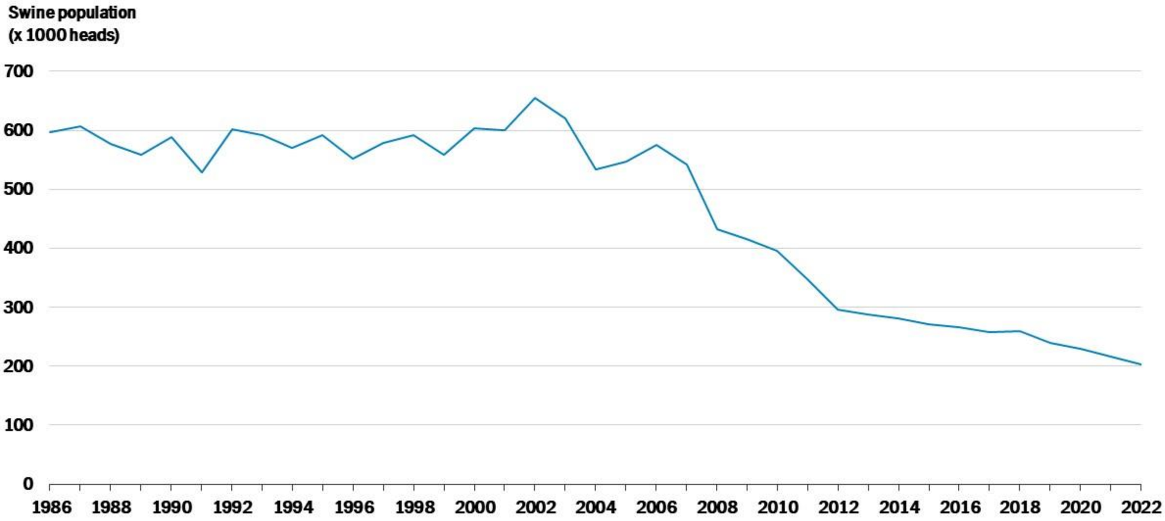

Figure 5.2.4: Number of swine in thousands.

Methane emissions have been estimated by applying default emission factors according to IPCC (2006) methodology, i.e. 1.5 kg per year.

5.2.2.3 Sheep (CRT 3.A.2.) and Goats (CRT 3.A.4)

The SORS has changed its methodology of estimating the population of sheep and started to publish data on the number of goats (Statistical Information, No. 197, 1998). For breeding sheep, re-established data from 1992 to 1997 are available. The total number of sheep (Figure 5.2.5) has been estimated on the basis of data on breeding sheep for the period 1992 to 1997 by applying the interacting ratio between breeding sheep and all sheep in 1997. For the time prior to 1992, the numbers from old statistical yearbook have been taken. The number of goats (Figure 5.2.5) has been estimated in the same way as the number of sheep. As goats have not been counted before 1992, we consider the number of 8.000 heads as an estimate. The population data does not include lambs and young goats.

Considering the rather small number of sheep and goats, Tier 1 methodology and default EFs from the IPCC (2006) guidelines have been used for estimating methane emissions; 8 kg of methane annually per head for sheep and 5 kg of methane for goats.

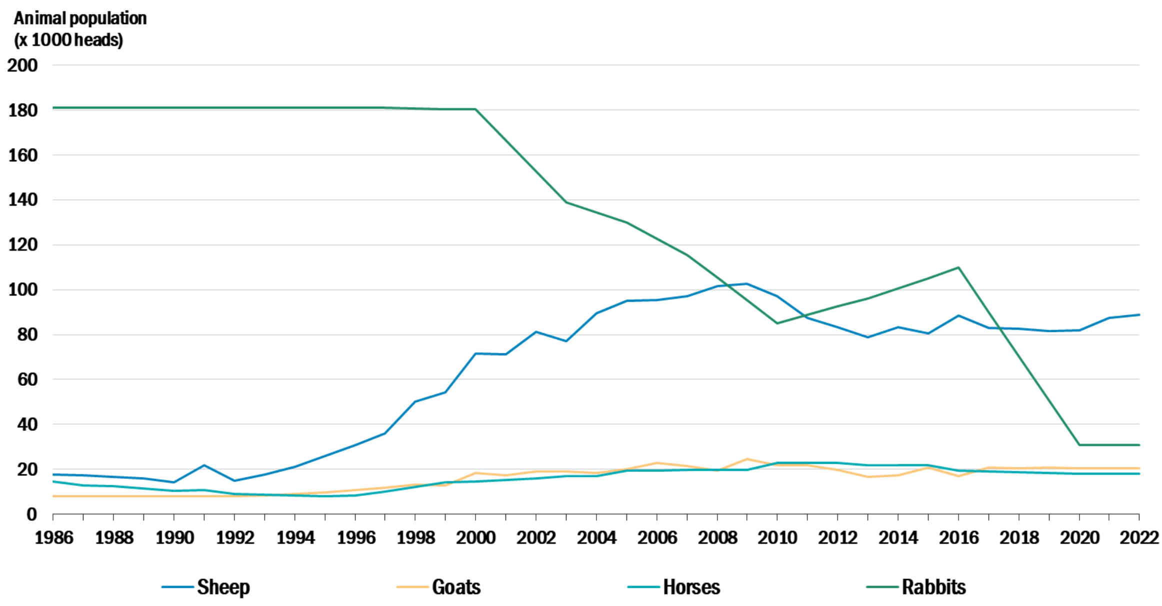

Figure 5.2.5: Number of sheep, goats, horses and rabbits in thousands.

5.2.2.4 Horses (CRT 3.A.4)

The number of horses (Figure 5.2.5) was taken from the SORS. Data are based on the Census of Agriculture (2000, 2010 and 2020) or the Farm Structure Surveys (2003, 2005, 2007, 2013 and 2016). For the years in between, the values were estimated by interpolation. For 2021 and 2022, the same values as for 2020 were used. Methane emissions have been estimated by applying default emission factors according to IPCC (2006) methodology, i.e. 18 kg per year.

5.2.2.5 Rabbits (CRT 3.A.4)

The number of rabbits (Figure 5.2.5) was taken from the SORS. Data are based on the Census of Agriculture (2000, 2010, and 2020) or the Farm Structure Surveys (2003, 2005, 2007, 2013 and 2016). For the years in between, the values were estimated by interpolation. For 2021 and 2022, the same values as for 2020 were used. Methane emissions have been estimated by applying emission factor used in the Italian GHG inventory, i.e. 0.08 kg per animal per year.

5.2.3 Uncertainties and time-series consistency

Data on the number of livestock are not collected according to ownership of the livestock but according to who manages the livestock. The sample for the statistical survey on the number of livestock is selected according to the sampling methodology. Data collected using the sample is representative for the entire country. The sample is divided into four strata; each of them is determined regarding the size class of agricultural holding. The sample thus covers all large agricultural holdings, while other agricultural holdings are selected proportional to size class and represent a specific weight in their size class. Based on information from SORS, the uncertainty of activity data is 10%.

According to 2006 IPCC Guidelines, the uncertainty of the EFs when using default methodology is at least 30%, but could be as high as 50%. When Tier 2 methodology is used, the uncertainty is likely to be in the range of 20%. As most emissions in this category are estimated using Tier 2 methodology, uncertainty estimate of 20% have been used

The combined uncertainty, calculated according to 2006 IPCC Guideline, Tier 1 methodology, amounts to 22.36%.

5.2.4 Category-specific QA/QC and verification

For calculation of emissions from agriculture a model which simultaneously assesses emissions of greenhouse gases, air pollutants and N balance has been developed. The main purpose of this model is the harmonization in reporting of the emissions of GHG and other pollutants. Calculations in the model have been thoroughly vetted by experts in the KIS and in the SEA. Any errors that were found have been corrected.

As an important QA/QC is also the ESD review, where all IEF and AD are compared with other countries and all outliers have to be justified.

5.2.5 Category-specific recalculations

The methane conversion factors (YM) for cattle have been updated. The values from the 2006 IPCC Guidelines have been replaced by values from the 2019 Refinement to the 2006 IPCC Guidelines. In the case of dairy cows, the YM values were linked to the intensity of milk production.

5.2.6 Category-specific planned improvements

No major improvements are planned

5.3 CH_4 Emissions from Manure Management (3.B)

5.3.1 Source category description

In storing solid and/or liquid manure, both methane and N_2O are emitted. Emissions depend largely on the type of the manure. Methane arises in significantly larger amounts when manure is managed as slurry, while N_2O prevails in storage of solid manure.

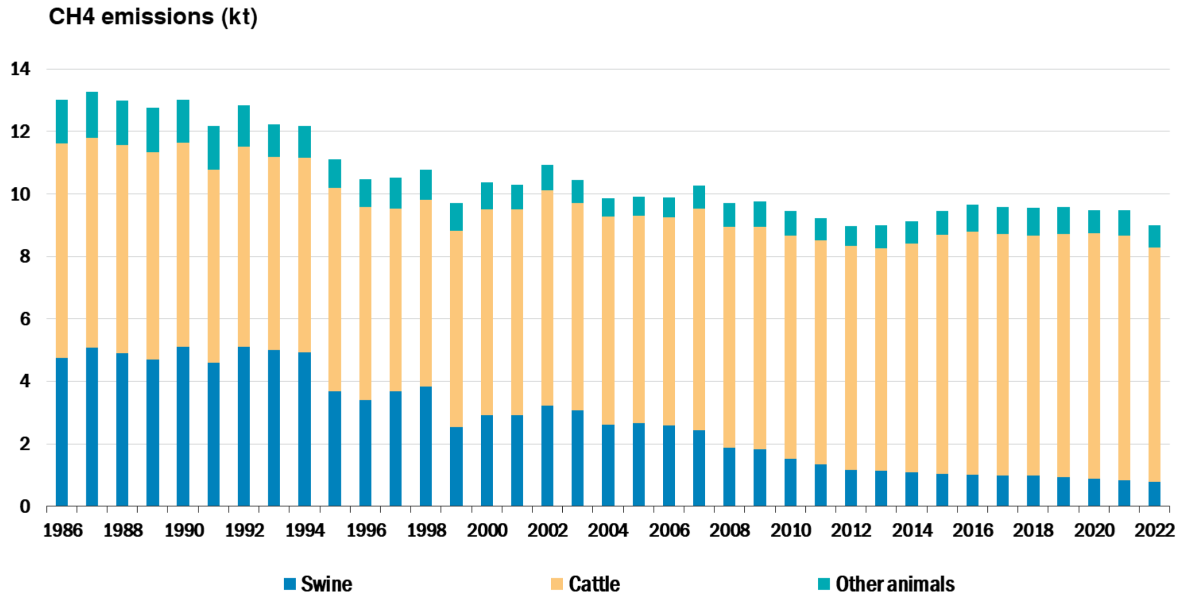

Figure 5.3.1: CH_4 emissions from manure management in Gg.

Significant quantities of methane are emitted during the decomposition of animal excreta. Under anaerobic conditions, methane-producing bacteria convert organic matter into methane. The quantities of produced methane are largely dependent on the type of manure management system and environment temperature. Storing manure in lagoons or as slurry produces significantly greater quantities of methane compared to grazing on pasture or solid manure storage.

To estimate the amount of methane produced during manure management (Figure 5.3.1), it is necessary to know the quantities of excreted volatile solids (VS), methane-producing capacity of manure (B_0, in m^3 per kg of VS), and the manure management system (MMS) which result in specific methane conversion factor (MCF). The climate in Slovenia is cool (average yearly temperature is about 11°C, Figure 5.3.2). The map with the average temperature in the period 1991-2020 is not available, yet.

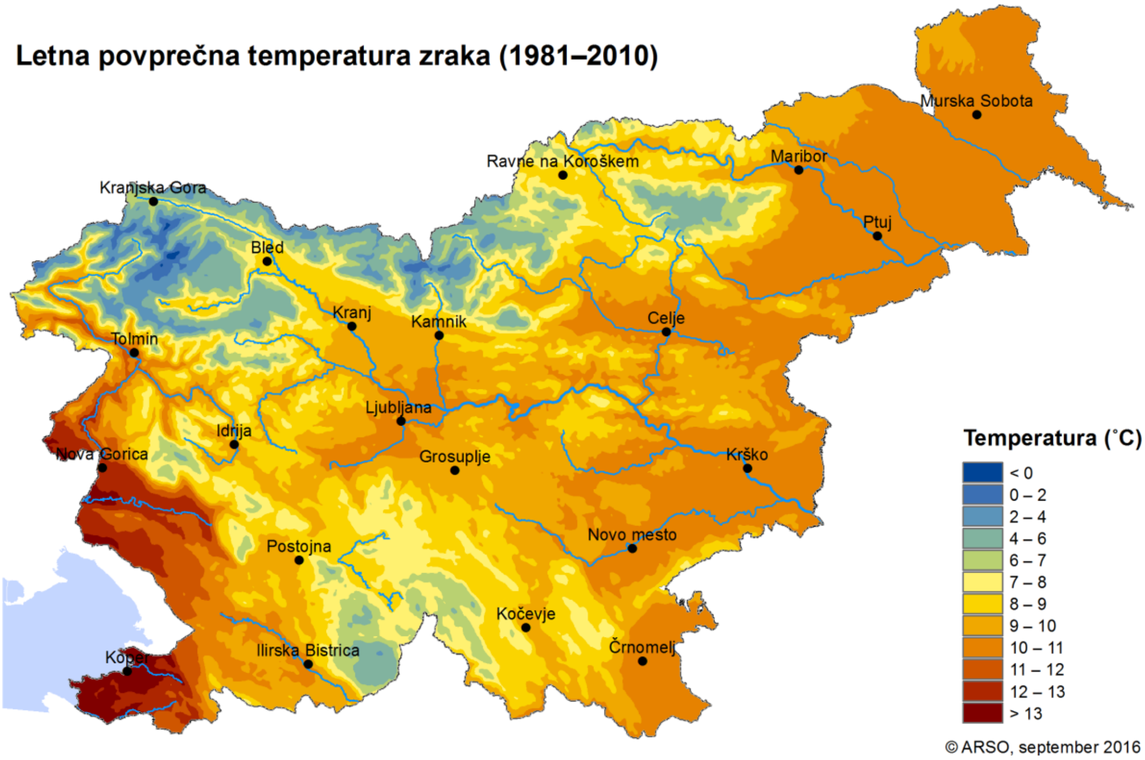

Figure 5.3.2: The average yearly air temperature in Slovenia in the period 1981-2010. (Sours: SEA)
http://meteo.arso.gov.si/met/sl/climate/maps/
https://meteo.arso.gov.si/uploads/probase/www/climate/image/sl/by_variable/temperature/annual-mean-air-temperature_81-10.png

5.3.2 Methodological issues

5.3.2.1 Cattle (CRT 3.B.1)

Annual quantities of volatile solids excreted via faeces and urine were estimated by means of data gathered while estimating the extent of enteric fermentation. The equation that was laid down by IPCC (2006) was applied. In comparison to previous methodology (IPCC, 1996) the energy of urine was taken into account in addition to energy of faeces. It was expressed as fraction of GE (UE=0.04). Through estimated intake of gross energy, the amount of volatile solids is directly linked to the production intensity (to milk production or daily weight gain).

$$VS(\text{kg/day}) = \left[GE \times (1 - \frac{DE\%}{100}) + (UE \times GE)\right] \times \left[\frac{1 - ASH}{18.45}\right]$$

In dairy cows the estimated amount of VS ranged between 1645 and 1974 kg per year and animal. For other cows, heifers and beef cattle the corresponding values were from 1515 to 1542, from 820 to 885 and from 813 to 845 kg per year and animal.

The annual emitted amount of methane ($E_{M\ MANURE}$) was estimated according to the equation:

$$E_{M\ MANURE} = VS\ (kg/day) \times 365\ days/year \times B_0\ (m^3/kg\ VS) \times 0.67\ kg/m^3 \times MCF$$

For methane producing capacity of manure (B_0) the value of 0.24 m^3/kg VS was considered for dairy cows and the value 0.18 m^3/kg VS for other bovine animals (IPCC, 2006). The methane conversion factor MCF, which tells us what fraction of methane producing capacity of manure is actually used, was calculated on the basis of fractions of individual manure storage systems and partial manure conversion factors for the average temperature 11 °C, which were found in appropriate tables (IPCC, 2006). Methane conversion factors 0.11, 0.19, 0.02, 0.19, and 0.01 were used for liquid manure storage with natural crust cover, liquid manure storage below animal confinements, solid manure storage in heaps, solid manure in deep bedding systems, and grazing, respectively. A value of 0.014 was used for anaerobic digesters. It was derived using Formula 1 (Table 10.17, IPCC, 2006), taking into account the average methane emissions from co-generation units according to Libetrau et al. (2013) and a factor of 0.00 for the second part of the formula, as suggested by the IPCC for covered storage of digestate (Table 10.17, IPCC, 2006).

The fraction of individual manure management systems was estimated on the basis of the results of farm census data from 1991 and 2000. Since manure management systems were not reported in the census, data on size and structure of cattle-breeding farms were used for rough estimates. It was considered that all farms with less than 10 heads of bovine animals had solid manure storage systems, that 30% of farms with 10-19 head of animals practiced liquid manure storage and 70% of them solid manure storage, and that all farms with 20 cows or more had liquid manure storage systems. Linear regression was used to estimate the changes in manure management systems in the period 1990-2000. After 2000, data on farm size and structure were reported by the SORS for the years 2003, 2005, 2007, 2010, 2013, 2016 and 2020. For the years with missing values, the proportions of various manure storage systems were obtained by interpolation. For the years which exceed the available time series we used the last available estimate. In 2005, the estimates based on farm structure were tested using the information on manure management that was collected in the frame of milk recording service on a large number of dairy farms (Babnik and Verbič, 2007; about 70% of total dairy cows were covered). Based on farm structure, it was estimated that 55.6% of dairy cows were kept on liquid systems (if grazing is not taken into account). The corresponding value based on farm questionnaires was only slightly lower (53.2%). It proves that the estimates based on farm structure can be considered reliable.

In 2010 data for the sample survey on agricultural production methods were collected for the first time along with the Agriculture Census (SORS). It gave considerably lower value for liquid systems (29.1%). The results are difficult to explain. Data on animal husbandry and manure storage practices from the 2020 Census were published in July 2023 (SORS, 2023). From the published data, it is not possible to obtain appropriate information for estimating methane emissions from manure storage facilities. The problem is mainly the following:

- the data are aggregated and refer to the sum of the most represented animal species (cattle, pigs, sheep, goats, poultry),
- the data refer to farms and do not take into account the number of animals in these farms. Since the type of animal husbandry is related to the size of the farm, it is not possible to estimate the amount of manure kept in different systems,
- slurry and the liquid fraction generated on farms with farmyard manure are considered together, so it is not possible to quantify the share of slurry systems.

Due to fact that there are no adequate data on agricultural production methods it was decided to preserve the consistency of time series and to retain estimates based on farm structure. We were not able to respect the recommendation of review to include the SORS information on manure management systems into the calculation procedure. It would make sense to check whether it is possible to obtain relevant information by processing the raw data collected by SURS.

Animals kept in liquid systems were further divided into animals kept in liquid manure storage with natural crust cover, animals kept in liquid manure storage below animal confinements and animals from which the excreta is treated in anaerobic digesters. Based on information on manure management that was collected in the frame of milk recording service on a large number of dairy farms in 2005 (Babnik and Verbič, 2007) it was estimated that the ratio between slurry stored in stores with natural crust and slurry stored below animal confinements is 0.46:0.54. Based on information from the same source the solid manure was divided into farmyard manure stored in heaps and deep bedding (0.90:0.10). The proportion of slurry treated in anaerobic digesters was estimated on the basis of data collected from biogas plants by the means of interview (data provided by Poje, unpublished). Based on above mentioned data and data on total number of cattle it was estimated that during the period 2006-2010 the proportion of digested cattle manures increased from 0.03 to 0.36 %. Anaerobic digesters were not markedly spread thereafter and therefore the same value was used for the period 2011-2022. Generally, biogas is produced from livestock manure which is generated within the farm.

The fraction of grazing bovine animals for 1990 has been estimated on the basis of data on grazing animals on mountain pastures and expert estimate on the scale of grazing on intensive grasslands (Verbič et al., 1999). In 2000, all grazing animals on mountain and other pastures were recorded. This census showed that in 2000, one way or another, 21% of animals were grazing. This data have been corrected with regard to the length of the grazing season, considering the fact that animals on mountain pastures will graze for 141 days on the average, and on other pastures for 210 days. As result, the corrected proportion of grazed animals for 2000 was estimated to be 0.117. The same procedure was used for the data obtained by sample survey on agricultural production methods in 2010. It showed that the corrected proportion of grazed animals increased to 0.126.

The estimate for 1990 was used for the period 1985-1990. For the period 1991-1999, the data on grazing were obtained by linear regression which was calculated on the basis of data for the years 1990 and 2000 and for the period 2001-2009 the estimates obtained by linear regression for the years 2000 and 2010. The 2020 census did not collect data on the number of animals kept on pasture. Extrapolated values based on the 2000-2010 period were used for the years through 2020. This resulted in a slight increase in the percentage of grazed animals (from 12.6% in 2010 to 13.6% in 2020). Grazing is supported by some measures of agricultural policy (organic farming, animal welfare measures), so it is assumed that the share of grazing animals in 2020 is not overestimated. For 2022, the same value as for 2020 was used.

Data on the number of livestock were the same as those used for calculating methane emissions from enteric fermentation. Emission factors are presented in the Table 5.3.1.

Table 5.3.1: CH_4 EFs for cattle for manure management in kg/head/year.

	1986	1987	1988	1989	1990	1991	1992	1993	1994
Dairy cows	19.6	19.5	19.5	19.6	19.6	20.4	20.2	20.4	20.9
Other cows	13.7	13.7	13.7	13.7	13.7	13.9	14.0	14.2	14.3
Heifers	7.3	7.3	7.3	7.3	7.3	7.4	7.5	7.5	7.7

Cattle for fattening	7.5	7.5	7.4	7.4	7.4	7.5	7.6	7.6	7.7
Breeding bulls	11.8	11.8	11.8	11.8	11.8	12.0	12.1	12.3	12.4
Other cattle	6.9	6.9	6.9	6.9	6.9	7.0	7.1	7.2	7.3
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Dairy cows	21.4	22.4	22.8	23.2	23.7	24.3	25.1	26.1	26.5
Other cows	14.5	14.7	14.8	14.9	15.1	15.3	15.6	16.0	16.3
Heifers	7.8	8.0	8.1	8.2	8.3	8.5	8.7	9.0	9.2
Cattle for fattening	7.8	7.9	8.0	8.0	8.1	8.2	8.4	8.5	8.7
Breeding bulls	12.6	12.7	12.9	13.0	13.2	13.4	13.7	14.0	14.3
Other cattle	7.3	7.4	7.5	7.6	7.7	7.9	8.2	8.5	8.6
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Dairy cows	26.5	27.2	27.8	28.5	29.1	29.3	29.7	29.8	30.0
Other cows	16.4	16.5	16.8	17.1	17.4	17.7	18.0	18.0	18.1
Heifers	9.2	9.4	9.6	9.8	10.0	10.1	10.3	10.3	10.3
Cattle for fattening	8.7	8.8	9.0	9.1	9.3	9.5	9.7	9.7	9.7
Breeding bulls	14.4	14.5	14.8	15.1	15.4	15.6	15.9	15.9	16.0
Other cattle	8.7	8.8	8.9	9.0	9.2	9.1	9.2	9.6	9.6
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Dairy cows	29.9	30.6	30.7	31.5	31.7	32.1	32.3	32.7	32.8
Other cows	18.1	18.3	18.5	18.7	18.9	18.9	19.0	19.1	19.2
Heifers	10.4	10.5	10.6	10.8	10.9	11.0	11.0	11.1	11.1
Cattle for fattening	9.7	9.9	10.0	10.1	10.1	10.1	10.2	10.3	10.3
Breeding bulls	16.0	16.2	16.4	16.6	16.7	16.8	16.9	17.1	17.1
Other cattle	9.6	9.8	10.0	10.1	10.1	10.2	10.4	10.4	10.4
	2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Dairy cows	33.2								
Other cows	19.2								
Heifers	11.2								
Cattle for fattening	10.3								
Breeding bulls	17.1								
Other cattle	10.3								

5.3.2.2 Swine (CRT 3.B.3)

Activity data

The population of swine (Figure 5.3.3) is divided into three segments:
a) commercial (industrial) pig farms,

b) market oriented family farms, and
c) small scale (subsistence) family farms.

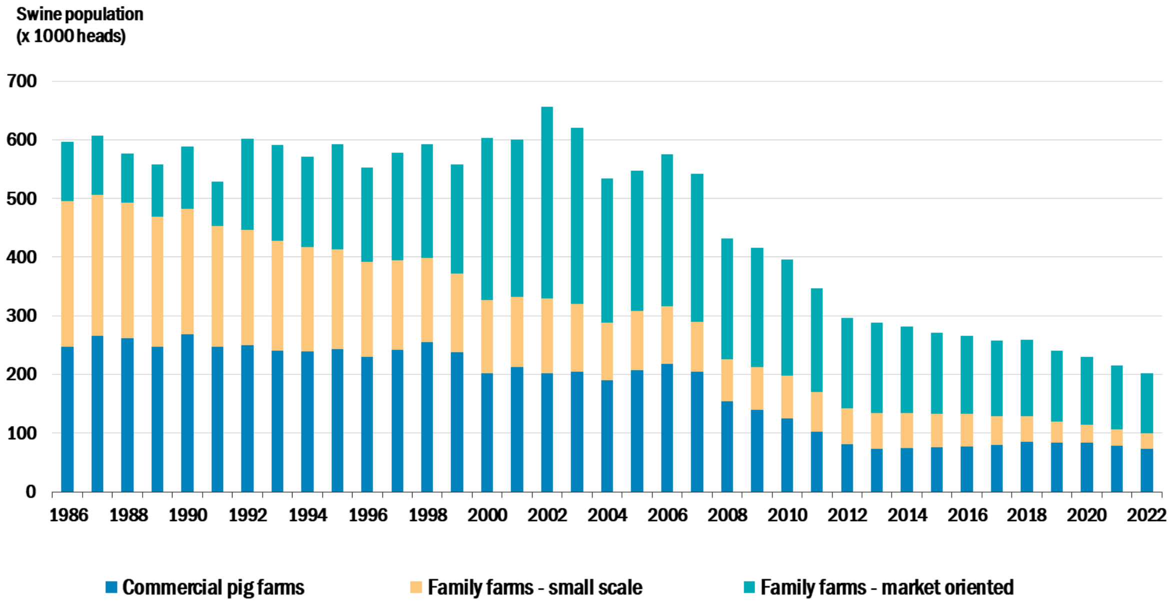

Figure 5.3.3: Number of swine in thousands.

Data published by the SORS allow a breakdown of the entire herd into commercial pig farms and family farms for the period 1986-2002. Family farms were further divided into market oriented and small scale farms. In 1986, the estimate of production for market oriented family farms was based on the data on acquisition of pigs from market oriented family farm production, which was published by the SORS. The number of swine in small scale family farm production has been estimated from the difference between the entire herd and market oriented production (commercial and market oriented family farms). For 2000, the number of pigs in the small scale family farm production has been estimated on the basis of the census of agricultural holdings. Pigs kept on farms with up to 10 pigs have been considered as small scale family farm production, pigs on family farms which kept more than 10 pigs have been considered as market oriented family farm production. From 1986 to 2000, the fraction of pigs in small scale family farm production kept diminishing. In the period between 1986 and 2000, the proportion of small scale production was obtained by interpolation. After 2000, data on farm structure for the years 2003, 2005, 2007, 2010, 2013, 2016 and 2020 have been reported by the SORS. These data were used to estimate the number of pigs on small scale family farms. For the years with non-existing data on farm structure (2001, 2002, 2004, 2006, 2008, 2009, 2011, 2012, 2014, 2015, 2017, 2018, 2019) the numbers of pigs on small scale family farms were obtained by interpolating the values for neighbouring years or by using the last available information (for 2021 and 2022). For the period after the year 2002 the number of pigs on commercial farms could not be obtained directly from the data reported by SORS. Therefore it was estimated using the data on farm structure for the years 2003, 2005, 2007, 2010, 2013, 2016 and 2020. The estimate is based on the number of pigs which are kept on farms with more than 399 pigs. The pigs belonging to this category (pigs kept on farms with more than 400 pigs) were allocated among commercial and market oriented family farms on the basis of their proportion in the year 2000. The pigs kept on farms with 10 to 399 pigs were entirely allocated to market oriented family farms.

Table 5.3.2: Proportion of pigs which are kept on organic farms during the period 2010-2022 (Sources: Ministry of agriculture, forestry and food and SORS)

	2010	2011	2012	2013	2014	2015	2016	2017
Total population of pigs	395,593	347,310	296,097	288,350	281,317	271,385	265,744	257,241
Number of pigs on organic farms	2,367	2,219	2,458	2,798	3,135	3,345	3,648	3,793
Proportion of pigs on organic farms (%)	0.60	0.64	0.83	0.97	1.11	1.23	1.37	1.47
	2018	**2019**	**2020**	**2021**	**2022**			
Total population of pigs	259,125	240,138	229,483	215,713	202,148			
Number of pigs on organic farms	3,203	3,252	2,992	3099	3185			
Proportion of pigs on organic farms (%)	1.24	1.35	1.30	1.44	1.58			

An investigation on the extent of organic pig production was made with the aim to find out if manure management practices on organic farms should be surveyed. It was found that in the period 2010-2022 only 0.6 to 1.6 % of total pigs were kept on organic farms. It was estimated that detailed information on manure management systems on these farms would not considerably contribute to improvement of data quality. The information on the number of pigs on organic farms for the period 2010-2022 is given in the Table 5.3.2.

Emission factors

Annual emissions of methane ($E_{M\ MANURE}$) have been estimated according to the IPCC method. Quantities of excreted volatile solids (VS) have been calculated using Western Europe default values of 0.46 kg of VS/day for breeding pigs and 0.30 kg of VS/day for fattening pigs (including piglets) (IPCC, 2006). For the methane-producing capacity of manure (B_0), the value for swine (0.45 m^3/kg VS; IPCC, 2006) has been applied. The average manure conversion factor (MCF) has been estimated with regard to the type of manure management system and partial manure conversion factors that had been laid down for various systems by IPCC (2006). Methane conversion factors 0.19, 0.02, 0.19, 0.68 were used for liquid manure storage, solid manure storage in heaps, solid manure in deep bedding systems, and uncovered anaerobic lagoons, respectively. A factor of 0.014 was used for anaerobic fermenters. The basis for determining this factor is described in the chapter dealing with cattle. The following estimates and assumptions were considered in the calculation of methane emissions from manure storage facilities.

Commercial Pig Farms

From 1985 to 1994 – using old-style separators on commercial farms, app. 20% of organic matter was separated from liquid manure. For this portion, the partial MCF for solid manure (0.02) has been taken into account. The remainder (80%) has been disaggregated into uncovered anaerobic lagoons (75%) and liquid manure (25%), taking into account a MCF 0.68 and 0.19, as suggested by IPCC (2006). The division into lagoons and liquid manure was founded on actual estimates of the extent of production on commercial farms, where the liquid portion of manure after separation was applied to fields and grassland. Considering the ratio between solid phase and liquid manure, which was either led into lagoons or used for fertilization, the average MCF = 0.45 has been calculated.

Years from 1995 to 1999 were a period of introducing new separators and the beginning of operation of an anaerobic digester in the Farm Ihan. Introducing new separators on commercial farms increased the estimated portion of separated solid phase to 40%. Since the construction of a new wastewater treatment plant in Farm Ihan, it has been considered that mechanic separation separated 80% of VS on that commercial farm, while the remainder (20%) was captured as biogas. For large commercial farms it is generally considered that the ratio between the liquid part, which flows off to lagoons, and the liquid part, which is used as fertilizer, is the same as prior to 1995 (3:1). The estimated average MCF for that period was 0.278. Due to new farm reconstructions leading to improved slurry separation and introduction of additional capacity of anaerobic digesters, the methane conversion factor MCF on big farms after 1999 had decreased to 0.147 until 2005 and further to 0.057 in 2010. We assume that managers are interested in achieving the shortest possible retention times in manure stores before gas production and therefore we have assumed that the MCF value for anaerobic digesters was 0.014 (see above).

Market oriented family farm production

For market oriented family farm production, it is considered that 95% of animal excreta are collected in the form of liquid manure and 5% in the form of solid manure. Based on the ratio between liquid manure and solid manure, the average manure conversion factor MCF = 0.182 was used for calculations until 2006. Since then, farm reconstructions occurred also on family farms and average MCF has decreased to 0.176 in 2010.

Small scale family farm production

For small scale family farm production, it is estimated that 95% of pigs are reared in solid manure storage systems and 5% in liquid manure systems. For this type of production the average manure conversion factor MCF = 0.029 was calculated on the basis of IPCC (2006) guidelines.

Detailed information on manure management systems are given in Table 5.3.3.

Table 5.3.3: Distribution of various manure management systems in pig production in %.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Slurry	28.1	25.0	34.5	36.0	35.5	35.1	34.1	36.6	37.4	40.1	50.3
Farmyard manure	35.5	37.5	32.3	31.5	31.1	28.7	29.1	26.6	24.6	24.5	22.1
Separation (solid fraction)	9.1	9.4	8.3	8.1	8.4	19.7	20.0	20.1	20.7	23.8	18.7

Anaerobic lagoons	27.4	28.1	24.9	24.4	25.1	14.8	15.0	15.1	15.5	06.4	5.0
Anaerobic digestion	0.0	0.0	0.0	0.0	0.0	1.6	1.7	1.7	1.7	5.1	4.0
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Slurry	49.4	53.6	52.5	50.7	48.8	48.6	49.0	48.9	49.9	54.1	54.7
Farmyard manure	21.3	20.9	20.1	19.9	19.7	18.4	17.1	18.2	19.2	20.2	21.1
Separation (solid fraction)	19.8	17.3	18.5	19.9	21.2	15.9	15.3	12.7	12.8	12.6	11.8
Anaerobic lagoons	5.3	4.6	5.0	5.3	5.7	4.3	4.1	3.4	3.4	0.0	0.0
Anaerobic digestion	4.2	3.7	4.0	4.3	4.6	12.9	14.4	16.9	14.7	13.1	12.4
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Slurry	55.4	56.0	55.3	54.5	53.8	54.2	54.6	55.1	55.5	55.5	55.5
Farmyard manure	22.0	22.9	22.8	22.6	22.4	20.5	18.6	16.8	14.9	14.9	14.9
Separation (solid fraction)	10.9	10.1	10.6	11.1	11.6	12.4	13.1	13.8	14.6	14.6	14.6
Anaerobic lagoons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anaerobic digestion	11.7	10.9	11.4	11.8	12.2	12.9	13.6	14.3	15.0	15.0	15.0

In the Table 5.3.4 country specific IEFs for swine are presented. The decrease in IEF for swine is due to improved slurry separation and introduction of additional capacity of anaerobic digesters.

Table 5.3.4: CH_4 EFs for manure management in pig production (in kg/head/year)

	1986	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
CH_4 EFs	8.0	8.3	8.5	8.4	8.7	8.7	8.5	8.5	8.6
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
CH_4 EFs	6.2	6.2	6.4	6.5	4.5	4.8	4.8	4.9	4.9
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
CH_4 EFs	4.9	4.9	4.5	4.5	4.3	4.4	3.8	3.9	3.9
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
CH_4 EFs	3.9	3.9	3.8	3.8	3.8	3.8	3.9	3.9	3.9
	2022								
CH4 EFs	3.9								

5.3.2.3 Poultry (CRT 3.B.4)

The number of poultry species (Figure 5.3.4) has been taken from the Statistical Yearbook. Emissions were calculated as a sum of emissions for broilers, layers, ducks, turkeys and geese. Methane produced during manure management was calculated by taking into account the quantities of excreted volatile solids (VS), methane-producing capacity of manure (B_0), and methane conversion factors (MCF) for the specific manure management systems. For excretion of VS 0.02, 0.01, 0.07 and 0.02 kg per animal per day were used for layers, broilers, turkeys and ducks, respectively (IPCC, 2006). No value for geese is available. Therefore, an estimate of 0.05 kg per animal per day was obtained on the basis of value for ducks taken into account the difference in body mass weight. For methane producing capacity of manure (B_0) the value of 0.39 m^3/kg VS was considered for layers and the value 0.36 m^3/kg VS for other poultry species (IPCC, 2006). For broilers, turkeys, geese and ducks exclusively floor system on bedding was assumed. For laying hens, combined floor system (1/4) and battery-cage systems (3/4) were assumed for 1990. Assumption was made on the basis of expert estimate (Udovič, personal communication). It was also assumed that in 50% the manure is removed daily and stored in tanks (liquid system) while in 50 % it is collected under the batteries (i.e. poultry manure without bedding). After introduction of dung drying system to certain farms a new estimates were obtained for 2002. Layers which were assumed to be kept in floor system, in system where manure is collected under the batteries and in dung drying system, were allocated to solid system. Layers which were assumed to be kept in system where the manure is removed daily and stored in tanks was allocated to liquid systems. Emission factor for poultry manure without litter (MCF=0.70) was used for manure which was allocated to liquid systems. For manure allocated to solid systems MCF for system with litter was used (MCF=0.015). It means that manure which is collected and dried under the batteries and manure from dung drying system were treated the same way as manure with litter. IPCC (2006) reported no MCF´s for dry manure without bedding. There is mentioned that MCF for aerobically treated manure are near zero and therefore for dry manure the use of MCF for manure with litter (0.015) seems more adequate than high MCF for manure without litter (0.70).

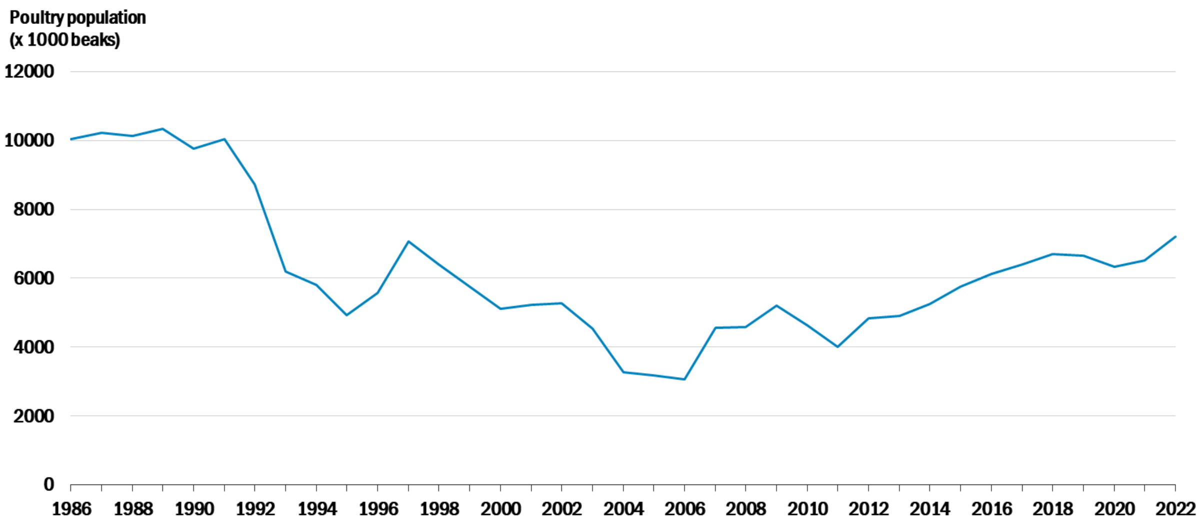

Figure 5.3.4: Number of poultry in thousands.

5.3.2.4 Sheep (CRT 3.B.2), Goats, (CRT 3.B.4), and Horses (CRT 3.B.4)

For excretion of VS 0.4, 0.3 and 2.13 kg per animal per day were used for sheep, goats and horses. For methane producing capacity of manure (B_0) the values of 0.19, 0.18, and 0.30 m^3/kg VS were applied, respectively (IPCC, 2006). The proportions of grazing animals were estimated by the means of expert opinion. It was estimated that during the grazing season all sheep, 80% of goats and 50% of horses were grazed (Verbič after consultations with experts of the public advisory service, personal communication). Two hundred and fifty days of grazing season has been considered for sheep and 210 for goats and horses. As a result, the proportions of grazed animals were estimated to be 0.685, 0.460 and 0.288 for sheep, goats and horses, respectively. For the remaining period it has been considered that these animals were kept in straw based (solid) systems. Manure conversion factors of 0.02 and 0.01 were applied for housed and grazed animals, respectively.

5.3.2.5 Rabbits (CRT 3.B.4)

The IPCC (2006) default emission factor of 0.08 kg/head/year was used for rabbits. It was assumed that rabbits are not grazed and that only the solid manure system was used.

5.3.3 Uncertainties and time-series consistency

Uncertainty of activity data amounts to 10% (Source: SORS, KIS).

The uncertainty estimate for EF in the 2006 IPCC Guidelines is 30% for default values and for Tier 2 EFs is not less than 20%. It is our experts' judgement that EFs for manure management are less accurate than those for enteric fermentation. According to their judgement, we are using uncertainty of 30% for 1986 and 25% for 2022.

Combined uncertainty amounts to 26.9%.

5.3.4 Category-specific QA/QC and verification

QA/QC procedures are described in the chapter 1.2.3 and 5.2.4. Input data, calculations and the results have been thoroughly vetted by experts in the KIS and in the SEA. Any errors that were found have been corrected.

As an important QA/QC is also an ESD review, where all IEF and AD are compared with other counties and all outliers have to be justified.

<u>Verification of the average temperature used for selection of MCF</u>

In the previous submissions we have used 12 °C to select MCF values. This is the upper limit of the average yearly temperature on the agricultural area in Slovenia. With 2021 submission we have started to use average temperature 11 °C for selection of MCF. We have used the same value for the entire period despite the review recommendation was different. We agree that over more than three decades the average temperature has been rising and that on the first look recommendation to use 10 °C for the early part of the time series, and 11 °C for the later years is meaningful. However, it is not easy to determine average temperature on agriculture area for each year.

To verify the use of the same average temperature over the whole reporting period we have compared a monthly temperature in the years 1986 and in 2020 on five meteorological stations on rural area and we have noticed that the average differences were between 0.2 and 0.9 °C in the warm period and between 2.4 and 3.4 °C in the winter time. We believe that CH_4 emissions from manure management during the winter period are negligible and that a majority of emissions is occurring in the summer months. For this reason using the same average temperature for the entire period does not cause a major error.

5.3.5 Category-specific recalculations

No recalculations have been performed for this category.

5.3.6 Category-specific planned improvements

It will be considered whether relevant information on manure storage practices can be obtained by processing the raw data collected as part of the 2020 Census.

5.4 N_2O Emissions from Manure Management (CRT 3.B)

5.4.1 Source category description

This category considers N_2O which is emitted, directly and indirectly, from treatment and storage of animal excreta before it is applied to agricultural land or used for other purposes. A considerable amount of N_2O evolves during storage of animal waste. Animal excreta are also source of indirect N_2O emissions. They are associated with volatilization of ammonia (NH_3) and nitric oxide (NO_X) from animal houses and manure stores. Volatilised N is deposited to soils and water surfaces where it causes indirect N_2O emissions. They are also attributed to livestock production and reported within this category. Nitrous oxide emitted directly or indirectly from excreta of grazing animals is reported under category “N_2O emissions from managed soils”.

On the Figure 5.4.1 the nitrogen excretions from the different manure management system in the period 1986-2022 are presented. In the past a solid storage was a main type of MMS used while in the recent years the liquid systems prevailed.

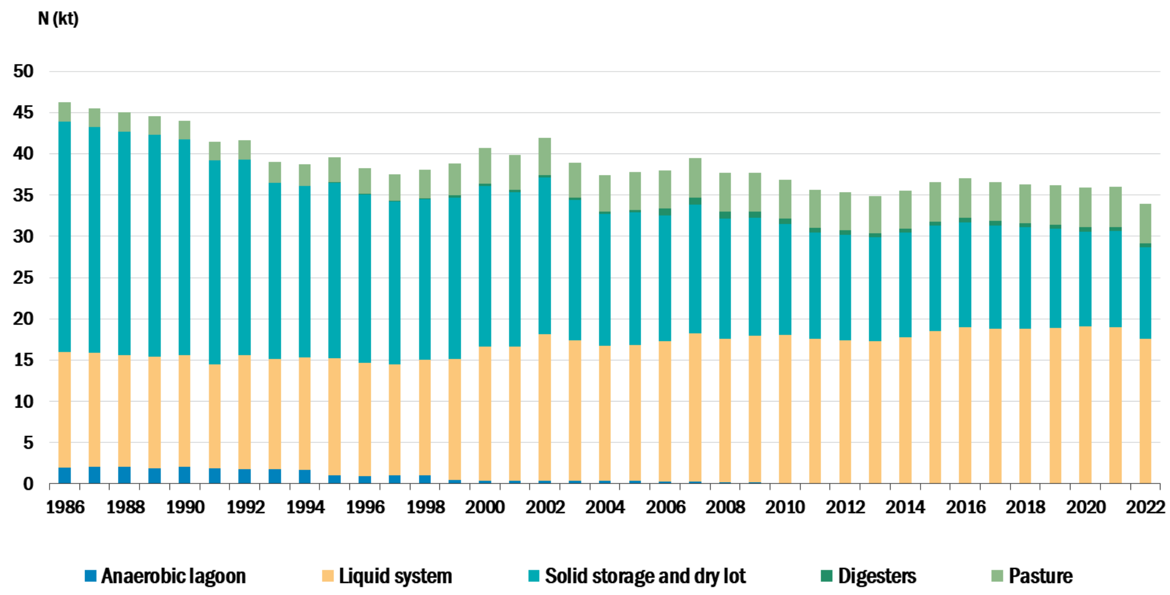

Figure 5.4.1: Nitrogen excretion per different MMS in kilotons.

5.4.2 Methodological issues

Mass balance approach which tracks nitrogen throughout the system was used to estimate N_2O emissions. It was done by the means of detailed EMEP/EEA (2019) methodology, which is also used for national NH_3 and NO_X emission inventory. Based on suggestion by IPCC (2006) (Chapter 10, 10.56), we have decided to use National NH_3 emission inventory for the estimation of nitrogen volatilization from MMS also for reporting of GHG emissions. EMEP/EEA (2019) Tier 2 methodology ensures that there is consistency between EMEP and IPCC methodology (see EMEP/EEA, 2019, Chapter 3.B Manure management, p. 21).

The methodology is based on principles of total N and total ammonia nitrogen (TAN) fluxes through the manure management system. The model starts out with TAN excretions followed by emissions of NH_3, N_2O, NO and N_2 from animal housing and manure stores. It was taken into account that only the nitrogen that was not lost from animal houses and manure stores is retained in animal manures. Therefore, emissions at each stage depend on the extent of emissions during the preceding stages. In case of slurry based systems mineralization of non-TAN N was taken into account and in the case of farmyard manure it was taken into account that a part of TAN is immobilised into organic matter. Ammonia losses that arise from the application of the manure to soil were also estimated within the same procedure. They were reported as a source of indirect N_2O emissions under the category "N_2O emissions from managed soils". In its final stage the procedure gives an information on the amount of total N returned to soil. It was used for assessment of N_2O emissions due to nitrification and denitrification processes which results from the use of animal manure applied to soils. These emissions are reported under category "N_2O emissions from managed soils".

EMEP/EEA methodology is based on total ammonia N flow (TAN) while IPCC (2006) is based on total N flow. Therefore, emission factors from one methodology cannot be directly used in another. However, EMEP/EEA EF are based on IPCC factors and therefore we can consider them as comparable (see EMEP/EEA, 2019, Chapter 3.B Manure management, p. 56). In fact IPCC factors were converted by taking into account the proportion of TAN in manure entering storage.

5.4.2.1 Direct N_2O emissions from manure management

Activity data

The activity data were obtained from the Statistical Office of the Republic of Slovenia (SORS). They include the number of cattle, pigs, sheep, goats, horses and poultry as well as average milk production per cow. Details are described under the Chapter 5.2.2.

Emission factors

In the first step nitrogen excretion from farm animals was estimated. It was obtained by multiplying the number of farm animals and nitrogen excretion rates on the level of individual animal species and category. The nitrogen excretion rates, which were taken into account, are presented in Table 5.4.1. The primary source was EMEP/EEA (2019), which is based on IPCC (2006). The reason for selecting EMEP/EEA (2019) was that they provide information on nitrogen excretion in kg per animal, which is easier to apply than IPCC (2006), which provides information on nitrogen excretion per 1000 kg body weight. In dairy cows the nitrogen excretion has been linked to productivity, i.e. milk production (M, kg/year) and milk urea concentration (MU, mg/100 ml). The equation proposed by WUR (2014) was used:

$$\text{N excretion (kg/year)} = 129.9 + 0.0089 \times (M - 7744) + 1.7 \times (MU - 26)$$

The data on the milk urea concentration for the period from 2004 onwards are taken from the CATTLE database (Agricultural Institute of Slovenia), which contains data for about 80% of all dairy cows in Slovenia. For the period before 2004, the average of the years 2004-2008 was used.

Table 5.4.1: Nitrogen excretion rates for the calculation of ammonia emissions from animal production

Animal category	N excretion (kg N head /year)	Source
Cattle		
Dairy cows	76.9-110.5	WUR (2014) taken into account milk production and milk urea concentration
Suckling cows	41	EMEP/EEA (2019), based on information from IPCC (2006)
Calves, fattening cattle, heifers	41	EMEP/EEA (2019), based on information from IPCC (2006)
Pigs		
Sows[a]	36	EMEP/CORINAIR (2002)
Fattening pigs	14	EMEP/CORINAIR (2002)
Small ruminants		
Sheep[b]	15.5	EMEP/EEA (2019), based on information from IPCC (2006)
Goats[c]	15.5	EMEP/EEA (2019), based on information from IPCC (2006)
Horses	47.5	EMEP/EEA (2019), based on information from IPCC (2006)
Poultry		
Laying hens	0.77	EMEP/EEA (2019), based on information from IPCC (2006)
Broilers	0.36	EMEP/EEA (2019), based on information from IPCC (2006)
Turkeys	1.64	EMEP/EEA (2019), based on information from IPCC (2006)
Geese	0.55	EMEP/EEA (2019)
Ducks	1.26	EMEP/EEA (2019), based on information from IPCC (2006)
Rabbits[d]	8.1	IPCC (2006)

[a] Sows and pregnant gilts; the value includes N excretion in piglets and boars
[b] Adult sheep (including breeding female sheep and other adult sheep, like rams and barren sheep); the excretion value includes N excretion in lambs
[c] Adult goats (including breeding female goats and other adult goats, like he goats and barren goats); the excretion value includes N excretion in kids
[d] The excretion value applies for does; the value includes excretion in other rabbit categories

Nitrogen excretion rates for dairy cattle are presented in Table 5.4.2.

Table 5.4.2: Nitrogen excretion rates for dairy cattle in kg N/head/year.

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Nex	77.4	76.9	77.0	77.2	77.0	81.2	77.5	77.2	79.1	80.5
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Nex	86.4	87.7	88.7	90.1	93.5	95.1	98.6	97.4	97.5	100.3
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nex	104.0	101.9	102.7	98.5	98.1	97.9	99.6	98.2	99.3	97.8
	2016	2017	2018	2019	2020	2021	2022			
Nex	102.2	101.4	104.3	105.1	108.2	108.4	110.5			

In case of pigs, EMEP/CORINAIR (2002) excretion rates were used. A decision was made on the basis of reporting mode on the number of pigs in Slovenia. EMEP/CORINAIR (2002) N excretion rates concerns fattening pigs from 20 kg onwards and sows which also include piglets up to 20 kg of body mass. The same categories are reported by SORS. EMEP/EEA 2019 categories are not harmonised with those used in Slovenia (piglets up to 8 kg of body weight) and are therefore not applicable without adjustments.

For the purpose of comparison, in 2018, EMEP/CORINAIR (2002) excretion rates were compared to values derived by the use of IPCC (2006) methodology. Based on data on herd structure in 2017, EMEP/CORINAIR (2002) excretion rates resulted in average excretion rate of

12.2 kg of N per pig and year (Table 5.4.3). The corresponding value for IPCC (2006) methodology (values for West European countries) was 13.3 kg. It was decided to stick with the EMEP/CORINAIR (2002) methodology, which was generally adopted for reporting of emissions of N compounds in Slovenia.

Calculation of the average nitrogen excretion rate for 2017 is presented on the Table 5.4.3, while population data for the period 1986-2022 is available in the Annex 3 to the NID.

Table 5.4.3: Calculation of the average excretion rates for swine for 2017 (an example)

	Population	Nex	Total N excreted
	heads	**kg/head/year**	**kg N**
Pigs < 20 kg live weight	58,657	IE	
Pigs 20 - 50 kg live weight	46,854	14	655,956
Fattening Pigs > 50 kg live weight	130,419	14	1,825,866
Boars	0,842	IE	
Sows	20,469	36	736,884
Of which gilts not yet covered	*2,2294*	36	-80,258
Total	**257,241**	**12.20**	**3,138,448**

Emissions from animal housing, manure stores and due to fertilization with animal manures in cattle production (CRT 3.B.1)

Emission factors, which tell us how much of N from animal excreta is lost to the atmosphere in the form of various gasses, including N_2O, depend on manure management systems. Total nitrogen excretion was allocated to four manure management systems (grazing, farmyard manure, slurry and anaerobic digesters). Nitrogen which is excreted in farmyard manure system was further divided in two fractions, farmyard manure (0.43) and liquid fraction (0.57). The latest corresponds to urine and effluent from storage of solid fraction.

The same information as those used to estimate CH_4 emissions from manure management was used for allocation of nitrogen to various manure management systems (see Chapter 5.2.2.). Factors, along with some additional basic information on manure management systems in cattle production, are presented in Table 5.4.4.

Table 5.4.4 shows the emission factors and basic information on manure management systems for the calculation of NH_3, N_2O, NO and N_2 emissions in cattle production. The main sources for emission factors is EMEP/EEA, 2019 with an exception related to the proportion of TAN at the level of excretion where EFs for a farmyard manure and urine are from Menzi et al., 1997.

Table 5.4.4: Emission factors and basic information on manure management systems in cattle production. (Sources for emission factors: EMEP/EEA, 2019 and Menzi et al., 1997 (marked with M)

		Tied housing system		Loose housing system
	Grazing	**Farmyard* manure**	**Liquid* fraction (urine)**	**Slurry and anaerobic digesters**
Proportion of TAN at the level of excretion (in kg/kg total N)*	0.60	0.30 (M)	0.825***(M)	0.60
Basic information				
Proportion of covered manure stores	/	0.00	0.90	0.50

		Tied housing system		Loose housing system
	Grazing	Farmyard* manure	Liquid* fraction (urine)	Slurry and anaerobic digesters
Proportion of manure incorporation (for arable land only)	/	0.20	0.20	0.20
Bedding material (kg per animal per year)	0	Cows: 730 Other cattle: 240	0	0
N added in bedding (kg per animal per year)	0.00	Cows: 2.92 Other cattle: 0.96	0.00	0.00
Mineralization of non-TAN N during storage (proportion of total non-TAN N)	/	0.00	0.00	Slurry: 0.10 Anaer. dig.: 0.32
Immobilization of TAN during storage (proportion of TAN)	/	0.0067	0.0000	0.0000
Emission factors (kg NH_3-N/kg TAN)				
From animal houses or during grazing (proportion of excreted TAN)	0.14	0.090	0.090	0.240
Emissions from uncovered manure stores (proportion of TAN entering the stores)	/	0.320	0.250	Slurry: 0.25 Anaer. dig.: 0.0266**
Emissions from covered manure stores (proportion of TAN entering the stores)	/	/	0.050	Slurry: 0.05 Anaer. dig.: 0.0266**
Emissions due to manure application – basic coefficients (proportion of TAN leaving the stores)	/	0.680	0.550	0.550
Emissions due to manure application – coefficients for immediate manure incorporation (proportion of TAN leaving the stores)	/	0.408	0.330	0.330
Emission factors (kg N_2O-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	/	0.020	0.000	Slurry: 0.010 Anaer. dig.: 0.000
Emission factors (kg NO-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	/	0.010	0.0001	Slurry: 0.0001 Anaer. dig.: 0.0000
Emission factors (kg N_2-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	/	0.300	0.003	Slurry: 0.003 Anaer. dig.: 0.000

* in farmyard manure system it was taken into account that 0.43 of N was retained in solid and 0.57 in liquid fraction

** emission factor refers to the total N

*** The value proposed by Menzi et al. (1997) is 0.7 and the use of this value implies that the total amount of TAN excreted in the manure system is less than in the grazing or slurry based manure system. To harmonize the total amount of TAN excreted, we used a value of 0.825, which is close to the upper limit of the range given in the EMEP / EEA 2019.

Based on expert estimate it was assumed for the entire reporting period that 20 % of animal manures used on arable land were incorporated into the soil within about 12 to 24 hours after application (Table 5.4.4). It was assumed that basic emission coefficients for the above mentioned practice are reduced by 40 % (mean value for incorporation within 12 and within 24 hours, ECE/EB AIR/2014/8). For the period 2015-2022 it was also taken into account that a certain part of slurry was applied by the means of low emission techniques (36, 42, 43, 44, 44, 44, 44 and 45% for arable land and 0,70, 0,69, 0,69, 0,70, 0,69, 0,41, 0,35 and 0,35 % for grasslands in years 2015, 2016, 2017, 2018, 2019, 2020, 2021 and 2022 respectively). The information is based on the area supported by Rural development programme (operation "low emission fertilization"). It was considered that low emission techniques were distributed into trailing hoses (70%) and trailing shoe (30 %). The estimates are based on information on investments in low emission equipment which was supported by the Rural development programme. For the efficiency of low emission techniques the values proposed by UNECE (2014) were taken into account.

Emissions from animal housing, manure stores and due to fertilization with animal manures in pig production (CRT 3.B.3)

The estimated N excretion, which was estimated separately for breeding pigs and fattening pigs, was allocated to five manure management systems (slurry, farmyard manure, manure after slurry separation (solid), uncovered anaerobic lagoons and anaerobic digesters). The procedure which was used to estimate the distribution of entire herd into different manure management systems is described in chapter dealing with CH_4 emissions from manure management (Chapter 5.2.2.). Emission factors and some additional information, which is needed to estimate N losses throughout the manure management system, are presented in Table 5.4.5. Due the same emission factors, data for farmyard manure and solid fraction from slurry separation are presented within the same column. The main sources for emission factors is EMEP/EEA, 2019 with an exception related to the aerobic lagoon where two factors are from EPA, 2004.

Table 5.4.5: Emission factors and basic information on manure management systems for the calculation of NH_3, N_2O, NO and N_2 emissions in pig production (Sources for emission factors: EMEP/EEA 2019 and EPA, 2004 (marked with EPA))

	Farmyard manure and solid*	Slurry	Anaerobic lagoon	Anaerobic fermenter
Proportion of TAN at the level of excretion (in kg/kg total N)*	0.70	0.70	0.70	0.70
Basic information				
Proportion of covered manure stores	0.00	0.50	0.00	1.00
Proportion of manure incorporation (for arable land only)	0.20	0.20	/	0.20
Bedding material (kg per animal per year)	FP: 200 S: 600	0	0	0
N added in bedding (kg per animal per year)	FP: 0.8 S: 2.4	0	0	0
Mineralization of non-TAN N during storage (proportion of total non-TAN N)	0	0.1	1*** (EPA)	0.32
Immobilization of TAN during storage (proportion of TAN)	0.0067	0.000	0.000	0.000
Emission factors (kg NH_3-N/kg N)				
From animal houses (proportion of excreted TAN	FP: 0.23 S: 0.24	FP: 0.27 S: 0.35	FP: 0.27 S: 0.35	FP: 0.27 S: 0.35
Emissions from uncovered manure stores (proportion of TAN entering the stores)	0.29	0.11	0.71*** (EPA)	0.0266**
Emissions from covered manure stores (proportion of TAN entering the stores)	/	0.022	/	0.0266**

	Farmyard manure and solid*	Slurry	Anaerobic lagoon	Anaerobic fermenter
Emissions due to manure application – basic coefficients (proportion of TAN leaving the stores)	0.450	FP: 0.40 S: 0.29	/	FP: 0.40 S: 0.29
Emissions due to manure application – coefficients for immediate manure incorporation (proportion of TAN leaving the stores)	0.270	FP: 0.240 S: 0.174	/	FP: 0.240 S: 0.174
Emission factors (kg N_2O-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	0.01	0.000	0.000	0.000
Emission factors (kg NO-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	0.01	0.0001	0.0001	0.0000
Emission factors (kg N_2-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	0.300	0.003	0.290	0.000

* solid fraction extracted from slurry during the separation process

** emission factor refers to the total N

Abbreviations: FP – Fattening pigs, S – Sows, FYM – farmyard manure

*** The EPA factor 0,71 refers to total nitrogen. For this reason, the mineralization factor was set to 1.

For the other low emission application techniques and their effectiveness the same assumptions as for cattle manures were used.

Emissions from animal housing, manure stores and due to fertilization with animal manures in poultry production (CRT 3.B.4)

Emissions in poultry production were calculated as a sum of emissions for broilers, layers, ducks, turkeys and geese. For broilers, turkeys, geese and ducks exclusively floor system on bedding was assumed. For laying hens, excreta were distributed into the solid and liquid system as described in chapter dealing with CH_4 emissions from manure management (Chapter 5.2.2.). Layers which were assumed to be kept in floor system, in system where manure is collected under the batteries and in dung drying system were allocated to solid system. Layers, which were assumed to be kept in system where the manure is removed daily and stored in tanks, were allocated to liquid systems. Emission factors for poultry rearing are given in 5.4.6.

Table 5.4.6: Emission factors for the calculation of NH_3, N_2O, NO and N_2 emissions in poultry production (Source for emission factors: EMEP/EEA 2019)

	Laying hens solid	Laying hens liquid	Broilers	Ducks	Turkeys	Geese
Proportion of TAN at the level of excretion (in kg/kg total N)*	0.70	0.70	0.70	0.70	0.70	0.70
Basic information						
Proportion of manure incorporation	0.20	0.20	0.20	0.20	0.20	0.20

	Laying hens solid	Laying hens liquid	Broilers	Ducks	Turkeys	Geese
Bedding material (kg per animal per year)	0*	/	0*	0*	0*	0*
N added in bedding (kg per animal per year)	0*	/	0*	0*	0*	0*
Mineralization of non-TAN N during storage (proportion of total non-TAN N)	0.00	0.10	0.00	0.00	0.00	0.00
Emission factors (kg NH_3-N/kg N)						
From animal houses (proportion of excreted TAN	0.41	0.41	0.21	0.24	0.35	0.57
Emissions from manure stores (proportion of TAN entering the stores)	0.14	0.14	0.30	0.24	0.24	0.16
Emissions due to manure application – basic coefficients (proportion of TAN leaving the stores)	0.690	0.690	0.38	0.540	0.540	0.450
Emissions due to manure application – coefficients for immediate manure incorporation (proportion of TAN leaving the stores)	0.414	0.414	0.228	0.324	0.324	0.270
Emission factors (kg N_2O-N/kg TAN)						
Emissions from manure stores (proportion of TAN entering the stores)	0.002	0.000**	0.002	0.002	0.002	0.002
Emission factors (kg NO-N/kg TAN)						
Emissions from manure stores (proportion of TAN entering the stores)	0.010	0.0001	0.010	0.010	0.010	0.010
Emission factors (kg N_2-N/kg TAN)						
Emissions from manure stores (proportion of TAN entering the stores)	0.30	0.003	0.30	0.30	0.30	0.30

* Sawdust; considered to contain no available N and to have no TAN immobilization potential

** EMEP/EEA 2019 guidebook does not propose any emission factor for liquid poultry manure. Therefore, emission factor which is given for liquid manure of other animal species was used.

Emissions from animal housing, manure stores and due to fertilization with animal manures in small ruminants and horses and rabbits (CRT 3.B.2 and CRT 3.B.4)

Nitrous oxide emissions in goats, sheep, horses and rabbits were estimated using the information presented in Table 5.4.7. Some specific emission factors for rabbits are missing in the 2019 EMEP/EEA emission inventory guidebook. Values for sheep were used due to similarity of excreta. Grazing and farmyard manure management system are typical for goats, sheep, horses. The proportions of grazing animals were estimated by the means of expert opinion (Verbič, after consultations with experts of the public advisory service, personal communication). The description and estimates are given in chapter dealing with CH_4 emissions (5.2.2.)

Table 5.4.7: Emission factors and basic information on manure management systems for the calculation of NH_3, N_2O, NO and N_2 emissions in sheep, goats and horses (Source for emission factors: EMEP/EEA, 2019)

	Sheep	Goats	Horses	Rabbits
Proportion of TAN at the level of excretion (in kg/kg total N)*	0.50	0.50	0.60	0.50[a]
Basic information				
Proportion of manure incorporation (for arable land only)	0.20	0.20	0.20	0.20
Bedding material (kg per animal per year)	91	91	1460	3.65
N added in bedding (kg per animal per year)	0.365	0.365	5.84	0.015
Immobilization of TAN during storage (proportion of TAN)	0.0067	0.0067	0.0067	0.0067
Emission factors (kg NH_3-N/kg N)				
From animal houses (proportion of excreted TAN)	0.22	0.22	0.22	0.22[a]
During grazing (proportion of excreted TAN)	0.09	0.09	0.35	NA
Emissions from manure stores (proportion of TAN entering the stores)	0.32	0.28	0.35	0.32[a]
Emissions due to manure application – basic coefficients (proportion of TAN leaving the stores)	0.90	0.90	0.90	0.90
Emissions due to manure application – coefficients for immediate manure incorporation (proportion of TAN leaving the stores)	0.54	0.54	0.54	0.54
Emission factors (kg N_2O-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	0.020	0.020	0.020	0.020[a]
Emission factors (kg NO-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	0.010	0.010	0.010	0.010
Emission factors (kg N_2-N/kg TAN)				
Emissions from manure stores (proportion of TAN entering the stores)	0.30	0.30	0.30	0.030

[a] There are no emission factors in EMEP/EEA emission inventory guidebook; values for sheep were used

5.4.2.2 Indirect N_2O emissions from manure management (CRT 3.B.5)

Indirect N_2O emissions from manure management are associated with volatilization of ammonia (NH_3) and nitric oxide (NO_X). The amount of N which is lost in the form of above mentioned compounds was estimated simultaneously with direct N_2O emissions using EMEP/EEA (2019) methodology (Chapter 5.4.2.1). Emission factor 0.01 kg N_2O-N per kg of volatilised N (NH_3-N and NO_X-N) was used, as suggested by IPCC (2006).

We have assumed that indirect N_2O emissions from manure management associated with leaching and run-off do not occur and notation key NO has been used. In Slovenia, storage of animal manures is regulated by a Decree on the protection of waters against pollution caused by nitrates from agricultural sources. The capacities of water tight stores are prescribed for liquid and solid manures. The first requirements regarding size and water tightness of animal manure stores were published in 1986 and later upgraded many times. Storage of farmyard manure in field heaps is prohibited since 2015. Inspectors supervise the implementation of the decree on individual farms. Penalties for non-compliance with the regulation are also prescribed. There are no data on the extent of field heaps that have been reduced by the ban of filed heap storage of farmyard manure. Due to fact that manure storage capacities were prescribed many years before the ban we estimate that situation is more or less the same over the entire reporting period.

5.4.3 Uncertainties and time-series consistency

Activity data consist of data on livestock populations, nitrogen excretion rates and MMS usage. The Nex has the larger contribution to the uncertainty of activity data. IPCC suggests that uncertainty range for default Nex is +/-50% but may be as low as 25%, if the country specific data about N intake and retention are available. In GHG inventory we are using other sources of Nex for cattle and swine which, we believe, better reflect the circumstances in Slovenia. It is expert judgment that overall uncertainty of AD in this category is 50% as recommended by IPCC..

Due to the use of IPCC default EF we have taken uncertainty estimates of 100% as suggested in the 2006 IPCC Guidelines.

Combined uncertainty amounts to 111.80%.

5.4.4 Category-specific QA/QC

QA/QC procedures are described in the chapter 1.2.3 and 5.2.4. Input data, calculations and the results have been thoroughly vetted by experts in the KIS and in the SEA. Any errors that were found have been corrected.

As an important QA/QC is also an ESD review, where all IEF and AD are compared with other counties and all outliers have to be justified.

5.4.5 Category-specific recalculations

The equations for estimating nitrogen excretion in dairy cows, which take into account the intensity of milk production, have been replaced by equations that also contain information on the milk urea concentration. The recalculations concern both direct (3.B.1.) and indirect emissions (3.B.5.).

5.4.6 Category-specific planned improvements

It will be considered whether relevant information on manure storage practices can be obtained by processing the raw data collected as part of the 2020 Census.

5.5 N_2O Emissions from Agricultural Soils (CRT 3.D)

5.5.1 Overview of category

Two sources of N_2O are distinguished in the IPCC methodology: direct N_2O emissions from managed soils and indirect emissions from managed soils.

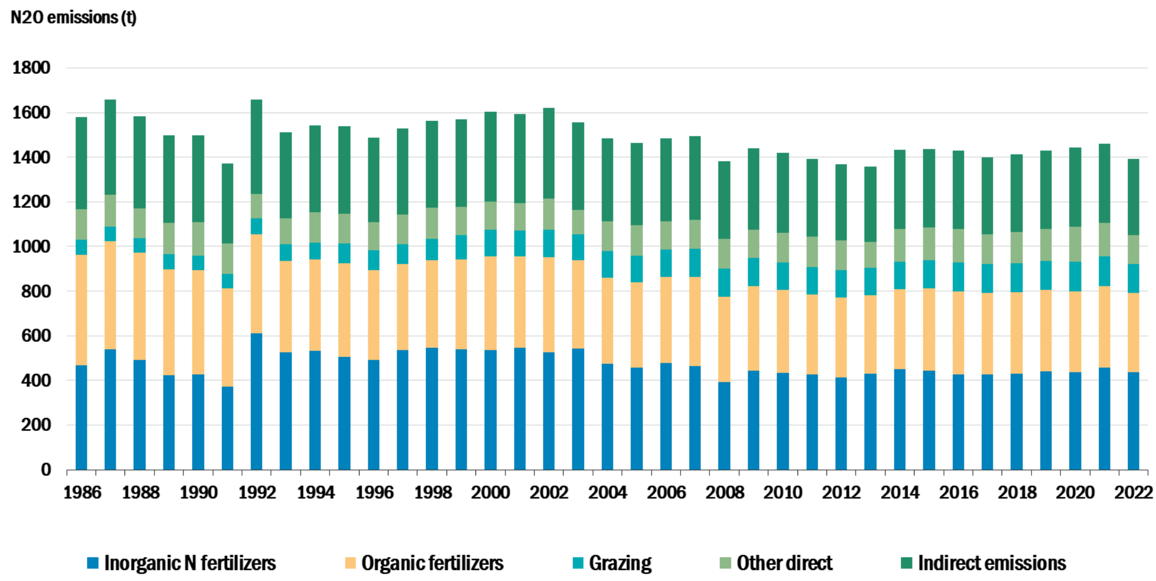

Figure 5.5.1: N_2O emissions from agricultural soil in Gg.

5.5.2 Direct N_2O Emissions from Managed Soils (CRT 3.D.a)

5.5.2.1 Category description

Sources of nitrogen, causing direct emissions of nitrous oxide into the atmosphere, are the following (Figure 5.5.1):

- mineral (inorganic) fertilizers;
- organic fertilizers, including animal manures, urban composts, digestates and sewage sludge;
- urine and dung deposited by grazing animals;
- crop residues;
- mineralization of soil organic matter which is associated with land use change or management of mineral soils;
- management of organic soils.

5.5.2.2 Methodological issues

Inorganic N fertilizers (CRT 3.D.a.1)

This estimate is based on the amount of N in mineral fertilizers that are annually consumed in Slovenia. The consumption of nitrogen from mineral fertilizers has been obtained from the Statistical Yearbook.
SORS collect data on fertilisers used in enterprises, companies and co-operatives involved in crop production. Likewise, they are taking into account the data on import, export, and production. The difference between all fertilizers sold in this country and the amount used by enterprises is the consumption of mineral fertilizers on family farms. Fertilizers that are not appropriate for agricultural production (mineral fertilizers for balcony flowers, lawns and similar) are not included.

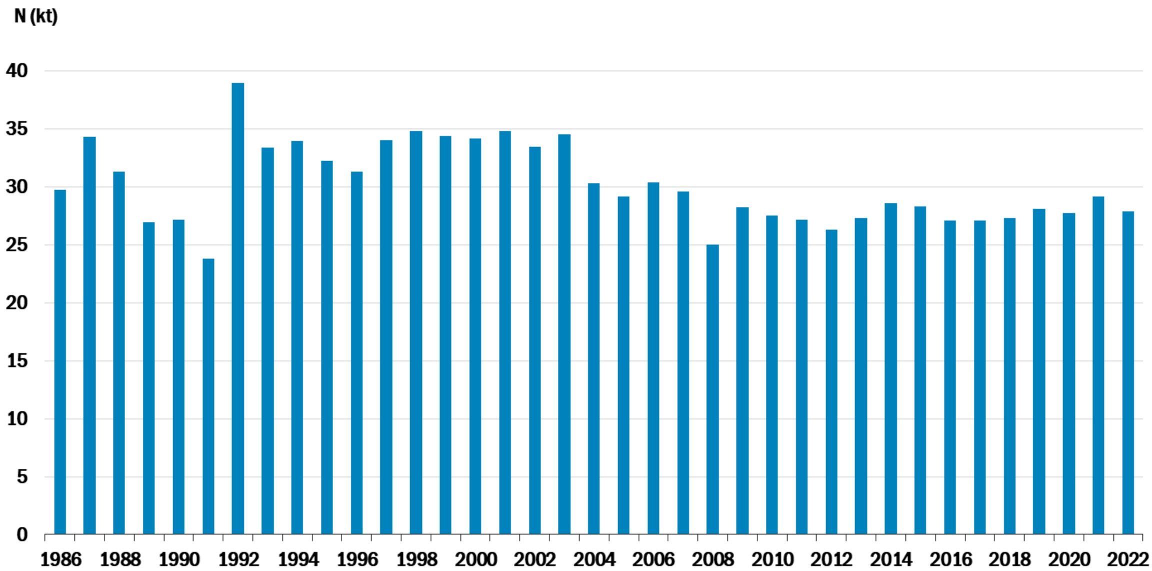

Figure 5.5.2: Amount of mineral fertilizers in kt N.

From 1987-1991 on the Figure 5.5.2, use of fertilizers shows constant decrease and a sharp increase in 1992 – the amount of fertilizers used in 1992 is the highest in the whole reporting period. One of the reasons is reduction in industrial production, poor economic situation and war for independence in 1991. In 1992, Slovenia became independent and economic situation started to improve. It is very likely that farmers did not use all fertilizers in the year 1992, had just renewed their stocks. The consumption of N fertilizers per hectare of utilised agricultural area was decreasing from 2001 to 2008. The decrease is, among others, attributable also to measures of Rural Development Programme which stimulates the expert based use of fertilizers. Consumption of N fertilizers decreased drastically in 2004 and in 2008. The main reasons for 2008 decrease was a considerable increase in mineral fertilizer price and consequently much lower use of fertilizers in agriculture.

The emission of nitrous oxide was calculated according to the Tier 1 method according to IPCC (2006) methodology. The emission factor 0.01 kg N_2O-N per kg of consumed N was applied. It has to be stressed that amounts of applied N were no longer adjusted for the amounts of NH_3 and NO_X volatilization after application to soil, which was required by IPCC (1996) methodology.

Organic N fertilizers (CRT 3.D.a.2)

a. Animal manure applied to soils (CRT 3.D.a.2.a)

The estimate is based on the amount of N in animal manures which is annually applied to agricultural area. The amount of N in the manure applied to soil has been calculated on the basis of methodology described in Chapter 5.4 (N_2O Emissions from Manure Management).
To get the amount of nitrogen in animal manures, nitrogen excreted by grazing animals and nitrogen which was lost from animal houses and manure stores (NH_3, NO_X, N_2O and N_2) were subtracted from the total amount of N excreted by farm animals. The emissions were estimated according to EMEP/EEA (2019). The emission factor of 0.01 kg N_2O-N per kg N in animal manure was used (IPCC, 2006). Similar as in case of mineral fertilizers, the N in animal manure were no longer adjusted for nitrogen which is lost after application to soil, as required by IPCC (1996) methodology.

b. Sewage sludge applied to soils (CRT 3.D.a.2.b)

Due to the very rigorous restrictions, fertilisation with sewage sludge in Slovenia is extremely low. Historical information on its use is also scarce. Data on sewage sludge deposited to agricultural area for years 1995 and 1998 were obtained from environmental reports. It was assumed that the amount of sewage sludge from waste water treatment plants during the period 1986- 1994 was equal to that in 1995 and that the same percent (30%) of sewage sludge have been deposited to agricultural area. Since 2000, data on sewage sludge applied to agricultural soils have been regularly obtained from the Slovenian reports prepared under the Sewage sludge directive. The data provider was the Environment Agency of the Republic of Slovenia. Values for 1996, 1997 and 1999 have been interpolated.

As data on N concentration in sewage sludge are not available in Slovenia, the value of 3.9 per cent N in dry matter has been taken from Austrian GHG inventory submission 2010.The emission factor of 0.01 kg N_2O-N per kg of N in sewage sludge (IPCC, 2006) was used to calculate the emissions. The amount of N in sewage sludge was not adjusted for nitrogen which was lost after application to soil.

c. Other organic fertilizers applied to soils (CRT 3.D.a.2.c)

Two sources of other organic fertilizers to soils were identified, i.e. urban composts and digestates from biogas facilities. Data on urban compost application to the agricultural soils have been obtained from the reports submitted by urban compost facilities to Environment Agency of the Republic of Slovenia. Data for the period 2014-2022 are available. For the period 1990-2013 the average value from the period 2014-2018 was considered. It was estimated that composts contained 14 kg of N per tonne. The estimate is based on the analyses of compost which were performed in the frame of monitoring programme for the period 2014-2018.

Data on digestates have been obtained from the reports submitted by biogas production plants to Environment Agency of the Republic of Slovenia. Biogas production from non-manure substrates started in 2006, however only the data for the period 2015-2022 are available. For the period 2006-2014 the quantities were estimated by linear regression taken into account zero value in 2005. In order to avoid double counting of N from animal manures, the latest was subtracted from the total estimate. From the information which was gathered from biogas plants in 2010 and some recent information it was estimated that animal manures represent 1/3 of substrate which is used for biogas production. It was estimated that digestates contained 2.5 kg of N per tonne. The estimate is based on the analyses of digestates during the period 2014-2018. It refers to a mixture of solid and liquid digestates as produced by biogas plants.

The emission factor of 0.01 kg N_2O-N per kg of N in urban composts or digestates (IPCC, 2006) was used to calculate the emissions.

Urine and dung deposited by grazing animals (CRT 3.D.a.3)

The estimate is based on the amount of N deposited to soils by grazing animals. This amount has been calculated on the basis of methodology described in Chapter 5.4 (N_2O Emissions from Manure Management). The values were not corrected for ammonia N which was lost from the grazing areas. In line with IPCC (2006) methodology, emission factor 0.02 kg N_2O-N per kg of deposited N was used for cattle and 0.01 kg N_2O-N per kg of deposited N for sheep, goats and horses.

Crop residues (CRT 3.D.a.4)

A considerable source of emissions of nitrous oxide into atmosphere is nitrogen from crop residue mineralization that remains or is returned to soil. The amount of crop residues were estimated on the basis of data on the production of individual field crops and fodder plants, including grassland forages.

The ratios between the edible (usable) crop part, which is reported by SORS, and part which remains on the fields were taken into account. Yields of the above-ground residue dry matter (AG_{DM}) were estimated by the use of equations presented in Table 5.5.2 (equations according to IPCC, 2006). Yields of below-ground residues were calculated by taking into account the ratio of below-ground residues to above-ground biomass (R_{BG-BIO}). Finally, the amount of N in crop residues was estimated by multiplying the total amount of above- and below-ground biomass (expressed on DM basis) and respective N concentrations in residues (Table 5.5.1).

For temporary grasses fraction of area which is renewed annually was considered to be 1/3. IPCC methodology envisages that crop residues that are used for other purposes have to be subtracted from the total amount of crop residue. No such correction has been applied for national inventory of N_2O emissions. In Slovenia crop residues from cereals are mainly used for bedding. In assessment of N_2O emissions from manure management N in bedding materials was not added to N excreted by farm animals. Therefore, it was not subtracted here. It has also been estimated that burning of crop residues is negligible.

To calculate emissions of nitrous oxide, the same emission factor as for other N sources (mineral and organic fertilizers, grazing, sewage sludge) (0.01 kg N_2O-N/kg N, IPCC, 2006) has been applied.

Table 5.5.1: Default factors for estimation of N added to soils from crop residues as applied in national inventory (Source: IPCC, 2006)

Crop	Dry matter fraction of harvested crop	Above-ground residue dry matter (AG_{DM}) (t) AG_{DM} = Crop (t, in DM) x slope + intercept		N conc. in above ground residues (N_{AG})	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	N conc. in below-ground residues (N_{BG})
		Slope	Intercept			
Cereals						
Wheat	0.89	1.51	0.52	0.006	0.24	0.009
Rye	0.88	1.09	0.88	0.005	0.24[1]	0.011
Barley	0.89	0.98	0.59	0.007	0.22	0.014
Oats	0.89	0.91	0.89	0.007	0.25	0.008
Maize for grains	0.87	1.03	0.61	0.006	0.22	0.007
Triticale	0.88[2]	1.09[2]	0.88[2]	0.005[3]	0.24[1]	0.011[3]
Buckwheat	0.88[2]	1.09[2]	0.88[2]	0.006[1]	0.24[1]	0.009[1]
Dried pulses						
Field peas	0.91	1.13	0.85	0.008	0.19	0.008
Kidney beans	0.91	1.13	0.85	0.008	0.19	0.008
Other dried pulses	0.91	1.13	0.85	0.008	0.19	0.008
Root crops						
Potatoes	0.22	0.10	1.06	0.019	0.20	0.014
Sugar beet	0.22	0.10	1.06	0.025[4]	0.20	0.014
Fodder beet	0.22	0.10	1.06	0.025[4]	0.20	0.014
Other fodder roots	0.22	0.10	1.06	0.025[4]	0.20	0.014
Industrial crops						
Rapeseed	0.88[2]	1.09[2]	0.88[2]	0.006[2]	0.24[1]	0.009[2]
Sunflower seed	0.88[2]	1.09[2]	0.88[2]	0.006[2]	0.24[1]	0.009[2]
Soya bean	0.91	0.93	1.35	0.008	0.19	0.008
Fodder crops						
Green maize (silage)	Above-ground residue considered to be 0, below ground supposed to be the same as in maize for grain					
Other annual green fodder	0.20[4]	0.30	0	0.015	0.54	0.012
Leguminous plants	0.88[4]	0.30	0	0.025	0.80	0.016
Grasslands						
Temporary grassland	0.88[4]	0.30	0	0.015	0.80	0.012
Permanent grassland	0.88[4]	0.30	0	0.015	0.80	0.012

[1] Value for wheat; [2] Value for grains; [3] Value for rye; [4] National estimate.

Mineralization/immobilization associated with loss/gain of soil organic matter (CRT 3.D.a.5)

For estimation of indirect N_2O emissions from managed soils arising from N mineralization due to change of land use or management on mineral soils through leaching/runoff were estimated by applying Tier 2 method (equation 11.8) and default emission factors being available in Table 11.1 of 2006 IPCC Guidelines (0.01 kg N_2O-N/kg N, IPCC, 2006). Data on annual loss of soil organic carbon in tonnes of C have been taken from the LULUCF sector. Value for R (C:N ratio) was also IPCC default (10 for management changes on Cropland remain Cropland).

Cultivation of organic soils (CRT 3.D.a.6)

Cultivation of soils with high contents of organic material (histosols) causes a release of a long-term bound N. Just like other N sources, mineralized N is considered to be available for N_2O formation. Nitrous oxide emissions were estimated on the basis of area of cultivated soils and default IPCC (2006) emission factor for temperate organic soils (8 kg N_2O-N per ha). The cultivated organic soil area has been obtained by covering two maps. Spatial information on the area of organic soils has been obtained from the Pedology map (1:25000) and information on land use has been obtained from the database of Ministry for Agriculture, Forestry and Food (Use of utilized agricultural area, 1:5000). Cultivated area was defined as a sum of two land categories, Fields and gardens (Code 1100) and Intensive orchards (Code 1221). Data for both categories exist from the year 2007 onwards. The data for the period 2000-2006 have been extrapolated on the basis of 2007-2013 series. For the period 1986-1999 the same values as for the year 2000 were used.

Detailed data about the area of cultivated organic soil and resulting N_2O emissions are presented in Table 5.5.2.

Table 5.5.2: Area of cultivated organic soil (in ha) and N_2O emissions (in tons)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Area	2096	2096	2096	2096	2096	2096	2096	2096	2096	2096	2096
N_2O	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3	26.3
	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005**	**2006**
Area	2096	2096	2096	2096	2116	2136	2156	2177	2197	2197	2217
N_2O	26.3	26.3	26.3	26.3	26.6	26.9	27.1	27.4	27.6	27.6	27.9
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2012**	**2013**	**2014**	**2015**	**2016**
Area	2254	2251	2266	2277	2343	2347	2347	2352	2497	2498	2498
N_2O	28.3	28.3	28.5	28.6	29.5	29.5	29.5	29.6	31.4	31.4	31.4
	2017	**2018**	**2019**	**2020**	**2021**	**2022**					
Area	2501	2489	2354	2356	2311	2309					
N_2O	31.4	31.3	29.6	29.6	29.0	29.0					

5.5.3 Indirect N_2O Emissions from Managed Soils (CRT 3.D.b)

5.5.3.1 Category description

Indirect N_2O emissions are caused by atmospheric deposition of volatilised N and by leaching/runoff of N compounds into waters. They are associated with volatilization of ammonia (NH_3) and nitric oxide (NO_X) from managed soils and with the leaching and runoff of nitrogen from agricultural soils into waters. Sources of nitrogen, causing indirect emissions of nitrous oxide into the atmosphere, are the following:

- mineral (inorganic) fertilizers;
- organic fertilizers, including animal manures, urban composts, digestates and sewage sludge;
- urine and dung deposited by grazing animals;
- crop residues;
- mineralization of soil organic matter which is associated with land use change or management of mineral soils.

Emissions associated with volatilization of ammonia (NH_3) and nitric oxide (NO_X) from animal houses and manure stores are reported under the category “3B Manure management”.
Indirect N_2O emissions from managed soils are presented within 2 sub-categories:

- atmospheric deposition
- nitrogen leaching and run-off.

5.5.3.2 Methodological issues

Atmospheric deposition (3Db1)

In fertilizing agricultural soils with nitrogen fertilizers, some N volatilises in form of ammonia and nitrogen oxides (NO_x). This nitrogen is deposited by precipitation and particulate matter on agricultural soil, in natural terrestrial ecosystems and waters and thus indirectly contributes to emissions of N_2O. Emissions are attributed to the place of origin of ammonia and NO_x, not to the place where N is re-deposited, causing N_2O emissions.

a. Mineral fertilizers applied to soils

Indirect emissions of nitrous oxide from mineral fertilizers depend to a large extent on the fraction of N that volatilises during fertilizing. Ammonia and NO_X emissions due to use mineral fertilizers were assessed according to EMEP/EEA (2019) methodology. Ammonia emissions were obtained by multiplying data on consumption of nitrogen from mineral fertilizers and emission factors for three main groups of fertilizers. Emission factors 0.008, 0.155 and 0.050 kg NH_3-N per kg of N were used for calcium ammonium nitrate (CAN), urea and other mineral (NP and NPK) fertilizers respectively. For the years 2016, 2017, 2018, 2019, 2020, 2021 and 2022 it was taken into account that low emission application techniques are used on 8.8, 11.8, 14.7, 17.6, 20.6, 23.5 and 26.5% of arable land, respectively. It was considered that 60% of urea is used on arable land and that urea incorporation reduces ammonia emissions by 50 %. The decision was made on the basis of the fact that investments in machinery which enables urea incorporation are supported by the Rural development programme. For the total amount of N in mineral fertilizers the same data as for direct N_2O emissions were used. In addition, data for urea consumption for the period 1994-2022 were obtained from SORS (personal communication). SORS does not publish these data, but they are reported to FAOSTAT and published with a slight delay. For the period 1985-1993 the proportion of urea in total mineral-N fertilizer consumption was estimated by extrapolation based on 1994-2013 period. The allocation of the rest of mineral-N fertilizes between CAN and other (NP and NPK) fertilizers for the period before the year 2002 was done on the basis of expert judgement (50:50) (Sušin, personal communication). From 2002 the data for CAN consumption are also available (SORS, personal communication, data not published in national statistics but reported to FAOSTAT). NO_X emissions were calculated by the use of an uniform emission factor, i.e. 0.040 kg NO_2 per kg of N applied in form of synthetic fertilizers (EMEP/EEA, 2019). For calculating indirect emissions of nitrous oxide, the emission factor of 0.01 kg N_2O-N/kg NH_3 and NO_X-N (IPCC, 2006) has been considered.

b. Animal manure applied to soils (CRT 3.D.a.2.a)

Numerous factors influence the fraction of volatilised N in form of ammonia and nitrogen oxides from agricultural soils. They include the losses of N from the preceding phase (animal houses and manure stores), as well as form of animal manure (farmyard manure or slurry) and the application techniques (splashing plate, incorporation, …). In estimating N volatilization due to application of animal manures to agricultural soils, all these factors were taken into account. Estimates of NH_3 loses were done simultaneously with direct N_2O emissions from manure management using EMEP/EEA (2019) methodology (Chapter 5.4.2.1). For emissions of NO_X, emission factor 0.040 kg NO_2 per kg of nitrogen, which is applied to soil in form of animal manures, was used (EMEP/EEA, 2019). In the second stage, emission factor 0.01 kg N_2O-N per kg of volatilised N (NH_3-N and NO_X-N) was used to asses N_2O emissions, as suggested by IPCC (2006).

c. Sewage sludge applied to soils

The same data on sewage sludge application to the agricultural soils have been used for estimation of indirect N_2O emissions as for direct ones. An emission factor 0.13 kg of ammonia per kg of total nitrogen applied by sewage sludge was used (EMEP/EEA, 2019). For emissions of NO_X, emission factor 0.040 kg NO_2 per kg of nitrogen, which is applied to soil in form of sewage sludge, was used (EMEP/EEA, 2019).

In the second stage, emission factor 0.01 kg N_2O-N per kg of volatilised N (NH_3-N and NO_X-N) was used to asses N_2O emissions, as suggested by IPCC (2006).

d. Other organic fertilizers applied to soils

The same data on the amount of urban composts and digestates application to the agricultural soils have been used as for direct emissions. For emissions of ammonia and NO_X default emission factors, as suggested by EMEP/EEA emission inventory guidebook (2019) were used (0.08 kg NH_3 and 0.04 kg NO_2 per kg of N applied to soils). In the second stage, emission factor 0.01 kg N_2O-N per kg of volatilised N (NH_3-N and NO_X-N) was used to asses N_2O emissions, as suggested by IPCC (2006).

e. <u>Urine and dung deposited by grazing animals</u>

Estimates on the amount of NH_3-N which is volatilized from grazing areas due to N deposited by grazing animals were done simultaneously with direct N_2O emissions using EMEP/EEA (2019) methodology (Chapter 5.4.2.1). For emissions of NO_X, emission factor 0.040 kg NO_2 per kg of nitrogen, which is deposited to soil in by grazing animals, was used (EMEP/EEA, 2019). In the second stage, emission factor 0.01 kg N_2O-N per kg of volatilised N (NH_3-N and NO_X-N) was used to asses N_2O emissions, as suggested by IPCC (2006).

Nitrogen leaching and run-off (CRT 3.D.b.2)

The nitrogen that enters groundwater and watercourses, mainly in the form of nitrates, is there subjected to nitrification and denitrification. This gives rise to some nitrous oxide, which is diffused into the atmosphere. Denitrification takes place mostly in groundwater, riverine sediments, and estuarine sediments. Nitrogen, which enters watercourses, contributes to emissions of nitrous oxide also during the course of nitrification. Algae and aquatic plants assimilate nitrates into organic matter, which, during decomposition, releases ammonia that is quickly nitrified in rivers, giving rise to some nitrous oxide in the process.

a. <u>Mineral fertilizers applied to soils</u>

It has been considered that 30% of total N from mineral fertilizers are leached and run-off into the groundwater and watercourses. In calculating emissions of nitrous oxide, it has been considered that for every kg of leached/run-off nitrogen, 0.0075 kg of N_2O-N is emitted (IPCC, 2006).

b. <u>Animal manure applied to soils</u>

It has been considered that for every kg of N, which is applied to agricultural area, 0.3 kg of N is leached and run-off to watercourses and groundwater (IPCC, 2006). To get the amount of N applied to agricultural area, total amount of nitrogen excreted by housed farm animals has been corrected for the amount of NH_3-N, N_2O-N and N_2 losses from animal houses and manure stores. The methodology of estimating annual quantities of N, which is applied to agricultural area, has already been described under Chapter 5.4.2.1. In calculating emissions of nitrous oxide, the same emission factor has been considered as in the case of nitrogen leaching/run-off due to mineral fertilizers (0.0075 kg N_2O-N/kg of leached/run-off N) (IPCC, 2006).

c. <u>Sewage sludge applied to soils</u>

Emissions of N_2O which resulted from leaching and run-off of nitrogen applied by sewage sludge were estimated by the use of same methodology as for animal manures. It has been considered that 0.3 kg of N per kg of applied N was lost into waters. Nitrous oxide emissions were then obtained by default factor 0.0075 kg N_2O-N per kg of leached/run-off N (IPCC, 2006).

d. <u>Other organic fertilizers applied to soils</u>

Emissions of N_2O which resulted from leaching and run-off of nitrogen applied by urban composts and digestates were estimated by the use of same methodology as for animal manures. It has been considered that 0.3 kg of N per kg of applied N was lost into waters. Nitrous oxide emissions were then obtained by default factor 0.0075 kg N_2O-N per kg of leached/run-off N (IPCC, 2006).

e. Urine and dung deposited by grazing animals

Emissions of N_2O which resulted from leaching and run-off of nitrogen deposited to agricultural soils by grazing animals were estimated on the basis of deposited N using the fraction of deposited N that is lost through leaching/run-off (0.3 kg per kg) and default emission factor 0.0075 kg N_2O-N per kg of leached/run-off N (IPCC, 2006). The amount of nitrogen deposited to agricultural soils by grazing animals was estimated as described in chapter dealing with manure management (Chapter 5.4.2.1).

f. Crop residues

Emissions of N_2O which arise from leaching and run-off of nitrogen as a result of crop residue mineralization were estimated by the use of same approach as for other N sources. The methodology for estimation of N in crop residues is given in chapter on Direct N_2O Emissions from Managed Soils (5.5.2.). It has been taken into account that 0.3 kg of N per kg of released N from crop residues is lost into waters. Emission factor 0.0075 kg N_2O-N per kg of leached/run-off N was used to calculate N_2O emissions (IPCC, 2006).

g. Mineralization of soil organic matter which is associated with land use change or management of mineral soils

Emissions of N_2O which arise from leaching and run-off of nitrogen as a result of mineralization of soil organic matter in mineral soils has been estimated as suggested by IPCC (2006). It has been taken into account that 0.3 kg of mineralized N is lost into waters. Emission factor 0.0075 kg N_2O-N per kg of leached/run-off N was used to calculate emissions (IPCC, 2006).

5.5.3.3 Uncertainties and time-series consistency

Uncertainty estimates are based on expert judgement.
Uncertainty of activity data amounts to 25% in 1986 and 10% in the recent years.
Uncertainty of emission factor amounts to 250%.
Combined uncertainty amounts to 250.20%.

5.5.3.4 Category-specific QA/QC and verification

QA/QC procedures are described in the chapter 1.2.3 and 5.2.4. Input data, calculations and the results have been thoroughly vetted by experts in the KIS and in the SEA. Any errors that were found have been corrected. QA/QC procedure includes inquiries about new/more reliable input information. In 2020, specific information on the use of various types of mineral fertilizers was obtained.

As an important QA/QC is also an ESD review, where all IEF and AD are compared with other counties and all outliers have to be justified.

5.5.3.5 Category-specific recalculations

The equations for estimating nitrogen excretion in dairy cows, which take into account the intensity of milk production, have been replaced by equations that also contain information on the milk urea concentration. The recalculations concern both the direct and indirect emissions of the category (3.D.a.2 and 3.D.b). The estimates for the proportion of fertilization with low-emission slurry spreading techniques were also corrected. The estimates in previous submissions referred to the total area of arable land and meadows, now they refer to the area that is fertilized. The recalculation concerns indirect emissions of nitrous oxide (3.D.b).

5.5.3.6 Category-specific planned improvements

It will be considered whether relevant information on manure storage practices can be obtained by processing the raw data collected as part of the 2020 Census. It will affect direct and indirect nitrous oxide emissions via the amount of nitrogen in animal manure.

5.6 Liming (CRT 3.G)

5.6.1 Category description

Emissions from liming of arable land are not a key source of CO_2 emissions in Slovenia. Lime is applied on agricultural land, especially on arable land, to keep the soil pH close to neutral, while the amount of lime applied on grassland is very small or negligible. No data are available on areas where lime is applied. This is also the reason why a breakdown of liming between arable and grassland areas is currently not possible. There is no information available to estimate the quantities of lime and dolomite applied separately. Therefore, a default value of the emission factor for limestone was used for the emission estimation.

5.6.2 Methodological issues

There are no detailed data on the application of limestone in Slovenia. However, expert estimates for the period 1986 to 1994 assumed that 100,000 Mg per year of limestone was applied to agricultural land.

In Slovenia, in the period from 1973 to 1991 drainage systems had been built on approximately 72,000 hectares of land, what represent more than 10 % of used agricultural land at that time. On figure 5.6.1 the area of individual agricultural operations in different time periods is represented. The red columns indicate drainage and yellow columns indicate agromeliorations. The latter are agricultural operations, which improve the physical, chemical and biological properties of the soil. Due to high soil acidity after reclamation from wetlands (pH is usually bellow 4.5) the liming is a necessary measure to improve soil fertility. The land reclamation had been the largest in the period 1986-1990 when on average around 6000 ha of land have been reclaimed from the wetlands each year. Liming was carried out with coarsely ground limestone in large quantities (even 15 t/ha). Approximately 80,000 to 90,000 tons of limestone have been used on reclaimed land each year and around 10,000 to 20,000 tonnes were used on other agricultural land.

In 1991 the construction of large drainage systems has been suspended with the adoption of a moratorium on the hydromeliorations. The reason for the adoption of the moratorium was mainly the increase of the ecological awareness, focus on the conservation of wetlands, which are among the most endangered and rare ecosystems in Europe and worldwide

Based on 2015 data that was obtained from the main lime producers in Slovenia and surrogate method, the estimates were provided for the period 1996-2015. Land use areas of agricultural holdings and GDP in agriculture were used as proxy data to apply the surrogate method (IPCC 2006).

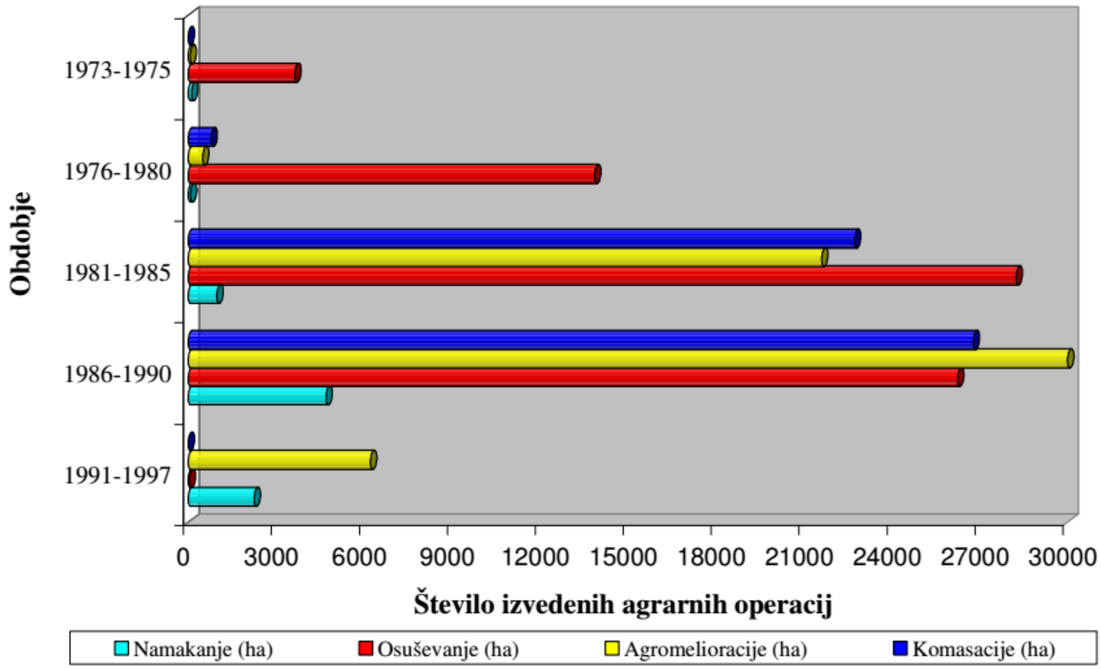

Figure 5.6.1: Area in hectares of different agricultural operations (irrigation-blue, drainage-red, agromelioration-yellow, land consolidation-blue), source: Miličić, 2007

Default emission factor (EF = 0.12) for limestone was adopted from the 2006 IPCC Guidelines.

For calculations of emissions due to liming Tier 1 methodology and equation 11.12 of the 2006 IPCC Guidelines were used.

$$CO_2 - C\ Emissions = (M_{Limestone} \bullet EF_{Limestone}) + (M_{Dolomite} \bullet EF_{Dolomite})$$

CO_2 –C Emissions – annual C emissions from lime application [t C yr $^{-1}$]
M – annual amount of calic limestone or dolomite [t yr $^{-1}$]
EF – emission factor (default value 0.12)

5.6.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgment.
The uncertainty of the activity data amounts to 50%.
The uncertainty of the emission factor is not applicable.

5.6.4 Category-specific QA/QC

No category-specific QA/QC were provided in this year's submission. However, general QA/QC, considering the figures check, correctness of the calculation used, data sources etc., were performed in the category, as it was subject to source specific recalculation.

5.6.5 Category-specific recalculations

No recalculations have been performed for this category.

5.6.6 Category-specific planned improvements

No improvements are planned for the next submission.

5.7 Urea application (CRT 3.H)

5.7.1 Category description

Adding urea to soils during fertilisation leads to a loss of CO_2. This source category is included because the CO_2 removal from the atmosphere during urea manufacturing is estimated in the IPPU Sector.

5.7.2 Methodological issues

Emissions have been calculated using Tier 1 approach and IPCC default EF of 0.20 for carbon emissions have been used. This is the absolute maximum emissions associated with urea fertilization.

Data on urea applied on the agriculture soils has been obtained from the SORS (unpublished data).

5.7.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgement.
The uncertainty of activity data amounts to 25% in 1986 and 10% in last years.
The uncertainty of emission factor amounts to 50%.

5.7.4 Category-specific QA/QC and verification

Besides QA/QC procedures described in the chapter 1.2.3 no additional QA/QC has been performed.

5.7.5 Category-specific recalculations

No recalculations have been performed for this category.

5.7.6 Category-specific planned improvements

No improvements are planned for the next submission.

5.8 Other carbon containing fertilizers (CRT 3.I)

5.8.1 Category description

In addition to liming, some limestone is applied to agricultural soils by CAN (Calcium Ammonium Nitrate) fertilizer. Carbon from the limestone is released to the atmosphere in the form of CO_2.

5.8.2 Methodological issues

CO_2 emissions due to fertilization with CAN were estimated based on the ratio of C to N in the fertilizer. Assuming that CAN contains 8% Ca in the form of $CaCO_3$, it was calculated that the fertilizer contains 2.4% C. The same principle as for liming was taken into account when estimating emissions, i.e. that the total amount of added C is lost to the atmosphere in the form of CO_2 (IPCC, 2006). The data on CAN consumption were obtained as described in 5.5.3.2.

5.8.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgement.
The uncertainty of activity data amounts to 25% in 1986 and 10% in last years.
The uncertainty of emission factor amounts to 50%.

5.8.4 Category-specific QA/QC and verification

Besides QA/QC procedures described in the chapter 1.2.3 no additional QA/QC has been performed.

5.8.5 Category-specific recalculations

Following recommendation from the ESD review, CO_2 emissions from the consumption of calcium ammonium nitrate (CAN) were included in the inventory for the entire reporting period.

5.8.6 Category-specific planned improvements

No improvements are planned for the next submission.

6 LULUCF (CRT sector 4)

6.1 Overview of sector

The LULUCF sector comprises GHG emissions and removals resulting activities relating to land use land-use change and forestry. According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006, hereinafter 2006 Guidelines) Slovenia classifies its national land into 6 land-use categories; Forest land, Cropland, Grassland, Wetlands, Settlements and Other land. Estimates of GHG emissions and removals in this sector are calculated from carbon stock changes in the five carbon pools, namely aboveground biomass, belowground biomass, dead wood, litter and soil. Reporting also includes emissions associated with N_2O emissions from drainage of organic soils, direct and indirect N_2O emissions from N mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils, and non-CO_2 emissions from biomass burning. In addition, GHG emissions and removals calculated from carbon stock changes in harvested wood products (HWP) are also reported. Direct N_2O emissions from N fertilization and CO_2 emissions from liming agricultural soils are reported in the Agriculture sector.

Table 6.1.1: Methods, EFs used and key categories indications for the year 2022 in the LULUCF sector

		CO_2		
		Method	EF	Key category
A. Forest land	1. Forest land remaining Forest land	CS,D,T1,T2,T3	CS, D	L, T
	2. Land converted to Forest land	CS,D,T1,T2,T3	CS, D	L, T
B. Cropland	1. Cropland remaining Cropland	D,T1,T2	CS, D	L
	2. Land converted to Cropland	D,T1,T2	CS, D	L, T
C. Grassland	1. Grassland remaining Grassland	D,T1,T2	CS, D	L, T
	2. Land converted to Grassland	D,T1,T2	CS, D	T
D. Wetlands		D,T1,T2	CS, D	-
E. Settlements	1. Settlements remaining Settlements	D,T2	CS,D	L, T
	2. Land converted to Settlements	D,T2	CS,D	L, T
F. Other land		D,T2	CS,D	-
G. Harvested wood products		D, T1	D	L, T
		CH_4		
		Method	EF	Key category
A. Forest land	1. Forest land remaining Forest land	D, T1	D	-
		N_2O		
		Method	EF	Key category
A. Forest land	1. Forest land remaining Forest land	D, T1	D	-
B. Cropland	2. Land converted to Cropland	D,T1	D	-

In 2022, the LULUCF sector acted as a CO_2 sink of -174 Gg CO_2 eq as total emissions from this sector were higher than total removals (Figure 6.1.1). The most important category is forest land, which accounts for 95% of the sector's total net emissions. The LULUCF sector has been a net sink in recent years, largely due to declines in sanitary fellings and mortality rates. In terms of the overall trend of net removals from the LULUCF sector, removals decreased by 35% from 1986 to 2022. Further decreases occurred from grassland and HWP. While net removals from grassland showed a decreasing trend, removals from HWP increased since 2016, due to increased biomass supply following natural disturbances in forests.

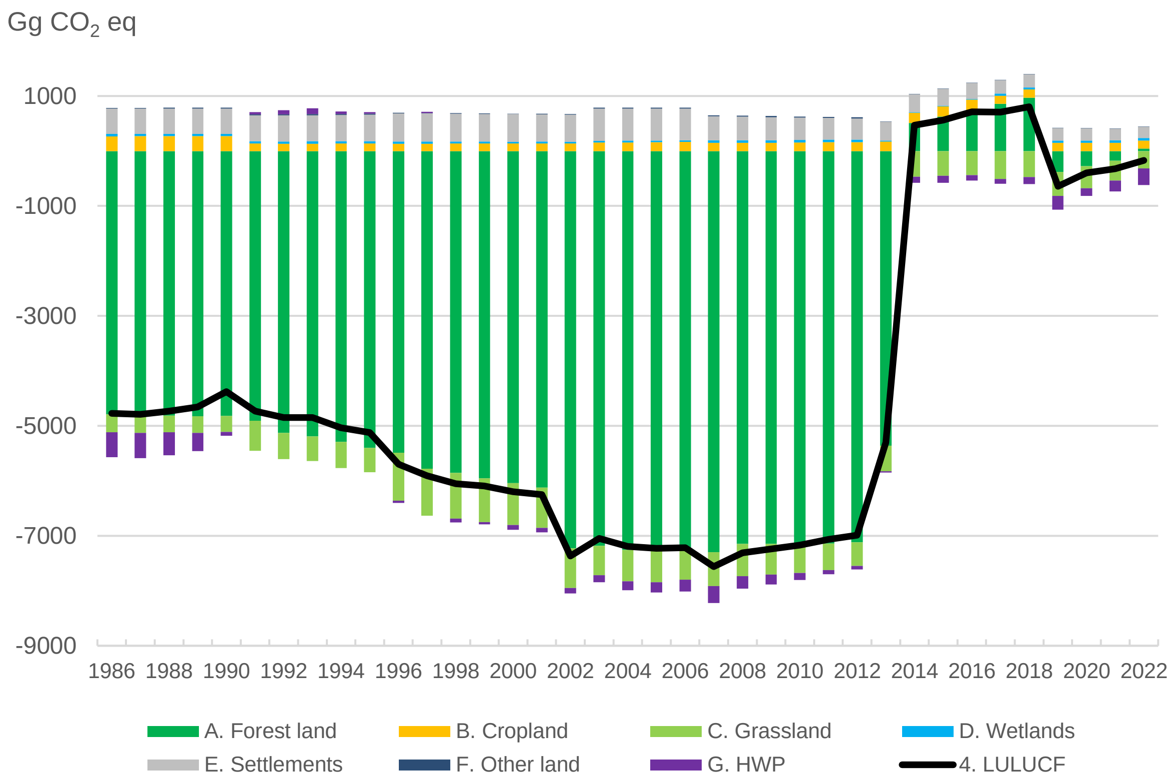

Figure 6.1.1: Net emissions and removals in the LULUCF sector from 1986 to 2022

For this inventory, above- and below-ground biomass are collectively referred to as “living biomass” and dead wood and litter are collectively referred to as “dead organic matter”. Data collection and calculations are based on the 2006 Guidelines and supplemented by country-specific methods.

Country-specific emission factors and carbon stock values for forest land and, in some cases, for cropland and grassland are derived from surveys and measurements and have been used wherever possible. For other land use categories, IPCC default values or expert judgements are used.

The areas and shares of land use in 2022 are shown in Table 6.1.2, while the comparison of area by land use category between 1986 and 2022 is shown in Figure 6.1.2.

Table 6.1.2: Area by categories of land use in the year 2022

Category	Area, kha	Share, %
Forest land	1206.10	59.49
Cropland	245.90	12.13
Grassland	405.40	20.00
Wetlands	15.10	0.74
Settlements	122.65	6.05
Other land	32.15	1.59
Sum	2027.30	100.00

Table 6.1.3 summarizes CO_2 emissions and removals as a result of carbon losses and gains for the period 1986-2022. Total net emissions of CO_2 from the LULUCF sector were -4,775 Gg CO_2 eq in the base year (1986) and -169 Gg CO_2 eq in 2022. The maximum value of net removals was in 2007. Since then, net removals from the LULUCF sector have been decreasing, which was initially related to the change in national forest policy (adoption of the National Forest Programme). However, Slovenian forests have been significantly affected by natural disturbances since 2014. The total harvest in damaged forests has increased by about 50% in the following years, mainly due to the increase in sanitary felling, which led to a significant decrease in net removals not only in forests but also in the sector.

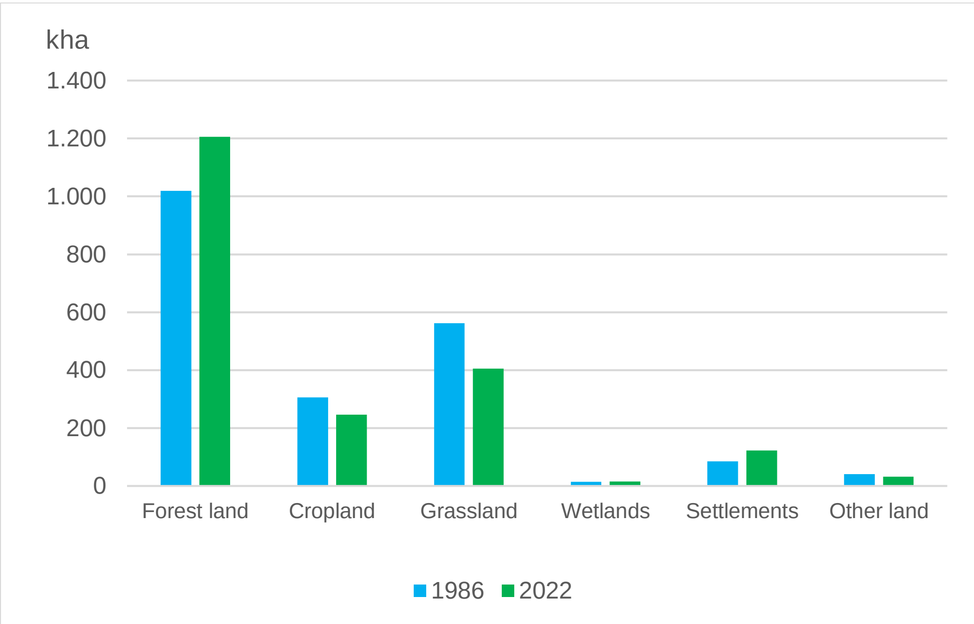

Figure 6.1.2: Land areas in 1986 and 2022

Emission trends showed that the largest change from the base year (1986) was for Wetlands and Other land. Forest land, Grassland and HWP were the sources of GHG removals, with HWP acting as a net source of emissions in the period 1991-1995 and in 1997 and Forest land in the period 2014-2018. Grassland acted as a sink throughout the whole period, mainly due to natural afforestation. In general, Grassland showed high interannual variability in net emissions trend, due to demographic changes and CAP subsidies that led to the abandonment of agricultural activity (i.e. mowing and grazing). Emissions from Cropland showed a stable trend in recent years and are not increasing as much.

Table 6.1.3: Emissions and removals from sector 4 LULUCF by top-level land categories and Harvested wood products in Gg CO_2 equivalent

Year	4. Total*	4.A FL	4.B CL	4.C GL	4.D WL	4.E SL	4.F OL	4.G HWP
GHG emissions/removals, Gg CO_2 equivalent								
Change to 1986 (%)	-96%	-101%	-44%	-2%	8%	-56%	-71%	-33%
2022	-174	42	150	-314	45	202	4	-305
2021	-325	-180	149	-360	43	211	4	-195
2020	-400	-277	150	-400	42	220	4	-142
2019	-643	-379	148	-437	40	229	4	-253
2018	803	968	151	-476	38	238	4	-126
2017	706	856	150	-508	36	247	4	-86
2016	711	742	192	-438	12	293	4	-102
2015	564	624	189	-451	13	306	4	-129
2014	468	512	183	-466	14	325	4	-113
2013	-5304	-5358	172	-467	16	344	5	-25
2012	-6991	-7117	162	-433	46	385	20	-64
2011	-7066	-7139	158	-484	46	397	20	-75
2010	-7167	-7145	153	-531	46	410	20	-129
2009	-7241	-7144	151	-561	46	420	19	-183
2008	-7308	-7146	149	-588	46	430	19	-228
2007	-7560	-7299	147	-613	45	440	19	-311
2006	-7214	-7218	164	-577	29	580	16	-219
2005	-7230	-7266	161	-578	30	582	16	-185
2004	-7190	-7256	157	-569	31	583	16	-164
2003	-7045	-7179	154	-535	32	584	15	-129
2002	-7367	-7229	138	-722	29	495	8	-98
2001	-6248	-6124	139	-734	31	498	8	-78
2000	-6197	-6043	136	-760	32	502	8	-85
1999	-6095	-5953	136	-799	33	505	9	-40
1998	-6055	-5856	135	-828	35	509	9	-71
1997	-5909	-5782	133	-855	36	512	10	24
1996	-5695	-5491	132	-870	37	516	10	-43
1995	-5119	-5403	138	-437	41	480	21	28
1994	-5034	-5293	135	-474	41	478	21	45
1993	-4848	-5193	134	-445	41	476	21	106
1992	-4848	-5127	133	-478	41	474	20	77
1991	-4732	-4908	134	-543	41	472	20	40
1990	-4379	-4818	270	-295	42	461	15	-67
1989	-4658	-4825	270	-305	42	461	15	-329
1988	-4735	-4816	270	-303	42	460	14	-416
1987	-4789	-4803	268	-324	42	460	14	-460
1986	-4775	-4793	267	-321	42	460	14	-457

*Total LULUCF emissions and removals include also indirect N_2O emissions from managed soils

6.2 Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories

Land use and land-use change

In the NID submissions until 2005, different vector layers of the Agricultural Land Use Map (ALUM) of the Ministry of Agriculture and the Environment (MAE), now called Ministry of Agriculture, Forestry and Food (MAFF), were used to represent land use and land-use changes for Slovenia. The previous approach to land representation included layers of ALUM, which were used to detect land use changes using Intersect tool of GIS software. This approach allowed us to obtain a good estimate of land use/cover trends compared to the earlier additional and less accurate data sources used for land use/cover change in previous reports. However, only one land-use change matrix was constructed to estimate the conversions between the six top-level categories and the other subcategories accordingly. Applying a constant land use change over the entire reporting period resulted in linear trends not only for land, but also for emissions and removals. In addition, there were some other difficulties associatied with the previous approach. The comparison of two vector layers resulted in unrealistic changes that do not occur in nature. These changes were also a consequence of changes in the methodology for collecting data in the ALUM database, which were subject to constant changes due to the adaptation of the Common Agricultural Policy (EU CAP).

A consistent representation of land use is essential and forms the basis for an objective estimation of GHG emissions and removals. The land use change matrix produced by the above approach was subject to problems that were consistently highlighted in the ERT's annual review reports. For this reason, MAFF supported a targeted research project “Bases for improving the reporting methodology of GHG emissions related to land use, land use change and forestry” in the period 2014-2016, coordinated by Slovenian Forestry Institute. The project aimed to improve land use change matrices, activity data estimates, emission factors, area stratification for cropland, use of higher Tier levels etc. The main project outputs (area estimation and land use change matrices) were first used in the 2016 NID annual submission. The methodology is described in more detail in the subsection 6.3.1.

The national land-use classes have seven main categories: agricultural land, forest, built-up areas and related surfaces, swamps and other marshy areas, dried open areas with special vegetation, open areas with little or no vegetation and on the end waters. According to the 2006 Guidelines, the Slovenian land use category of agricultural land use is divided into two categories, namely cropland and grassland, and the categories dried open areas with special vegetation, open areas with little or no vegetation are in one class (Table 6.2.1).

The definitions of each land use category from the 2006 Guidelines for Slovenia are described below, while the classification of national land use classes from ALUM according to the six main categories from the 2006 Guidelines is presented in the table 6.2.1.

6.2.1 Forest land

Forest land is defined as land spanning more than 0.25 hectares with forest trees higher than 5 meters and canopy cover more than 10%, or trees able to reach this threshold *in situ.* It includes overgrown land (i.e. natural afforestation) on an area of at least 0.25 ha which has not been used for agricultural purposes in the last 20 years and on which forest trees can reach a height of at least 5 meters and a canopy cover has reached 75%. Forest land includes riparian and windbreak strips, wider than one tree height of a mature tree, in an area of at least 0.25 ha. Forest land also includes other wooded land, which is land covered with forest trees or other woody vegetation on an area of at least 0.25 ha and which has not been used for agricultural purposes in the last 20 years, including forest stables for game breeding and areas under power lines in forests on an area of at least 0.25 ha. Fores infrastructure that is not valued as a separate area is an integral part of forest. All Forest land is assumed managed.

6.2.2 Cropland

Cropland is defined as land suitable for agricultural production. Annual cropland includes arable land for annual crop production (cereals, potatoes, forage crops, vegetable crops, oilseeds, ornamental plants, herbs, strawberries, hop fields, etc), agricultural fallow land, and also temporary meadows and greenhouses. Perennial cropland includes areas for permanent crops such as vineyards, extensive and intensive orchards, olive groves, nurseries (for vines, fruit and forest trees), forest plantations and forest trees on agricultural land.

6.2.3 Grassland

Grassland is defined as agricultural land covered with grass and other herbage that is regularly mowed or grazed. This land is neither cultivated nor fallow. Perennial grassland includes overgrown areas, trees and shrubs, and forest trees on agricultural land with a minimum canopy cover of 10%. An annual grassland includes permanent meadows and pastures, including alpine pastures, and swampy meadows and pastures. The latter are located on organic or mineral-organic soils where groundwater rises only a few times a year. It also includes uncultivated arable land. It is assumed that all Grassland is managed.

6.2.4 Wetlands

Wetlands are defined as land that is temporarily or permanently saturated by water. Wetlands include areas such as fens, marshes, bogs and reeds that are not use for agriculture. Inland waters (larger rivers, lakes and reservoirs) are also part of Wetlands. Although there are small areas of raised bogs, it is assumed that all Wetlands are managed.

6.2.5 Settlements

Settlements are defined as infrastructure components where buildings, roads, parking places, mines, quarries and all other infrastructure are in human use. All Settlements are assumed to be managed.

6.2.6 Other land

Other land is defined as land with a vegetation height of less than 2 meters or land with a vegetation cover of less than 75% that is not used for agriculture. This includes developed areas with little or no vegetation such as rocks, sands, sandbars (greater than 5000 m^2), waste and other open areas. This category includes all areas not classified under other land use definitions.

Table 6.2.1: Categories from ALUM delivered in six main categories from 2006 Guidelines

LULUCF category	LULUCF subcategory	National class ID	Category description
FOREST LAND	FL	2000	Forest
CROPLAND	CL_a	1100	Arable land
	CL_a	1160	Hop fields
	CL_a	1190	Green houses
	CL_w	1180	Other permanent crops on arable land
	CL_w	1211	Vineyards
	CL_w	1212	Nursery
	CL_w	1221	Intensive orchards
	CL_w	1222	Extensive orchards
	CL_w	1230	Olive groves
	CL_w	1240	Other permanent crops
	CL_w	1420	Forest plantation
GRASSLAND	GL_a	1300*	Meadows and pastures*
	GL_a	1321	Swampy meadows and pastures
	GL_a	1330	Alpine meadows
	GL_a	1600	Uncultivated agriculture land
	GL_w	1410	Overgrown areas
	GL_w	1500	Trees and shrubs
	GL_w	1800	Forest trees on agricultural land
WETLANDS	WL	4100	Swamps
	WL	4210	Reeds
	WL	4220	Other marshy areas
	WL	7000	Waters (inland water bodies)
SETTLEMENTS	SL	3000	Built-up areas and related surfaces
OTHER LAND	OL	5000	Dried open areas with special vegetation
	OL	6000	Open areas with little or no vegetation

Note: In accordance with the Rules on Land Use data base (2008), the class of alpine meadows (1330) was removed from the Slovenian land use classification in 2006. Therefore, these areas were included in other relevant classes (e.g. 1300, 5000).

6.3 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

6.3.1 Development of land-use change matrices

The targeted research project “Bases for improving the reporting methodology of GHG emissions related to land use, land use change and forestry” has provided the opportunity to interpret land uses based on the national land classification for the three time points 2002, 2006 and 2012. Accordingly, two land use change matrices were constructed. The land use estimation was based on digital orthophoto imagery on a systematic 1 km x 1 km grid using a point sampling method. A total of 20,253 grid points per sample year were photointerpreted simultaneously on one screen. This means that the theoretical location for three points was sampled at the same time. Other sources of spatial information, such as land cover from satelite imagery (Landsat), corresponding land use maps from ALUM and LPIS, and other maps were also used to verify the problematic points (mostly related to agricultural land).

For the period until 2002, land use data from the Statistical Yearbook of the Statistical Office of the Republic of Slovenia were used, as well as forest data from Slovenia Forest Service, since no digital ortophotos are available for this period. Two baaselines were used to simulate land use conversions between land use subcategories for the period 1986-2002. The first is the transition rates available in the existing literature (Ferreira and Petek 2005, Kobler et al. 2005, Petek 2005, SORS 2005, Pišek 2012, Pirnat and Kobler 2014, Bole 2015) and the second is the transition trends observed during the project in the 2002-2006 and 2006-2012 matrices.

In 2018, a new land use estimate was conducted based on digital orthophotos from 2016, 2017 and 2018. This estimate re-examined all land use changes resulting from the intersection of the previous point sample from 2012 and current vector layer from ALUM. The estimate also considered the vector layer from LPIS for agricultural land and the digital canopy model (based on LiDAR) from Laser scanning of Slovenia. The estimate is representative for the year 2017, which was compared with the previous estimate (2012). On this basis, the new land use change matrix for the period 2012-2017 was defined, where the annual land use changes were calculated by interpolation (Table 6.3.6).

Table 6.3.1: Land-use change matrix for the period 1986-1990 in hectares

1986-1990	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	$Total_{1986}$
FL	1016195	100	300	1000	500	100	600	100	1018895
CL_a		241952	900	4500	600		700		248652
CL_w		600	54957	700	700				56957
GL_a	100	1100	1800	317691	13800	300	5800		340591
GL_w	8000	2400	500	17300	193144		200		221544
WL					100	14415	200		14715
SL		800		5100			79502		85402
OL				2000	3000			35545	40545
$Total_{1990}$	1024295	246952	58457	348291	211844	14815	87002	35645	2027300

Table 6.3.2: Land-use change matrix for the period 1990-1995 in hectares

1990-1995	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	Total1990
FL	1019595	200	400	1800	1100	100	900	200	1024295
CL_a		231916	1000	10000	736		3300		246952
CL_w		300	51057	4000	3000		100		58457
GL_a	200	1100	1800	311791	27000	400	6000		348291
GL_w	82000	200	200	12000	117344		100		211844
WL					100	14415	300		14815
SL		600		5000			81402		87002
OL				500	1000			34145	35645
Total1995	1101795	234316	54457	345091	150280	14915	92102	34346	2027300

Table 6.3.3: Land-use change matrix for the period 1995-2002 in hectares

1995-2002	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	Total1995
FL	1096095	100	500	1900	1100	100	2000		1101795
CL_a		214716	1800	13800	700		3300		234316
CL_w		300	49757	3200	600		600		54457
GL_a		3500	5100	291721	39410		5360		345091
GL_w	114255	334	394	4700	30396		200		150280
WL					300	13950	665		14915
SL		100		499			91025	478	92102
OL				330	2544			31472	34346
Total2002	1210350	219050	57550	316150	75050	14050	103150	31950	2027300

Table 6.3.4: Land-use change matrix for the period 2002-2006 in hectares

2002-2006	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	Total2002
FL	1204650	100	300	1900	1100	100	2100	100	1210350
CL_a		211350	400	5600	300		1400		219050
CL_w		300	52850	3200	600		600		57550
GL_a	200	2600	2700	291150	17300		2200		316150
GL_w	1900	400	100	3800	68650		200		75050
WL					100	13750	200		14050
SL		100		500			102450	100	103150
OL				100				31850	31950
Total2006	1206750	214850	56350	306250	88050	13850	109150	32050	2027300

Table 6.3.5: Land-use change matrix for the period 2006-2012 in hectares

2006-2012	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	$Total_{2006}$
FL	1201650	100	300	1900	1100	400	1100	200	1206750
CL_a		205450	100	7500			1800		214850
CL_w		700	51050	4100	200		300		56350
GL_a		2400	1000	292050	8400	100	2300		306250
GL_w	4700	400	400	6700	75050		800		88050
WL						13850			13850
SL			100	200	100		108750		109150
OL	100							31950	32050
$Total_{2012}$	1206450	209050	52950	312450	84850	14350	115050	32150	2027300

Table 6.3.6: Land-use change matrix for the period 2012-2016 in hectares

2012-2016	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	$Total_{2012}$
FL	1204350		300	900	100		800		1206450
CL_a		190350		18600			100		209050
CL_w		500	48350	3800	300				52950
GL_a		6600	800	290650	13200		1200		312450
GL_w	3700	300	200	4500	76050		100		84850
WL						14350	0		14350
SL							115050		115050
OL								32150	32150
$Total_{2016}$	1208050	197750	49650	318450	89650	14350	117250	32150	2027300

Table 6.3.7: Land-use change matrix for the period 2016-2020 in hectares

2016-2020	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	$Total_{2016}$
FL	1205850		100	1400	300	200	200		1208050
CL_a		192550	700	4000		200	300		197750
CL_w		400	47450	1600			200		49650
GL_a		4500	500	306150	4700	100	2500		318450
GL_w	900		100	2100	86050		500		89650
WL						14350			14350
SL			100				117150		117250
OL								32150	32150
$Total_{2020}$	1206750	197450	48950	315250	91050	14850	120850	32150	2027300

Although many changes in nature took place in the period 2002-2012, the extent of conversions resulting from the previous land use change matrix was not realistic for Slovenia. The majority of converted areas resulting from the previous methodology, were small land use changes occurring due to differences in polygons boundaries that create so called “sliver polygons” when intersecting two layers. Another weakness of the vectorization process was the subjective delineation by which different land use types are determined in terms of polygons. The latter were often misinterpreted in the past, mainly due to the poor quality of orthophotos and the subjectivity of the interpreters, which led to unreal changes. Some of the changes can also be attributed to the rasterization process. All these problems have already been discussed (Miličić and Udovč 2012, Nastran and Žižek Kulovec 2014). The research of Nastran and Žižek Kulovec (2014) showed that the area of deforestation estimated with the previous methodology is about 10 times higher than the official value in the annual reports of Slovenia Forest Service.

The point sampling method allowed us to verify deforestation rates, and to discover the actual land use changes in nature. It was found that the deforestation rate ranged from 675 and 1425 ha per year in the period 2002-2012. This is about 2-3 times higher than the deforestation reported by SFS in its annual reports. However, it should be emphasized that the point sampling estimates include conversions of forest land to wetlands and of forest land to other land. These types of deforestation are also considered to be human-induced, as they occur on previously managed land. Therefore, the results suggest that the deforestation rate is about 900 ha per year, which is slightly more compared to previous independent studies (Nastran and Žižek Kulovec 2014).

Land-use areas for each land use were calculated using following equation:

$$Area_{LU, yearofinventory} = Area_{LU, previousinventoryyear} + Area_{landconvertedtoLU} \quad \textbf{(Equation 1)}$$

$Area_{LU, yearof\ inventory}$ - area of selected land use category in year of inventory [ha]
$Area_{LU, previousinventoryyear}$ - area of selected land use category in previous year [ha]
$Area_{landconvertedtoLU}$ - area of land converted to selected land use category [ha]

The standard error (in %) of an area estimate obtained for the years 2002, 2006 and 2012 in the targeted project (Mali et al. 2016) and for the year 2017 are presented below (Table 6.3.7).

Table 6.3.8: Standard error (%) of an area estimate for the land-use categories

Land-use category	Standard error, %			
	2002-2006	2006-2012	2012-2016	2016-2020
Forest land remaining forest land	0.6	0.6	0.6	0.6
Land converted to forest land	21.8	14.6	16.4	33.3
Cropland remaining cropland	1.8	1.8	2.0	2.0
Land converted to cropland	12.6	14.6	11.0	13.9
Grassland remaining grassland	1.5	1.5	1.4	1.4
Land converted to grassland	8.6	8.1	6.5	11.6
Wetlands remaining wetlands	8.6	8.5	8.3	8.3
Land converted to wetlands	100.0	44.7	n.a.	44.7
Settlements remaining settlements	3.0	3.0	2.9	2.8
Land converted to settlements	12.2	12.6	21.3	16.4
Other land remaining other land	5.6	5.6	5.5	5.5
Land converted to other land	70.7	70.7	n.a.	n.a.

Table 6.3.9: Areas per LULUCF land-use categories from 1986 to 2022 in kha

Year	4. Total	4.A Forest Land	4.B. Cropland	4.C Grassland	4.D Wetlands	4.E Settlements	4.F Other Land
Area, kha							
2022	2027.30	1206.10	245.90	405.40	15.10	122.65	32.15
2021	2027.30	1206.42	246.15	405.85	14.97	121.75	32.15
2020	2027.30	1206.75	246.40	406.30	14.85	120.85	32.15
2019	2027.30	1207.07	246.65	406.75	14.72	119.95	32.15
2018	2027.30	1207.40	246.90	407.20	14.60	119.05	32.15
2017	2027.30	1207.72	247.15	407.65	14.47	118.15	32.15
2016	2027.30	1208.05	247.40	408.10	14.35	117.25	32.15
2015	2027.30	1207.65	251.05	405.40	14.35	116.70	32.15
2014	2027.30	1207.25	254.70	402.70	14.35	116.15	32.15
2013	2027.30	1206.85	258.35	400.00	14.35	115.60	32.15
2012	2027.30	1206.45	262.00	397.30	14.35	115.05	32.15
2011	2027.30	1206.50	263.53	396.80	14.27	114.07	32.13
2010	2027.30	1206.55	265.07	396.30	14.18	113.08	32.12
2009	2027.30	1206.60	266.60	395.80	14.10	112.10	32.10
2008	2027.30	1206.65	268.13	395.30	14.02	111.12	32.08
2007	2027.30	1206.70	269.67	394.80	13.93	110.13	32.07
2006	2027.30	1206.75	271.20	394.30	13.85	109.15	32.05
2005	2027.30	1207.65	272.55	393.53	13.90	107.65	32.02
2004	2027.30	1208.55	273.90	392.75	13.95	106.15	32.00
2003	2027.30	1209.45	275.25	391.98	14.00	104.65	31.98
2002	2027.30	1210.35	276.60	391.20	14.05	103.15	31.95
2001	2027.30	1194.84	278.34	406.08	14.17	101.57	32.29
2000	2027.30	1179.33	280.08	420.96	14.30	99.99	32.63
1999	2027.30	1163.83	281.82	435.84	14.42	98.42	32.98
1998	2027.30	1148.32	283.56	450.73	14.54	96.84	33.32
1997	2027.30	1132.81	285.29	465.61	14.67	95.26	33.66
1996	2027.30	1117.30	287.03	480.49	14.79	93.68	34.00
1995	2027.30	1101.79	288.77	495.37	14.91	92.10	34.35
1994	2027.30	1086.29	292.10	508.32	14.89	91.08	34.61
1993	2027.30	1070.79	295.43	521.28	14.87	90.06	34.87
1992	2027.30	1055.29	298.75	534.23	14.85	89.04	35.13
1991	2027.30	1039.79	302.08	547.18	14.83	88.02	35.39
1990	2027.30	1024.29	305.41	560.13	14.81	87.00	35.65
1989	2027.30	1022.94	305.46	560.63	14.79	86.60	36.87
1988	2027.30	1021.59	305.51	561.13	14.76	86.20	38.10
1987	2027.30	1020.24	305.56	561.63	14.74	85.80	39.32
1986	2027.30	1018.89	305.61	562.13	14.71	85.40	40.55

Average carbon stocks of carbon pools and data source

Above-ground biomass carbon stock were estimated based on data obtained by the national forest inventory (FECS) and national research studies (e.g. Mali et al., 2017b; Mali et al., 2018b).

Dead organic matter and soil organic carbon were determined from forest soil monitoring in 2007 as part of the BioSoil project.

Litter and soil organic carbon (SOC) stocks of agricultural land were estimated based on monitoring carried out in recent years (Mali et al., 2016; Mali et al., 2017a; Mali et al., 2018a; Šinkovec et al., 2020). The average values are shown in tables 6.3.10, 6.3.11, and 6.3.12. The values of SOC stocks were estimated for the depth of 0-30 cm of the mineral part of soil. Note that forest land, wetlands, settlements and other land were not subject of this monitoring.

Table 6.3.10: Average carbon stocks in living biomass

Land use	Above-ground biomass [t C ha^{-1}]	Below-ground biomas [t C ha^{-1}]	Living biomass [t C ha^{-1}]
Forest land*	*80.53	19.45	99.98
Cropland annual	2.07	0.69	2.76
Cropland perennial	9.29	6.48	15.77
Grassland annual	1.89	NA	1.89
Grassland perennial	35.02	13.13	48.15
Wetlands	16.85	7.25	24.09
Settlements	6.65	2.64	9.29
Other land	5.00	NA	5.00

* The value for forest land refers to the period 2020-2023

Table 6.3.11: Average carbon stocks in dead organic matter

Land use	Dead wood [t C ha^{-1}]	Litter [t C ha^{-1}]	Dead organic matter [t C ha^{-1}]
Forest land	6.03	10.41	16.43
Cropland annual	NA	NA	NA
Cropland perennial	NA	3.70	3.71
Grassland annual	NA	NA	NA
Grassland perennial	2.27	7.58	9.85
Wetlands	NA	NA	NA
Settlements	NA	NA	NA
Other land	NA	NA	NA

* The value for forest land refers to the period 2020-2023

Table 6.3.12: Average soil organic carbon stocks

Land use	Mineral soil [t C ha^{-1}]	n
Forest land	103.31 ± 7.90	136
Cropland annual	86.00 ± 5.29	183
Cropland perennial	77.80	Area weighted average
Vineyards	59.90 ± 6.61	35
Intensive orchards	71.32 ± 6.40	23
Extensive orchards	90.55 ± 8.84	30
Grassland annual	94.86 ± 4.31	141
Grassland perennial	101.53	Area weighted average
Overgrown areas	93.47 ± 14.42	30
Trees and shrubs	107.16 ± 20.95	23
Wetlands	10.76	Area weighted average
Wetlands	158.21 ± 29.59	25
Waters	0	/
Settlements	29.85	Area weighted average
Green urban areas	88.14 ± 23.37	25
Sealed areas	0	/
Other land	33.18	EJ

In 2022 and 2023, soil monitoring in wetlands and settlements was conducted as part of the inventory for non-forest land (Marinšek et al., 2023). The average soil organic carbon (SOC) stocks were estimated for the top 30 cm of soil (0-30 cm).

For wetlands, SOC stock assessments focused on swamps, reeds, and other marshy areas across 25 sites, yielding an average value of 158.21 t C ha^{-1}. It was assumed that SOC stock for all inland water bodies, which are also classified as part of wetlands, is zero. This assumption resulted in an area-weighted average SOC stock of 10.76 t C ha^{-1} for the entire wetlands category.

Similarly, SOC stock in settlements was assessed at 25 representative sites, with an average value of 88.14 t C ha^{-1}. It was assumed that sealed areas within settlements have an SOC stock of zero by default. The area-weighted average SOC stock for settlements was calculated based on the proportion of green spaces (33.86%) and sealed urban areas.

For other land category, the SOC stock was estimated by expert judgment. This involved calculating a weighted average based on the areas of national land use classes 5000 and 6000, which were used as weights (see Table 6.2.1).

6.4 Forest Land (4A)

6.4.1 Source category description

Forest land category includes CO_2 emissions from changes in carbon stock in living biomass (above and below ground biomass), in dead organic matter (dead wood and litter) and soils. Carbon stock changes are reported in Forest land remaining Forest land and in Land converted to Forest land. Also non-CO_2 emissions from biomass burning are reported.

The forest area in Slovenia in 2022 was 1206.10 kha, which is 59.49% of the country's land area. Most Slovenian forests are located in beech, fir-beech and beech-oak sites (70%), which have a relatively high production capacity. The share of growing stock of conifers was 43.6 % in 2018, and of broadleaves 56.4%. Main tree species are beech (*Fagus sylvatica*), spruce (*Picea abies*), fir (*Abies alba),* sessile oak (*Quercus petraea*) and Scotch pine (*Pinus sylvestris*). These species represent 79.0% of total growing stock (beech 33.4%, spruce 28.6%, fir 7.9%, oak 5.3%, and Scotch pine 3.9%).

Majority, 77.8% of forests in Slovenia are private property, 22.2% of forests are public (owned by the state or local communities) (Annual report on forests, SFS 2012). Larger and undivided forest estates of state-owned forests enable good professional management. Private forest estates are small, with an average area of only 3 ha and even these are further fragmented into several separate plots. For the great majority of these estates forests are not of economic interest. Private forest property is becoming even more fragmented as the number of forest owners is increasing. According to the latest data there are already 314,000 (with co-owners even 489,000) forest owners in Slovenia. The major fragmentation of forest property, the number of forest owners and co-owners, present a serious obstacle to professional work in private forests, to optimal timber production and utilization of forest potential (Slovenia Forest Service, 2011).

All forests in Slovenia are considered managed, because forest management plans are prepared for all forests, regardless ownership, conservation degree or natural conditions.

According to Forest Act (1993, Article 2);

(1) Forest is defined as land overgrown with forest trees in the form of stand or other forest plants which provides any of the functions of a forest. Forest according to this Act also includes overgrown land defined as forest land in the spatial element of the forest management plan.

(2) The forest infrastructure (e.g. forest road network) not allocated into separate lot is an integral part of the forest land.

(3) The following are not forest within the meaning of this act: individual forest trees, groups of forest trees up to an area of 0.05 hectares, non-autochthonous riverine and windbelt trees, avenues, parks, plantations of forest trees, pens for rearing game, and pastures overgrown with forest trees if used for pasturing, irrespective of how they are described in the land register.

(4) The provisions of this act and regulations issued on the basis hereof shall also apply to forest trees which grow outside forests insofar as they are specifically defined.

Table 6.4.1: Activity data for Forest land (1986 – 2022) in kha

Year	4.A. Total Forest Land	4.A.1. Forest Land remaining Forest Land	4.A.2. Land converted to Forest Land	4.A.2.1 Cropland converted to Forest Land	4.A.2.2 Grassland converted to Forest Land	4.A.2.3 Wetland converted to Forest Land	4.A.2.4 Settlements converted to Forest Land	4.A.2.5 Other Land converted to Forest Land
Area, kha								
2022	1206.10	1194.15	11.95	NO	11.85	NO	NO	0.10
2021	1206.42	1178.38	28.05	NO	27.95	NO	NO	0.10
2020	1206.75	1162.61	44.14	NO	44.04	NO	NO	0.10
2019	1207.07	1146.83	60.24	NO	60.14	NO	NO	0.10
2018	1207.40	1131.06	76.34	NO	76.24	NO	NO	0.10
2017	1207.72	1115.29	92.44	NO	92.34	NO	NO	0.10
2016	1208.05	1099.52	108.53	NO	108.43	NO	NO	0.10
2015	1207.65	1083.72	123.93	NO	123.83	NO	NO	0.10
2014	1207.25	1067.80	139.45	NO	139.35	NO	NO	0.10
2013	1206.85	1051.89	154.96	NO	154.86	NO	NO	0.10
2012	1206.45	1035.97	170.48	NO	170.38	NO	NO	0.10
2011	1206.50	1020.38	186.12	NO	186.03	NO	NO	0.08
2010	1206.55	1004.79	201.76	NO	201.69	NO	NO	0.07
2009	1206.60	1003.62	202.98	NO	202.93	NO	NO	0.05
2008	1206.65	1002.44	204.21	NO	204.17	NO	NO	0.03
2007	1206.70	1001.27	205.43	NO	205.41	NO	NO	0.02
2006	1206.75	1000.09	206.66	NO	206.66	NO	NO	NO
2005	1207.65	999.49	208.16	NO	208.16	NO	NO	NO
2004	1208.55	998.89	209.66	NO	209.66	NO	NO	NO
2003	1209.45	998.29	211.16	NO	211.16	NO	NO	NO
2002	1210.35	997.69	212.66	NO	212.66	NO	NO	NO
2001	1194.84	996.48	198.36	NO	198.36	NO	NO	NO
2000	1179.33	995.27	184.06	NO	184.06	NO	NO	NO
1999	1163.83	994.06	169.76	NO	169.76	NO	NO	NO
1998	1148.32	992.85	155.47	NO	155.47	NO	NO	NO
1997	1132.81	991.64	141.17	NO	141.17	NO	NO	NO
1996	1117.30	990.43	126.87	NO	126.87	NO	NO	NO
1995	1101.79	989.22	112.58	NO	112.58	NO	NO	NO
1994	1086.29	988.13	98.16	NO	98.16	NO	NO	NO
1993	1070.79	987.05	83.74	NO	83.74	NO	NO	NO
1992	1055.29	985.96	69.33	NO	69.33	NO	NO	NO
1991	1039.79	984.88	54.92	NO	54.92	NO	NO	NO
1990	1024.29	983.79	40.50	NO	40.50	NO	NO	NO
1989	1022.94	982.44	40.50	NO	40.50	NO	NO	NO
1988	1021.59	981.09	40.50	NO	40.5	NO	NO	NO
1987	1020.24	979.74	40.50	NO	40.5	NO	NO	NO
1986	1018.89	978.39	40.50	NO	40.5	NO	NO	NO

Table 6.4.2: Emissions/removals from Forest land (1986 – 2022) in Gg CO_2

Year	4.A. Total Forest Land	4.A.1. Forest Land remaining Forest Land	4.A.2. Land converted to Forest Land	A.2. Land converted to Forest Land				
				4.A.2.1 Cropland converted to Forest Land	4.A.2.2 Grassland converted to Forest Land	4.A.2.3 Wetlands converted to Forest Land	4.A.2.4 Settlements converted to Forest Land	4.A.2.5 Other Land converted to Forest Land
GHG emissions/removals, Gg CO_2								
2022	-80.58	-3.63	-76.96	NO	-74.90	NO	NO	-2.06
2021	-181.20	-3.58	-177.62	NO	-175.56	NO	NO	-2.06
2020	-281.52	-3.53	-277.99	NO	-275.93	NO	NO	-2.06
2019	-381.54	-3.48	-378.06	NO	-376.00	NO	NO	-2.06
2018	966.85	1444.69	-477.83	NO	-475.78	NO	NO	-2.06
2017	849.50	1424.54	-575.04	NO	-572.99	NO	NO	-2.05
2016	733.23	1404.39	-671.16	NO	-669.11	NO	NO	-2.05
2015	622.31	1384.22	-761.91	NO	-759.86	NO	NO	-2.05
2014	511.44	1363.89	-852.45	NO	-850.40	NO	NO	-2.04
2013	-5361.22	-4419.28	-941.94	NO	-939.90	NO	NO	-2.04
2012	-7142.56	-6112.18	-1030.39	NO	-1028.35	NO	NO	-2.04
2011	-7144.81	-6020.20	-1124.61	NO	-1122.91	NO	NO	-1.70
2010	-7147.06	-5928.22	-1218.84	NO	-1217.48	NO	NO	-1.36
2009	-7147.38	-5921.28	-1226.10	NO	-1225.08	NO	NO	-1.02
2008	-7147.71	-5914.35	-1233.35	NO	-1232.67	NO	NO	-0.68
2007	-7302.55	-6061.94	-1240.61	NO	-1240.27	NO	NO	-0.34
2006	-7284.03	-6040.35	-1243.68	NO	-1243.68	NO	NO	NO
2005	-7271.04	-6022.26	-1248.79	NO	-1248.79	NO	NO	NO
2004	-7258.02	-6004.18	-1253.84	NO	-1253.84	NO	NO	NO
2003	-7244.95	-5986.12	-1258.83	NO	-1258.83	NO	NO	NO
2002	-7232.20	-5968.08	-1264.12	NO	-1264.12	NO	NO	NO
2001	-6132.08	-4956.45	-1175.63	NO	-1175.63	NO	NO	NO
2000	-6046.90	-4959.23	-1087.67	NO	-1087.67	NO	NO	NO
1999	-5962.23	-4961.99	-1000.23	NO	-1000.23	NO	NO	NO
1998	-5878.06	-4964.73	-913.33	NO	-913.33	NO	NO	NO
1997	-5794.39	-4967.45	-826.95	NO	-826.95	NO	NO	NO
1996	-5499.22	-4758.12	-741.09	NO	-741.09	NO	NO	NO
1995	-5407.80	-4752.31	-655.49	NO	-655.49	NO	NO	NO
1994	-5316.98	-4747.09	-569.89	NO	-569.89	NO	NO	NO
1993	-5226.70	-4741.88	-484.82	NO	-484.82	NO	NO	NO
1992	-5136.95	-4736.67	-400.28	NO	-400.28	NO	NO	NO
1991	-4923.68	-4607.41	-316.27	NO	-316.27	NO	NO	NO
1990	-4835.23	-4602.33	-232.90	NO	-232.9	NO	NO	NO
1989	-4828.17	-4596.02	-232.15	NO	-232.15	NO	NO	NO
1988	-4821.11	-4589.70	-231.41	NO	-231.41	NO	NO	NO
1987	-4814.05	-4583.38	-230.66	NO	-230.66	NO	NO	NO
1986	-4806.98	-4577.07	-229.91	NO	-229.91	NO	NO	NO

The net emissions in category Forest land in the period 1986-2022 were from -4,806.98 Gg CO_2 to -80.58 Gg CO_2 with a maximum value of -7302.55 Gg CO_2 in 2007.

Forest land remaining forest land (CO_2) and land converted to forest land (CO_2) were identified as key source categories according to level and trend. Concerning the CH_4 or N_2O emissions, forest land remaining forest land and land converted to forest land have not resulted as a key source.

6.4.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The information of forest area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present forest area in the period 1986-2001. Until 1993 data on forest area were collected by forest and agro-forest enterprises that managed state-owned and private forests. Data of other forests and those that were subject of so called social property had been collected by the state bodies and local authorities. In the period 1993-2001 the main provider of forest data to the SORS was the Slovenia Forest Service (SFS). Data on forest area are provided by the SFS through renovation of forest management plans, covering the entire forest land. The basic information on forests by forest management units, districts and compartments and other administrative units can be view by the Forest data viewer (http://prostor.zgs.gov.si/pregledovalnik/?locale=en) of the SFS. The estimation of forest area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project "Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry". The approach used for representing areas of Forest land follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition and of land-use changes from and to Forest land is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of Forest land:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Land-use database of the Statistical Yearbook of the Statistical Office RS,
- Forest stand map of the Slovenia Forest Service,
- Agricultural Land Use Map of the Ministry of Agriculture, Forestry and Food,
- LiDAR data of the Surveying and Mapping Authority RS,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

6.4.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The definition of forest follows the definition of the national law. According to the Forest Act (2007), the definition of forest has been revised. The Forest Act defines forest as land covered with forest trees in the form of stands that can reach a minimum height of 5 m and a minimum area of 0.25 hectares (2,500 m^2). Abandoned agricultural land with an area of more than 0.25 ha, abandoned for more than 20 years, with a minimum tree height of 5 m and a canopy cover of at least 75 % is defined as forest.

In distinguishing between forest and abandoned agricultural land where spontaneous afforestation has occurred, particular attention should be paid to the change in data collection methodology. Forest land remaining Forest land includes only those areas designated as forest (national class 2000) by the Slovenia Forest Service. According to the Slovenian Classification of Land Use (Interpretation Key 2013), which defines the national classes, the following areas are also included in the forest definition: areas that have been cut down (i.e. temporarily unstocked) due to final felling (regeneration) as part of a forestry operation or natural disasters (e.g. landslide, windthrow), forest plantations designated by the Slovenia Forest Service, forest clearings along the route of power lines, pipelines and ski lifts, forest road network, mountain pine stands, forest areas approved for grazing, enclosures in the forest for breeding game, areas covered with ferns designated by the SFS. All other land is classified in other national classes (e.g. 1410 or 1500) as Land converted to Forest land.

6.4.4 Methodological issues

6.4.4.1 Forest land remaining Forest land

During 1986-2022, annual removals and emissions ranged between -4,577.07 and -3.63 Gg CO_2. The maximum value of removals in this subcategory was in 2012. In the period 2014-2018, the category acted as a net source of emissions, which was mostly due to natural disturbances, beginning with the ice break that occurred in early 2014 (Veselič et al., 2015; Nagel et al., 2016). In subsequent years, there were massive bark beetle outbreaks in the forests, resulting in a significant increase in sanitary felling (de Groot et al., 2018). In addition, there were some windthrows in 2017 and 2018 that further damaged the forests. NFI data for the period 2012-2018 showed that felling in 2014-2018 increased by more than 50% compared to the previous period, while mortality also increased significantly. The calculation for this period also shows that the net increment in forests has decreased.

With the transition to the panel system, the first cycle of the National Forest Inventory (NFI) covering the period 2020–2023 was completed in 2023. Data collected from over 3,000 sample plots reveal that the forest growing stock has remained at 2018 levels. However, the carbon stock in forests has slightly decreased, though the reasons for this decline are not yet clear. It is important to note that data from the NFI plots cannot be directly compared with the FECS data due to differences in sampling grids. Based on insights from other Member States, it is presumed that forest increment has decreased, while mortality has likely increased, potentially as a result of prolonged or intermittent drought periods.

Carbon stock changes in living biomass

Above-ground biomass

Above-ground biomass includes all living biomass above the soil including stem, stump, branches, bark, seeds, and foliage.

The carbon stock in the living biomass (C) was calculated from the merchantable volume multiplied by the wood density (WD), the biomass expansion factor (BEF), the root-to-shoot ratio (R) and the carbon fraction of dry matter (CF). These parameters, with the exception of the carbon fraction of dry matter, are determined separately for the main tree species.

$C = (V_j \times D_j \times BEF_j) \times (1 + R_j) \times CF$ **(Equation 2)**

V – merchantable growing stock volume
D – basic wood density
BEF – biomass expansion factor
R – root shoot ratio
j – tree species

Growing stock volume

Growing stock is the volume over bark of all living trees greater than 9.99 cm in diameter at breast height (1.3 m). Includes the merchantable volume of stem from the ground to a top diameter of 6.99 cm, excluding stump and branches.

Biomass expansion factor

Growing stock dependent biomass expansion factors (BEF) were determined using the generalized functions (Teobaldelli et al,. 2009), considering different forest types/genera (i.e. broadleaved, conifers, Abies & Picea, Larix, and Pinus). The reciprocal equation (Equation 3) was used to express the relationship between BEF, defined as the ratio of tree biomass compartment to stand volume. Looking at the country-specific average values for BEF, BCEF and R, they are comparable and within the range of the default values (Table 3A.1.10, IPCC, 2003 and Tables 4.4 and 4.5, IPCC, 2006).

$$y = a + \frac{b}{x}$$ **(Equation 3)**

y – biomass expansion factor (dimensionless)
x – mean growing stock (m^3/ha)
a, b – coefficient of the non-linear regression model

Table 6.4.3: Values for parameters a and b according to Teobaldelli et al. (2009)

Forest type/genera	a	b
Broadlevaed	1,171	4,423
Conifers	1,153	12,400
Abies & Picea	1,126	8,002
Larix sp.	1,104	8,797
Pinus sp.	1,102	17,990

Table 6.4.4: Average values for BEF, BCEF and R for the ten most important tree species in Slovenia

Tree species	BEF	BCEF	R
Fagus sylvatica	1.19	0.694	0.24
Picea abies	1.15	0.461	0.29
Abies alba	1.15	0.460	0.29
Quercus petraea	1.19	0.690	0.31
Pinus sylvestris	1.18	0.496	0.29
Acer pseudoplatanus	1.19	0.619	0.25
Carpinus betulus	1.19	0.750	0.25

Castanea sativa	1.19	0.570	0.24
Pinus nigra	1.21	0.508	0.30
Ostrya carpinifolia	1.22	0.768	0.31

Root-to-shoot ratio

The ratio of below-ground biomass to above-ground biomass (R) for temperate continental forests was used according to Table 4.4 of the 2006 Guidelines. For conifers, Quercus spp. and other broadleaf species, different R ratios were used depending above-ground biomass stock. The average R values for key tree species in Slovenia are shown in Table 6.4.4.
Basic wood density

Based on analyses of national data from previous studies by Slovenian Forestry Institute and Biotechnical Faculty, the basic wood density (D) was estimated to be 0.584 t/m^3 for beech and 0.394 t/m^3 for fir. For other tree species, the default values from Table 4.14 of the 2006 Guidelines were used.

Carbon fraction of dry matter

The default value given in the Table 4.3 of the 2006 Guidelines has been adopted as the carbon fraction (CF) of dry matter (CF = 0.47 t C/t d.m.).

Consistent with the decision tree in the 2006 Guidelines, carbon stock changes in living biomass in Forest land remaining Forest land are estimated by Stock-Difference Method (Tier 3). The method requires biomass carbon stock inventories at two points in time. Biomass change is the difference between the biomass at two points in time, divided by the number of years between inventories. Data from forest inventories from Slovenia Forest Service and Slovenian Foresty Institute were used for the calculations.

For calculations the equation 2.5 from 2006 Guidelines was used:

$$\Delta C = \frac{(C_{t2} - C_{t1})}{t_2 - t_1}$$ **(Equation 4)**

ΔC – annual carbon stock change in living biomass [t C yr^{-1}]
C_t – carbon stock in living biomass at time t_1 or t_2 [t C]

Forest and Forest Ecosystem Condition Survey – FECS (Kušar et al., 2010) data from 2000, 2007, 2012 and 2018 and from the national forest inventory (NFI) 2020-2023 were used to apply stock-difference method. The NFI 2020-2023 was conducted on concentric permanent fixed plots of a sampling grid with density 2 km × 2 km. The volume of above-ground biomass was 330.65 m^3/ha (Table 6.4.5).

Table 6.4.5: Average growing stock volume

Year	Above-ground biomass [m^3 ha^{-1}]	n
2007	313.69 ± 13.39	724
2012	333.94 ± 13.65	760
2018	329.63 ± 13.69	759
2020-2023	330.65 ± 7.01	3027

FECS data prior to 2000 do not exist, so the alternative method was used to estimate carbon stocks in the period 1986-2000. However, the interpolation/extrapolation method over the long period does not seem to be consistent with the IPCC guidelines. Therefore, we attempted to use a better approach. We compared FECS data on growing stock with data collected in the forest inventory by the Slovenia Forest Service for the purpose of forest management planning.

For this reason, the overlap method was used in accordance with the 2006 Guidelines. To estimate the emissions/removals for the living biomass, the recalculation according to equation 5.1 (IPCC 2006) was performed.

$$y_0 = x_0 * \left(\frac{1}{(n-m+1)} * \sum_{i=m}^{n} \frac{y_i}{x_i} \right)$$ **(Equation 5)**

y_0 – the recalculated estimate computed using the overlap method
x_0 – the estimate developed using the previously used method (SFS data series)
y_i, x_i – the estimates prepared using the new (FECS data provided by SFI) and previously used methods during the period of overlap, as denoted by years m through n

<u>Carbon stock changes in dead organic matter</u>

Consistent with the decision tree in the 2006 Guidelines, carbon stock changes in dead organic matter on Forest land remaining Forest land are estimated by Tier 2 according to Equation 2.17.

$$\Delta C_{FF_{DOM}} = \Delta C_{FF_{DW}} + \Delta C_{FF_{LT}}$$ **(Equation 6)**

$\Delta C_{FF_{DOM}}$ *– annual change in carbon stocks in dead organic matter [t C yr^{-1}]*

$\Delta C_{FF_{DW}}$ *– change in carbon stocks in dead wood [t C yr^{-1}]*

$\Delta C_{FF_{LT}}$ *– change in carbon stocks in litter [t C yr^{-1}]*

Dead wood

The dead wood pool includes all non-living woody biomass not contained in litter, either standing, lying on the ground, or in the soil (IPCC 2003). According to the FECS 2007 definition, dead wood in Slovenia includes:

- Dead standing and lying trees (DBH ≥10 cm);
- Stumps (D >10 cm and H ≥20 cm);

- Snags (D >10 cm and H ≥50 cm);
- Coarse woody debris (D ≥10 cm and L ≥50 cm).

Carbon stock changes in dead wood were estimated based on FECS data from 2000, 2007, 2012 and 2018. However, it should be noted that the value for the year 2000 was estimated. For this year, only dead standing and lying trees were measured not other dead wood types. Therefore, the total dead wood stock in 2000 was estimated based on the linear trend between the 2007 and 2012 data for other types of dead wood biomass, such as stumps, snags and coarse wood debris, using a surrogate method in accordance with 2006 Guidelines. Change in carbon stock in dead wood was estimated using the Stock-Difference method (Equation 2.19, Volume 4, IPCC 2006).

$$\Delta C_{FF}(DW) = \left[A * \frac{(DW_{t2} - DW_{t1})}{T} \right] * CF$$ **(Equation 7)**

$\Delta C_{FF}(DW)$ – annual change in carbon stocks in dead wood [t yr $^{-1}$]
A – area of managed forest land remaining forest land [ha]
DW_{t2} – dead wood stock at time t_2 for managed forest remaining forest [t d. m.]
DW_{t1} – dead wood stock at time t_1 for managed forest remaining forest [t d. m.]
T – time period between t_1 and t_2 [yr]
CF – carbon fraction of dry matter [t d. m.]

According to FECS 2007, 2012 and 2018, the dead wood stock was 19.75, 19.76, 24.22 m^3/ha), respectively. The latest data from the NFI 2020-2023 show that the average dead wood volume was 25.11 m^3/ha.

Litter

Litter includes all non-living biomass less than 10 cm in diameter, lying dead, in various states of decomposition above the mineral or organic soil. This includes litter, fumic, and humic layers. Living fine roots (less than 2 mm) are included in litter if they cannot be empirically distinguished from it.

The average carbon stock in forest litter was estimated at 10.41 t C/ha (Table 6.4.6) based on forest soil monitoring conducted in 2007 on a systematic 8 km × 8 km grid as part of the Forest and Forest Ecosystem Condition Survey (FECS). Separate estimates of carbon stocks in the O_l, O_f and O_h subhorizons were made on the basis that each organic subhorizon was sampled separately using a 25 cm × 25 cm frame. The volume of roots and coarse fragments (soil skeleton >2 mm) was subtracted from the volume of the soil sample.

Carbon stock in litter was calculated according to following equation:

$$C_{pool} = \sum_{i=1}^{k} (\%C_{org,i} \cdot M_{105°C,i} / 100)$$ **(Equation 8)**

C_{pool} - carbon stock [t ha^{-1}]
C_{org} - the organic carbon content and clay content (both in %)
$M_{105°C,i}$ - quantity of dry soil in sub horizon i [t ha^{-1}]
k - number of soil horizon in soil profile

Table 6.4.6: Average carbon stock in forest litter

Layer	Average carbon stock [t ha^{-1}]	n
O_l horizon	1.44 ± 0.15	143
O_{fh} horizon	8.85 ± 1.42	145
Litter (O_l + O_{fh})	10.41 ± 1.50	143

It is assumed that the average transfer rate into the litter pool is equal to the transfer rate out of the litter pool, so the net carbon stock change is zero. The results of the soil survey (Kobal et al., 2013) for the period 1996-2006 show no statistically significant differences in the carbon stock change of litter. The results are explained and presented below (Figure 6.4.1).

Carbon stock changes in soils

The average soil organic carbon (SOC) stock was estimated at 103.31 t C/ha (Table 6.4.7) based on forest soil monitoring conducted in 2007 on a systematic 8 km × 8 km grid as part of the Forest and Forest Ecosystem Condition Survey (FECS). The SOC stock was estimated for the depth of 0-40 cm of the mineral part of the soil.

Carbon stock in the mineral part of the soil was calculated using the following equation:

$$C_{pool} = \sum_{i=1}^{k} (\%C_{org,i} \cdot d_i \cdot \rho_i \cdot 100)$$ **(Equation 9)**

C_{pool} - carbon stock [Gg ha^{-1}]
D_i - thickness [m] of soil horizon I
ρ_i - soil bulk density [g cm^{-3}]
k - number of sub horizon in soil profile

Since bulk density measurements were not available, soil bulk density [g/cm^3] was estimated from the following pedotransfer function (Equation 10). The upper equation for mineral soils is based on data from Hoekstra and Poelman (1982), the lower equation for peat soils is derived from Van Wallenburg (1988) and the middle equation is a linear interpolation (for clay=0) between the two (Reinds et al. 2001).

$$\rho_i = \begin{cases} 1/(0{,}625 + 0{,}05 \cdot \%C_{org} + 0{,}0015 \cdot \%clay) \rightarrow if\ \%C_{org} \leq 5\% \\ 1{,}55 - 0{,}0814 \cdot \%C_{org} \rightarrow if\ 5\% < \%C_{org} \leq 15\% \\ 0{,}725 - 0{,}337 \cdot \log_{10} \%C_{org} \rightarrow if\ \%C_{org} \geq 15\% \end{cases} \quad \textbf{(Equation 10)}$$

ρ_i - soil bulk density [g cm^{-3}]
C_{org} - the organic carbon content and clay content (both in %)

Table 6.4.7: Average soil organic carbon stock of forest land

Layer	Average carbon stock [t C ha^{-1}]	n
M_{10} horizon	35.25 ± 2.06	141
M_{40} horizon	68.32 ± 6.22	136
Forest land	103.31 ± 7.90	136

The stock of soil organic carbon (SOC) in forest land is assumed to be constant, regardless of changes in forest management, forest types, and disturbance regimes. In other words, the SOC stock in the mineral part of forest soil remains constant so long as the land remains forest. The results of the soil survey (Kobal et al., 2013) for the period 1996-2006 show no statistically significant differences in the SOC stock of forest soils (Figure 6.4.1).

For the year 1996, three subsamples of soil were collected from each plot for the organic (i.e. litter) and mineral layers. For the mineral part of the soil, samples were taken with a soil auger (∅ = 7 cm) at a fixed depth (0-5, 5-10, 10-20, and 20-40 cm) and for organic layer within 25 × 25 cm square. Subsamples were collected at 5 m intervals from the plot centre in a 120° clockwise direction and pooled for laboratory analysis (composite samples). The volume of roots and coarse fragments (soil skeleton >2 mm) was subtracted from the volume of the soil sample. For 2006, soil survey was conducted using the BioSoil demonstration project methodology. Soil subsamples for the organic and mineral layers were collected as in 1996, with 5 replicates in each plot (centre of a plot and cardinal direction). The volume of roots and coarse fragments was subtracted from the volume of the soil sample. A paired t-test was used to evaluate changes over time.

Litter carbon stock changes increased slightly from 1996 to 2006 when the national forest soil survey were conducted as part of the ICP Forests and BioSoil demonstration projects/surveys. The differences in litter stock changes are not statistically significant ($p = 0.205$). Carbon stock changes in mineral forest soils for the same time period decrease, but the changes are not significant ($p = 0.052$).

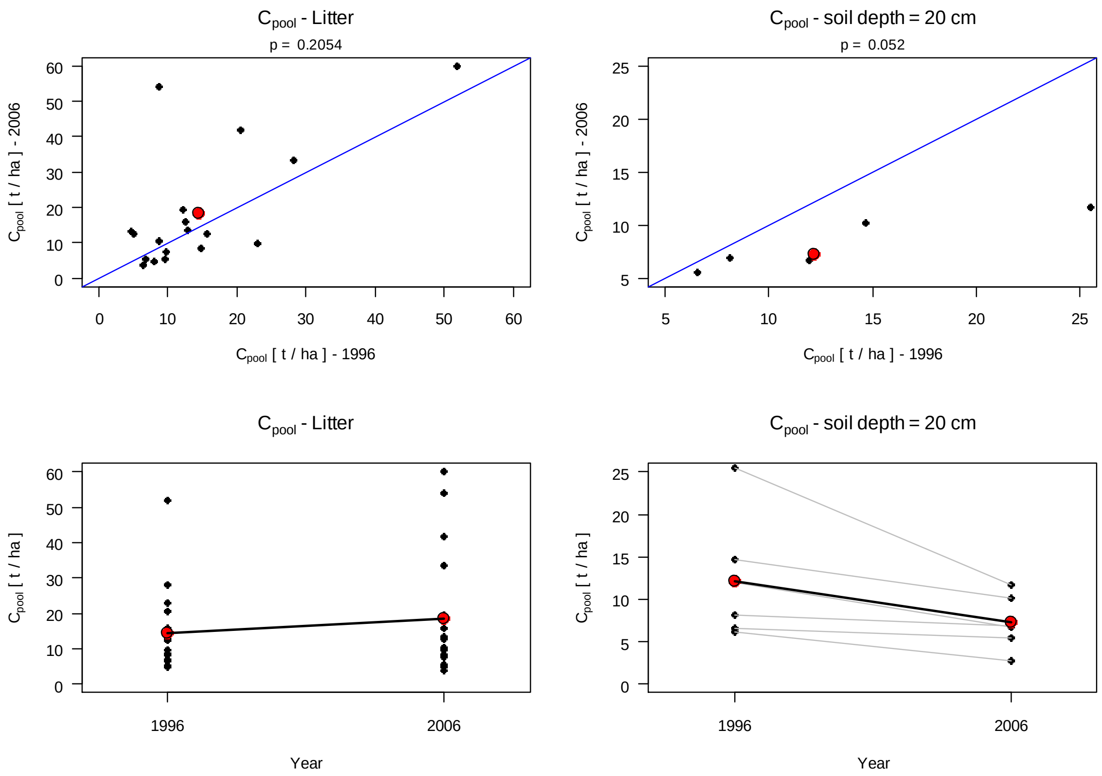

Figure 6.4.1: Carbon stock in forest soils and litter (1996-2006)

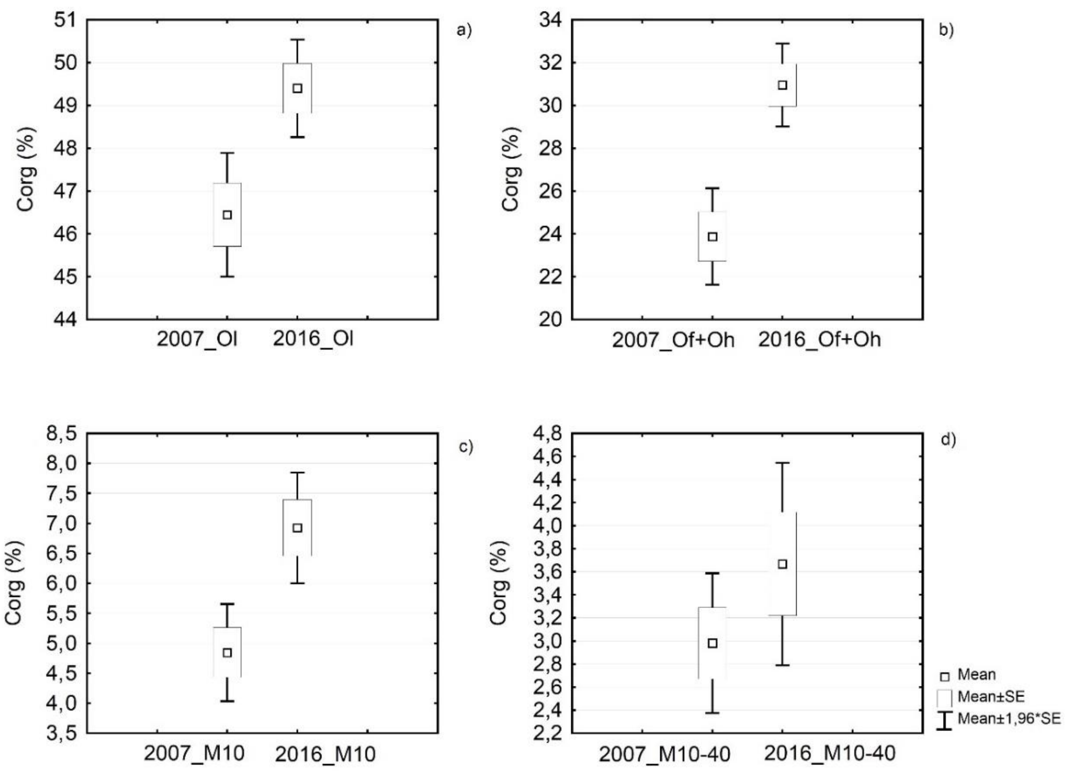

Figure 6.4.2: Carbon stock in forest soils and litter (2007-2016)

Forest soil monitoring at the national level (8 km × 8 km grid) resumed in 2016 with the re-visitation of permanent sampling plots. Preliminary results (n=30 plots) show the increasing trend of soil organic carbon of mineral and organic layers of forest soils. The differences in carbon stocks were significant in the organic (i.e. litter, fumic and humic) layers, known as litter pool and also in the mineral part up to a depth of 10 cm (Figure 6.4.2 a,b,c). However, the analysis showed no significant differences in the SOC stocks in the mineral part of forest soil at the depth of 10-40 cm between 2007 and 2016 (Figure 6.4.2 d).

6.4.4.2 Non-CO_2 greenhouse gas emission

N_2O Emissions from N Fertilization and Drainage of Soils

Fertilization and drainage as well as rewetting of forests are not a common practices in Slovenia. Therefore, no emissions are reported in CRT tables 4(I) and 4(II). Regulation on the protection of waters against pollution caused by nitrates from agricultural sources (2009) prohibits fertilization of forest land. Article 11 of the Regulation also prohibits fertilization on overgrown agricultural land and on infertile land and inland waters. Apparently, there is no legal document that regulates the area of drainage and rewetting of forest land. However, the Rules on forest protection state that any intervention in a forest area that may lead to devaluation of the forest must be approved by the Slovenia Forest Service, which keeps a register of interventions in the forest, containing in particular information on the exact location of the intervention, its content, the area affected and the causes of the intervention, the time of implementation and the operator of the intervention, as well as the legality of the intervention.

Emissions from wildfires

It should be noted that emissions from forest fires refer to the entire forest area (i.e. the total forest land). Since controlled burning is not allowed in Slovenia, all fires in forests are classified as “wildfires”. It is assumed that all fires affected productive forests. The area of forest fires in Slovenia is relatively small, less than 0.5% of forest. To estimate GHG emissions released directly from forest fires, the Tier 2 method (based on area burned and mass of fuel at the country level) was used. Equation 2.27 (IPCC 2006) was used to calculate emissions from wildfires.

$$L_{fire}\left[tGHG\right] = A * M_B * C_f * G_{ef} * 10^{-3}$$ **(Equation 11)**

A – area burnt [ha]
M_B – mass of fuel available for combustion [kg d.m. ha $^{-1}$]
C_f – combustion factor (dimensionless)
G_{ef} – emission factor (g kg^{-1} dry matter burnt)

Default emission factors were used for all GHGs (IPCC 2006, Table 2.5). The values of emission factors for extra tropical forest were adopted. Data on mass of available fuel (M_B) were taken from the Forest Fire Database of the Slovenia Forest Service, where these data have been recorded since 1994. The database contains information on the location, type of fire, area burned, type of vegetation burned and so on. The fraction of biomass combusted (C = 0.45) was taken from Table 2.6 (IPCC 2006). Emissions from wildfires were estimated using Equation 2.27 of the 2006 Guidelines.

Table 6.4.8: Emission factors used from Table 2.5 (IPCC 2006)

Gas		Emission factor (G_{ef}) [g / kg d.m.]
CO_2	carbon dioxide	1,569
CO	carbon oxide	107
CH_4	methane	4.7
NO_x	nitrogen oxide	3.0
N_2O	nitrous oxide	0.26
NMHC	non methane hydrocarbons	10

According to national statistics, about 70% of forest fires occur in the Karst region. Since 2004, the data have been published every year and have been used accordingly to estimate the mass of available fuel. As suggested by the ERT, the amount of dead organic matter (average for Slovenia) was included in the mass of available fuel.

Note that wildfires are not covered by the national forest inventory because the applied sampling grid size is too large, so there is no double counting of CO_2 emissions from wildfires in forest land remaining forest land.

Table 6.4.9: Productive forest land affected by wildfires and resulting GHG emissions 1986-2022

Year	Area (ha)	CO_2 (kt)	CO (kt)	CH_4 (kt)	NO_x (kt)	N_2O (kt)	NMVOC (kt)
2022	3188.99	108.871	7.425	0.326	0.208	0.018	0.694
2021	24.60	1.070	0.073	0.003	0.002	0.000	0.007
2020	73.38	3.811	0.260	0.011	0.007	0.001	0.024
2019	72.75	2.565	0.175	0.008	0.005	0.000	0.016
2018	15.15	0.582	0.040	0.002	0.001	0.000	0.004
2017	176.47	5.833	0.398	0.017	0.011	0.001	0.037
2016	237.41	7.970	0.543	0.024	0.015	0.001	0.051
2015	47.98	1.829	0.125	0.005	0.003	0.000	0.012
2014	13.03	0.599	0.041	0.002	0.001	0.000	0.004
2013	48.36	2.461	0.168	0.007	0.005	0.000	0.016
2012	606.53	22.507	1.535	0.067	0.043	0.004	0.143
2011	159.08	4.768	0.325	0.014	0.009	0.001	0.030
2010	52.06	1.420	0.097	0.004	0.003	0.000	0.009
2009	114.73	3.321	0.226	0.010	0.006	0.001	0.021
2008	46.69	1.541	0.105	0.005	0.003	0.000	0.010
2007	98.61	2.941	0.201	0.009	0.006	0.000	0.019
2006	1022.81	58.379	3.981	0.175	0.112	0.010	0.372
2005	142.23	4.306	0.294	0.013	0.008	0.001	0.027
2004	76.87	2.102	0.143	0.006	0.004	0.000	0.013
2003	1592.84	58.634	3.999	0.176	0.112	0.010	0.374
2002	77.47	2.839	0.194	0.009	0.005	0.000	0.018
2001	240.36	6.982	0.476	0.021	0.013	0.001	0.044
2000	124.14	3.747	0.256	0.011	0.007	0.001	0.024
1999	321.10	8.596	0.586	0.026	0.016	0.001	0.055
1998	725.10	19.642	1.340	0.059	0.038	0.003	0.125
1997	383.33	10.813	0.737	0.032	0.021	0.002	0.069
1996	243.75	7.007	0.478	0.021	0.013	0.001	0.045

Year	Area (ha)	CO_2 (kt)	CO (kt)	CH_4 (kt)	NO_x (kt)	N_2O (kt)	NMVOC (kt)
2022	3188.99	108.871	7.425	0.326	0.208	0.018	0.694
1995	148.88	4.211	0.287	0.013	0.008	0.001	0.027
1994	835.47	21.018	1.433	0.063	0.040	0.003	0.134
1993	1196.92	29.928	2.041	0.090	0.057	0.005	0.191
1992	344.97	8.573	0.585	0.026	0.016	0.001	0.055
1991	559.51	13.819	0.942	0.041	0.026	0.002	0.088
1990	615.77	15.114	1.031	0.045	0.029	0.003	0.096
1989	120.00	2.927	0.200	0.009	0.006	0.000	0.019
1988	181.75	4.406	0.300	0.013	0.008	0.001	0.028
1987	393.00	9.466	0.646	0.028	0.018	0.002	0.060
1986	515.00	12.326	0.841	0.037	0.024	0.002	0.079

All data related to the burned areas are based on databases of Slovenia Forest Service (SFS). The areas are identified and geo-located. The annual data related to fires are annually published by SFS. All GHG emission from forest fires are reported under Forest land remaining forest land.

6.4.4.3 Land converted to Forest land

Data for land-use change from other land use to forest land are described in chapter 0 and chapter 6.3.1. For the calculation of the annual change in carbon stocks in other land converted to Forest land the Tier 2 (IPCC 2006) approach is used.

The average annual area converted from other land uses to forest land in the period 2002-2020 is between 0.53 and 0.78 kha according to land use change matrices (Table 6.3.4 to Table 6.3.7). As described in chapter 0 the land use change to forests appear only from grassland. Conversions to forest land are not direct human induced. The areas are under spontaneous afforestation (natural expansion) of forest. However, the SFS system of forest management differentiates forest lands covered by management plans according to production function and other ecological and social functions.

Definition of forest (Forest Act) in relation to management plans; land with an area of more than 0.25 hectares with trees higher than 5 meters or trees able of reaching this threshold *in situ*. This includes abandoned agricultural land (cropland, grassland) with natural expansion of forest (canopy cover > 75%) that has existed for more than 20 years.

Carbon stock changes in living biomass

The carbon stock change of living biomass was calculated considering the increase and decrease of carbon stock with respect to the areas in transition to forest land. Annual increment of stem wood over bark on land converted to forest was estimated using NFI data (i.e. FECS). Equation 2.15 and Equation 2.16 from the 2006 Guidelines were used for the calculation. The method of converting volume to biomass for estimating carbon stocks in living biomass follows that described in subsection 6.4.4.1.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L \quad \textbf{(Equation 12)}$$

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 losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1}

$$\Delta C_{CONVERSION} = \Sigma \left[(B_{AFTER} - B_{BEFORE}) \times \Delta A\right] \times CF$$ **(Equation 13)**

$\Delta C_{CONVERSION}$ – initial change in biomass carbon stocks on land converted to another land category, tonnes C yr^{-1}
B_{AFTER} – biomass stocks on land type i immediately after the conversion, tonnes d.m. ha^{-1}
B_{BEFORE} – biomass stocks on land type i before the conversion, tonnes d.m. ha^{-1}
ΔA – annual area of land use converted to forest land, ha yr^{-1}
CF – carbon fraction of dry matter, tonne C (tonnes d.m.)$^{-1}$

Carbon stock changes in dead organic matter

The annual change in carbon stocks in dead wood and litter due to conversion of land to forest land was estimated using Equation 2.23 of the 2006 Guidelines. The default time period for the transition from the old to the new land-use category is 20 years for the carbon stock increases after Tier 1.

$$\Delta C_{DOM} = \frac{(C_n - C_o) \bullet A_{on}}{T_{on}}$$ **(Equation 14)**

ΔC_{DOM} - annual change in carbon stocks in dead wood or litter, tonnes C yr^{-1}
C_0 - dead wood/litter stock, under the old land-use category, tonnes C ha^{-1}
C_n - dead wood/litter stock, under the new land-use category, tonnes C ha^{-1}
A_{on} - area undergoing conversion from old to new land-use category, ha
T_{on} – time period of the transition from old land-use category to forest land (default = 20 years)

Carbon stock changes in soils

For calculations of carbon stock changes in soils in land converted to forest land the Tier 2 method was applied, using equation 2.25 (IPCC 2006). Emissions or removals were calculated by country-specific avarage carbon stocks in mineral soils of forest land and grassland.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$ **(Equation 15)**

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1}
SOC_0 – average carbon stock in forest soils, tonnes C ha^{-1}
SOC_{0-T} average carbon stock in grassland soils, tonnes C ha^{-1}
D – transition period (default = 20 years)

Country-specific value for forest soil (SOC_{FL} = 103.31 t C ha^{-1}) was estimated from forest soil monitoring (Table 6.4.7). Country-specific values for annual and perennial grassland soil (SOC_{GL_a} = 94.86 t C ha^{-1}, SOC_{GL_w} = 101.53 t C ha^{-1}) were estimated from agricultural soil monitoring (Table 6.3.12).

Organic soils

Activity data for organic soils was revised using area data from the Pedology Map, which is consistent with the areas in the Agriculture sector. It is assumed that no land with organic soils is converted to forest land. Therefore, emissions from organic soils on land converted to forest land were not reported. For 70% of the national land-use classes that have organic soils, the annual difference in land use change is less than 1%, while in the other 30% of classes the difference rarely exceeds 5%. The difference is analysed by cross-tabulation of vector layers and the result is in most cases due to the methodology ("sliver" effect). Therefore, we believe that areas with organic soils are more likely to be stable.

Non-CO_2 emissions from wildfires

Emissions from wildfires on land converted to forest land are included in emissions from wildfires, estimated and reported under forest land remaining forest land, as no separation is available in the SFS database. Therefore, the notation key “included elsewhere” (IE) is used in the corresponding CRT table.

6.4.5 Uncertainties and time-series consistency

A process of using models to time-shift the forest estate forwards to represent future forest growth and forest managed, and backwards to improve historical estimates, is performed to minimize errors. As the estimation of carbon stocks is continuously being improved both past and future will be recalculated.

The FECS is based on a very comprehensive quality assurance system, which allows the exact identification of the right location of the grid and sample points guarantees the repeated measurement of the same trees. It also indicates at once implausible figures for individual parameters during the measurements on site and any missing trees compared to the period before.

One of the objective of FECS was to obtain accurate and reliable data on the status of the volume of growing stock (carbon stock) and dead wood stock as basis for UNFCCC reporting for all Slovenian forests. Uncertainties related to the 95% confidence interval are expressed as twofold standard errors of the mean are presented in Table 6.4.10.

Table 6.4.10: Uncertainties from FECS 2000, 2007, 2012 and 2018

Parameter	FECS 2000	FECS 2007	FECS 2012	FECS 2018
Growing stock	±4.68 %	±4.21 %	±4.08 %	±4.20 %

Dead wood		±11.27 %	±9.72 %	±9.88 %
Litter		±14.41 %		
Soil		±7.65 %		

6.4.6 Source specific QA/QC and verification

The data based on forest statistics are produced by the Slovenian Forestry Institute (SFI). Data descriptions are available in Slovenian language.

QC measures related to national Forestry Inventory data were:

- A manual for FECS was prepared.
- Field instruments were calibrated and checked.
- All methods were tested in pilot inventory in 2006 (grid 16 x 16 km).
- In preparatory phase all field personnel was trained for:
    - correct use equipments.
    - correct measurements and classifications.
    - understanding of the guidelines and specific instructions.
- Verification measurements were carried out during field seasons - 4 teams from SFI were controlling the field measurements and work of Slovenian Forest Service teams.
- Field data was entered in database and checked for major discrepancies.
- All data used for our calculation is saved on our data server and are protected from unauthorized access.

All soil samples (from soil inventory on 8 km x 8 km) were delivered and stored in laboratory at SFI according to internal quality management system.

General QA/QC, taking into account the figures check, correctness of the calculation used, data sources etc., were performed in the category, as it was subject to source specific recalculation.

6.4.7 Source specific recalculations

Recalculations were conducted for the period 2018-2021 for the forest land remaining forest due to updated emission factors for living biomass and dead wood, derived from recent estimates from the NFI 2020-2023. Minor adjustment have been applied to other years as well owing to refinements in the method used for calculating the merchantable volume. Additionally, recalculations were made for land converted to forest land, incorporating updated emission factors specifically for dead wood.

6.4.8 Source specific planned improvements

No major improvements are planned for this category in the next annual submission.

6.5 Cropland (4B)

6.5.1 Source category description

The cropland category includes CO_2 emissions from changes in carbon stock in living biomass and soils. Changes in carbon stock are reported under Cropland remaining cropland and in Land converted to cropland.

Cropland covered 12.13% of the country's land area in 2022. Cropland land use is divided into two subcategories: annual cropland (arable land, temporary meadows, hop fields, greenhouses) and perennial cropland (other permanent crops on arable land, vineyards, nurseries, intensive orchards, extensive orchards, olive groves, other permanent crops, forest plantations).

Emissions in the Cropland category decreased by 44% between 1986 and 2022 (i.e., from 259.99 to 145.10 Gg CO_2). Cropland remaining Cropland and Land converted to Cropland are the key categories in the trend analysis.

Table 6.5.1: Activity data for Cropland (1986 – 2022) in kha

Year	4.B. Total Cropland	4.B. Organic soil	4.B.1. Cropland remaining Cropland	4.B .2. Land converted to Cropland	4.B.2.1 Forest Land converted to Cropland	4.B.2.2 Grassland converted to Cropland	4.B.2.3 Wetland converted to Cropland	4.B.2.4 Settlements converted to Cropland	4.B.2.5 Other Land converted to Cropland
Area, kha									
2022	245.90	2.31	218.75	27.15	1.25	25.55	NO	0.35	NO
2021	246.15	2.31	218.89	27.26	1.31	25.61	NO	0.34	NO
2020	246.40	2.36	219.03	27.37	1.37	25.67	NO	0.33	NO
2019	246.65	2.35	219.18	27.47	1.43	25.72	NO	0.32	NO
2018	246.90	2.49	219.32	27.58	1.49	25.78	NO	0.31	NO
2017	247.15	2.50	219.46	27.69	1.55	25.84	NO	0.30	NO
2016	247.40	2.50	219.60	27.80	1.61	25.90	NO	0.29	NO
2015	251.05	2.50	223.87	27.18	1.62	25.25	NO	0.30	NO
2014	254.70	2.50	228.67	26.03	1.67	23.94	NO	0.42	NO
2013	258.35	2.35	233.47	24.88	1.72	22.62	NO	0.54	NO
2012	262.00	2.35	238.27	23.73	1.76	21.31	NO	0.66	NO
2011	263.53	2.34	239.69	23.84	1.81	21.27	NO	0.76	NO
2010	265.07	2.28	241.11	23.96	1.87	21.23	NO	0.87	NO
2009	266.60	2.27	241.67	24.93	1.90	21.98	NO	1.05	NO
2008	268.13	2.25	242.24	25.89	1.93	22.73	NO	1.23	NO
2007	269.67	2.25	242.81	26.86	1.97	23.48	NO	1.42	NO
2006	271.20	2.22	243.37	27.83	2.00	24.23	NO	1.60	NO
2005	272.55	2.20	244.55	28.00	2.00	24.23	NO	1.77	NO
2004	273.90	2.18	245.72	28.18	2.00	24.23	NO	1.95	NO
2003	275.25	2.16	246.90	28.35	2.00	24.23	NO	2.12	NO
2002	276.60	2.14	248.07	28.53	2.00	24.23	NO	2.30	NO
2001	278.34	2.12	249.49	28.85	2.01	24.35	NO	2.49	NO
2000	280.08	2.10	250.91	29.16	2.03	24.46	NO	2.67	NO
1999	281.82	2.10	252.34	29.48	2.04	24.58	NO	2.86	NO
1998	283.56	2.10	253.76	29.80	2.06	24.70	NO	3.04	NO
1997	285.29	2.10	255.18	30.12	2.07	24.82	NO	3.23	NO
1996	287.03	2.10	256.60	30.43	2.09	24.93	NO	3.41	NO
1995	288.77	2.10	258.02	30.75	2.10	25.05	NO	3.60	NO
1994	292.10	2.10	260.50	31.60	2.08	25.84	NO	3.68	NO
1993	295.43	2.10	262.98	32.45	2.06	26.63	NO	3.76	NO
1992	298.75	2.10	265.45	33.30	2.04	27.42	NO	3.84	NO
1991	302.08	2.10	267.93	34.15	2.02	28.21	NO	3.92	NO
1990	305.41	2.10	270.41	35.00	2.00	29.00	NO	4.00	NO
1989	305.46	2.10	270.46	35.00	2.00	29.00	NO	4.00	NO
1988	305.51	2.10	270.51	35.00	2.00	29.00	NO	4.00	NO
1987	305.56	2.10	270.56	35.00	2.00	29.00	NO	4.00	NO
1986	305.61	2.10	270.61	35.00	2.00	29.00	NO	4.00	NO

Table 6.5.2: Emissions from Cropland (1986 – 2022) in Gg CO_2

Year	4.B. Total Cropland	4.B.1. Cropland remaining Cropland	4.B.2. Land converted to Cropland	4.B.2.1 Forest Land converted to Cropland	4.B.2.2 Grassland converted to Cropland	4.B.2.3 Wetland converted to Cropland	4.B.2.4 Settlements converted to Cropland	4.B.2.5 Other Land converted to Cropland
GHG emissions/removals, Gg CO_2								
2022	145.10	84.35	60.74	12.26	45.55	NA	2.94	NA
2021	144.64	85.36	59.28	12.39	44.47	NA	2.42	NA
2020	145.75	87.94	57.81	12.51	43.39	NA	1.90	NA
2019	143.64	87.30	56.34	12.64	42.32	NA	1.38	NA
2018	146.57	91.70	54.87	12.77	41.24	NA	0.86	NA
2017	145.01	91.58	53.43	12.93	40.16	NA	0.34	NA
2016	186.85	90.94	95.91	32.72	63.61	NA	-0.42	NA
2015	183.64	89.91	93.73	32.85	61.45	NA	-0.57	NA
2014	177.70	87.49	90.21	33.08	58.93	NA	-1.80	NA
2013	167.01	80.31	86.70	33.32	56.42	NA	-3.04	NA
2012	156.90	84.34	72.56	30.48	46.19	NA	-4.11	NA
2011	153.78	83.48	70.30	30.22	45.68	NA	-5.60	NA
2010	148.49	80.45	68.04	29.95	45.16	NA	-7.08	NA
2009	146.06	79.34	66.72	29.63	46.48	NA	-9.39	NA
2008	143.78	78.37	65.41	29.31	47.80	NA	-11.70	NA
2007	141.99	77.90	64.10	28.99	49.11	NA	-14.00	NA
2006	158.15	77.52	80.63	40.85	55.40	NA	-15.62	NA
2005	155.08	75.72	79.35	40.24	56.53	NA	-17.42	NA
2004	151.63	73.55	78.08	39.64	57.66	NA	-19.22	NA
2003	148.56	71.75	76.81	39.04	58.79	NA	-21.03	NA
2002	132.46	68.68	63.78	33.29	53.68	NA	-23.19	NA
2001	133.44	70.56	62.88	32.82	55.16	NA	-25.10	NA
2000	130.32	68.26	62.06	32.44	56.64	NA	-27.02	NA
1999	130.11	68.87	61.24	32.05	58.12	NA	-28.93	NA
1998	129.37	68.95	60.42	31.66	59.60	NA	-30.84	NA
1997	127.34	67.74	59.60	31.27	61.08	NA	-32.75	NA
1996	126.53	67.76	58.78	30.88	62.55	NA	-34.66	NA
1995	131.51	67.84	63.68	41.64	55.01	NA	-32.97	NA
1994	128.84	64.79	64.05	41.01	56.84	NA	-33.80	NA
1993	127.40	62.98	64.42	40.37	58.67	NA	-34.62	NA
1992	126.47	61.68	64.79	39.74	60.50	NA	-35.44	NA
1991	127.64	62.47	65.16	39.11	62.33	NA	-36.27	NA
1990	262.85	65.46	197.39	32.48	199.28	NA	-34.37	NA
1989	263.59	66.67	196.93	32.01	199.28	NA	-34.37	NA
1988	262.74	66.28	196.46	31.54	199.28	NA	-34.37	NA
1987	261.42	65.43	195.99	31.07	199.28	NA	-34.37	NA
1986	259.99	64.47	195.52	30.61	199.28	NA	-34.37	NA

6.5.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The information of cropland area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present cropland area in the period 1986-2001. The estimation of cropland area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project "Bases for improving the methodology of greenhouse gas emissions in relation to land use, land use change and forestry". The estimation of cropland area and annual land-use changes for the years 2013, 2014 and 2015 were extrapolated. The approach used for representing cropland areas follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to cropland is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of cropland areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Land-use database of the Statistical Yearbook of the Statistical Office RS,
- Agricultural Land Use Map and LPIS database of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

6.5.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The cropland is not defined specifically in terms of national legislation or land-use classification. However, the Agricultural Land Act (2011) defines agricultural land as land suitable for the agricultural production. The Act refers to the national land-use classes determined by Article 6 of the Rules on the register of actual agricultural and forest land use (2006). For the need of the GHG reporting the Cropland category includes the following land-use classes (Table 6.2.1); arable land, including fields and gardens, hop fields, green houses, other permanent crops on arable land, vineyards, nursery, intensive and extensive orchards, olive groves, other permanent crops and forest plantation.

6.5.4 Methodological issues

6.5.4.1 Cropland remaining Cropland

Annual emissions from cropland remaining cropland ranged from 64.47 Gg CO_2 in 1986 to 84.35 Gg CO_2 in 2022.

Carbon stock changes in living biomass

Annual Cropland remaining annual Cropland

According to the 2006 Guidelines, the increase in biomass stocks of annual crops in a year is assumed to be equal to the biomass losses due to harvest and mortality in the same year, so there is no net accumulation of biomass carbon stocks.

Perennial Cropland remaining perennial Cropland

Table 6.5.3: Estimated area of perennial cropland in the period 1986-2022 in ha

Year	Intensive orchards	Extensive orchards	Vineyards	Olive groves	Other perennial crops	Total area
2022	2413	17940	15205	2413	483	38454
2021	2387	17745	15040	2387	477	38037
2020	2361	17551	14875	2361	472	37620
2019	2348	17409	14808	2271	408	37245
2018	2335	17266	14738	2183	345	36867
2017	2322	17121	14667	2096	284	36489
2016	2308	16975	14592	2010	223	36108
2015	2381	17268	14637	1962	257	36505
2014	2478	17732	14822	1931	294	37257
2013	2577	18203	15003	1897	332	38013
2012	2679	18679	15182	1860	372	38773
2011	2667	18831	15544	1790	372	39204
2010	2655	18984	15912	1718	372	39641
2009	2624	19009	16179	1633	369	39815
2008	2593	19035	16446	1548	367	39989
2007	2562	19061	16717	1461	364	40165
2006	2530	19085	16989	1374	361	40339
2005	2539	19327	17099	1378	345	40688
2004	2545	19555	17195	1382	328	41004
2003	2553	19800	17304	1386	310	41353
2002	2561	20046	17412	1390	293	41702
2001	2540	19883	17271	1379	290	41363
2000	2519	19720	17129	1367	288	41023
1999	2498	19557	16987	1356	286	40684
1998	2477	19394	16846	1345	283	40345
1997	2456	19231	16704	1334	281	40006
1996	2436	19068	16563	1322	278	39667
1995	2415	18905	16421	1311	276	39327
1994	2448	19162	16644	1329	280	39862
1993	2480	19419	16867	1347	283	40396
1992	2513	19675	17090	1364	287	40931
1991	2546	19932	17313	1382	291	41465
1990	2579	20189	17537	1400	295	41999
1989	2556	20011	17382	1388	292	41628
1988	2533	19832	17227	1375	290	41257

1987	2511	19654	17072	1363	287	40886
1986	2488	19476	16917	1350	284	40515

Aggregate data for perennial cropland (orchards and vineyards) are available from the Statistical Office of the Republic of Slovenia as of 1956. For the calculation of the annual change of carbon stock in the living biomass of perennial cropland remaining perennial Cropland, Tier 1 (Gain-Loss) method was used, which is well described in the Austrian NID. According to this approach, the annual change in biomass was calculated using the Equation 16.

$$\Delta C = A_0 \times G_i) - (A_{0-T} \times 1/R \times C_B) \quad \textbf{(Equation 16)}$$

ΔC – annual change in biomass
G – biomass accumulation rate
i – perennial crop type
R – rotation period
C_B – biomas carbon stock at harvest (i.e. at the end of rotation period)
A_0 – area of perennial cropland remaining perennial cropland
A_{0-T} – area of perennial cropland before rotation period

Country-specific average above-ground carbon stocks of perennial crops were estimated based on measurements conducted in 2017 (Mali et al., 2017b). Below-ground biomass was estimated using equations for linear relation between above-ground and below-ground biomass (Canaveira et al., 2018).

Table 6.5.4: Biomass carbon stock and accumulation rate of perennial crops

Perennial crop	Above-ground carbon stock (t C ha^{-1})	Above- and below-ground carbon stock (t C ha^{-1})	Biomass accumulation rate (t C ha^{-1} yr^{-1})	Rotation period (years)
Intensive orchards	8.45 ± 4.71	13.28	0.664	20
Extensive orchards	14.16 ± 3.90	23.74	0.791	30
Vineyards	1.90 ± 0.52	4.70	0.157	30
Olive groves	9.14 ± 1.37	11.73	0.391	30
Other perennial crops	12.88 ± 6.29	16.74	0.837	20

The average biomass carbon stock was calculated from the empirical data, such as vineyards (n = 16), intensive orchards (n = 9) and extensive orchards (n = 60), the estimate for olive groves and other perennial crops published by Canaveira et al. (2018). The latter were estimated based on the assumption that the carbon stock at harvest is 1, 2, and 40 t C ha^{-1} for other permanent crops on arable land, other permanent crops, and forest plantations, respectively. The average biomass carbon stock of perennial crops was weighted by the associated area of these crops in Slovenia to obtain an average value (i.e. a country-specific value of 15.77 t C ha^{-1}). This value was used to estimate emissions and removals from land conversion to cropland and vice versa.

Perrenial Cropland converted to annual Cropland

The average annual land-use change from perennial Cropland to annual Cropland from 2002 to 2020 ranged from 75 to 117 ha.

For the calculation of annual change in carbon stocks in living biomass of perennial cropland converted to annual cropland the Tier 1/Tier 2 method was applied and equations 2.15 and 2.16 (IPCC 2006) were used.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L \qquad \textbf{(Equation 17)}$$

ΔC_B – annual change in carbon stocks in biomass on land converted to annual cropland, in t C yr^{-1}
ΔC_G – annual increase in carbon stocks in biomass due to growth on land converted to annual cropland, in tonnes C yr^{-1}
$\Delta C_{CONVERSION}$ – initial change in carbon stocks in biomass on land converted to annual cropland, in t C yr^{-1}
ΔC_L – annual decrease in biomass carbon stocks due to losses on land converted to annual cropland, in t C yr^{-1}

$$\Delta C_{CONVERSION} = \Sigma\ [(B_{AFTER} - B_{BEFORE}) \times \Delta A] \times CF \qquad \textbf{(Equation 18)}$$

$\Delta C_{CONVERSION}$ – initial change in biomass carbon stocks on land converted to annual cropland, t C yr^{-1}
B_{AFTER} – biomass stocks immediately after the conversion, t d.m. ha^{-1}
B_{BEFORE} – biomass stocks before the conversion, t d.m. ha^{-1}
ΔA – annual area of land converted to annual cropland, ha yr^{-1}
CF – carbon fraction of dry matter, t C (t d.m.)$^{-1}$

It is assumed that the annual change in carbon stock in annual crop biomass due to growth is equal to the annual decrease in biomass due to loss. The country-specific value for carbon stock in perennial crops before conversion (C_{BEFORE} = 15.77 t C ha^{-1}) was used. The biomass stock immediately after conversion is zero.

Annual Cropland converted to perennial Cropland

The average annual land-use change from annual cropland to perennial cropland from 2002 to 2020 ranged from 16 to 100 ha.

For the calculation of annual change in carbon stocks in living biomass of annual cropland converted to perennial cropland the Tier 1/Tier 2 method was applied and equations 2.15 and 2.16 (IPCC 2006) were used.

The country-specific value for carbon accumulation rate of perennial crops (ΔC_G = 0.789 t C ha^{-1} yr^{-1}) was estimated as a weighted average of perennial crops based on national and published data (Table 6.5.4). The country-specific value for carbon stock in annual crops before conversion (C_{BEFORE} = 2.76 t C ha^{-1}) was estimated from SORS data. The biomass stock immediately after conversion is zero.

Carbon stock changes in dead organic matter

The Tier 1 method of the 2006 Guidelines assumes that dead wood stocks are not present on cropland remaining cropland. Therefore, it is not necessary to estimate carbon stock changes for this pool. It is assumed that there is no carbon stock change in litter on annual cropland remaining annual cropland. The average carbon stock in litter on perennial cropland was estimated using data published by the Agricultural Institute of Slovenia (Šinkovec et al., 2020). In their study, they used the metod proposed by Velázquez-Martí et al. (2011) to quantify residual biomass from pruning. According to a survey of the largest wine, fruit and olive producers in Slovenia, it is assumed that all wood residues are stored in permanent crops, where they are mulched on site. The country-specific value (i.e. 3.70 t C ha^{-1}) was calculated as a weighted average based on the estimates for vineyards, intensive orchards and olive groves.

Carbon stock changes in soils

Mineral soils

Annual Cropland remaining annual Cropland and Perennial Cropland remaining perennial Cropland

Emissions from arable mineral soils were estimated using Tier 1 because there is currently no regular soil monitoring to estimate emission from the remaining land in this category. Equation 2.25 (IPCC 2006) was used and the approach suggested by Hiederer et al. (2016). Stratification of cropland and preparation of vector layers for stock change factors was performed by Agricultural Institute of Slovenia. It is assumed that the change in management regime has occured since 2007. Therefore, emissions and removals from arable mineral soils are reported only from 2007. Note that the same method was used for annual cropland remaining annual cropland and perennial cropland remaining perennial cropland to estimate SOC stock changes.

There are two main reasons why carbon stock change in mineral soils for annual cropland remaining annual cropland (also for annual grassland remaining annual grassland) was estimated using a Tier 1 method for the period 2007-2018. First, in order to generate vector maps for comparing the stocks of SOC in 2007 and 2016, a number of input data (i.e. vector layers) were obtained from different institutions, such as land-use map from ICAS/LPIS system, Agri-Environment-Climate payments requirement map (major crops, all crops), gross nitrogen input map from livestock manure, and soil map (mineral, organic). Based on these data, 4 different vector layers were created for land use, management, input and reference stock, for 2007 and 2006, respectively. Input data have only been available since 2007, so it was not technically possible to stratify properly because land use, management and input data were not available. Second, based on discussion with experts from Agricultural Institute of Slovenia, it can be assumed that the change in management by farmers in 2007 was due to external stimuli, such as Rural Development Programme 2007-2013 (e.g. different subsidy payment schemes, a change in cropping patterns and/or different management technologies), especially the Agri-Environment-Climate measure, which included many more operations related to land management, compared to the previous RDP. Permanent soil monitoring on agricultural land is expected, but we cannot say when. However, it seems that the reform of the EU CAP and related new legislative proposals will require member states to monitor indicators of progress, including soil quality.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

$$SOC = \sum_{c,s,i} \left(SOC_{REF_{c,s,i}} \bullet F_{LU_{c,s,i}} \bullet F_{MG_{c,s,i}} \bullet F_{I_{c,s,i}} \bullet A_{c,s,i} \right)$$

(Equation 19)

$\Delta C_{CCmineral}$ – annual change in carbon stock in mineral soils [t C yr $^{-1}$]
SOC_0 – soil organic carbon stock in the inventory year [t C ha^{-1}]
SOC_{0-T} – soil organic carbon stock T years prior to the inventory [t C ha^{-1}]
D – time [default 20 years]
A – land area [ha]

SOC_{REF} – default reference value for soil organic carbon stock (i.e. 88 t C ha^{-1}) for mineral soil according to Table 2.3 of the 2006 IPCC guidelines (Warm temperate, moist, HAC soils)
F_{LU}, F_{MG}, F_I – relative stock change factors for different management activities on cropland according to Table 5.5 of the 2006 IPCC guidelines (Temperate, Moist/Wet; F_{LU} = 0.69 for arable land and F_{LU} = 1 for perennial crops; F_{MG} = 1 for regularly tilled arable land, F_{MG} = 1.05 for reduced tillage, and F_{MG} = 1.15 for no-till; F_I = 1.0 for medium input, F_I = 1.11 for high input with organic manure, and F_I = 1.44 for high input without organic manure)

Organic soils

The total area of (cultivated) organic soils in the cropland category was 2,309 ha in 2022. According to expert opinion, the arable land on organic soils has been relatively constant since 1995 (Agricultural institute of Slovenia, 2006).

For the calculations of emissions from organic soils, the Tier 1/Tier 2 method and Equation 2.26 from the 2006 Guidelines were used. Default emission factor (EF = 10 t ha^{-1}) for warm temperate climatic temperature regime) from Table 5.6 (IPCC 2006) was used.

$$\Delta C = \sum (A * EF)$$

(Equation 20)

A – land area of organic soils
EF – emission factor for climate type (10 t ha^{-1})

Annual Cropland converted to perennial Cropland

For calculations of carbon stock changes in mineral soils from annual cropland to perennial cropland and the Tier 2 method was applied, using equation 2.25 (IPCC 2006). Net emissions were calculated by country-specific avarage carbon stocks in mineral soils of annual and perennial cropland (Table 6.3.12).

$\Delta C_{Mineral}$ = conversion area for a transition period of 20 years * ΔC_{SOC} **(Equation 21)**

$$\Delta C_{soc} = \frac{(SOC_n - SOC_o)}{T}$$

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1}
SOC_n – average carbon stock of soils in perennial cropland, tonnes C ha^{-1}
SOC_o – average carbon stock of soils in annual cropland, tonnes C ha^{-1}
T – transition period (default = 20 years)

Perrenial Cropland converted to annual Cropland

Emissions/removals were calculated by country specific values for carbon stocks in mineral soils of perennial cropland and annual cropland, respectively. Calculation steps and input data follow the equation 21, where SOC_n is average carbon stock of annual cropland and SOC_o is average carbon stock of perennial cropland.

6.5.4.2 Land converted to Cropland

The average annual area converted from other land uses to cropland during 2002-2020 was between 1,600 and 1,750 ha according to the land-use change matrices. However, there are also conversions of forest land to cropland and grassland to cropland. There are no conversions of wetlands and other land to cropland, and conversions of settlements to cropland are also rare.

<u>Carbon stock changes in living biomass</u>

For the calculation of annual change in carbon stocks in living biomass of land converted to cropland the Tier 1/Tier 2 method and Equations 2.15 and 2.16 (IPCC 2006) were used.

$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$ **(Equation 22)**

ΔC_B – annual change in carbon stock in biomass on land converted to cropland, in t C yr^{-1}
ΔC_G – annual increase in carbon stock in biomass due to growth on land converted to cropland, in tonnes C yr^{-1}
$\Delta C_{CONVERSION}$ – initial change in carbon stock in biomass on land converted to cropland, in t C yr^{-1}
ΔC_L – annual decrease in biomass carbon stock due to loss on land converted to cropland, in t C yr^{-1}

$\Delta C_{CONVERSION} = \Sigma [(B_{AFTER} – B_{BEFORE}) \times \Delta A] \times CF$ **(Equation 23)**

$\Delta C_{CONVERSION}$ – initial change in biomass carbon stock on land converted to cropland, t C yr^{-1}
B_{AFTER} – biomass stock immediately after the conversion is 0, t d.m. ha^{-1}
B_{BEFORE} – biomass stock before the conversion, t d.m. ha^{-1}
ΔA – annual area of land converted to cropland, ha yr^{-1}
CF – carbon fraction of dry matter, t C $(t\ d.m.)^{-1}$

A country-specific value for the annual accumulation rate of perennial crop (ΔC_G = 0.789 t C ha^{-1}) was used. The average carbon stocks in living biomass under the previous land-use categories are the same as those in Table 6.3.10. It is assumed that the carbon stock in biomass immediately after conversion (B_{AFTER}) is zero, since the land is cleared of all vegetation before planting crops (Tier 1). The same assumption was made for annual and perennial cropland.

Carbon stock changes in dead organic matter

Carbon stock changes in dead organic matter were calculated for dead wood and litter pool in conversion from Forest land to Cropland. The following equation was used:

$$\Delta C_{LC_{DOM}} = \Delta C_{LC_{DW}} + \Delta C_{LC_{LT}}$$ **(Equation 24)**

$\Delta C_{LC_{DOM}}$ *– annual change in carbon stock in dead organic matter [t C yr $^{-1}$]*

$\Delta C_{LC_{DW}}$ *– change in carbon stock in dead wood [t C yr $^{-1}$]*

$\Delta C_{LC_{LT}}$ *– change in carbon stock in litter [t C yr $^{-1}$]*

For calculations of annual change in carbon stocks in dead wood the following equation was used:

$$\Delta C_{LC_{DW}} = \text{annual area of converted land} * \Delta C_{DW}$$ **(Equation 25)**

$$\Delta C_{DW} = \frac{(C_n - C_o)}{T}$$

C_n – dead wood stock under the new land-use category [t C ha-1]
C_o – dead wood stock under the old land-use category [t C ha^{-1}]
T – time period of the transition from old to new land-use category [yr]

Dead wood carbon stocks (C_o) were calculated from FECS 2007, FECS 2012 and FECS 2018 data. The Tier 1 default transition period is 1 year for carbon losses.

For calculations of annual change in carbon stocks in litter the following equation was used:

$$\Delta C_{LC_{LT}} = \text{annual area of converted land} * \Delta C_{LT}$$ **(Equation 26)**

$$\Delta C_{LT} = \frac{(C_n - C_o)}{T}$$

C_n – litter stock under the new land-use category [t C ha^{-1}]
C_o – litter stock under the old land-use category [t C ha^{-1}]
T – time period of the transition from old to new land-use category [yr]

The value for carbon stock in litter (C_{before} = 10.41 t C ha^{-1}) was used from the research study of Slovenian Forestry Institute (Kobal and Simončič, 2011). The Tier 1 default transition period is 1 year for carbon losses.

Carbon stock changes in soils

Mineral soils

For calculations of emissions from soils in Land converted to Cropland Tier 2 methodology and equation 2.25 (IPCC 2006) were used.

$$\Delta C_{LCmineral} \frac{[SOC_0 - SOC_{0-T})]}{T} \qquad \textbf{(Equation 27)}$$

$\Delta C_{LCmineral}$ – annual change in carbon stock in mineral soils [t C yr $^{-1}$]
SOC_0 – soil organic carbon stock in the inventory year [t C ha^{-1}]
SOC_{0-T} – soil organic carbon stock T years prior to the inventory [t C ha^{-1}]
T – time [default 20 years]
A – land area [ha]

$$SOC = SOC_{CL}$$

SOC_{CL} – country-specific value for organic carbon stock in mineral soil for cropland

Slovenian national value for organic carbon stock in mineral soil for cropland (annual cropland: $SOC_{CLannual}$ = 86.00 t ha^{-1}; perennial cropland: $SOC_{CLperennial}$ = 77.80 t ha^{-1}) are presented in Table 6.3.12.

Organic soils

Activity data for organic soils was revised using area data from the Pedology Map, which is consistent with the areas in the Agriculture sector. It is assumed that no land with organic soils is converted to forest land. Therefore, emissions from organic soils on land converted to forest land were not reported. For 70% of the national land-use classes that have organic soils, the annual difference in land use change is less than %, while in the other 30% of classes the difference rarely exceeds 5%. The difference is analysed by cross-tabulation of vector layers and the result is in most cases due to the methodology ("sliver" effect). Therefore, we believe that areas with organic soils are more likely to be stable.

N_2O emissions from N mineralization/immobilizaton

For calculations of N_2O emmisions associated with land conversion to Cropland Tier 1 methodology using equations 11.1 and 11.8 (IPCC 2006) and default emission factors from the Table 11.1 were used. The direct N_2O emissions as result of loss of soil C from soil organic matter due to change in land management in Cropland remaining cropland (Cropland annual to cropland perennial and vice versa) are estimated in Agriculture sector (CRT sector 3).

$$N_2O - N_{Direct} = N_2O_{Ninputs} - N$$

(Equation 28)

$$N_2O_{Ninputs} - N = EF_1 * F_{SOM}$$

N_2O-N_{Direct} – annual direct N_2O–N emissions produced from managed soils (kg N2O–N yr^{-1})

F_{SOM} – annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management (kg N yr^{-1})

EF_1 – IPCC default emission factor used to estimate direct N_2O emissions from managed soils [kg N_2O-N $(kg\ N)^{-1}$]. The default value is 0.01 kg N_2O-N $(kg\ N)^{-1}$

According to 2006 Guidelines conversion of N_2O-N emissions to N_2O emissions for reporting purposes is performed by using the following equation: N_2O = N_2O-N * 44/28.

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 was estimated using the following equation:

$$F_{SOM} = \sum_{LU}\left[\left(\Delta C_{Mineral,\ LU} * \frac{1}{R}\right) * 1000\right]$$ **(Equation 29)**

F_{SOM} – *annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management (kg N yr^{-1})*
$\Delta C_{Mineral,\ LU}$ – *average annual loss of soil carbon for each land-use type (t C)*
R – *C:N ratio of soil organic matter. Default value for the C:N ratio is 15.*

Values for annual carbon stock change in soils ($\Delta C_{Mineral,\ LU}$) were taken from calculations of carbon stock changes in soils for Land converted to Cropland (Forest land and Grassland to Cropland). For emission factor (EF_1), the default value (0.01 kg N_2O-N/kg N) was used.

Indirect N_2O emissions from N leaching and run-off

For estimation of indirect N_2O emissions from managed soils arising from N mineralization due to change of land use or management on mineral soils through leaching/runoff were estimated by applying Tier 1 method (Equation 11.10) and default emission factors from the Table 11.3 of GPG (IPCC 2006). However, these emissions are partly reported under Agriculture sector (CRT sector 3).

6.5.5 Uncertainties and time-series consistency

Uncertainties were analysed as uncertainty in activity data (Table 6.3.8) and uncertainty in variables such as emission factors, growth rates, effects of land management factors, etc. Uncertainties were determined from empirical data, IPCC default values and expert judgement.

Table 6.5.5: Uncertainties for emission factors

Variable	Cropland remaining cropland (95 % CI)	Land converted to cropland (95% CI)
Living biomass	85 %	202 %
Litter	40 %	40 %
Mineral soil	16 %	65 %
Organic soil	90 %	NA

6.5.6 Category-specific QA/QC and verification

There were no category-specific QA/QC and verification in this annual submission. However, general QA/QC, taking into account the figures check, correctness of the calculation used, data sources etc., were performed in the category, as it was subject to source specific recalculation.

6.5.7 Category-specific recalculations

Recalculations have been undertaken for the period 1986-2021 concerning land converted to cropland, incorporating updated emission factors for living biomass and dead organic matter (conversions from forest land to cropland) and updated emission factors for mineral soil (conversions from settlements to cropland).

6.5.8 Source-specific planned improvements

No major improvements are planned for this category in the next annual submission.

6.6 Grassland (4C)

6.6.1 Source category description

Grassland category includes CO_2 emissions from changes in carbon stock in living biomass and in soils. Carbon stock changes are reported in Grassland remaining Grassland and in Land converted to Grassland. Grassland covered 20.00% of country total area in 2022.

Grassland land use includes: meadows and pastures, swampy meadows and pastures, alpine meadows, trees and bushes, overgrown areas, forest trees on agricultural land, and uncultivated agriculture land.

Net removals in the grassland category increased from -321.57 to -315.08 Gg CO_2 between 1986 and 2022. Grassland remaining grassland (CO_2) was identified as key source category according to the level and trend. Land converted to grassland (CO_2) was identified as key source category according to trend.

Table 6.6.1: Activity data for Grassland in 1986 – 2022 in kha

Year	4.C. Total Grassland	4.C. Organic soil	4.C.1. Grassland remaining Grassland	4.C.2. Land converted to Grassland	4.C.2.1 Forest Land converted to Grassland	4.C.2.2 Cropland converted to Grassland	4.C.2.3 Wetlands converted to Grassland	4.C.2.4 Settlements converted to Grassland	4.C.2.5 Other Land converted to Grassland
Area, kha									
2022	405.40	1.14	342.25	63.15	9.55	52.60	0.10	0.80	0.10
2021	405.85	1.19	340.96	64.89	9.55	53.81	0.14	0.87	0.51
2020	406.30	1.18	339.66	66.64	9.56	55.03	0.19	0.94	0.92
2019	406.75	1.15	338.37	68.38	9.56	56.24	0.23	1.01	1.33
2018	407.20	1.09	337.08	70.12	9.56	57.46	0.27	1.09	1.74
2017	407.65	0.95	335.79	71.86	9.57	58.67	0.31	1.16	2.15
2016	408.10	0.95	334.49	73.61	9.57	59.89	0.36	1.23	2.56
2015	405.40	0.94	334.15	71.25	9.75	56.82	0.40	1.30	2.97
2014	402.70	0.99	331.93	70.77	10.08	54.70	0.42	2.30	3.27
2013	400.00	0.82	329.71	70.29	10.41	52.57	0.44	3.30	3.57
2012	397.30	0.83	327.49	69.81	10.74	50.44	0.46	4.30	3.87
2011	396.80	0.81	324.05	72.75	10.82	52.02	0.48	5.25	4.17
2010	396.30	0.88	320.62	75.68	10.90	53.60	0.50	6.20	4.47
2009	395.80	0.80	318.09	77.71	10.78	53.26	0.52	7.42	5.72
2008	395.30	0.82	315.56	79.74	10.65	52.92	0.55	8.65	6.97
2007	394.80	1.06	313.02	81.78	10.52	52.58	0.58	9.87	8.22
2006	394.30	1.14	310.49	83.81	10.40	52.24	0.60	11.10	9.47
2005	393.52	1.23	308.52	85.01	10.03	51.44	0.60	12.25	10.70
2004	392.75	1.27	306.54	86.21	9.65	50.64	0.60	13.40	11.92
2003	391.98	1.30	304.57	87.41	9.28	49.84	0.60	14.55	13.15
2002	391.20	1.34	302.59	88.61	8.90	49.04	0.60	15.70	14.37
2001	406.08	1.34	316.49	89.59	8.85	48.05	0.58	16.90	15.21
2000	420.96	1.33	330.39	90.57	8.79	47.06	0.56	18.11	16.05
1999	435.84	1.32	344.29	91.56	8.74	46.07	0.55	19.31	16.89
1998	450.73	1.32	358.19	92.54	8.69	45.08	0.53	20.51	17.73
1997	465.61	1.31	372.09	93.52	8.63	44.09	0.51	21.72	18.57
1996	480.49	1.33	385.99	94.50	8.58	43.10	0.49	22.92	19.41
1995	495.37	1.34	399.88	95.49	8.53	42.11	0.48	24.12	20.25
1994	508.32	1.35	413.73	94.59	8.32	40.19	0.48	24.40	21.20
1993	521.28	1.37	427.58	93.69	8.12	38.27	0.48	24.67	22.15
1992	534.23	1.38	441.43	92.79	7.91	36.34	0.49	24.95	23.10
1991	547.18	1.39	455.28	91.90	7.70	34.42	0.50	25.22	24.05
1990	560.13	1.41	469.13	91.00	7.50	32.50	0.50	25.50	25.00
1989	560.63	1.42	469.63	91.00	7.50	32.50	0.50	25.50	25.00
1988	561.13	1.43	470.13	91.00	7.50	32.50	0.50	25.50	25.00
1987	561.63	1.45	470.63	91.00	7.50	32.50	0.50	25.50	25.00
1986	562.13	1.46	471.13	91.00	7.50	32.50	0.50	25.50	25.00

Table 6.6.2: Emissions from Grassland (1986 – 2022) in Gg CO_2

Year	4.C. Total Grassland	4.C.1. Grassland remaining Grassland	4.C.2. Land converted to Grassland	4.C.2.1 Forest Land converted to Grassland	4.C.2.2 Cropland converted to Grassland	4.C.2.3 Wetland converted to Grassland	4.C.2.4 Settlements converted to Grassland	4.C.2.5 Other Land converted to Grassland
GHG emissions/removals, Gg CO_2								
2022	-315.08	-376.98	61.90	157.49	-83.41	-2.21	-10.20	0.23
2021	-361.11	-404.99	43.88	155.88	-91.55	-3.16	-11.05	-6.24
2020	-401.35	-431.70	30.35	155.14	-96.23	-4.10	-11.90	-12.55
2019	-438.33	-457.71	19.38	154.86	-99.05	-5.05	-12.75	-18.63
2018	-476.57	-483.94	7.37	154.42	-102.67	-6.00	-13.60	-24.79
2017	-509.06	-509.16	0.10	155.17	-103.37	-6.94	-14.45	-30.31
2016	-438.87	-399.52	-39.35	88.99	-67.93	-7.89	-15.30	-37.22
2015	-452.07	-410.54	-41.53	88.93	-62.15	-8.84	-16.15	-43.33
2014	-467.04	-410.09	-56.95	88.83	-61.74	-9.28	-28.07	-46.69
2013	-467.51	-407.50	-60.01	89.16	-50.68	-9.72	-39.99	-48.79
2012	-433.42	-422.92	-10.50	187.96	-85.39	-10.16	-50.43	-52.48
2011	-484.98	-444.73	-40.24	184.85	-95.91	-10.60	-61.69	-56.89
2010	-532.38	-465.42	-66.96	182.07	-104.45	-11.05	-72.91	-60.62
2009	-561.86	-462.80	-99.06	179.48	-105.48	-11.60	-87.40	-74.06
2008	-588.39	-459.55	-128.84	177.08	-105.38	-12.15	-101.88	-86.52
2007	-613.67	-456.17	-157.50	174.72	-104.99	-12.70	-116.35	-98.18
2006	-577.96	-495.90	-82.06	259.64	-91.85	-11.71	-128.89	-109.25
2005	-579.27	-460.49	-118.79	255.14	-93.20	-11.71	-142.77	-126.24
2004	-569.53	-423.54	-145.99	251.40	-91.01	-11.71	-156.44	-138.23
2003	-535.75	-383.82	-151.94	249.07	-82.37	-11.71	-169.74	-137.19
2002	-722.55	-397.91	-324.64	138.60	-109.27	-10.61	-185.23	-158.14
2001	-734.82	-401.93	-332.89	136.83	-104.33	-10.21	-199.46	-155.72
2000	-760.65	-407.04	-353.61	134.98	-103.30	-9.82	-213.80	-161.67
1999	-799.66	-413.03	-386.63	132.77	-105.47	-9.42	-228.25	-176.26
1998	-829.15	-418.33	-410.82	130.84	-105.16	-9.03	-242.61	-184.86
1997	-855.72	-423.44	-432.28	128.99	-104.13	-8.63	-256.96	-191.54
1996	-870.65	-427.86	-442.79	127.41	-100.61	-8.24	-271.24	-190.11
1995	-438.21	-78.83	-359.38	170.81	-60.04	-9.26	-260.22	-200.67
1994	-474.85	-102.24	-372.60	168.29	-54.04	-9.37	-263.94	-213.55
1993	-445.74	-115.46	-330.28	167.30	-36.14	-9.48	-263.41	-188.55
1992	-479.05	-138.53	-340.52	164.84	-29.73	-9.59	-266.98	-199.06
1991	-543.75	-166.16	-377.59	161.69	-28.65	-9.70	-272.46	-228.46
1990	-295.69	194.77	-490.46	101.84	-80.94	-9.50	-268.35	-233.50
1989	-306.09	185.93	-492.02	100.28	-80.94	-9.50	-268.35	-233.50
1988	-303.39	180.25	-483.64	98.90	-79.99	-9.50	-267.42	-225.63
1987	-324.28	168.88	-493.16	97.19	-80.75	-9.50	-268.16	-231.93
1986	-321.57	163.21	-484.78	95.80	-79.80	-9.50	-267.23	-224.05

6.6.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The information of grassland area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present grassland area in the period 1986-2001. The estimation of area of Grassland for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project “Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry”. The estimation of cropland area and annual land-use changes for the years 2013, 2014 and 2015 were extrapolated. The approach used for representing grassland areas follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to grassland is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of grassland areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Land-use database of the Statistical Yearbook of the Statistical Office RS,
- Agricultural Land Use Map and LPIS database of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

6.6.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The grassland is not defined specifically in terms of national legislation. However, the Agricultural Land Act (2011) defines agricultural land as land suitable for the agricultural production. The Act refers to the national land-use classes determined by Article 6 of the Rules on the register of actual agricultural and forest land use (2006). For the need of the GHG reporting the Grassland category includes the following land-use classes (Table 6.2.1); meadows and pastures, swampy meadows and pastures, uncultivated agriculture land, overgrown areas, mixed land use, and forest trees on agricultural land.

6.6.4 Methodological issues

6.6.4.1 Grassland remaining grassland

<u>Carbon stock changes in living biomass</u>

Annual Grassland remaining annual Grassland

The Tier 1 assumption is that the carbon stock of living biomass does not change on annual grassland. The rationale is that neither management nor intensity change over time. Therefore, it is assumed that annual plant growth and losses balance each other out.

Perennial Grassland remaining perennial Grassland

Annual carbon stock change in living biomass of perennial grassland remaining perennial grassland was estimated by Gain-Loss method (Equation 2.7, IPCC 2006). Country-specific annual accumulation rate of 0.99 t C ha^{-1} $year^{-1}$ for perennial biomass (above- and below-ground) was used in the calculation of gains, while it is assumed that loss is close to zero.

Perennial grassland includes Overgrown areas, Trees and shrubs and Forest trees on agricultural land (see Table 6.2.1). Although these lands are considered to be managed, the woody vegetation on these lands is considered to have resulted primarily from the abandonment of agricultural activity. Harvesting or gathering of wood for fuel purposes is assumed to predominate on forest land, while losses on the remaining perennial grassland are assumed to be primarily due to natural mortality and removal (which is assumed to be minor). The latter also occur naturally, of course, but no country-specific data are available because there is currently no continuous monitoring.

Perennial Grassland converted to Annual Grassland

For the calculation of annual change in carbon stocks in living biomass of perennial grassland converted to annual grassland the Tier 1/Tier 2 method was applied and equations 2.15 and 2.16 (IPCC 2006) were used.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L \quad \textbf{(Equation 30)}$$

ΔC_B – annual change in carbon stocks in biomass on land converted to annual grassland, in t C yr^{-1}
ΔC_G – annual increase in carbon stocks in biomass due to growth on land converted to annual grassland, in tonnes C yr^{-1}
$\Delta C_{CONVERSION}$ – initial change in carbon stocks in biomass on land converted to annual grassland, in t C yr^{-1}
ΔC_L – annual decrease in biomass carbon stocks due to loss on land converted to annual grassland, in t C yr^{-1}

$$\Delta C_{CONVERSION} = \Sigma\, [(B_{AFTER} - B_{BEFORE}) \times \Delta A] \times CF \quad \textbf{(Equation 31)}$$

$\Delta C_{CONVERSION}$ – initial change in biomass carbon stocks on land converted to annual grassland, t C yr^{-1}
B_{AFTER} – biomass stocks immediately after the conversion, t d.m. ha^{-1}
B_{BEFORE} – biomass stocks before the conversion, t d.m. ha^{-1}
ΔA – annual area of land converted to annual grassland, ha yr^{-1}
CF – carbon fraction of dry matter, t C $(t\ d.m.)^{-1}$

Country-specific carbon stock in perennial above-ground biomass of 35.02 t C ha^{-1} was calcualated as the weighted average for the prevailing perennial grassland types; overgrown areas (n = 37), trees and shrubs (n = 49) and forest trees on agricultural land (n = 25). The carbon stocks in perennial grassland was measured in 2017 and 2018 (Mali et al., 2017b; Mali et al., 2018b). Below ground biomass was estimated using a default root to shoot ratio according to the 2006 Guidelines.

Annual Grassland converted to Perennial Grassland

To calculate the annual change in carbon stock in the living biomass of perennial grassland converted to annual grassland, the Tier 1/Tier 2 method was applied and Equations 2.15 and 2.16 of the 2006 Guidelines were used. The country-specific value for carbon stock in annual grassland, equivalent to 1.89 t C ha^{-1}, was estimated from SORS data.

It is assumed that all woody vegetation is lost in the year of land use change and that biomass stock immediately after the conversion is zero.

<u>Carbon stock changes in dead organic matter</u>

The Tier 1 method of the 2006 Guidelines assumes that dead wood and litter stocks are at equilibrium, so there is no need to estimate the carbon stock changes for these pools.

<u>Carbon stock changes in soils</u>

Annual Grassland remaining annual Grassland

For calculations of carbon stock changes in soils in grassland remaining grassland, the equation 2.24 (IPCC 2006) was used.

$$\Delta C_{GGsoils} = \Delta C_{GG\min eral} - L_{GGorganic} + \Delta C_{inorganic} \quad \textbf{(Equation 32)}$$

$\Delta C_{GGsoils}$ *- annual change in carbon stocks in soil [t C yr $^{-1}$]*

$\Delta C_{GGmineral}$ *- annual change in carbon stocks in mineral soils [t C yr $^{-1}$]*

$L_{GGorganic}$ *- annual loss of carbon from drained organic soils [t C yr $^{-1}$]*

$\Delta C_{GGinorganic}$*- annual change in inorganic carbon stocks from soils [t C yr $^{-1}$]*

Mineral soils

For the calculations of annual carbon stock changes in mineral soils in annual grassland remaining annual grassland Tier 1 method and Equation 2.25 (IPCC 2006) were used, followed by the approach suggested by Hiederer et al. (2016). The default reference soil organic carbon stock (i.e. 88 t C ha^{-1}) for mineral soils from Table 2.3 (IPCC 2006) was used, considering warm temperate, moist climate region and HAC soil type. Soil organic carbon stocks were estimated for each time period between 2006 and 2017 using default reference carbon stocks (SOC_{REF}) and default stock change factors (F_{LU}, F_{MG}, F_I) from Table 6.2 (IPCC 2006).

Stratification of grassland area and preparation of vector layers for stock change factors was performed by Agricultural Institute of Slovenia. It is assumed that the change in management regime has occured since 2007. Therefore, emissions and removals from annual grassland mineral soils are reported only from 2007. The reasons for using the Tier 1 method in grassland remaining grassland are the same as for cropland remaining cropland and are described in more detail in subsection 6.5.4.1.

It should be noted that the change in net carbon stock in mineral soils per area appears incorrect for category 4.C.1 (grassland remaining grassland). The change in carbon stock in mineral soils for the subcategory “GL_a to GL_a” reported under 4.C.1 was estimated for 2007–2018 only, causing a trend change in mineral soil carbon stock change per area. In addition, the changes in land-use management occurred in 2007 following the introduction of initiatives such as the Rural Development Programme 2007–2013, which resulted in, for example, a range of subsidy payment regimes and incentives to change crop types and/or adopt different management technologies and agri-environment-climate policy measures (which provided for additional activities to be undertaken in the country related to soil management).

Organic soils

The total area of organic soils of grassland was 1.144 kha in 2022. Emissions from organic soils are not reported beacuse the GPG2003 assumed that emissions from organic soils are caused by drainage and other management disturbances (e.g. grazing management practices). In constrast, it appears that under the 2006 Guidelines, only drainage is assumed to cause emissions from organic soil (“managed” vs. “drained” grassland organic soil in Table 3.4.6 of the GPG2003 and Table 6.3 of the 2006 Guidelines, respectively). As drainage of managed grassland organic soil is not a common practice in Slovenia, emissions are not reported here.

Perennial Grassland remaining perennial Grassland

At the country level, there is no permanent soil monitoring on areas of perennial grassland remaining perennial grassland. However, because this category includes land that is predominantly uncultivated, it is assumed that the soils are not subject to disturbance. Therefore, the carbon stock of perennial grassland remaining perennial grassland is conservatively assumed to be in equilibrium.

Annual Grassland converted to Perennial Grassland

For calculations of carbon stock changes in mineral soils from annual grassland to perennial grassland the Tier 2 method was applied, using equation 2.25 (IPCC 2006). Net emissions were calculated by country-specific avarage carbon stocks in mineral soils of annual and perennial grassland (Table 6.3.12).

$\Delta C_{Mineral}$ = conversion area for a transition period of 20 years * ΔC_{SOC} **(Equation 33)**

$$\Delta C_{SOC} = \frac{(SOC_n - SOC_o)}{T}$$

$\Delta C_{Mineral}$ - annual change in carbon stocks in mineral soils, tonnes C yr^{-1}
SOC_n – average carbon stock of soils in perennial grassland, tonnes C ha^{-1}
SOC_o – average carbon stock of soils in annual grassland, tonnes C ha^{-1}
T – transition period (default = 20 years)

Perennial Grassland converted to Annual Grassland

Emissions/removals were calculated by country specific values for carbon stocks in mineral soils of perennial grassland and annual grassland, respectively. Calculation steps and input data follow the equation 3, where SOC_n is average carbon stock of annual grassland and SOC_o is average carbon stock of perennial grassland.

6.6.4.2 Land converted to Grassland

According to the results from the point sampling conversions from all categories to Grassland occur, although conversions from Wetlands are very rare. The average annual area converted from other land uses to Grassland in the period 2002-2020 ranged between 3,525 and 8,200 ha.

Carbon stock changes in living biomass

For the calculations of the annual change in carbon stocks in living biomass on land converted to grassland the Tier 2 methodology and equations 2.15 and 2.16 (IPCC 2006) were used.

A country-specific value for the annual accumulation rate of perennial grassland (ΔC_G = 0.994 t C ha^{-1}) was used. The average carbon stocks in living biomass under the previous land-use categories are the same as those in Table 6.3.10. It is assumed that the carbon stock in biomass immediately after conversion (B_{AFTER}) is zero, since the land is cleared of all vegetation before planting vegetation (Tier 1). The same assumption was made for annual and perennial grassland.

Carbon stock changes in dead organic matter

Carbon stock changes in dead organic matter were calculated for dead wood and litter pool in conversion from forest land to grassland. The following equation was used:

$$\Delta C_{LG_{DOM}} = \Delta C_{LG_{DW}} + \Delta C_{LG_{LT}}$$ **(Equation 34)**

$\Delta C_{LG_{DOM}}$ – *annual change in carbon stocks in dead organic matter [t C yr^{-1}]*

$\Delta C_{LG_{DW}}$ – *change in carbon stocks in dead wood [t C yr^{-1}]*

$\Delta C_{LG_{LT}}$ *– change in carbon stocks in litter [t C yr -1]*

For calculations of annual change in carbon stocks in dead wood the following equation was used:

$\Delta C_{LG_{DW}}$ *= annual area of converted land * ΔC conversion* **(Equation 35)**

$\Delta C_{conversion} = C_{after} - C_{before}$

C_{after} – carbon after conversion is 2.27 t C ha^{-1}
C_{before} – carbon stock in dead wood [t C ha^{-1}]

Values for carbon stock in dead wood (C_{before}) were calculated from FECS 2007, 2012 and 2018.

For calculations of annual change in carbon stocks in litter the following equation was used:

$\Delta C_{LG_{LT}}$ *= annual area of converted land * ΔC conversion*

(Equation 36)

$\Delta C_{conversion} = C_{after} - C_{before}$

C_{after} – carbon after conversion is 7.58 t C ha^{-1}
C_{before} – carbon stock in litter [t C ha^{-1}]

The value for carbon stock in litter (C_{before} = 10.41 t C ha^{-1}) was used from the Slovenian Forestry Institute study (Kobal and Simončič, 2011).

Country-specific values for dead wood and litter for C_{after} were estimated based on the study by Mali et al. (2018b).

Carbon stock changes in soils

Tier 2 method and Equation 2.25 (IPCC 2006) were used to calculate emissions from soils on land converted to grassland.

$$\Delta C_{LG\,mineral} \frac{[SOC_0 - SOC_{0-T}) * A]}{T}$$ **(Equation 37)**

$\Delta C_{LGmineral}$ – annual change in carbon stock in mineral soils [t C yr^{-1}]
SOC_0 – soil organic carbon stock in the inventory year [t C ha^{-1}]
SOC_{0-T} – soil organic carbon stock T years prior to the inventory [t C ha^{-1}]
T – time [default 20 years]
A – land area [ha]

$SOC = SOC_{GL}$

SOC_{GL} – country-specific value for organic carbon stock in mineral soil

Slovenian national value for organic carbon stock in mineral soil for grassland (grassland annual: $SOC_{GLannual}$ = 94.86 t ha^{-1}; grassland perennial: $SOC_{GLperennial}$ = 101.53 t ha^{-1}) are presented in Table 6.3.12.

Organic soil

Activity data for organic soils were revised using area data from Pedology Map, which are consistent with those of the agricultural sector. However, emissions from organic soils were not estimated. For explanation, see subsection 6.5.4.1.

N_2O emissions from N mineralization/immobilizaton

Equations 11.1 and 11.8 and the default emission factors from Table 11.1 (IPCC 2006) were used for the calculations of N_2O emissions associated with land conversion to grassland. The Tier 1 method was used to estimate direct N_2O emissions due to land use conversions from forest land and cropland to grassland. Additionally, the same approach was used to estimate direct N_2O emissions from the conversion of perennial grassland to annual grassland.

Indirect N_2O emission from N leaching and run-off

For the estimation of indirect N_2O emissions from N mineralization due to land use change in mineral soils through leaching/runoff, the Tier 1 method was applied using Equation 11.10 and default emission factors from Table 11.3 of the 2006 Guidelines. Indirect N_2O emissions are estimated due to land use changes from forest land and cropland to grassland and from perennial grassland to annual grassland.

6.6.5 Uncertainties and time-series consistency

Uncertainties were analysed as uncertainty in activity data (Table 6.3.8) and uncertainty in variables such as emission factors, growth rates, effects of land management factors, etc. Uncertainties were determined from empirical data, IPCC default values and expert judgement.

Table 6.6.3: Uncertainties for emission factors

Variable	Grassland remaining grassland (95 % CI)	Land converted to grassland (95% CI)
Living biomass	85 %	189 %
Dead organic matter	54 %	60 %
Mineral soil	100 %	65 %

6.6.6 Category-specific QA/QC and verification

No specific QA/QC and verification for grassland was used in the 2023 NID submission. However, a general QA/QC was cerried out considering the verification of figures, correctness of calculation used, data sources etc. in the category as it was subject to source-specific recalculation.

6.6.7 Category-specific recalculations

Recalculations for the period 1986-2021 for land converted to grassland were made based on updated emission factors for living biomass and dead organic matter (conversions from forest land to grassland) and updated emission factors for mineral soil (conversions from settlements to grassland and from wetlands to grassland).

6.6.8 Source-specific planned improvements

No major improvements are planned for this category in the next annual submission.

6.7 Wetlands (4D)

6.7.1 Source category description

Wetlands are defined under the 2006 Guidelines as land that is covered or saturated by water all or part of the year and does not fall into the categories of forest land, cropland, crassland or settlements. Emissions in wetlands remaining wetlands are not estimated, conversions from other land uses to wetlands, except for forest land and grassland, do not occur in Slovenia.

Wetlands covered 0.74% of the country's area in 2022. Wetlands include: swamps, reeds, other marshy areas and water bodies (inland water bodies). Emissions from wetlands ranged from 39.41 Gg CO_2 in 1986 to 43.59 Gg CO_2 in 2022.

Table 6.7.1: Activity data of Wetlands 1986 – 2022 in kha

Year	4.D Total wetlands	4.D.1 Wetlands remaining wetlands	Land converted to wetlands					
			4.D.2 Land converted to wetlands	4.D.2.1 Forest converted to wetlands	4.D.2.2 Cropland converted to wetlands	4.D.2.3 Grassland converted to wetlands	4.D.2.4 Settlements converted to wetlands	4.D.2.5 Other land converted to wetlands
Area, kha								
2022	15.10	13.75	1.35	0.80	0.30	0.25	NO	NO
2021	14.97	13.74	1.23	0.76	0.25	0.22	NO	NO
2020	14.85	13.72	1.13	0.73	0.20	0.20	NO	NO
2019	14.72	13.71	1.01	0.69	0.15	0.17	NO	NO
2018	14.60	13.69	0.91	0.66	0.10	0.15	NO	NO
2017	14.48	13.68	0.80	0.62	0.05	0.13	NO	NO
2016	14.35	13.66	0.69	0.59	NO	0.10	NO	NO
2015	14.35	13.65	0.70	0.60	NO	0.10	NO	NO
2014	14.35	13.55	0.80	0.62	NO	0.18	NO	NO
2013	14.35	13.45	0.90	0.64	NO	0.26	NO	NO
2012	14.35	13.35	1.00	0.66	NO	0.34	NO	NO
2011	14.26	13.25	1.01	0.61	NO	0.40	NO	NO
2010	14.19	13.15	1.04	0.57	NO	0.47	NO	NO
2009	14.09	13.05	1.04	0.52	NO	0.52	NO	NO
2008	14.01	12.95	1.06	0.48	NO	0.58	NO	NO
2007	13.93	12.85	1.08	0.44	NO	0.64	NO	NO
2006	13.85	12.75	1.10	0.40	NO	0.70	NO	NO
2005	13.90	12.72	1.18	0.40	NO	0.78	NO	NO
2004	13.95	12.70	1.25	0.40	NO	0.85	NO	NO
2003	14.00	12.68	1.32	0.40	NO	0.92	NO	NO
2002	14.05	12.65	1.40	0.40	NO	1.00	NO	NO
2001	14.17	12.69	1.48	0.41	NO	1.07	NO	NO
2000	14.30	12.73	1.57	0.42	NO	1.15	NO	NO
1999	14.42	12.76	1.66	0.43	NO	1.23	NO	NO
1998	14.54	12.80	1.74	0.44	NO	1.30	NO	NO
1997	14.67	12.84	1.83	0.45	NO	1.38	NO	NO
1996	14.79	12.88	1.91	0.46	NO	1.45	NO	NO
1995	14.91	12.91	2.00	0.48	NO	1.52	NO	NO
1994	14.89	12.89	2.00	0.48	NO	1.52	NO	NO
1993	14.86	12.87	1.99	0.48	NO	1.51	NO	NO
1992	14.85	12.85	2.00	0.49	NO	1.51	NO	NO
1991	14.83	12.83	2.00	0.50	NO	1.50	NO	NO
1990	14.81	12.81	2.00	0.50	NO	1.50	NO	NO
1989	14.79	12.79	2.00	0.50	NO	1.50	NO	NO
1988	14.76	12.76	2.00	0.50	NO	1.50	NO	NO
1987	14.74	12.74	2.00	0.50	NO	1.50	NO	NO
1986	14.71	12.71	2.00	0.50	NO	1.50	NO	NO

Table 6.7.2: Emission from Wetlands (1986 – 2022) in Gg CO_2

Year	4.D Total wetlands	4.D.1 Wetlands remaining wetlands	Land converted to wetlands					
			4.D.2 Land converted to wetlands	4.D.2.1 Forest converted to wetlands	4.D.2.2 Cropland converted to wetlands	4.D.2.3 Grassland converted to wetlands	4.D.2.4 Settlements converted to wetlands	4.D.2.5 Other land converted to wetlands
GHG emissions/removals, Gg CO_2								
2022	43.59	NO,NE	43.59	34.92	4.64	4.03	NO	NO
2021	41.91	NO,NE	41.91	34.31	3.95	3.64	NO	NO
2020	40.23	NO,NE	40.23	33.71	3.27	3.26	NO	NO
2019	38.55	NO,NE	38.55	33.10	2.58	2.87	NO	NO
2018	36.87	NO,NE	36.87	32.49	1.89	2.49	NO	NO
2017	35.25	NO,NE	35.25	31.95	1.20	2.10	NO	NO
2016	11.48	NO,NE	11.48	9.94	NO	1.54	NO	NO
2015	11.72	NO,NE	11.72	10.18	NO	1.54	NO	NO
2014	13.29	NO,NE	13.29	10.52	NO	2.78	NO	NO
2013	14.87	NO,NE	14.87	10.86	NO	4.01	NO	NO
2012	45.16	NO,NE	45.16	39.80	NO	5.36	NO	NO
2011	44.95	NO,NE	44.95	38.62	NO	6.33	NO	NO
2010	44.74	NO,NE	44.74	37.43	NO	7.31	NO	NO
2009	44.54	NO,NE	44.54	36.33	NO	8.21	NO	NO
2008	44.34	NO,NE	44.34	35.23	NO	9.11	NO	NO
2007	44.14	NO,NE	44.14	34.13	NO	10.01	NO	NO
2006	27.42	NO,NE	27.42	16.63	NO	10.79	NO	NO
2005	28.42	NO,NE	28.42	16.47	NO	11.95	NO	NO
2004	29.43	NO,NE	29.43	16.32	NO	13.11	NO	NO
2003	30.43	NO,NE	30.43	16.17	NO	14.26	NO	NO
2002	27.48	NO,NE	27.48	12.06	NO	15.42	NO	NO
2001	28.74	NO,NE	28.74	12.16	NO	16.57	NO	NO
2000	30.00	NO,NE	30.00	12.27	NO	17.73	NO	NO
1999	31.27	NO,NE	31.27	12.38	NO	18.89	NO	NO
1998	32.54	NO,NE	32.54	12.49	NO	20.04	NO	NO
1997	33.80	NO,NE	33.80	12.60	NO	21.20	NO	NO
1996	35.07	NO,NE	35.07	12.71	NO	22.36	NO	NO
1995	38.80	NO,NE	38.80	14.73	NO	24.07	NO	NO
1994	38.71	NO,NE	38.71	14.72	NO	23.99	NO	NO
1993	38.62	NO,NE	38.62	14.71	NO	23.91	NO	NO
1992	38.54	NO,NE	38.54	14.70	NO	23.84	NO	NO
1991	38.45	NO,NE	38.45	14.69	NO	23.76	NO	NO
1990	39.88	NO,NE	39.88	16.23	NO	23.65	NO	NO
1989	39.76	NO,NE	39.76	16.11	NO	23.65	NO	NO
1988	39.64	NO,NE	39.64	16.00	NO	23.65	NO	NO
1987	39.52	NO,NE	39.52	15.88	NO	23.65	NO	NO
1986	39.41	NO,NE	39.41	15.76	NO	23.65	NO	NO

6.7.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The information of wetlands area is based on multiple data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present wetlands area in the period 1986-2001. Besides, data on area of Wetlands until 2001 were complemented by the information from the land cover map (based on Landsat TM, ETM – EURIMAGE, Eurostat/CESD), being available for the years 1993, 1997 and 2001 and officially published (SORS 2005). The estimation of wetlands area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project “Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry”.

The estimation of cropland area and annual land-use changes for the years 2013, 2014 and 2015 were extrapolated. The approach used for representing areas of Wetlands follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to wetlands is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of wetlands areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Agricultural Land Use Map of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

6.7.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The wetlands are not defined specifically in terms of national legislation. However, the Rules on delineation of surface water bodies (2005) defines that detached surface water bodies are determined for large streams, natural lakes, sea and brackish water, artificial channels, water reservoirs on rivers and artificial lakes.

For the need of the GHG reporting the Wetlands category includes the following land-use classes (Table 6.2.1); swamps, reeds, other marshy areas, and waters (inland water bodies). In line with the land-use classification (Identification key 2013) waters (class 7000) includes running and standing waters, channels, temporarily dry riverbeds, sandy beaches and dunes, gravel areas along or in the streams, river islands covered with vegetation, running waters in the forest (if recognizable from the map), capture and reservoirs, and fishponds.

6.7.4 Methodological issues

6.7.4.1 Wetlands remaining wetlands

Slovenia has not reported emissions from flooded land remaining flooded land due to lack of data. As the Ljubljana marsh, the largest Slovenian and southernmost European wetland (area of about 160 km^2), is subject to regular flooding and drainage activiites (e.g. clearing of the drainage channels), emissions do occur in this wetland. However, there is currently insufficient data to apply the Wetlands Supplement.

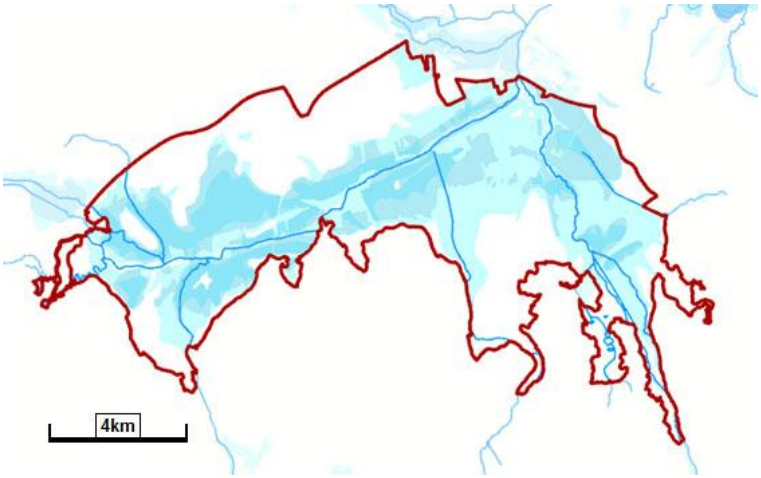

Figure 6.7.1 : Ljubljana Marsh and the Ljubljanica river basin with floodwater area (shaded)

6.7.4.2 Land converted to wetlands

According to the results from the point sampling there are no conversions from other land uses to Wetlands, exluding those from Forest land. Due to necessary assurance for Slovenian land area consistency through whole time series, also conversion from Settlements (one example in the period 2002-2006) was taken into account.

Carbon stock changes in living biomass

For the estimation of the annual change in carbon stocks of living biomass in Land converted to Wetlands the equation 7.10 of the 2006 Guidelines was applied:

$$\Delta C_{LWflood,LB} = \left[\sum_i A_i * (B_{After} - B_{Before}) \right] * CF$$ **(Equation 38)**

Ai – area of land converted annually to Flooded land from original land use (from Forest land and from Grassland) (ha yr^{-1})
B_{After} – biomass immediately following conversion to flooded land, tonnes d. m. ha^{-1} (default = 0)
B_{Before} – biomass in land immediately before conversion to flooded land, tonnes d.m. ha^{-1}
CF – carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m.)$^{-1}$

Carbon stock changes in soils

The Tier 2 method and Equation 2.25 (IPCC 2006) were used to calculate emissions from soils in areas converted to wetlands

$$\Delta C_{LG\,\min eral} \frac{[SOC_0 - SOC_{0-T}) * A]}{T}$$ **(Equation 39)**

$\Delta C_{LGmineral}$ – annual change in carbon stock in mineral soils [t C yr $^{-1}$]
SOC_0 – soil organic carbon stock in the inventory year [t C ha^{-1}]
SOC_{0-T} – soil organic carbon stock T years prior to the inventory [t C ha^{-1}]
T – time [default 20 years]
A – land area [ha]

The country-specific value for organic carbon stock in mineral soil for wetlands: SOC_{WL} = 10.76 t ha^{-1} is presented in Table 6.3.12.

Uncertainties and time-series consistency

Uncertainties were applied in accordance with the default vaules for emission factors (IPCC, 2006), while uncertainties for activity data are presented in Table 6.3.8.

6.7.5 Category-specific QA/QC and verification

No specific QA/QC and verification for grassland was used in the 2022 NID submission. However, a general QA/QC was cerried out considering the verification of figures, correctness of calculation used, data sources etc. in the category as it was subject to source-specific recalculation.

6.7.6 Category-specific recalculations

Recalculations have been made for the period 1986-2021 concerning land converted to wetlands based on updated emission factors for living biomass and dead organic matter (conversions from forest land to wetlands) and updated emission factors for mineral soil (conversions from forest land to wetlands and from grassland to wetlands).

6.7.7 Source-specific planned improvements

No major improvements are planned for this category in the next annual submission.

6.8 Settlements (4E)

6.8.1 Source category description

Settlements covered 6.05% of country area in 2022. Settlements include: built-areas and related surfaces.

This land use category is described (IPCC 2006) as including all developed land, i.e. residential, transportation, commercial, and production (commercial, manufacturing) infrastructure of any size, unless it is already included under other land-use categories. Settlements includes land along streets, in residential (rural and urban) and commercial lawns, in public and private gardens, in golf courses and athletic fields, and in parks, provided such land is functionally or administratively associated with particular cities, villages or other settlement types and is not accounted for in another land-use category.

Ne emissions in settlements decreased from 413.32 to 177.92 Gg CO_2 between 1986 and 2022.

Settlements remaining settlements (CO_2) was identified as key source category based on the level and trend.

Table 6.8.1: Activity data of Settlements (1986-2022) in kha

Year	4.E Total settlement	4.E.1. Settlements remaining settlements	Land converted to settlements					
			4.E.2 Land converted to settlement	4.E.2.1 Forest converted to settlement	4.E.2.2 Cropland converted to settlement	4.E.2.3 Grassland converted to settlement	4.E.2.4 Wetland converted to settlement	4.E.2.5 Other lands converted to settlement
Area, kha								
2022	122.65	101.90	20.75	4.30	4.95	11.30	0.20	NO
2021	121.75	100.19	21.56	4.54	5.38	11.34	0.29	NO
2020	120.85	98.49	22.36	4.77	5.81	11.39	0.39	NO
2019	119.95	96.78	23.17	5.01	6.25	11.43	0.48	NO
2018	119.05	95.07	23.98	5.24	6.68	11.48	0.58	NO
2017	118.15	93.36	24.79	5.48	7.11	11.52	0.67	NO
2016	117.25	91.66	25.59	5.71	7.54	11.57	0.77	NO
2015	116.70	89.93	26.77	5.80	8.07	12.04	0.86	NO
2014	116.15	87.79	28.36	5.78	8.73	12.93	0.92	NO
2013	115.60	85.65	29.95	5.76	9.38	13.82	0.98	NO
2012	115.05	83.51	31.54	5.74	10.04	14.72	1.04	NO
2011	114.07	81.43	32.63	5.74	10.37	15.42	1.10	NO
2010	113.08	79.36	33.72	5.73	10.70	16.13	1.16	NO
2009	112.10	77.55	34.55	5.70	10.53	17.11	1.21	NO
2008	111.12	75.74	35.37	5.67	10.35	18.09	1.26	NO
2007	110.13	73.93	36.20	5.63	10.18	19.08	1.31	NO
2006	109.15	72.13	37.02	5.60	10.00	20.06	1.36	NO
2005	107.65	70.43	37.22	5.22	9.68	20.96	1.36	NO
2004	106.15	68.73	37.42	4.85	9.35	21.86	1.36	NO
2003	104.65	67.03	37.62	4.47	9.03	22.76	1.36	NO
2002	103.15	65.33	37.82	4.10	8.70	23.66	1.36	NO
2001	101.57	63.60	37.97	3.96	8.32	24.37	1.32	NO
2000	99.99	61.88	38.11	3.83	7.94	25.07	1.27	NO
1999	98.42	60.16	38.25	3.69	7.55	25.78	1.23	NO
1998	96.84	58.44	38.40	3.56	7.17	26.48	1.18	NO
1997	95.26	56.72	38.54	3.42	6.79	27.19	1.14	NO
1996	93.68	55.00	38.68	3.29	6.41	27.89	1.09	NO
1995	92.10	53.28	38.82	3.15	6.03	28.60	1.05	NO
1994	91.08	52.52	38.56	3.12	5.52	28.88	1.04	NO
1993	90.06	51.77	38.29	3.09	5.02	29.16	1.03	NO
1992	89.04	51.01	38.03	3.06	4.51	29.44	1.02	NO
1991	88.02	50.26	37.76	3.03	4.00	29.72	1.01	NO
1990	87.00	49.50	37.50	3.00	3.50	30.00	1.00	NO
1989	86.60	49.10	37.50	3.00	3.50	30.00	1.00	NO
1988	86.20	48.70	37.50	3.00	3.50	30.00	1.00	NO
1987	85.80	48.30	37.50	3.00	3.50	30.00	1.00	NO
1986	85.40	47.90	37.50	3.00	3.50	30.00	1.00	NO

Table 6.8.2: Emissions from Settlements (1986 – 2022) in Gg CO_2

Year	4.E Total settlement	4.E.1. Settlements remaining settlements	Land converted to settlements					
			4.E.2 Land converted to settlement	4.E.2.1 Forest converted to settlement	4.E.2.2 Cropland converted to settlement	4.E.2.3 Grassland converted to settlement	4.E.2.4 Wetland converted to settlement	4.E.2.5 Other lands converted to settlement
GHG emissions/removals, Gg CO_2								
2022	177.92	-98.34	276.26	74.36	47.84	154.98	-0.93	NO
2021	186.30	-96.69	282.99	77.27	51.75	155.34	-1.37	NO
2020	194.67	-95.05	289.72	80.17	55.65	155.70	-1.81	NO
2019	203.05	-93.40	296.44	83.08	59.55	156.06	-2.25	NO
2018	211.42	-91.75	303.17	85.98	63.46	156.42	-2.69	NO
2017	219.86	-90.10	309.96	88.95	67.36	156.78	-3.13	NO
2016	265.13	-88.46	353.58	156.34	67.18	133.62	-3.57	NO
2015	277.48	-86.78	364.26	157.65	71.93	138.69	-4.01	NO
2014	294.88	-84.72	379.60	157.66	77.89	148.33	-4.29	NO
2013	312.28	-82.65	394.94	157.67	83.86	157.97	-4.57	NO
2012	351.41	-80.59	432.00	149.43	96.18	191.23	-4.85	NO
2011	362.52	-78.59	441.11	148.31	99.25	198.67	-5.12	NO
2010	373.63	-76.59	450.22	147.19	102.32	206.11	-5.40	NO
2009	382.62	-74.84	457.46	145.70	100.79	216.61	-5.63	NO
2008	391.61	-73.10	464.71	144.20	99.26	227.11	-5.87	NO
2007	400.60	-71.35	471.96	142.71	97.73	237.61	-6.10	NO
2006	539.52	-69.61	609.13	275.65	103.85	231.54	-1.91	NO
2005	540.32	-67.97	608.29	267.85	101.10	241.24	-1.91	NO
2004	541.13	-66.32	607.45	260.07	98.35	250.94	-1.91	NO
2003	541.94	-64.68	606.62	252.29	95.60	260.65	-1.91	NO
2002	451.91	-63.04	514.95	156.11	89.49	267.29	2.06	NO
2001	454.66	-61.38	516.04	152.73	86.12	274.92	2.27	NO
2000	457.70	-59.72	517.42	149.63	82.75	282.55	2.48	NO
1999	460.73	-58.06	518.79	146.54	79.38	290.19	2.69	NO
1998	463.77	-56.40	520.16	143.44	76.02	297.82	2.89	NO
1997	466.80	-54.74	521.54	140.33	72.65	305.45	3.10	NO
1996	469.83	-53.08	522.90	137.23	69.28	313.09	3.31	NO
1995	432.95	-51.42	484.37	98.91	63.12	321.91	0.43	NO
1994	430.95	-50.69	481.64	97.67	58.53	324.96	0.48	NO
1993	428.96	-49.96	478.92	96.44	53.94	328.02	0.52	NO
1992	426.96	-49.23	476.19	95.20	49.34	331.07	0.57	NO
1991	424.96	-48.50	473.46	93.97	44.75	334.13	0.62	NO
1990	414.58	-47.77	462.35	83.46	33.82	345.29	-0.22	NO
1989	414.26	-47.39	461.65	82.76	33.82	345.29	-0.22	NO
1988	413.95	-47.00	460.95	82.06	33.82	345.29	-0.22	NO
1987	413.63	-46.61	460.25	81.36	33.82	345.29	-0.22	NO
1986	413.32	-46.23	459.54	80.65	33.82	345.29	-0.22	NO

6.8.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The information of settlements area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present settlements area in the period 1986-2001. The estimation of settlements area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project “Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry”. The approach used for representing settlements areas follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to settlements is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of settlements areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Agricultural Land Use Map of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

6.8.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The settlements is not defined specifically in terms of national legislation. However, the Rules on recording land use data in the land cadaster (1982) specified land use related to man-made objects and properties, such as residential and industry buildings, outbuildings, garage, functional objects, monuments, roads, railways, market squares, parking places, waste dumps, open warehouses etc. For the need of the GHG reporting the Settlements category includes the land-use class 3000 (Table 6.2.1), i.e. built-up areas and related surfaces. According to Interpretation key (2013) the latter includes all lands associated with buildings, roads, settlements, houses, parking places, mines and quarries and other infrastructure related to human activities.

6.8.4 Methodological issues

6.8.4.1 Settlements remaining Settlements

Carbon stock changes in living biomass

The 2006 Guidelines defined methods for estimating changes in carbon stock in biomass, dead organic matter, and soil carbon stock changes in settlements remaining settlements. The estimation of carbon stock changes in living biomass is based on crown cover area, using a Tier 2a approach. The country-specific value for crown cover (AT) is 9.4% was used from the WISDOM study (2006). During the informal recommendation of the EU review (i.e. Trial review of the 2021 greenhouse gas inventory for the LULUCF sector of Slovenia) the reviewer recommended Slovenia to use this value as it refers to tree cover in settlements.

Equation 8.2 of the 2006 Guidelines was used to estimate the annual carbon accumulation attributed to biomass increment. A default value of 2.8 t C ha crown cover^{-1} year^{-1} was used (IPCC 2019). Urban trees are assumed to be net sinks as the active growing period (AGP) was estimated to be less than 20 years.

Carbon stock changes in dead organic matter

In line with 2006 Guidelines the Tier 1 default assumes all carbon contained in dead wood and litter is lost during conversion and does not take account of any subsequent accumulation. Therefore, changes in carbon stocks of DOM are assumed zero.

Carbon stock changes in soils

The Tier 1 method assumes that inputs equal outputs, so that C stocks in the settlement soil do not change.

6.8.4.2 Land converted to Settlements

The average annual area converted from other land uses to Settlements in the period 2002-2020 is in the range between 925 and 1,675 ha.

Carbon stock changes in living biomass

The fundamental equation for estimating changes in carbon stocks associated with land-use conversions is the same as applied for other areas of land-use conversion (land converted to forest land, cropland or grassland). The default assumption for Tier 2 estimate is that all living biomass present before conversion to Settlement will be lost in the same year as the conversion takes place, and that carbon stocks following conversion are equal to zero. For calculations of emissions from other land uses converted to settlements Tier 2 methodology and equations 2.15 and 2.16 (IPCC 2006) were used.

Carbon stock changes in dead organic matter

In line with 2006 Guidelines the Tier 1 default assumes all carbon contained in dead wood and litter is lost during conversion and does not take account of any subsequent accumulation. Therefore, changes in carbon stocks of DOM are assumed zero.

Carbon stock changes in soils

For calculations of emissions from soils in land converted to Settlements Tier 2 methodology and equation 2.25 (IPCC 2006) were used.

$$\Delta C_{LSmineral} \frac{[SOC_0 - SOC_{0-T}) * A]}{T}$$

(Equation 40)

$\Delta C_{LGmineral}$ – annual change in carbon stock in mineral soils [t C yr $^{-1}$]
SOC_0 – soil organic carbon stock in the inventory year [t C ha^{-1}]
SOC_{0-T} – soil organic carbon stock T years prior to the inventory [t C ha^{-1}]

T – time [default 20 years], A – land area [ha]
SOC_{SL} – country-specific value for organic carbon stock in mineral soil (see Table 6.2.8.)

In 2022, the Slovenian Forestry Institute estimated the proportion of unsealed settlement areas on the basis of a visual analysis of digital orthophotos. In this study, 1,000 sample plots were randomly distributed at country level, taking into account the area of settlements. The estimated proportion of unsealed settlement area equals to 33.86%. In 2023, the average SOC stock for urban areas was reported as 88.14 t C ha^{-1}, based on the findings of Marinšek et al. (2023).

N_2O emissions from N mineralization/immobilizaton

For calculations of N_2O emissions associated with land conversion to settlements, the Tier 1 methodology was used, using Equations 11.1 and 11.8 and default emission factors from the Table 11.1 (IPCC 2006). Direct N_2O emissions are estimated due to land use conversions from forest land, cropland, grassland and wetlands to settlements.

Indirect N_2O emission from N leaching and run-off

The Tier 1 method (Equation 11.10) and default emission factors from Table 11.3 of the 2006 Guidelines were used to estimate indirect N_2O emissions from N mineralization due land use changes in mineral soils through leaching/runoff. Indirect N_2O emissions are estimated due to land use changes from forest land, cropland, grassland and wetlands to settlements.

6.8.5 Uncertainties and time-series consistency

The uncertainty estimates are not reported here.

6.8.6 Category-specific QA/QC and verification

No specific QA/QC and verification for grassland was used in the 2022 NID submission. However, a general QA/QC was cerried out considering the verification of figures, correctness of calculation used, data sources etc. in the category as it was subject to source-specific recalculation.

6.8.7 Category-specific recalculations

Recalculations have been made for the period 1986-2021 for land converted to settlements based on updated emission factors for living biomass, dead organic matter and mineral soil.

6.8.8 Category-specific planned improvements

There are no specific planned improvements in this category in the near future.

6.9 Other land (4F)

6.9.1 Source category description

Under the 2006 Guidelines, other land is defined as a category that includes bare soil, rock, ice and any unmanaged land areas that does not fall into any of the other five categories. This land use category is included so that the sum of identified land is consistent with the national land area.

Other land took up 1.59% of the national land area in 2022. Other land includes: open areas with little or no vegetation and dried open areas with special vegetation.

Emissions in other land decreased by 72% (i.e. from 13.71 to 3.80 Gg CO_2) between 1986 and in 2022.

Table 6.9.1: Activity data of other land (1986-2022) in kha

Year	4.F Other land	4.F.1. Other land remaining other land	Land converted to other land					
			4.F.2. Land converted to other land	4.F.2.1 Forest Land converted to other land	4.F.2.2 Cropland converted to other land	4.F.2.3 Grassland converted to other land	4.F.2.4 Wetlands converted to other land	4.F.2.5 Settlements converted to other land
Area, kha								
2022	32.15	31.75	0.40	0.30	NO	NO	NO	0.10
2021	32.15	31.68	0.47	0.30	NO	NO	NO	0.17
2020	32.15	31.61	0.54	0.30	NO	NO	NO	0.24
2019	32.15	31.55	0.60	0.30	NO	NO	NO	0.30
2018	32.15	31.48	0.67	0.30	NO	NO	NO	0.37
2017	32.15	31.41	0.74	0.30	NO	NO	NO	0.44
2016	32.15	31.34	0.81	0.30	NO	NO	NO	0.51
2015	32.15	31.27	0.88	0.30	NO	NO	NO	0.58
2014	32.15	31.23	0.92	0.34	NO	NO	NO	0.58
2013	32.15	31.19	0.96	0.38	NO	NO	NO	0.58
2012	32.15	31.15	1.00	0.42	NO	NO	NO	0.58
2011	32.13	31.13	1.00	0.43	NO	NO	NO	0.58
2010	32.12	31.11	1.01	0.43	NO	NO	NO	0.58
2009	32.10	31.10	1.00	0.42	NO	NO	NO	0.58
2008	32.08	31.09	0.99	0.42	NO	NO	NO	0.58
2007	32.07	31.08	0.99	0.41	NO	NO	NO	0.58
2006	32.05	31.07	0.98	0.40	NO	NO	NO	0.58
2005	32.02	31.07	0.95	0.40	NO	NO	NO	0.55
2004	32.00	31.07	0.93	0.40	NO	NO	NO	0.53
2003	31.98	31.07	0.90	0.40	NO	NO	NO	0.50
2002	31.95	31.07	0.88	0.40	NO	NO	NO	0.48
2001	32.29	31.46	0.83	0.42	NO	NO	NO	0.41
2000	32.63	31.84	0.79	0.45	NO	NO	NO	0.34
1999	32.98	32.23	0.75	0.48	NO	NO	NO	0.27
1998	33.32	32.61	0.70	0.50	NO	NO	NO	0.20
1997	33.66	33.00	0.66	0.52	NO	NO	NO	0.14
1996	34.00	33.39	0.62	0.55	NO	NO	NO	0.07
1995	34.35	33.77	0.58	0.58	NO	NO	NO	NO
1994	34.61	34.05	0.56	0.56	NO	NO	NO	NO
1993	34.87	34.32	0.54	0.54	NO	NO	NO	NO
1992	35.13	34.60	0.53	0.53	NO	NO	NO	NO
1991	35.39	34.87	0.52	0.52	NO	NO	NO	NO
1990	35.65	35.15	0.50	0.50	NO	NO	NO	NO
1989	36.87	36.37	0.50	0.50	NO	NO	NO	NO
1988	38.10	37.60	0.50	0.50	NO	NO	NO	NO
1987	39.32	38.82	0.50	0.50	NO	NO	NO	NO
1986	40.55	40.05	0.50	0.50	NO	NO	NO	NO

Table 6.9.2: Emissions from other land (1986-2022) in Gg CO_2

Year	4.F Other land	4.F.1. Other land remaining other land	Land converted to other land					
			4.F.2. Land converted to other land	4.F.2.1 Forest Land converted to other land	4.F.2.2 Cropland converted to other land	4.F.2.3 Grassland converted to other land	4.F.2.4 Wetlands converted to other land	4.F.2.5 Settlements converted to other land
GHG emissions/removals, Gg CO_2								
2022	3.80	NA	3.80	3.86	NO	NO	NO	-0.06
2021	3.75	NA	3.75	3.86	NO	NO	NO	-0.10
2020	3.71	NA	3.71	3.86	NO	NO	NO	-0.14
2019	3.67	NA	3.67	3.86	NO	NO	NO	-0.19
2018	3.63	NA	3.63	3.86	NO	NO	NO	-0.23
2017	3.59	NA	3.59	3.86	NO	NO	NO	-0.27
2016	3.55	NA	3.55	3.86	NO	NO	NO	-0.31
2015	3.50	NA	3.50	3.86	NO	NO	NO	-0.35
2014	4.02	NA	4.02	4.37	NO	NO	NO	-0.35
2013	4.53	NA	4.53	4.89	NO	NO	NO	-0.35
2012	19.35	NA	19.35	19.70	NO	NO	NO	-0.35
2011	19.24	NA	19.24	19.59	NO	NO	NO	-0.35
2010	19.13	NA	19.13	19.48	NO	NO	NO	-0.35
2009	18.82	NA	18.82	19.18	NO	NO	NO	-0.35
2008	18.52	NA	18.52	18.87	NO	NO	NO	-0.35
2007	18.22	NA	18.22	18.57	NO	NO	NO	-0.35
2006	15.48	NA	15.48	14.98	NO	NO	NO	0.50
2005	15.34	NA	15.34	14.83	NO	NO	NO	0.51
2004	15.21	NA	15.21	14.68	NO	NO	NO	0.53
2003	15.07	NA	15.07	14.53	NO	NO	NO	0.54
2002	7.18	NA	7.18	5.14	NO	NO	NO	2.03
2001	7.54	NA	7.54	5.46	NO	NO	NO	2.08
2000	7.90	NA	7.90	5.79	NO	NO	NO	2.12
1999	8.27	NA	8.27	6.11	NO	NO	NO	2.16
1998	8.63	NA	8.63	6.43	NO	NO	NO	2.20
1997	8.99	NA	8.99	6.75	NO	NO	NO	2.24
1996	9.36	NA	9.36	7.07	NO	NO	NO	2.28
1995	20.74	NA	20.74	20.74	NO	NO	NO	NO
1994	20.36	NA	20.36	20.36	NO	NO	NO	NO
1993	19.97	NA	19.97	19.97	NO	NO	NO	NO
1992	19.59	NA	19.59	19.59	NO	NO	NO	NO
1991	19.20	NA	19.20	19.20	NO	NO	NO	NO
1990	14.17	NA	14.17	14.17	NO	NO	NO	NO
1989	14.06	NA	14.06	14.06	NO	NO	NO	NO
1988	13.94	NA	13.94	13.94	NO	NO	NO	NO
1987	13.82	NA	13.82	13.82	NO	NO	NO	NO
1986	13.71	NA	13.71	13.71	NO	NO	NO	NO

6.9.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The information of other land area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present other land area in the period 1986-2001. The estimation of other land area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project “Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry”. The approach used for representing other land areas follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to other land is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of other land areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Agricultural Land Use Map of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

6.9.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

The other land is not defined specifically in terms of national legislation. This category includes all land areas that do not fall into any of the other five top-level land-use categories which is in line with the 2006 Guidelines. For the need of the GHG reporting the Other Land category includes the following land-use classes (Table 6.2.1); dried open areas with special vegetation and open areas with little or no vegetation.

6.9.4 Methodological issues

6.9.4.1 Other land remaining Other land

Consistent with the IPCC Guidelines, change in carbon stocks and non-CO_2 emissions and removals would not need to be assessed for the category of “Other land remaining Other land” assuming that it is typically managed. At present, no guidance can be given for “Other land” that is managed. “Other land” is included, however, for checking overall consistency of land area and tracking conversions to and from other land.

6.9.4.2 Land converted to Other land

According to the results from the point sampling there are only conversions from Forest land and from Settlements to Other land.

Carbon stock changes in living biomass

For calculations of emissions from other land uses converted to other land Tier 2 methodology and equations 2.15 and 2.16 (IPCC 2006) were used. There is no national data available on biomass carbon stocks on other land. Since other land includes predominantely bare soil in mountain areas, it is assumed that biomass stock is zero.

Carbon stock changes in dead organic matter

All biomass carbon stocks are assumed to be emitted in the year of conversion, thus there is no accumulation of DOM stocks (Tier 1 assumption, IPCC 2006).

Carbon stock changes in soil

For calculations of emissions from soils in land converted to Other land Tier 2 methodology and equation 2.25 (IPCC 2006) were used. The country-specific value for soil organic carbon of 33.18 t C ha^{-1} was used. It was calcualted as the weighted average, taking into account the SOC values of grassland annual and grassland perennial and areas for dried open areas with special vegetation and open areas with little or no vegetation (national land-use ID class 5000 and 6000).

6.9.5 Uncertainties and time-series consistency

The uncertainty estimates are not reported here.

6.9.6 Category-specific QA/QC and verification

No specific QA/QC and verification was used for Other land. However, general QA/QC, taking into account the figures check, correctness of the calculation used, data sources etc., were performed in the category, as it was subject to source specific recalculation.

6.9.7 Category-specific recalculations

Recalculations have been made for the period 1986-2021 for land converted to other land based on updated emission factors for living biomass and dead organic matter (conversions from forest land to other land) and updated emission factors for mineral soil (conversions from settlements to other land).

Direct N_2O emissions from N mineralization/immobilization and indirect N_2O emissions from managed soils (nitrogen leaching and run-off

Recalculations were made on the basis of updated emission factors for all land use changes where the change in soil organic carbon stocks is negative.

6.9.8 Category-specific planned improvements

No category-specific improvement are planned in the near future.

6.10 Harvested wood products (4G)

6.10.1 Source category description

Harvested wood products (HWP) include all wood materials leaving the harvest sites. Typically, HWP is sawnwood, veener sheets, particle board, fibreboard, wood pulp, mechanical wood pulp, chemical wood pulp, paper and paperboard. Note that wood products in soild waste disposal sites (SWDS) are not included in the calculation of HWP carbon stock changes in the LULUCF sector.

In 2022, HWP contributed to a net removals of -304.87 kt CO_2 (Table 6.10.1). The largest contribution resulted from the sawnwood, followed by wood panels and paper products. In recent years, HWP show an increasing trend of net removals.

6.10.2 Methodological issues

Emissions and removals for HWP were calculated using primary product groups and conversion factors as shown in Table 6.10.1. Data sources are industry reports, official statistical data and national studies.

Time series start with 1900 using all available sources of information (historical records, official statistics, independent studies). E.g.: for fibreboard production, annual data are used from the year 1946 (one of the first companies to produce fibreboard in Europe).

The product group ''plywood'' was not included in our calculations because these products are derived from sawnwood and veneer and would therefore cause double counting of carbon inflow. The carbon input from domestic pulpwood in paper and paperboard production was estimated using data for the production of wood pulp (mechanical and chemical pulp).

The revised first order decay method (FOD) according to the 2006 Guidelines and Pingoud and Wagner (2006) was used. The calculation of net emissions follows the recommended method according to IPCC 2006 (Equation 12.1).

The estimate uses the product categories, half-lives and methodologies as proposed in paragraph 27, page 31 of FCCC/KP/AWG/2010/CRP.4/Rev.4:

- Sawnwood: 35 years,
- WBP (Particle boards, Fibreboards, Veneer): 25 years,
- Paper and Paperboard: 2 years.

Table 6.10.1: Emissions from Harvested wood products (1986-2022) in Gg CO_2

Year	4.G Harvested wood products	Category			
		4.G Sawnwood	4.G Wood panels	4.G Paper and paperboard	4.6 HWP in SWDS
GHG emissions/removals, Gg CO_2					
2022	-304.87	-272.71	-48.70	16.54	NO
2021	-195.13	-177.40	-30.89	13.17	NO
2020	-142.18	-110.58	-25.47	-6.13	NO
2019	-252.87	-195.82	-52.22	-4.82	NO
2018	-125.92	-115.05	-16.65	5.79	NO
2017	-85.75	-50.63	-39.28	4.17	NO
2016	-101.84	-44.27	-42.87	-14.70	NO
2015	-129.04	-45.76	-67.41	-15.87	NO
2014	-112.83	-22.26	-72.23	-18.34	NO
2013	-25.38	-3.84	-39.30	17.77	NO
2012	-64.02	-16.38	-63.54	15.89	NO
2011	-74.55	-36.81	-58.72	20.97	NO
2010	-128.97	-91.59	-46.58	9.20	NO
2009	-182.54	-137.60	-65.77	20.83	NO
2008	-228.47	-181.82	-76.42	29.76	NO
2007	-310.86	-264.98	-86.26	40.38	NO
2006	-218.65	-216.44	-33.58	31.38	NO
2005	-184.59	-146.23	-24.86	-13.50	NO
2004	-164.13	-124.48	-33.38	-6.27	NO
2003	-128.98	-94.23	-28.53	-6.22	NO
2002	-97.97	-39.40	-48.95	-9.63	NO
2001	-77.69	-28.51	-40.10	-9.08	NO
2000	-85.11	-39.91	-29.88	-15.32	NO
1999	-39.82	3.26	-24.95	-18.13	NO
1998	-71.50	-19.78	-38.64	-13.08	NO
1997	24.01	56.12	-17.67	-14.45	NO
1996	-42.77	-28.35	-20.27	5.86	NO
1995	28.38	49.81	-25.23	3.81	NO
1994	45.38	39.66	-21.91	27.63	NO
1993	105.98	67.82	-11.95	50.11	NO
1992	76.88	28.62	-3.34	51.60	NO
1991	39.54	15.65	-25.45	49.34	NO
1990	-67.01	-67.54	-35.04	35.56	NO
1989	-328.98	-212.43	-109.99	-6.56	NO
1988	-415.72	-293.15	-99.95	-22.62	NO
1987	-459.61	-319.71	-102.37	-37.53	NO
1986	-457.00	-352.78	-82.16	-22.07	NO

Table 6.10.2: Production of harvested wood products based on domestic harvest in Slovenia for the period 1986-2022 in m^3 or tons

	Sawnwood [m^3]	Wood panels [m^3]	Paper and paperboard [tonnes]
2022	992175	91031	18831
2021	868257	82791	24018
2020	782054	81300	36566
2019	881149	96656	34619
2018	782239	72861	28225
2017	707180	84610	30260
2016	700541	84782	40704
2015	697811	101935	38210
2014	669790	103335	36130
2013	651929	78239	13966
2012	667112	92610	18647
2011	695278	85295	19410
2010	762470	73943	29785
2009	817691	83108	25819
2008	874273	83190	25666
2007	972061	84990	26533
2006	903769	53530	39579
2005	815842	47701	68925
2004	784960	53975	62427
2003	746175	50551	61084
2002	673782	66994	61504
2001	654539	64366	59201
2000	661304	61318	60459
1999	608371	58574	58667
1998	635299	66929	52298
1997	541906	55617	50246
1996	644400	55565	36914
1995	554245	56764	39184
1994	567618	54014	27904
1993	535902	47028	22307
1992	582496	42082	32075
1991	602282	53315	44064
1990	699876	59277	61410
1989	867718	106562	90240
1988	957877	97978	97006
1987	979935	99317	99820
1986	1016771	80863	84093

Table 6.10.3: Conversion factors and primary product groups used in calculation

Classifi -cation	Description of commodity	Air dry density	C conv. factor	C conv. factor	Source
UNECE		[g/cm³]	[Gg C/1000 tonnes]	[Gg C/1000m³]	
5.	Sawnwood	-	-	0.23	IPCC (2003, national estimate based on composition of coniferous and broadleaved sawn wood)
6.1	Veneer sheets	-	-	0.295	IPCC (2003)
6.3	Particle board	0.65	0.425	0,28	National estimate based on IPCC and data from producers of particle boards in Slovenia
6.4.	Fibreboard	0.81-1.00	0.425	0.344-0.425	National estimate based on IPCC and data from producers of fibreboards in Slovenia
7	Wood pulp	1.00*	0.45	-	UNECE, IPCC (2003, 2006)
7.1	Mechanical wood pulp	1.00*	0.45	-	UNECE, IPCC (2003, 2006)
7.3	Chemical wood pulp	1.00*	0.45	-	UNECE, IPCC (2003, 2006)

*“air dried metric ton” is assumed to be 10% mcw (pulp and paper moisture content is reflected on a “wet basis” (mcw) - one air-dried metric ton of pulp is assumed to be 900 kg of oven dry fibre and 100 kg of contained water (UNECE)

Method for calculation of carbon inflow

Carbon inflow to HWP pool is calculated according to equations 38 and 39.

$$Inflow\ HWP = \sum_{i}^{n} (F_{DPPA\ i} \times HWP_i)$$ **(Equation 41)**

Where:

HWP_i – primary product i (sawnwood, veneer, particle boards, fibreboards, wood pulp)

F_{DPPAi} – factor for selected primary product groups defining the share of domestic INDRW input compared to all wood consumption in the production (total wood consumption covers roundwood, woodchip, wood particles and wood residues)

$$F_{DPPAi} = \frac{Domestic\ INDRW\ Consumption_i}{WOOD\ Consumption_i}$$ **(Equation 42)**

HWP are calculated separately for sawnwood, veneer, particle board, fibreboard and virgin pulp with time series starting from year 1900 using all existing sources of information (historical records, official statistics independent studies). The domestic share of roundwood is calculated separately for product group sawnwood and veneer and product group consisting of WBP and product group virgin pulp.

As the production process of sawnwood and veneer use logs as input material and to be as close to real roundwood flows from domestic sources the FDPPA is the same for both products. However, the calculation for sawnwood uses HL 35 y and calculation for veneer uses HL 25 y. Product groups: sawnwood, WBP and paper and paperboard are calculated and reported separately.

Factors and data sources for primary product groups

1.F_{DPPAi} for sawn wood and veneer (F_{SW+V})

$$F_{SW+V} = \frac{Production\ LOGS - Export\ LOGS}{Production\ LOGS + Import\ LOGS - Export\ LOGS}$$ **(Equation 43)**

Data sources for calculation of amounts of domestic round wood accounted in product group sawn wood and veneer are based on data from Statistical Office of the Republic of Slovenia (SORS), industrial reports and independent national studies. Due to changes in statistical data collection amounts of produced sawn wood in period 1996-2009 are calculated using conversion factors and mass balance of logs consumption.

2. F_{DPPAi} for particle boards and fibreboards (F_{WBP})

$$F_{WBP} = \frac{Domestic\ INDRW\ Consumption_{WBP}}{WOOD\ Consumption_{WBP}}$$ **(Equation 44)**

Data sources for calculation of F_{WBP} until 2009 are official data and industry reports. From 2010 onwards, data were obtained directly from producers and included in calculations (data from companies: production, input material, type of input material (roundwood, wood residues), quantities from import and from domestic sources). Due to small number of companies to obtain realistic figures and confidential data of national statistics covering industry we suppose our direct full coverage of production is, despite time-consuming process, precise and unbiased.

3. F_{DPPAi} for wood pulp **(**F_{WP}**)**

$$F_{WP} = \frac{Domestic\ INDRW\ Consumption_{WP}}{WOOD\ Consumption_{WP}}$$ **(Equation 45)**

Data sources for calculation of F_{WP} are based on industry reports for years before 1990, interpolation for missing years and direct full data coverage obtained from domestic producers (production, input material, type of input material: roundwood, wood residues quantities of input material originating from import and from domestic sources, percentage of pulp in production process) was used for the period 2004-2016.

6.10.3 Uncertainties and time-series consistency

The expert estimate for the uncertainty of the activity data was 30% in 1986 and is 25% in recent years while uncertainty of the emission factors is 50%.

6.10.4 Category-specific QA/QC and verification

The methodology used in the submission of information on reference levels for forest management by Slovenia (FMRL Submission) and updated for this report is based on Equation 12.1 from the 2006 Guidelines. Some country-specific methodologies are also described in the FMRL Submission (MAFF, SFI, SFS 2011).

In the category, a general QA/QC was performed considering theverification of figures, the correctness of the calculation used, the data sources etc., as it was subject to source-specific recalculation.

Table 6.10.4: Comparison between C Inflow and C in domestic INDRW (1.000 t C)

	2005	2006	2007	2008	2009	Average
Domestic INDRW*	292	382	329	324	299	325
Inflow - model	242	251	275	251	237	251
Share HWP Inflow/Dom. INDRW	0.83	0.66	0.83	0.77	0.79	0.77

*Carbon in consumption of domestic INDRW is calculated separately for coniferous and broadleaved INDRW using basic densities 0.40 t/m^3 and 0.58 t/m^3, respectively.

Estimates of carbon Inflow are consistent with consumption of domestic industrial round wood. The difference present losses which occur during processing to selected primary products.

6.10.5 Category-specific recalculations

No recalculations have occurred in this category.

6.10.6 Category-specific improvements

No category-specific improvements are planned in the near future.

7 WASTE (CRT sector 5)

7.1 Overview of sector

In this chapter the following sources are presented:

- Solid waste disposal (5.A),
- Biological treatment of solid waste – composting (CRT 5.B),
- Incineration of waste (CRT 5.C), and
- Wastewater treatment and discharge (CRT 5.D).

Table 7.1.1: Methods, EFs used and key categories indications for the year 2022 in the Waste sector.

	CO_2			CH_4			N_2O		
	Method	EF	Key category	Method	EF	Key category	Method	EF	Key category
Solid waste disposal	NA	NA	NA	T2	CS, D	L	NA	NA	NA
Composting	NA	NA	NA	T1	D	-	T1	D	-
Incineration	T2	D	-	T2	D	-	T2	D	-
Domestic WW	NA	NA	NA	T1	CS, D	L	T1	D	-
Industrial WW	NA	NA	NA	T1	CS, D	T	NA	NA	NA

In this sector methane emissions from Solid waste disposal sites and from Waste water treatment are the key categories according to the level assessment (Table 7.1.1).

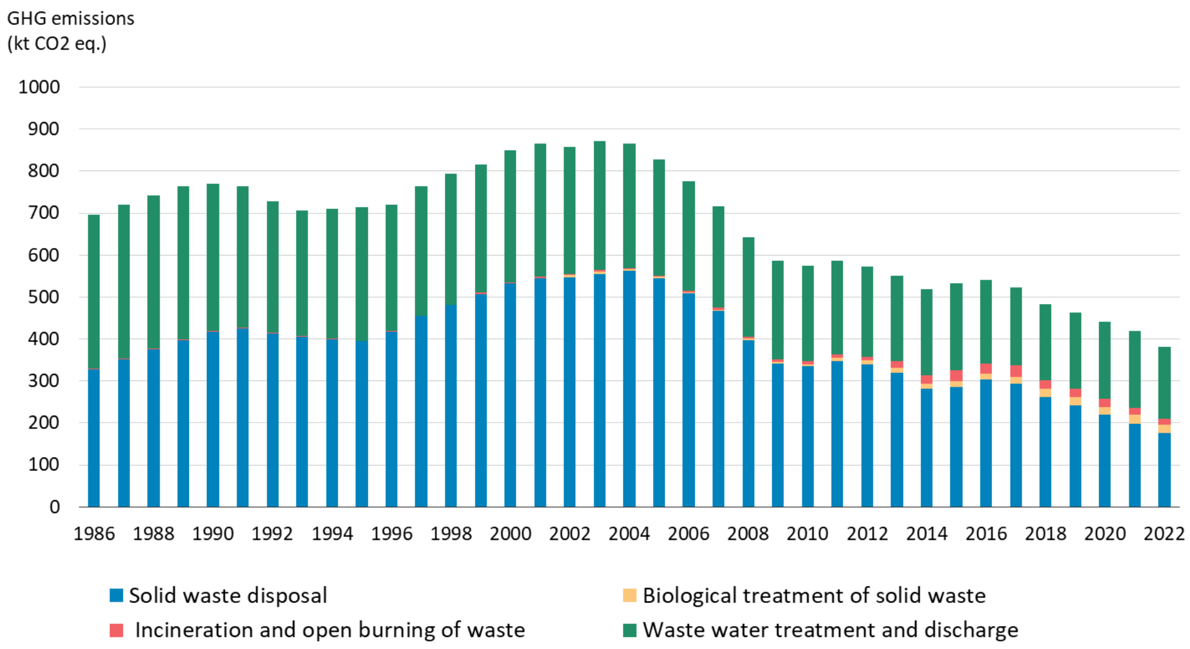

Figure 7.1.1: Emissions from solid waste disposal on land and from wastewater handling in Gg CO_2 eq.

In 2022, emissions from the Waste sector amounted to 380 Gg CO_2 eq, or 2.4 per cent of the total GHG emissions. Since 1986 emissions decreased by 45.7 per cent. The key driver for the decline of emissions is the decrease of biodegradable part of the municipal waste deposited on the SWD sites and increase of gas recovery on the SWD sites and in the wastewater treatment plants. (Figure 7.1.1).

Methane emissions from the Waste sector are the second largest source of methane and represents 17.1% of the all methane emissions in Slovenia in 2022. The fraction of methane emissions in this sector amounts to 85.8%, while the remaining part represent N_2O (10.5%) and CO_2 emissions (3.7%). Solid waste handling contributes 46.4% to the total emissions from this sector, wastewater handling 44.9%, composting 5.0%, and incineration of waste 3.3%.

Emissions from solid waste disposal started to decline in 2005 and since then emissions decreased by 68.4% due to the strong decrease of deposited biodegradable part of municipal waste and gas recovery. In 2013 the emissions were the first time lower compared to the base year and in 2022 were lower by 46.1%. Emissions from waste waters were by 48.9% lower than in the base year what is mostly due to recovery of gas in wastewater treatment plants and the decrease in industrial production.

In Slovenia, 9.4 million tonnes of waste was generated, almost quarter more than in 2020. Almost two-thirds (6 million tonnes) of total waste generated was construction and demolition waste, dominated by soil and stones, followed by municipal waste with 12% and by waste from thermal processes with 8% of total waste generated.

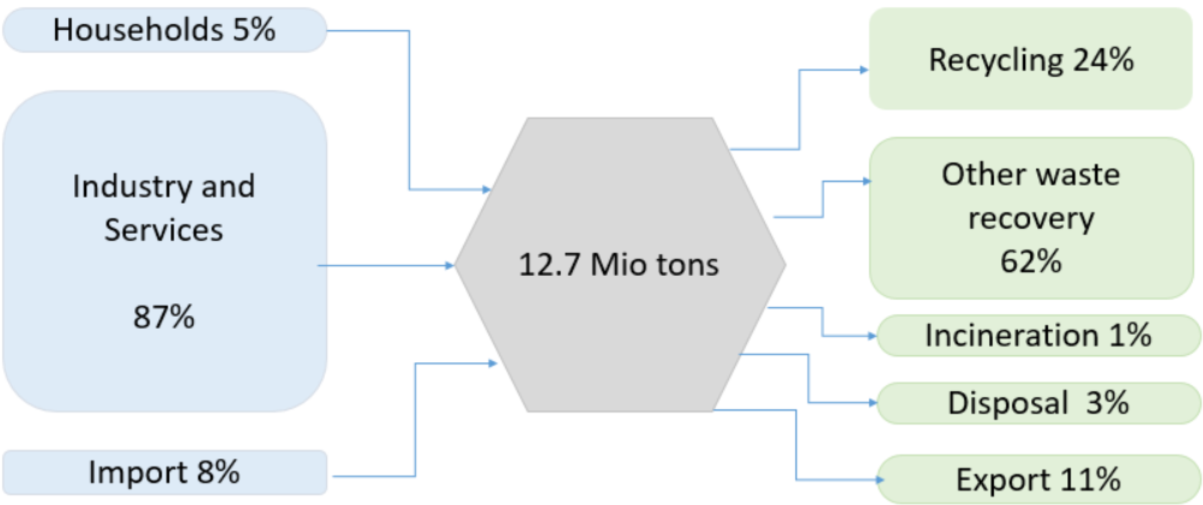

Figure 7.1.2: Waste stream in Slovenia in 2022

In 2022, approximately 384 kt of waste was disposed of; 163 kt tonnes of waste was landfilled, of which 93% on municipal waste landfill sites, 5% on industrial waste landfill sites and 2% on hazardous waste landfill sites. Mixed fractions of municipal waste and residues after mechanical and biological waste treatment dominated among the landfilled waste (42%), followed by construction and demolition waste (28%), and waste from mechanical treatment of other waste (18%). Other types of waste were landfilled in smaller amounts.

The waste regulations have introduced a 5-stage waste hierarchy, according to which the top priority is given to the prevention of waste generation, followed by preparing for reuse, recycling, other recovery procedures (e.g. energy recovery), whereas waste disposal (e.g. landfilling, incineration without energy recovery) is deemed to be the least preferred option.

The volume of separately collected fractions of municipal waste has been increasing in recent years. The system of door-to-door separate collection of waste facilitates further processing of separately collected waste (recycling and recovery). In this way we contribute to the conservation of natural resources and to a decrease in the negative environmental impacts of waste deposited in landfills (e.g. CH_4 emissions and other landfill gasses and leachate waters, which has the impact on groundwater).

With the introduction of the separate collection of municipal waste and statutory requirements regarding the processing of mixed residual waste prior to disposal, the amount of deposited municipal waste in relation to generated waste has been declining. In 2002, 84% of generated municipal waste was deposited (712 kt), compared to 7.3% in 2021 (76 kt).

Waste management pays particular attention to packaging waste, not so much because of the generated quantities and risk potential, but primarily because of its enormous volume, short life cycle and substantial portion of organic matter. Up to 2004, the majority of Slovenian packaging waste ended up in landfills. With the introduction of regulations providing for the payment of an environmental tax on packaging, the separate collection of packaging waste, the establishment of a system for processing packaging waste, and by focusing on achieving the objectives set for the recovery and recycling of packaging waste, packaging waste management has seen substantial improvement.

Relevant legislation

The Decree on the landfill of waste is the main act in which the EU Landfill Directive was transposed. Thus in 2006, when Decree on the landfill of waste cancelled the mentioned Rules on the landfill of waste, Slovenia fully complied with the requirements of the Landfill Directive.

On the political level Slovenia started with the activities on the field of waste management in 1996, when also strategic orientations for waste management were prepared. On this basis National environmental action Programme was adopted in 2006 and set the enforcement of modern forms of waste management as priority objective. A period of systematic regulation in the field of waste management followed, with the adoption of implementing acts on the basis of EPA.

The National environmental action Programme formed the basis for the Operational Programme for waste disposal and its goal was the reduction of deposited biodegradable waste for the period 2009-2013; it was adopted by the government in 2008. However, the Rules on the landfill of waste adopted in 2000 had already comprised provisions regarding reduction of biodegradable waste and these were also included in the Decree on the treatment of biodegradable waste, which was adopted in 2008 and repealed the mentioned Rules.

The Operational Programme from 2008 was project oriented, focusing on goals:

- at least 65% or more of the produced municipal waste should be redirected in other type of treatment and at least 42% of them should be reused;
- all kitchen waste should be extracted and biologically processed;
- the remainder of waste should be processed in a way that the content of organic carbon will not exceed 5%;
- in the structure of the whole deposited waste 47% of the deposited biodegradable waste should be reduced to 16% until 2013 or 2015 that means in average 5% per year.

Measures for achieving the listed goals are also a part of the Operational Programme:

- the existing landfills should be closed down, if the adjustment to the existing provisions were too expensive or technically difficult to manage;
- reconstruction and enlargement of the existing landfills, which will be operating until the end of 2008;
- construction of a new infrastructure for treatment, recovery and disposal of waste for regional centres for waste management and national centres for thermal treatment.

Decree on the landfill of waste also includes annex 4. It specifies the volume of biodegradable substance in municipal waste, which can be deposited in all landfills in the territory of Slovenia per year. It also sets that the amount of deposited biodegradable waste should be decreased:

- by 10% in years 2008-2009,
- by 5% in years 2009 – 2010, 2011– 2012 and 2013 – 2015 in accordance with the 1995 amount.

A new strategic document, Operational Programme from 2013 adopted in this area provides the certain measures for achieving the following targets by 2020:

- increasing the recycling rate of municipal waste to 61–64%;
- increasing the incineration rate to approximately 25%; and
- decreasing the disposal of municipal waste in landfills to 11–15%.

In December 2015, the European Commission presented an ambitious package of measures aimed at achieving a transition to a circular and thus more competitive economy with a more sustainable use of resources. The package also includes amended legislative proposals on waste with ambitious targets: the EU's common goal by 2030 is 65% of municipal waste recycling, 75% of packaging waste recycling, and a binding target of reducing the amount of waste that ends up at landfills to a maximum of 10% of municipal waste.

In 2016, Slovenia adopted the Waste Management Plan as well as the Waste Prevention Programme, which serve as a basis for achieving ambitious objectives by 2030.

Main measures, which already in the past contributed to reducing the quantities of deposited biodegradable waste, are waste separation at source and mechanical biological treatment of mixed municipal waste. In most municipalities, door-to-door collection systems are used for waste packaging, bio-waste, and paper.

Since 2016, the mechanical biological treatment of mixed municipal waste prior to disposal in municipal waste management centres has been mandatory. That is why all facilities for mechanical and biological treatment of mixed municipal waste in Slovenia had to be upgraded in order to meet the country's needs.

Biological treatment of solid waste in Slovenia covers composting and anaerobic digestion. The only GHG emissions included in the inventory are emissions from composting. In 2022 emissions from this source (CH_4 and N_2O) amounted only 19.1 kt CO_2 eq. There are no CH_4 emissions from the anaerobic digestion in the MB treatment plant because the generated CH_4 is fully recovered. All MB treatment plants in Slovenia are very new and meet high technical standards, which ensure that unintentional CH_4 emissions are flared. N_2O emissions from the process are assumed to be negligible, while the CO_2 emissions are of biogenic origin.

Waste incineration is not an important source of GHG emissions in Slovenia. The large amount of waste is incinerated in one small thermal power plant and in the industry (mostly cement plants) and corresponding emissions are reported in the Energy sector. Emissions from the remaining incinerated waste are reported in the Waste sector. They arise mostly from incineration of clinical and hazardous wastes. Emissions from this source in 2022 were 14.0 Gg CO_2 eq.

Waste-water treatment and discharge is the second most important source of GHG emissions in the waste sector. In 2022 emissions from this source amounted to 170.6 kt CO_2 eq. The majority (96%) of this emissions arose from domestic waste waters and remaining 4% from industrial waste water. Waste water is treated in municipal waste-water treatment plants classified by level of treatment as specified in regulations. As a rule, primary treatment is defined as the mechanical or chemical elimination of a smaller quantity of organic loading and some suspended substances. Secondary treatment is a process of biological purification. It removes a large amount of organic substances and nutrients (20%-30%). Tertiary treatment eliminates organic matter and a large amount of nutrients (nitrogen, phosphors). According to the 2022 data approximately 71% of population in Slovenia was connected to waste-water treatment plants and nearly 29% of the population still uses septic tanks.

7.2 Solid Waste Disposal Sites (CRT 5.A)

7.2.1 Category description

Methane is emitted during anaerobic fermentation of degradable organic substances in solid waste disposal sites in processes, which may last several decades. If waste were not disposed of on solid waste disposal sites, the degradation would take place in aerobic conditions without methane formation. Methane emissions from waste disposal are thus of anthropogenic origin and, consequently, a constituent part of national GHG inventories in accordance with IPCC methodology.

7.2.2 Methodological issues

The IPCC methodology for estimating CH_4 emissions from SWDS is based on the First Order Decay (FOD) method. This method assumes that the degradable organic component (degradable organic carbon, DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are formed. If conditions are constant, the rate of CH_4 production depends solely on the amount of carbon remaining in the waste. As a result the emissions of CH_4 from waste deposited in a disposal site are the highest in the first few years after deposition, then gradually decline as the degradable carbon in the waste is consumed by the bacteria responsible for the decay. Transformation of degradable material in the SWDS to CH_4 and CO_2 is by a chain of reactions and parallel reactions.

A full model is likely to be very complex and vary with the conditions in the SWDS. However, according to the 2006 IPCC Guidelines the overall decomposition process can be approximated by first order kinetics which is used in the IPCC model.

For Slovenian inventory the Tier 2 method and IPCC model has been used for calculation of GHG emissions with combination of default parameters and country specific data.

The CH_4 emissions from solid waste disposal for a single year can be estimated using the equation below. Part of the CH_4 generated is oxidised in the cover of the SWDS, or can be recovered for energy or flaring.

$$CH_4 \text{ emitted} = \left[\sum_x CH_4 \text{ generated}_{x,T} - R_T\right] * (1 - OX_T)$$

where:
T = inventory year
X = waste category or type/material
R_T = CH_4 recovered (Gg/yr) in year T
OX_T = oxidation factor (fraction) in year T

The CH_4 generation potential (L_0) of the waste that is disposed in a certain year will decrease gradually throughout the following decades. In this process, the release of CH_4 from this specific amount of waste decreases gradually. The FOD model is built on an exponential factor that describes the fraction of degradable material which each year is degraded into CH_4 and CO_2.

One key input in the model is the amount of degradable organic matter (DOCm) in waste disposed into SWDS. This is estimated based on the information on disposal of different waste categories (municipal solid waste (MSW), sludge, industrial and other waste) and the different waste types/material (food, paper, wood, textiles, etc.) included in these categories.

The equations for estimating the CH_4 generation are given below. As the mathematics are the same for estimating the CH_4 emissions from all waste categories/waste types/materials, no indexing referring to the different categories/waste materials/types is used in the equations below.

$$L_0 = DDOCm * F * 16/12$$

and

$$DDOCm = W \bullet DOC \bullet DOC_F \bullet MCF$$

where:
L_o = methane generation potential, Gg CH_4
F = fraction by volume of CH_4 in landfill gas (volume fraction)
16/12 = conversion from C to CH_4 (molecular weight ratio)
DDOCm = mass of decomposable DOC deposited, Gg
W = mass of waste deposited, Gg
DOC = degradable organic carbon in the year of deposition (fraction, Gg C/Gg waste)
DOC_F = fraction of DOC that can decompose (fraction)
MCF = CH_4 correction factor for aerobic decomposition in the year of deposition (fraction)

With a first order reaction, the amount of product is always proportional to the amount of reactive material. This means that the year in which the waste material was deposited in the SWDS is irrelevant to the amount of CH_4 generated each year. It is only the total mass of decomposing material currently in the site that matters.

This also means that when we know the amount of decomposing material in the SWDS at the start of the year, every year can be regarded as year number 1 in the estimation method, and the basic first order calculations can be done by these two simple equations, with the decay reaction beginning on the 1st of January the year after deposition.

$$DDOCma_T = DDOCmd_T + (DDOCma_{T-1} * e^{-k})$$

and

$$DDOCm\ decomp_T = DDOCma_{T-1} * (1 - e^{-k})$$

where:
T = inventory year
$DDOCma_T$= DDOCm accumulated in the SWDS at the end of year T, Gg
$DDOCma_{T-1}$= DDOCm accumulated in the SWDS at the end of year (T-1), Gg
$DDOCmd_T$= DDOCm deposited into the SWDS in year T, Gg
DDOCm $decomp_T$= DDOCm decomposed in the SWDS in year T, Gg
k reaction constant, k= ln(2)/t1/2 (y^{-1})
t1/2= half-life time (y)

The simple FOD spreadsheet model (IPCC Waste Model) has been developed on the basis of equations shown above. The spreadsheet keeps a running total of the amount of decomposable DOC in the disposal site, taking account of the amount deposited each year and the amount remaining from previous years. This is used to calculate the amount of DOC decomposing to CH_4 and CO_2 each year.

The IPCC Waste Model provides two options for the estimation of the emissions from MSW, that can be chosen depending on the available activity data. We have used the first option which is based on waste composition data. This option is better in cases when rapid changes in waste composition occur what is a case in Slovenia in the recent period.

Activity data and parameters

The amount of MSW waste in the period 1964 – 1994

There are no data on the amount of waste prior to 1995. The first regulated municipal solid waste disposal site, the Ljubljana Barje SWDS, started its operation in 1964. An estimate for the period 1964 - 1994 was performed based on the presumption that in 1964, 50% of population was included in municipal waste collection system and that this percentage slightly increased and reached 70% in 1978 and 83% in 1994. All collected municipal waste was deposited on the MSW disposal sites.

For industrial waste it was estimated that only around 3% of generated industrial waste was deposited on MSW disposal sites. All other industrial waste was inert.

The amount of generated waste per person as well as amount of industrial waste for the period 1964-1994 were calculated using GDP per capita as a key driver. This surrogate methodology is in line with the 2006 IPCC GL and was also recommended by the ERT. For Slovenia data on GDP are available since 1990. Data on GDP before 1990 are available for SFR Yugoslavia only. With the overlap methodology it was estimated that the GDP in Slovenia in the period 1970-1990 was 3 times higher than in Yugoslavia. Data are presented in the table 7.2.1.

Since 1995 we have used actual data on the amount of waste.

Table 7.2.1: Quantities of MSW in the period 1964 - 1994.

year	Urban population	Coverage in %	Waste generation rate in kg/cap/y.	Deposited waste (kt) = Collected	GDP per capita in US$	Industrial waste (kt)	Deposited on MSW disposal sites (kt)
1964	815,277	50	86.0	70.078	-	-	70.000
1965	858,215	52	86.0	73.769	-	-	70.000
1966	901,587	54	86.0	77.497	-	-	70.000
1967	930,016	55	86.0	79.941	-	-	70.000
1968	1,022,225	60	86.0	87.867	-	-	70.000
1969	1,045,553	61	86.0	89.872	-	-	70.000
1970	1,070,438	62	86.0	92.011	2,160	2,347.778	70.433
1971	1,095,004	63	91.7	100.397	2,327	2,374.597	71.238
1972	1,120,964	64	94.5	105.884	2,407	2,387.571	71.627
1973	1,147,981	65	118.6	136.148	3,109	2,500.557	75.017
1974	1,176,430	66	158.3	186.272	4,264	2,686.557	80.597
1975	1,206,015	67	174.6	210.513	4,735	2,762.454	82.874
1976	1,237,108	68	193.9	239.894	5,298	2,853.081	85.592
1977	1,269,157	69	231.3	293.589	6,386	3,028.186	90.846
1978	1,303,834	70	270.7	352.967	7,531	3,212.543	96.376
1979	1,336,436	71	334.0	446.314	9,369	3,508.559	105.257
1980	1,368,870	72	339.4	464.623	9,528	3,534.124	106.024
1981	1,399,752	73	331.9	464.524	9,308	3,498.743	104.962
1982	1,424,409	74	301.1	428.901	8,414	3,354.802	100.644
1983	1,449,828	75	305.9	443.501	8,554	3,377.224	101.317
1984	1,476,530	76	314.6	464.563	8,808	3,418.099	102.543
1985	1,519,326	77	320.9	487.608	8,991	3,447.610	103.428
1986	1,544,960	78	333.6	515.431	9,360	3,506.979	105.209
1987	1,571,675	79	341.4	536.624	9,587	3,543.549	106.306
1988	1,599,990	80	340.9	545.398	9,570	3,540.936	106.228
1989	1,599,523	80	353.2	564.944	9,929	3,598.596	107.958
1990	1,598,472	80	323.4	516.952	9,063	3,459.156	103.775
1991	1,601,414	80	238.8	382.400	6,603	3.063.114	91.893
1992	1,616,624	81	236.4	382.119	6,532	3,051.788	91.554
1993	1,632,311	82	239.6	391.093	6,626	3,066.887	92.007
1994	1,650,746	83	271.1	447.471	7,541	3,214.217	96.427

<u>The amount of waste in the period 1995 – 2001</u>

According to the data provided by SORS around 700-750 kt of waste have been deposited on the SWDS in that period. It is inferred that this amount, due to the unclear definition of municipal waste, included industrial waste as well. For the present submission this amount has been disaggregated to the municipal and industrial waste. The calculation of quantities in the table 7.2.2 take into account the assumption that all collected municipal waste was landfilled in 1995 and that this fraction was 0.89 in 2001, and the coverage has increased from 84% in 1995 to 90% in 2001.

Table 7.2.2: Quantities of landfilled MSW and industrial waste in the period 1995-2001

year	Urban population	Waste generation rate in kg/cap/y.	Fraction landfilled	Deposited MSW (kt)	GDP per capita in US$	Industrial waste (kt)	Deposited Industrial waste (kt)
1995	1,669,504	355.0	1	592.674	10,723	3,726.431	114.326
1996	1,692,494	383.6	0.98	636.226	10,812	3,740.824	112.689
1997	1,708,689	371.0	0.96	608.501	10,445	3,681.743	108.864
1998	1,724,865	394.8	0.94	640.176	11,139	3,793.496	110.060
1999	1,747,290	404.6	0.92	650.364	11,422	3,839.099	109.250
2000	1,771.342	380.0	0.90	605.799	10,204	3,642.992	101.645
2001	1,795,222	372.8	0.89	595.703	10,500	3,690.540	100.921

<u>The amount of waste in the period 2002 – 2022</u>

Since 2002 all data from waste collection system in Slovenia are very detailed and are also publicly available from the SORS database SI-STAT. The data are collected by means of forms which are set down by the law and must be filled in once a year by the waste collector. On the basis of these data, the SORS generates its annual reports on waste handling. Results from these reports are presented in the table 7.2.3.

Table 7.2.3: Quantities of landfilled waste in the period 2001 - 2022.

year	Urban population	Waste generation rate in kg/cap/y.	Fraction landfilled	Deposited MSW (kt)	Industrial waste (kt)	Deposited Industrial waste (kt)
2002	1,842,447	426.3	0.84	712.471	4,067.315	108.965
2003	1,847,015	440.6	0.79	692.880	4,570.267	127.252
2004	1,857,214	417.0	0.75	625.062	5,634.562	102.402
2005	1,881,047	422.2	0.78	658.367	5,170.200	94.179
2006	1,879,971	431.0	0.84	725.074	5,693.728	115.264
2007	1,878,048	438.5	0.78	688.617	5,916.184	123.057
2008	1,921,498	456.3	0.74	679.603	5,904.332	143.119
2009	1,981,065	447.0	0.69	631.082	5,580.967	119.661
2010	2,028,768	421.6	0.65	562.722	5,441.859	60.502
2011	2,052,496	351.7	0.58	419.228	5,330.250	85.769
2012	2,056,262	361.8	0.42	314.952	3,722.431	73.413
2013	2,059,114	414.4	0.26	224.001	3,779.395	50.723
2014	2,061,623	432.5	0.23	207.676	3,785.627	50.238
2015	2,063,077	450.5	0.22	208.618	4,242.916	52.202
2016	2,064,241	464.8	0.06	54.885	4,516.811	58.131
2017	2,066,161	477.8	0.07	67.011	5,185.112	75.611
2018	2,070,050	495.2	0.06	57.276	7,363.418	87.769
2019	2,089,310	509.4	0.07	76.387	7,349.537	79.720
2020	2,100,126	487.6	0.07	76.148	6,643.101	75.844
2021	2,107,007	517.9	0.05	55.368	8,344.150	78.609
2022	2,108,732	495.9	0.07	76.285	11,659.227	118.129

The coverage of the public collecting system has increased from 91% in 2002 to 100% in 2011 and since then 100% coverage is assumed until now. The data on urban population and amount of deposited waste are presented on the table 7.2.1 to table 7.2.3, while the data on the total deposited waste (MSW and industrial waste) and corresponding biodegradable part of waste is presented on the table 7.2.4. below. The information on the composition of waste, which is the basis for determining the bio part of waste, is presented in the next section.

Table 7.2.4: Quantities of landfilled waste (MSW and industrial) and amount of biodegradable waste in the period 1964 - 2022.

Year	Deposited waste (kt)	Biodegradable waste (kt)
1964	140.078	39.937
1965	143.769	41.671
1966	147.497	43.424
1967	149.941	44.572
1968	157.867	48.297
1969	159.872	49.240
1970	162.444	50.288
1971	171.634	54.310
1972	177.511	56.928
1973	211.165	71.491
1974	266.869	95.608
1975	293.386	107.228
1976	325.486	121.309
1977	384.435	147.072
1978	449.343	175.532
1979	551.571	220.293
1980	570.646	228.975
1981	569.486	228.822
1982	529.545	211.648
1983	544.817	218.577
1984	567.106	228.599
1985	591.036	239.518
1986	620.640	252.774
1987	642.930	262.844
1988	651.626	266.960
1989	672.902	298.917
1990	620.726	279.192
1991	474.293	211.861
1992	473.673	226.963
1993	483.100	236.035
1994	543.898	273.651
1995	707.000	384.817
1996	748.916	412.092
1997	717.364	394.242
1998	750.236	414.317
1999	759.614	420.654
2000	707.444	391.818
2001	696.624	361.557
2002	821.436	409.880
2003	820.132	366.094
2004	727.464	304.019
2005	752.546	299.099
2006	840.338	311.707
2007	811.674	293.262
2008	822.722	289.315
2009	750.743	265.102
2010	623.224	187.146
2011	504.997	176.665
2012	388.365	130.324
2013	274.724	93.320
2014	257.914	56.831
2015	260.820	85.583
2016	113.016	5.182
2017	142.622	0.125
2018	145.045	0.004
2019	156.107	0.007
2020	198.631	0.085
2021	133.974	0.004
2022	194.414	0.028

Composition of waste

The following data on composition of waste have been estimated:

A = fraction of waste that is paper and textiles
B = fraction of waste that is garden waste, park waste or other non-food waste
C = fraction of waste that is food waste
D = fraction of waste that is wood or straw

The fractions used for GHG emission calculations are presented in the table 7.2.8.

For the mixed MS waste, which represents the major part of municipal and similar types of waste, we have assumed the composition or fractions A, B, C in D, as stated in the Operational programme of waste disposal to be the same for the entire period 1964 to 1988: A:12%, B:5%, C:25%, D:5%.

These values have been changed to A: 15%, B: 8%, C: 32%, D: 8% for 1995 (the base year for the Operational programme) and to determine values in between and for the period 1996 to 2004 the expert estimates which are based on the periodic sample analyses have been used.

In 2005 and partly in 2006, new screening analyses of mixed municipal waste were performed. The results were as followed: 22.1% A, 17.5% C and 7.5% D, or, together, 47% of all degradable wastes. Considering all waste disposed of in SWDS and fraction of degradable waste in other types of disposed wastes, we have estimated the following composition of waste for 2005: A: 20.4%, C: 16.5% and D: 7.1%. The fraction of waste "garden waste or park waste" is zero because since 2004 a legislation prohibits deposition of such a type of waste on SWDS. For the industrial waste the same composition have been assumed for the entire period 1964 to 2007; A: 5%, C: 0.5%, and D: 4.5%.

In the period 2008-2015 the screening analyses have been done for the mixed part of municipal solid waste (code 20 03 01) for every landfill many times per year and results are presented in the table 7.2.5.

Table 7.2.5: Amounts of wastes deposited on municipal SWDS and results for screening analyzes for the mixed MSW (code from LoW 20 03 01) for the period 2008 to 2015.

year	All waste deposited on the SWDS (t)	Municipal solid waste – MSW (t)	Mixed fraction of MSW – code 20 03 01 (t)	A paper textiles %	C food waste %	D wood straw %
2008	822,722	684,719	616,588	20.2	13.5	9.2
2009	750,743	627,686	524,734	14.8	14.4	11.1
2010	623,224	557,901	516,502	14.0	13.8	5.6
2011	504,997	419,228	380,414	19.9	16.6	5.2
2012	388,365	314,952	290,284	18.9	17.2	4.5
2013	274,724	224,001	203,945	18.9	17.2	4.5
2014	257,914	207,676	188,387	17.9	17.7	3.8
2015	260,820	208,618	188,638	17.9	17.7	3.8

For all other types of MSW and for the industrial waste the composition as presented on table 7.2.6 has been used. The data on amount of waste are available according to the classification in the List of waste (LoW). LoW is a list of hazardous and non-hazardous waste listed in the Annex 4 of the Decree on Waste (OJ RS, No 103/2011) and is available on the web site: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000D0532:20020101:EN:PDF
Waste is classified into groups according to the origin. In addition to the name, each waste has a six-digit classification number.

Table 7.2.6: A composition data for the different types of biodegradable waste used in the period 2008-2015

Main code	Type of wastes	Additional code	A paper and textile	C food	D wood
02 01	wastes from agriculture, horticulture, forestry, hunting and fishing	01, 02, 03, 99		100%	
02 01	wastes from agriculture, horticulture, forestry, hunting and fishing	07			100%
02 02	wastes from the preparation and processing of meat, fish and other foods	01, 02, 03, 99		100%	
02 03	wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea…	01, 02, 03, 04, 99		100%	
02 04	wastes from sugar processing	99		100%	
02 05	wastes from the dairy products industry	01, 99		100%	
02 06	wastes from the baking and confectionery industry	01, 02		100%	
02 07	wastes from the production of alcoholic and non-alcoholic beverages	01, 02, 04			
03 01	wastes from wood processing and the production of panels and furniture	01, 05, 99			100%
03 03	wastes from pulp, paper and cardboard production and processing	01			100%
03 03	wastes from pulp, paper and cardboard production and processing	07, 10, 99	100%		
04 02	wastes from the textile industry	09, 10, 21, 22, 99	50%		
15 01	packaging	01	100%		
15 01	packaging	03			100%
15 01	packaging	09	100%		
15 02	other	03	50%		
17 02	wood, glass and plastic	01			100%
17 09	Mixed constriction waste	04			20%
19 08	wastes from waste water treatment plants	01, 02	10%		5%
19 12	wastes from the mechanical treatment of waste	01	100%		
19 12	wastes from the mechanical treatment of waste	07			100%
19 12	wastes from the mechanical treatment of waste	08	50%		
19 12	wastes from the mechanical treatment of waste	12	10%		5%
20 01	separately collected fractions	08, 25		100%	
20 01	separately collected fractions	10, 11	50%		
20 01	separately collected fractions	38			100%
20 02	garden and park wastes	01			100%
20 03	other municipal wastes - mixed municipal wastes	01, 99	Table 7.2.5	Table 7.2.5	Table 7.2.5
20 03	other municipal wastes	03	20%	10%	5%
20 03	Bulky waste	07			35%

Since 2016, the mechanical biological treatment (MBT) of mixed municipal waste prior to disposal in municipal waste management centres has been mandatory. That is why all facilities for mechanical and biological treatment of mixed municipal waste in Slovenia had to be upgraded in order to meet the country's needs. The treated municipal waste has to fulfil the following restrictions before they are allowed to be disposed on the SWDS.

- heating value: does not exceed 6 MJ / kg of dry matter,
- TOC: does not exceed 18% by weight of dry MB treated municipal waste and
- AT4: does not exceed 10 mg O_2 /g dry matter of biodegradable waste.

For such a treated waste it is assumed that no biodegradable component is included any more.

Since 2016 all amount of MSW which is landfilled was inert or pre-treated. A small amount of industrial waste which has a biodegradable part is still allowed to be deposited on MSW disposal sites. For 2022 the composition presented in the table 7.2.7. have been used.

Table 7.2.7: Composition of deposited biodegradable waste in 2022.

Main code	Type of wastes	Additional code	A paper and textile	D wood
15 02	absorbents, filter materials, wiping cloths and protective clothing	03	50%	
17 02	wood, glass and plastic	01		100%
17 09	mixed constriction waste	04		10%
19 08	wastes from waste water treatment plants	02	2%	3%

The average yearly values of fractions of degradable waste as used for GHG emission calculations for the period 1964 to 2022 are presented in the table 7.2.8.

Table 7.2.8: Fractions of degradable waste in deposited MSW and industrial waste.

year	Municipal solid waste					Industrial waste			
	A paper textiles	B garden waste	C food waste	D wood straw	Degradable MSW in %	A paper textiles	C food waste	D wood straw	Degradable industrial waste in %
1964-1988	12	5	25	5	47	5.0	0.5	4.5	10
1989	13	6	26	6	51	5.0	0.5	4.5	10
1990	13	6	27	6	52	5.0	0.5	4.5	10
1991	13	6	28	6	53	5.0	0.5	4.5	10
1992	14	7	29	7	57	5.0	0.5	4.5	10
1993	14	7	30	7	58	5.0	0.5	4.5	10
1994	14	7	31	7	59	5.0	0.5	4.5	10
1995	15	8	32	8	63	5.0	0.5	4.5	10
1996	15	8	32	8	63	5.0	0.5	4.5	10
1997	15	8	32	8	63	5.0	0.5	4.5	10
1998	16	8	31	8	63	5.0	0.5	4.5	10
1999	16	8	31	8	63	5.0	0.5	4.5	10
2000	17	8	30	8	63	5.0	0.5	4.5	10
2001	17	6	28	8	59	5.0	0.5	4.5	10
2002	18	4	26	8	56	5.0	0.5	4.5	10

year	Municipal solid waste					Industrial waste			
	A paper textiles	B garden waste	C food waste	D wood straw	Degradable MSW in %	A paper textiles	C food waste	D wood straw	Degradable industrial waste in %
2003	18	2	23	8	51	5.0	0.5	4.5	10
2004	19	NO	21	7	47	5.0	0.5	4.5	10
2005	20.4	NO	16.5	7.1	44	5.0	0.5	4.5	10
2006	20.8	NO	14.2	6.4	41.4	5.0	0.5	4.5	10
2007	19.7	NO	13.2	7.9	40.8	5.0	0.5	4.5	10
2008	18.6	NO	12.4	9.5	40.5	5.1	0.4	4.3	9.8
2009	13.1	NO	16.8	10.0	39.9	1.3	0.6	9.1	11.0
2010	13.2	NO	13.0	6.2	32.4	7.5	0.6	0.0	8.1
2011	18.4	NO	15.2	7.3	40.9	1.8	0.1	4.4	6.2
2012	17.8	NO	16.0	6.1	39.9	3.0	0.0	3.3	6.3
2013	17.7	NO	15.9	6.1	39.7	4.0	0.0	4.6	8.7
2014	9.5	NO	13.3	4.3	27.1	0.8	0.1	0.2	1.1
2015	16.6	NO	16.2	5.5	38.4	5.5	0.0	5.0	10.6
2016	NO	NO	NO	NO	NO	5.9	NO	3.0	8.9
2017	NO	NO	NO	NO	NO	0.028	NO	0.138	0.166
2018	0.002	NO	NO	0.002	0.004	0.000	NO	0.002	0.002
2019	NO	NO	NO	NO	NO	0.005	NO	0.001	0.006
2020	NO	NO	NO	NO	NO	0.012	NO	0.073	0.085
2021	NO	NO	NO	NO	NO	0.004	NO	0.000	0.004
2022	NO	NO	NO	NO	NO	0.005	NO	0.022	0.027

Methane correction factor (MCF)

MCF accounts for the effect of management practices on CH_4 generation. Unmanaged disposal sites present lower methane-generating potential, because a larger fraction of waste decomposes aerobically in the top layers of the unmanaged SWDS.
The IPCC guidelines describe a managed SWDS as a site with one off the following:

- cover material
- mechanical compacting
- levelling of waste

For calculation implied MCF the following default MCF from 2006 IPCC Guidelines, Vol. 5 from Table 3.1 have been used:

- 0.6 for uncategorised SWDS and
- 1 for managed SWDS

In 1964, the Ljubljana-Barje SWDS started to operate as our first managed solid waste disposal site. Other existing solid waste disposal sites were unmanaged at that time. According to our estimate, roughly a half of the waste was collected at managed SWDS (Ljubljana – Barje) and a half at unmanaged SWDS. As the depth of the unmanaged SWDS at that time is unknown, we considered them as non-categorised and assumed a MCF of 0.6 for them, while assuming a MCF of 1 for managed SWDS. For the entire period 1964-1976, emissions have been calculated with an average value of MCF, i.e. 0.8.

The year 1977 presented an accelerated rate of controlled placement of waste, which resulted in disposing of three quarters of waste on managed solid waste disposal sites in that year; we have therefore assumed a MCF of 0.90. After that year, all other solid waste disposal sites progressively introduced managing practices and since 1986 all other SWDS in Slovenia may be classified as managed SWD sites. Accordingly, MCF increased linearly in the period from 1977 to 1986, and it has been equal to 1 since 1986. This calculation is presented on the Table 7.2.9.

Table 7.2.9: Calculation of MCF.

Year	Unmanaged SWDS	Managed SWDS	calculation	Implied MCF
1964 - 1976	50 %	50 %	(0.6 * 50 + 1 * 50) / 100	0.8
1977	25 %	75 %	(0.6 * 25 + 1 * 75) / 100	0.9
1978 - 1985	Linear interpolation from 25 % to 0 %	Linear interpolation from 75 to 100 %	Linear interpolation	Linear interpolation
Since 1986	0 %	100 %	1 * 100 / 100	1

Fraction of degradable organic carbon that can decompose (DOC_f) is an estimate of the fraction of carbon that is ultimately degraded and converted into landfill gas, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in SWDS. In the present submission CH_4 emissions have been calculated with the advanced IPCC model from the 2019 Refinement which enable the use of different DOCf which varies with the type of waste. The following values have been used in the calculation model: 0.1 for less decomposable waste (wood and straw), 0.5 for moderately decomposable waste (paper and textiles) and 0.7 for highly decomposable waste (food).

Fraction of CH_4 in generated landfill gas (F) reflects the fact that biogas mainly consists of CH_4 and CO_2 (usually considered half of each gas). We apply 0.5 as the most commonly used value in our estimates.

Oxidation factor (OX) reflects the portion of CH_4 from SWDS that is oxidised in the soil or other material covering the waste. The amount of CH_4 that oxidises turns primarily to CO_2. If OX is zero, no oxidation takes place, and if OX is 1, then 100% of CH_4 is oxidised. We assumed that, in our case, OX was very close to zero until 2008, when we start using 0.1.

The oxidation value of 0.1 is justified for well-managed landfills which are covered with soil or other material. In the past very few SWDSs in Slovenia, although they were managed, use the cover material. In 2006 Slovenia started to implement EU legislation and until 2008 all SWDSs became well managed (are covered with soil or other material). It is very hard to estimate the oxidation factor before 2008 but according to the 2006 IPCC GL, use of 0.1 is appropriate since 2008 only.

The half-life value, $t_{1/2}$ is the time taken for the DOC_m in waste to decay to the half its initial mass. In the FOD model the reaction constant k has been used. The relationship between k and $t_{1/2}$ is: $k = \ln(2)/t_{1/2}$. The half-life is affected by a wide variety of factors; the most important are the composition of waste and climatic conditions. In the Slovenian inventory the IPCC default values for temperate and wet climatic conditions from the 2006 IPCC GL, Vol.5, Table 3.3 have been used (Table 7.2.10).

Table 7.2.10: IPCC default methane generation rate (k) values and DOC used in the IPCC waste model.

Type of Waste		IPCC Range	IPCC default	Half-life (years)	DOC
Slowly degrading waste	A. paper, textiles	0.05-0.07	0.06	11.6	0.4
	D. wood, straw	0.02-0.04	0.03	23.1	0.43
Moderately degrading waste	B. garden, park	0.06-0.10	0.10	6.9	0.2
Rapidly degrading waste	C. food	0.1-0.2	0.185	3.7	0.15

CH_4 recovery (R) is the amount of CH_4 generated at SWDS that is recovered and combusted (e.g. flared or used for energy). The amount of methane that is recovered and flared or oxidised in gas engines is subtracted from the annual methane emissions.

Data on the quantities of recovered methane are available directly from SWDS. In the past (1990-2004) this data were obtain by memorandum with each of three larger SWDS in the country with methane recovery. According to the Slovenian landfill regulation all landfill operators were obliged to build landfill gas capture facilities by the end of 2005. Since then data on methane recovery were available from the annual reports from the disposal sites. This reports have to be prepared according to the Slovenian legislation. Data are available separately for flaring and for energy use. Emissions from the energy use of methane are reported in the Energy sector in 1.A.4.a Commercial and Institutional, while emissions from flaring are not included in the inventory. A detailed data on methane recovery are presented in the Figure 7.2.1 and Table 7.2.11.

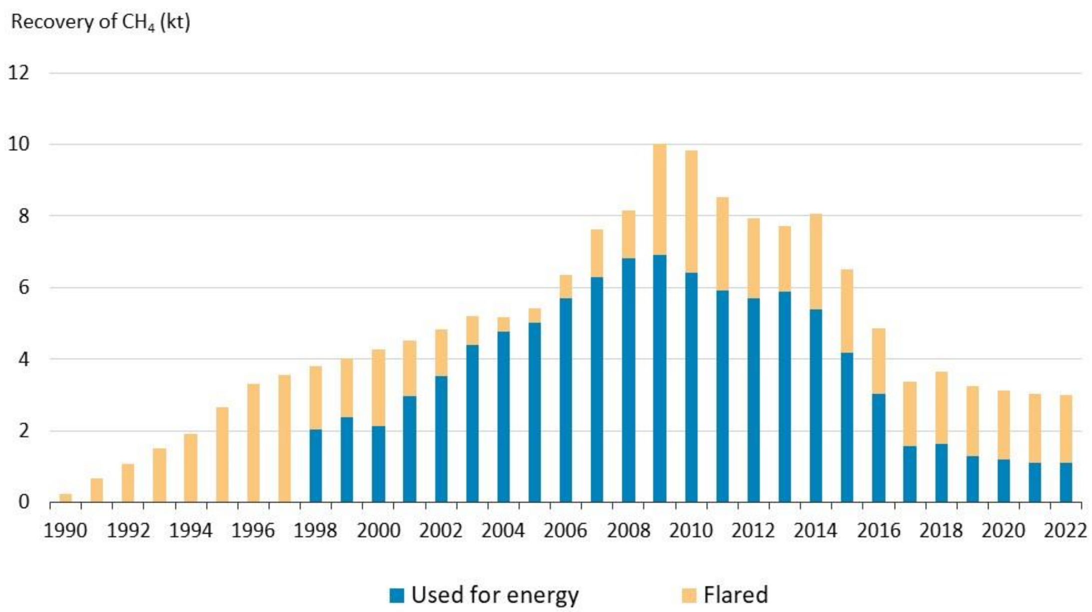

Figure 7.2.1: Methane recovery in tons.

Table 7.2.11: Recovery of methane, generated at SWDS

	Unit	1990	1991	1992	1993	1994	1995	1996	1997
Recovery	t CH_4	250	667	1,085	1,502	1,920	2,650	3,310	3,552
flared	t CH_4	250	667	1,085	1,502	1,920	2,650	3,310	3,552
used for electricity	t CH_4	NO	NO	NO	NO	NO	NO	NO	NO
used for electricity	TJ	NO	NO	NO	NO	NO	NO	NO	NO
	Unit	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Recovery	t CH_4	3,794	4,036	4,278	4,520	4,820	5,210	5,165	5,422
flared	t CH_4	1,770	1,655	2,155	1,564	1,288	825	383	402
used for electricity	t CH_4	2,024	2,381	2,123	2,956	3,532	4,385	4,782	5,020
used for electricity	TJ	102	120	107	149	178	221	241	253
	Unit	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Recovery	t CH_4	6,366	7,633	8,165	10,011	9,816	8,513	7,938	7,728
flared	t CH_4	651	1,344	1,359	3,087	3,396	2,601	2,243	1,835
used for electricity	t CH_4	5,715	6,289	6,806	6,924	6,420	5,912	5,695	5,893
used for electricity	TJ	288	317	343	349	324	298	287	297
	Unit	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Recovery	t CH_4	8,054	6,517	4,860	3,808	3,664	3,246	3,123	3,024
flared	t CH_4	2,660	2,341	1,824	2,245	2,042	1,961	1,931	1,926
used for electricity	t CH_4	5,394	4,176	3,036	1,563	1,622	1,285	1,193	1,098
used for electricity	TJ	272	210	153	79	82	65	60	55
	Unit	**2022**							
Recovery	t CH_4	3,008							
flared	t CH_4	1,903							
used for electricity	t CH_4	1.105							
used for electricity	TJ	56							

In some cases the amount of methane in the generated landfill gas is too low to support energy recovery or even flaring. In these cases a passive landfill gas bio-filter vents could be used. In Slovenia in many closed SWDS this method of methane emission reduction is used. The number of closed sites is increasing in recent years due to the increasingly stringent environmental standards that must be met by operated landfills. The amount of methane oxidized in bio-filter system is not available, however we are assuming that it is not negligible in the recent year.

CH_4 Emissions

Emissions estimates according to the first order decay method are presented in the Figure 7.2.2. The contribution to the generated methane emissions from each type of biodegradable waste is presented with the chart diagram while the red line represents final emissions taking into consideration also the recovery.

The first order decay method takes into account also the contribution of waste disposed of in the past; therefore the reduction of quantity of disposed of biodegradable waste is shown only after a certain time delay.

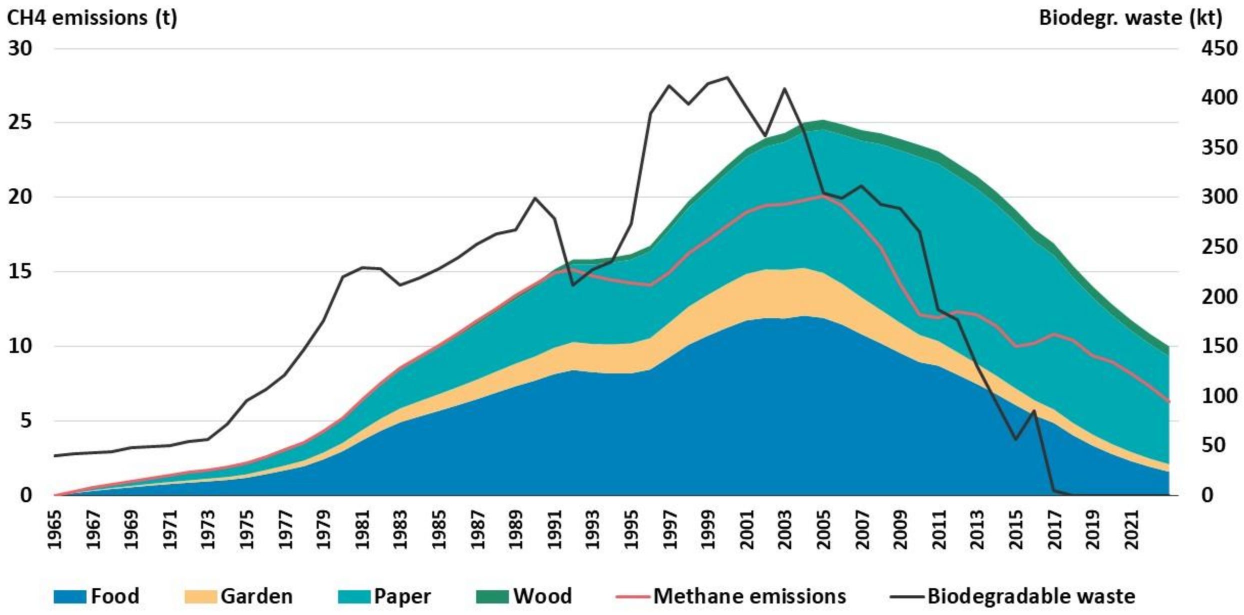

Figure 7.2.2: Methane emissions from SWDS in t CH_4 and amount of deposited biodegradable part of waste.

7.2.3 Uncertainty and time series consistency

For 2020 submission the amount of deposited waste and composition data have been improved and since than the time series are consistent.

Following the recommendation from the 2020 review for the present submission uncertainty estimates are improved and description is included in the NID.

For calculation of CH_4 emissions from the SWDS the FOD method is used. To calculate emissions with this model in addition to the activity data many parameters are used and for every parameter and AD the uncertainty estimate have been made.

Activity data are amount of waste deposited on SWD and waste composition. Although these data are on the high quality in the recent years for emissions nowadays it is also important the quality of data which are used in the past. To determine overall uncertainty of AD used in the base year and in the year 2020 the uncertainties, which are suggested in the 2006 IPCC GL have been used.

Following the information on uncertainty from the waste experts, amount of waste deposited on the SWDS and composition of these data in the period 1962-1994 has uncertainty around 50%. For later period uncertainties suggested in the 2006 IPCC GL have been used: for the period 1995-2001 it was 30% for amount and for the composition. Since 2002 the amount of waste is weighted on all SWDS and regular sampling of mixed fraction of MSW was made and uncertainty in this case is suggested to be 10%. Using this data on uncertainty the combined uncertainty of AD has been calculated for the base year and the last reporting year to be 71% and 36%, respectively.

For the parameters used in the FOD model the default uncertainties has been used as suggested in the Table 3.5 in the Waste chapter of the 2006 IPCC GL. They are presented in the table 7.2.12 below.

Table 7.2.12: Parameter uncertainties used in the present submission.

Parameter	Uncertainty in %	Comment
MCF	0	For 1986 we have used 10%
DOCf	20	
F	5	
R	10	The metering is on place
OX	100	
DOC	7 - 47	Ranges for the IPCC default values are provided in Table 2.4
k	0 - 46	Ranges for the IPCC default values are provided in Table 3.3

To assess influence of DOC and k on the total uncertainty, a FOD model has been used and generated CH_4 emissions have been calculated with the combination of the extreme values of DOC and k for different types of waste (food, garden, paper and textile, wood and straw). The highest difference in percentage was used as the uncertainty of emissions related to these two parameters. The highest combined uncertainty for generated emissions was 50% in 1986 and 39% in 2020.

Taking into account all uncertainties for AD and parameters as presented above the total combined uncertainty of CH_4 emissions in 1986 was 84% and in 2020 was 67%.

7.2.4 Category-specific QA/QC and verification

Besides general QC checks, source specific checks have been performed for 2014 submission and the following procedures have been done:

- Comparison of CS values on MSW generated and waste composition with IPCC default values;
- Comparison of CH_4 emissions calculated with the IPCC waste model with the results from the old FOD method (from IPCC GPG);
- Comparison of the recovery data from SEA with data from SORS.

7.2.5 Category-specific recalculations

Emissions of CH_4 from solid waste disposal were recalculated for the period 2018-2021 due to the improvement of data on landfilled gas which is flared. After carefully investigation of reports from SWD it was found out that in recent years some SWD are not reported this amount to the competent authority despite the amount of gas flared was measured and recorded in their evidence.

7.2.6 Category-specific planned improvements

No improvements are planned for the next submission.

7.3 Biological Treatment of Solid Waste (CRT 5.B)

Biological treatment of solid waste in Slovenia covers composting and anaerobic digestion. The only GHG emissions included in the inventory are emissions from composting.

7.3.1 Composting

7.3.1.1 Category description

Composting is an aerobic process and a large fraction of the degradable organic carbon (DOC) in the waste is converted into CO_2. Composting can also produces emissions of N_2O and CH_4.

7.3.1.2 Methodological issues

Amount of composted waste on the wet weight have been obtained from SORS for all years since 2002. In 2022 108.545 kt of wet waste have been composted. A household composting is not included in these data, because there is no data on the amount of composted waste and also no IPCC default EFs which are appropriate for home composting. No data prior 2002 is available.

In the CRT tables amount of composited waste is presented in kt of dry mater because the unit cannot be changed. For this reason the dry amount composted waste is calculated from the wet weight assuming a moisture content of 60% in wet waste as recommended in the 2006 IPCC GL.

On the figure 7.3.1 amount on composted waste is presented, while a nominal data are available in the CRT tables.

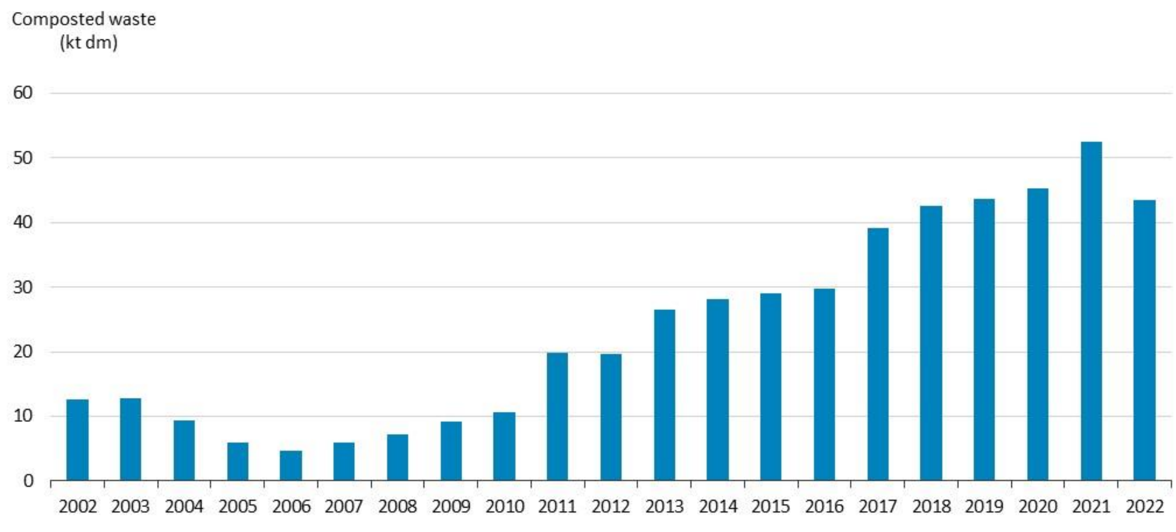

Figure 7.3.1: Amount of composted waste in kt of dry weight.

Emission factors have been taken from 2006 IPCC GL, Vol. 5 Table 4.1 for dry weight: 10 g CH_4 / kg waste and 0.6 g N_2O / kg waste.

7.3.1.3 Uncertainty and time series consistency

The composted waste is weighted and uncertainty is 10%. It is the same value as used for the deposited waste since 2002 and is recommended in the 2006 IPCC GL.

Uncertainties in the default emission factors can be estimated using the ranges given in Table 4.1. in the Waste chapter of 2006 IPCC GL. We have used the highest value; it is 100% for CH_4 EF and 150% for N_2O EF.

7.3.1.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

7.3.1.5 Category-specific recalculations

No recalculation have been performed.

7.3.1.6 Category-specific planned improvements

No improvements are planned for the next submission

7.3.2 Anaerobic Digestion at Biogas Facilities

The treatment of waste in the anaerobic digesters can be divided into two periods. Before 2015 the waste which has been treated in the biogas facilities was only the waste with the waste code 02 01 06 "Animal faeces, urine and manure (including spoiled straw), and effluent, collected separately and treated off-site". Emissions from this source were not included in the previous submissions. For the present submission emissions from the treatment of this type of waste in anaerobic digesters have been calculated for the first time, however, these emissions are reported in the Agriculture sector.

Waste treatment in the anaerobic digesters of other types of waste only started in 2015 with new legislation. This prohibits the disposal of biodegradable waste without prior MBT treatment. For this reason, all devices used for this purpose are very new and practically emission-free. All anaerobic digestion facilities are using gas detection sensors, to monitor the levels of methane and other gases within the facility. These sensors can detect any potential gas leaks or other issues that could affect the safety and efficiency of the anaerobic digestion process. The digestion process is also continuously monitored to maintain the appropriate temperature and pH conditions for optimal digestion, and properly manage the digestate.

In the period 2015-2022 between 85 and 158 kt of waste was treated in these facilities. If IPCC default EF of 0.8 g CH_4/kg of wet waste is used, the highest emissions would be 0.126 kt CH4 or 3.5 kt CO_2 eq in the year 2019. This value is below our threshold of significance (8 kt CO_2 eq). However, the experts assume that these emissions are close to zero. For these reason notation key NE is used in the CRT category 5B2. As well the notation key NE is also used for N_2O emissions which are negligible according to the IPCC GL.

7.4 Waste incineration (CRT 5.C)

7.4.1 Category description

The purpose of waste incineration until 2008 in Slovenia was to remove waste which was not allowed to be deposited on the SWDS, the amount of incinerated waste was small and emissions from this source were less than 5 Gg CO_2 eq. Since 2009 the incinerated amount of waste has increased and emissions in 2022 were 14.0 kt CO_2 eq.

7.4.2 Methodological issues

The amount of waste incinerated in Slovenia have been obtained from SEA and the data are presented in the Table 7.4.1.

Until 2014 only the total amount of each type of waste is available while since then the data is available according to the six digit code from the list of waste for individual plant. Incinerated waste was divided to biogenic and non-biogenic part and non-biogenic part was further disaggregated in three types of waste (hazardous, clinical and municipal). CO_2 emissions from biogenic waste are not included in the national total amount of emissions.

Emission factors are presented in the table 7.4.3. CO_2 emission factors have been calculated using Equation 5.1 from 2006 IPCC Guideline as follows:

$$EF = dm * TCC * FCF * OX * 44/12$$

EF – CO_2 emission factor in t/t
dm – dry matter content in % of wet weight;
TCC – total carbon content in % of dry weight,
FCF – fossil carbon fraction in % of TCC
OX – oxidation factor
44/12 - conversion factor from C to CO_2

The exemption was CO_2 EF for fossil liquid waste for which Equation 5.3 have been used.

$$EF = TCC * FCF * OX * 44/12$$

Parameters used for calculation of CO_2 EF are IPCC default and are presented on the Table 7.4.2. Source is 2006 IPCC Guidelines, Vol 5, Table 2.4, 2.5, 2.6 and 5.2.

Source for CH_4 EF is 2006 IPCC Guidelines, Vol 5, Table 5.3, while N_2O EFs are from Table 5.5 and 5.6. According to the information on combustion technique in two most important incineration plants EF for the semi-continuous incineration have been used.

Table 7.4.1: Amount of waste incinerated in tons in Slovenia in the period 1986 – 2022.

Year	biogenic	municipal solid waste	clinical waste	hazardous waste
1986 – 1993	0	0	0	815
1994	0	0	132	456
1995	0	0	0	268
1996	0	0	0	389
1997	0	0	214	73
1998	10	0	205	335
1999	0	0	85	1,031
2000	0	0	109	1,261
2001	0	0	280	1,190
2002	260	0	441	946
2003	235	0	534	1,382
2004	110	15	138	1,366
2005	291	2	113	1,325
2006	345	4	108	1,616
2007	676	9	160	1,987
2008	533	33	148	2,091
2009	630	19	193	2,585
2010	31	21	671	2,836
2011	251	9	660	2,860
2012	221	11	578	7,714
2013	132	10	524	6,883
2014	29	10	267	8,235
2015	41	12	195	11,110
2016	71	1	299	8,993
2017	133	2	247	10,906
2018	98	2	238	8,310
2019	171	1	276	8,215
2020	271	NO	266	7,703
2021	247	NO	467	5,553
2022	284	NO	386	5,841

Until 2014 only the total amount of each type of waste is available while since then the data is available according to the six digit code from the list of waste for individual plant. Incinerated waste was divided to biogenic and non-biogenic part and non-biogenic part was further disaggregated in three types of waste (hazardous, clinical and municipal). CO_2 emissions from biogenic waste are not included in the national total amount of emissions.

Emission factors are presented in the table 7.4.3. CO_2 emission factors have been calculated using Equation 5.1 from 2006 IPCC Guideline as follows:

$$EF = dm * TCC * FCF * OX * 44/12$$

EF – CO_2 emission factor in t/t
dm – dry matter content in % of wet weight;
TCC – total carbon content in % of dry weight,

FCF – fossil carbon fraction in % of TCC
OX – oxidation factor
44/12 - conversion factor from C to CO_2

The exemption was CO_2 EF for fossil liquid waste for which Equation 5.3 have been used.
EF = TCC * FCF * OX * 44/12

Parameters used for calculation of CO_2 EF are IPCC default and are presented on the Table 7.4.2. Source is 2006 IPCC Guidelines, Vol 5, Table 2.4, 2.5, 2.6 and 5.2.

Source for CH_4 EF is 2006 IPCC Guidelines, Vol 5, Table 5.3, while N_2O EFs are from Table 5.5 and 5.6. According to the information on combustion technique in two most important incineration plants EF for the semi-continuous incineration have been used.

Table 7.4.2: Parameters used for the calculation of CO_2 EF.

	Unit	Wood and paper	MSW	Clinical waste	Fossil liquid waste	Other industrial
dm (%)	%	85	90	65	NA	50
TCC	%	50	3	60	80	50
FCF	%	0	100	40	100	90
OF	%	100	100	100	100	100

Table 7.4.3: Emission factors used in the period 1986 – 2022

	Unit	Wood and paper	MSW	Clinical waste	Fossil liquid waste	Other industrial
CO_2	t / t waste	0	0.099	0.572	2.933	0.825
CH_4	g/ t waste	6	6	6	6	6
N_2O	g/ t waste	10	50	100	9.8	100

According to the data for 2014 and 2015 around three quarters (77%) of hazardous waste is liquid industrial waste and the remaining amount is other industrial type of waste. Because no data on composition of hazardous waste is available before the same composition has been used for all years before.

Since 2016 the actual yearly data has been used. The proportion of the liquid waste in the hazardous waste and corresponding CO_2 and N_2O emission factors are presented in the Table 7.4.4.

Table 7.4.4: CO2 and N2O emission factors used for hazardous waste.

	Unit	Until 2015	2016	2017	2018	2019	2020	2021	2022
liquid	%	77	84.4	79.7	78.1	78.7	80.7	77.8	72.5
CO_2	t / t waste	2.448	2.604	2.505	2.472	2.484	2.525	2.466	2.354
N_2O	g/ t waste	30.55	23.87	28.11	29.55	29.04	27.25	29.83	34.57

7.4.3 Uncertainty and time series consistency

According to the 2006 IPCC GL uncertainty of incineration waste in developed countries is around ± 5 percent for amount of waste on the wet basis. In 1986 the uncertainty was much higher. After consultation with the waste experts the same uncertainty value (50%) as used for AD for SWD has been recommended.

CO_2 emissions are calculated with the default parameters and uncertainties were determined following information on uncertainties from the 2006 IPCC GL. The values we have used are in the table below.

Table 7.4.3: Parameter uncertainties used for the CO_2 EF.

Parameter	MSW – fossil part	Clinical waste	Industrial waste - liquid	Industrial waste - other	Comment
dm content	50	50	NA	50	
total CC	100	20	20	20	Same as for SWD
fossil C fraction	0	20	NA	20	Same as for SWD
OF	0	0	0	0	Combustion is complete
CO_2 EF	111.8	57.4	20	57.4	

The conversion of waste amounts from wet weight to dry weight adds additional uncertainty which could be in the range between ± 10 percent up to ± 50 percent and even more. In our case we have no data on dry content of the incinerated waste and for this reason default values have been used and the uncertainty is 50%. The final uncertainty of AD in 1986 was 71% and in the 2020 was 50%.

The total final uncertainty for EF is different for every year because it depends of share of each type of waste in the particular year. In 2020 this uncertainty was 27.4, because majority of incinerated waste is liquid industrial (hazardous) waste. For other two GHG default values for N_2O and CH_4 emission factors are used and uncertainty ranges have been estimated to be ± 100 percent, as recommended in the 2006 IPCC GL.

7.4.4 Category-specific QA/QC and verification

This category has been checked by the general QC procedures described in the Chapter 1.2.3.

7.4.5 Category-specific recalculations

GHG emissions for 2021 have been recalculated due to the error in EF used for hazardous waste.

7.4.6 Category-specific planned improvements

No improvements are planned for this category.

7.5 Emissions from Wastewater Treatment and Discharge (CRT 5.D)

7.5.1 Category description

Wastewater could be a source of methane (CH_4) when treated or disposed anaerobically. It can also be a source of nitrous oxide (N_2O) emissions. Carbon dioxide (CO_2) emissions from wastewater are not considered in the IPCC Guidelines because these are of biogenic origin and should not be included in national total emissions. Wastewater originates from a variety of domestic and industrial sources and may be treated on site (uncollected), sewered to a centralized plant (collected) or disposed untreated nearby or via an outfall. IPCC methodology requires separate handling of domestic and industrial wastewater. Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only.

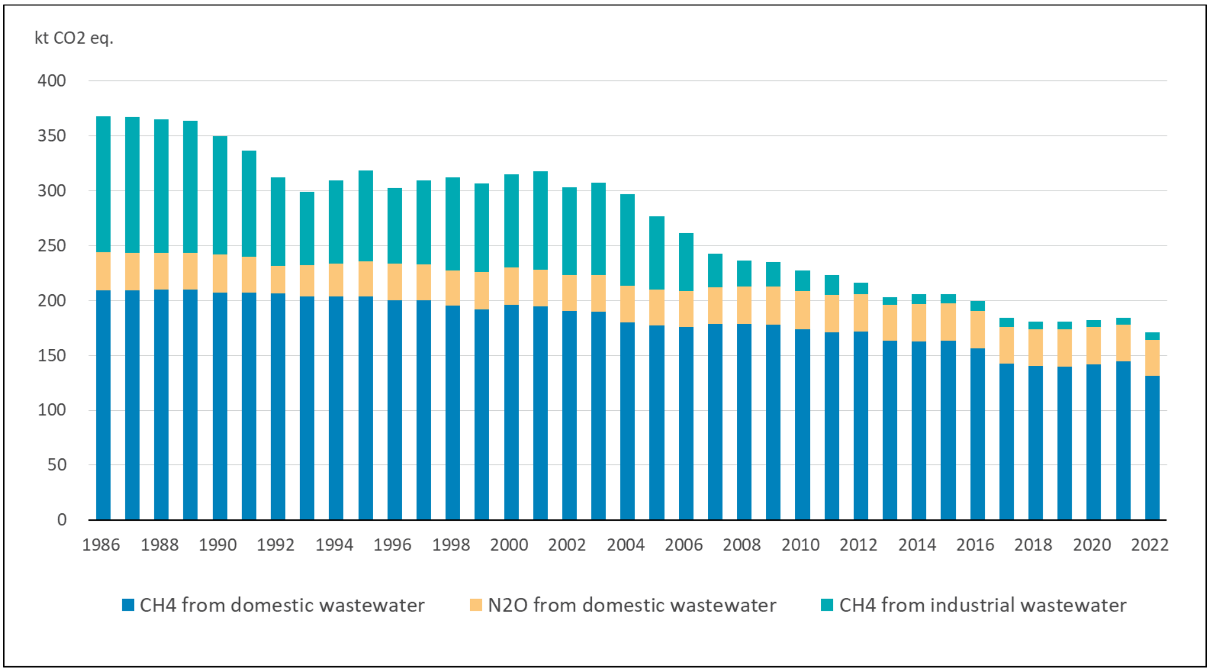

Figure 7.5.1: Emissions of methane and nitrous oxide from wastewater treatment.

Wastewater as well as its sludge components can produce CH_4 if it degrades anaerobically. The extent of CH_4 production depends primarily on the quantity of degradable organic material in the wastewater, the temperature, and the type of treatment system. With increases in temperature, the rate of CH_4 production increases. This is especially important in uncontrolled systems and in warm climates. Below 15°C, significant CH_4 production is unlikely because methanogens are not active.

N_2O is associated with the degradation of nitrogen components in the wastewater (urea, nitrate, protein). Domestic wastewater includes human sewage mixed with other household wastewater, which can include effluent from shower drains, sink drains, washing machines. N_2O emissions can occur as direct emissions from treatment plants or indirect emissions from wastewater after disposal effluent into waterways (rivers, lakes, sea). Direct emissions from nitrification and denitrification at wastewater treatment plants are much smaller than those from effluent.

Table 7.5.1: Methane and nitrous oxide emissions from wastewater treatment.

Year	Domestic wastewater	Domestic wastewater	Industrial wastewater	Domestic wastewater	Domestic wastewater	Industrial wastewater
	CH_4 emissions (kt)	N_2O emissions (kt)	CH_4 emissions (kt)	CH_4 emissions (kt CO_2 eq.)	N_2O emissions (kt CO_2 eq.)	CH_4 Emissions (kt CO_2 eq.)
1986	7.47	0.13	4.42	209.1	34.6	123.9
1987	7.48	0.13	4.41	209.4	34.0	123.6
1988	7.48	0.13	4.34	209.6	33.6	121,5
1989	7.49	0.13	4.30	209.6	33.6	120.4
1990	7.39	0.13	3.84	207.0	35.0	107,6
1991	7.39	0.12	3.44	206.9	32.9	96.3
1992	7.37	0.09	2.89	206.4	25.1	80,8
1993	7.27	0.11	2.38	203.6	28.8	66.5
1994	7.27	0.11	2.70	203.5	30.3	75,6
1995	7.27	0.12	2.96	203.5	31.9	82.8
1996	7.15	0.13	2.45	200.2	33.2	68,7
1997	7.14	0.12	2.74	200.0	32.5	76.6
1998	6.98	0.12	3.03	195.3	31.8	84,8
1999	6.85	0.13	2.87	191.8	34.4	80.3
2000	6.99	0.13	3.04	195.9	34.1	85,2
2001	6.95	0.13	3.21	194.5	33.3	90.0
2002	6.80	0.12	2.86	190.4	32.9	80.0
2003	6.77	0.13	3.01	189.5	33.4	84.2
2004	6.42	0.13	3.00	179.9	33.2	83,9
2005	6.32	0.12	2.38	176.9	32.9	66.6
2006	6.27	0.12	1.88	175.6	33.0	52.6
2007	6.38	0.13	1.09	178.5	33.3	30,5
2008	6.37	0.13	0.83	178.4	34.5	23.4
2009	6.36	0.13	0.79	178.0	34.9	22.2
2010	6.21	0.13	0.67	173.9	34.4	18.9
2011	6.10	0.13	0.65	170.8	34.0	18.3
2012	6.13	0.13	0.40	171.5	33.8	11.1
2013	5.82	0.13	0.25	163.0	33.1	7.1
2014	5.81	0.13	0.31	162.8	34.1	8.6
2015	5.84	0.13	0.30	163.4	33.6	8.4
2016	5.59	0.13	0.30	156.5	34.1	8.5
2017	5.08	0.13	0.30	142.3	33.7	8.4
2018	5.01	0.13	0.25	140.2	33.6	7.0
2019	4.99	0.13	0.25	139.6	34.3	7.1
2020	5.05	0.13	0.22	141.5	34.1	6.2
2021	5.17	0.12	0.24	144.7	33.0	6.7
2022	4.68	0.12	0.23	131.0	33.0	6.6

Calculations of CH_4 and N_2O emissions from domestic and industrial wastewater treatment and discharge were performed following with 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Figure 7.5.1 and Table 7.5.1 show CH_4 and N_2O emissions from domestic and industrial wastewater treatment for the period 1986-2022. Emissions in Figure 7.5.1 are expressed in kt CO_2 equivalent.

7.5.2 Methodological issues

Domestic Wastewater

CH_4 EMISSIONS

Modified 2006 IPCC methodology has been used in calculating the emission of methane from domestic wastewater treatment and discharge. Emissions of CH_4 from domestic wastewater were calculated separately per individual discharge pathway. Sum up of CH_4 emissions for all pathways results was performed subsequently.

As the first step, it is necessary to determine the total amount of organically degradable material in the wastewater (TOW) for each pathway. TOW is the activity data for this source category. It is expressed in terms of biochemical oxygen demand (kg BOD/year). The equation for calculation of TOW is:

$$TOW_j = P * BOD * I * 0.001 * 365 * T_j$$

TOW_j - total organics in wastewater for each discharge pathway, j (kg BOD/year)
P - country population (number of person)
BOD - country-specific per capita BOD (g/person/day)
0.001 - conversion from grams BOD to kg BOD
I - correction factor for additional industrial BOD discharged into sewers
T_j - share of population included into each discharge pathway, j (fraction)

Secondly, the emission factors for each domestic wastewater treatment and discharge pathway have to be estimated. The emission factor is a function of the maximum CH_4 producing potential (B_0) and the methane correction factor (MCF) for the wastewater treatment and discharge system. The B_0 is the maximum amount of CH_4 that can be produced from a given quantity of organics in the wastewater. The MCF indicates the extent to which the CH_4 producing capacity (B_0) is realised in each type of treatment and discharge pathway and system. MCF is an indication of the degree to which the system is anaerobic. As emission factor is expressed in kg CH_4/kg of degradable organic component:

$$EF_j = B_0 * MCF_j$$

EF_j - emission factor (kg CH_4/kg BOD)
j - each treatment and discharge pathway
B_0 - maximum CH_4 producing capacity (kg CH4/kg BOD)
MCF_j - methane correction factor for each discharge pathway, j (fraction)

In the third step, emission for each domestic wastewater treatment and discharge pathways have to be estimated.

$$CH_4\ Emissions\_{j} = ((TOW_j - S_j) * EF_j) - R_j$$

CH_4 Emissions_$_j$	- CH_4 emissions for each discharge pathway (kg CH_4/year)
TOW_j	- total organics in wastewater for each discharge pathway, j (kg BOD/year)
S_j	- organic component removed as sludge for each discharge pathway (kg BOD/year)
R_j	- amount of CH_4 recovered for each discharge pathway (kg CH_4/year)

In the end, the total national emission of methane from domestic wastewater is estimated. Individual emission estimates for each discharge pathway are sum up.

The equation for the calculation of annual CH_4 emissions is as follows:

$$CH_4\ emissions = \sum_j CH_4\ Emissions\_{j}$$

CH_4 Emissions	- total annual CH_4 emissions in the country (kg CH_4/year)
CH_4 Emissions_ j	- CH_4 emissions for each discharge pathway (kg CH_4/year)

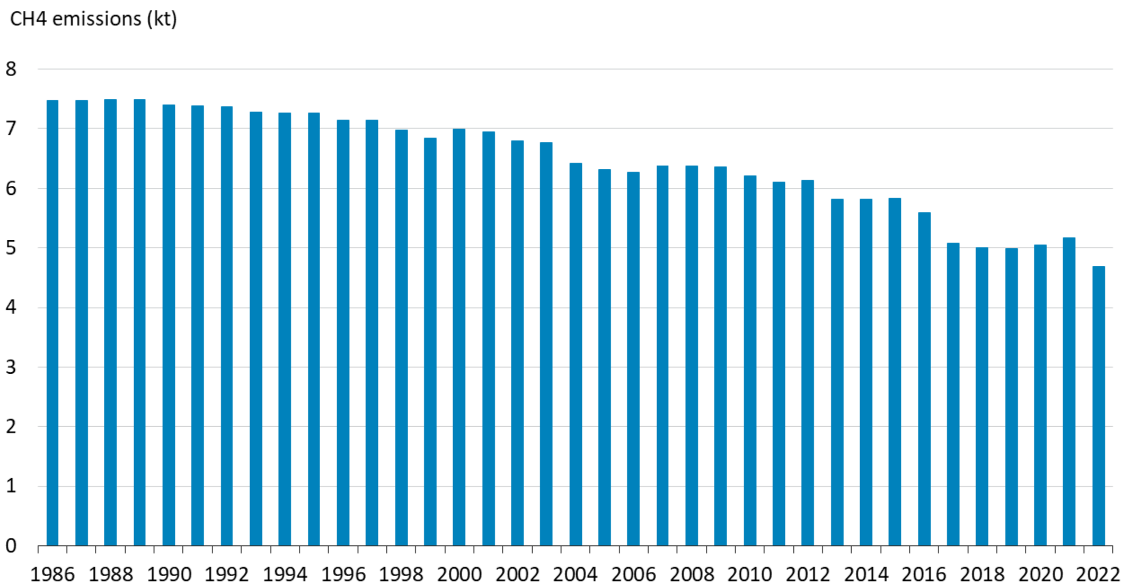

Figure 7.5.2: CH_4 emissions from domestic wastewater treatment.

CH_4 emissions from domestic wastewater treatment and discharge for the period 1986 - 2022 are shown in Figure 7.5.2. Emissions were decreased in 2016 - 2022 due to a smaller share of the population connected to septic tanks.

The total organically degradable material in domestic wastewater (total organic product - TOW) is presented in Table 7.5.2.

Table 7.5.2: Total organically degradable material (TOW) in domestic wastewater.

Year	Total organics in domestic wastewater (kt BOD)	Year	Total organics in domestic wastewater (kt BOD)	Year	Total organics in domestic wastewater (kt BOD)	Year	Total organics in domestic wastewater (kt BOD)
1986	46.78	1996	47.47	2006	49.15	2016	52.40
1987	47.03	1997	47.49	2007	49.63	2017	52.73
1988	47.15	1998	47.41	2008	49.82	2018	53.21
1989	47.21	1999	47.68	2009	50.48	2019	53.63
1990	47.36	2000	47.80	2010	50.68	2020	54.01
1991	47.40	2001	47.95	2011	51.09	2021	53.84
1992	47.36	2002	48.04	2012	51.26	2022	54.32
1993	47.33	2003	48.14	2013	51.47		
1994	47.39	2004	48.91	2014	51.55		
1995	47.48	2005	49.22	2015	51.71		

Wastewater treatment and discharge pathways

Dispersed settlements and a large number of communities with less than 2000 inhabitants exert a strong influence on the extent and structure of municipal infrastructure as well as on the organisation of municipal activities. Domestic wastewater has been treated in centralized aerobic wastewater plants, septic tanks and latrines.

In 2022, about 70.5% of the population was connected to centralized aerobic wastewater treatment plants (secondary and tertiary treatment). 29.3% of the population use septic tanks and only 0.2% use latrines. The number of inhabitants included in various types of domestic wastewater treatment is shown in Table 7.5.3.

Data on inhabitants included in various types of domestic wastewater treatment and the database on municipal wastewater treatment plants are obtained by the Slovenian Environment Agency (SEA).

5.D.1 Domestic Wastewater CRT subcategory comprises emissions from all types of wastewater treatment, wastewater sewered to centralized plants (collected) and treated on site (uncollected).

Degradable organic component indicator (BOD):
For domestic wastewater, biochemical oxygen demand (BOD) is the recommended parameter used to measure the degradable organic component of the wastewater. The BOD concentration indicates only the amount of carbon that is aerobically biodegradable. The IPCC default, as well as national legislation value of 60 g BOD/person/day or 21900 kg BOD/1000 person/year, was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.14, Table 6.4).

Correction factor for additional industrial BOD discharged into sewers (I):
The factor expresses the BOD from industries and establishments (restaurants, butchers or grocery stores) that is co-discharged with domestic wastewater. The IPCC default value of 1.25 was used only for sewered, collected wastewater (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.14). For septic tanks and latrines value of I is 1 was used for emission calculations.

Table 7.5.3: Number of inhabitants included in various types of domestic wastewater treatment.

Year	Number of inhabitants (in 1000)				
	Primary treatment	Secondary and tertiary treatment	Septic tanks	Latrines	Country population
1986	307	295	905	483	1985
1987	313	303	911	478	1994
1988	319	312	913	467	1996
1989	325	320	909	453	1996
1990	331	328	913	443	2000
1991	337	336	917	428	1999
1992	343	345	916	409	1994
1993	349	353	911	390	1989
1994	355	361	910	377	1989
1995	361	370	914	364	1990
1996	367	378	912	347	1987
1997	373	386	916	331	1985
1998	547	253	872	310	1978
1999	499	309	885	306	1988
2000	531	274	901	294	1990
2001	479	348	895	284	1994
2002	438	406	892	271	1995
2003	438	425	1014	259	1996
2004	420	630	867	120	1998
2005	394	689	860	80	2003
2006	78	1038	854	60	2010
2007	78	1056	872	41	2026
2008	27	1108	879	20	2032
2009	9	1145	876	18	2047
2010	10	1174	852	16	2050
2011	9	1201	833	14	2055
2012	9	1201	838	12	2059
2013	9	1224	819	10	2061
2014	9	1230	818	8	2063
2015	0	1238	822	6	2064
2016	0	1281	780	4	2066
2017	0	1364	699	4	2067
2018	0	1391	685	4	2081
2019	0	1410	681	4	2096
2020	0	1413	691	4	2109
2021	0	1405	698	4	2107
2022	0	1487	622	4	2109

Maximum methane producing capacity (B_0):
The methane producing potential (B_0) is the maximum amount of CH_4 that can be produced from a given quantity of organics (as expressed in BOD) in the wastewater. The CH_4 producing potential varies according to the composition of the wastewater and its degradability, but the IPCC Guidelines provide only one default value of B_0. The IPCC default of 0.6 kg CH_4/kg BOD was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.12, Table 6.2).

Methane conversion factor (MCF):
The calculated amount of generated methane depends on the methane conversion factor, which tells us which fraction is actually transformed into methane. The MCF indicates the extent to which the CH4 producing capacity (Bo) is realised in each type of treatment and discharge pathway. Thus, it is an indication of the degree to which the system is anaerobic. MCF is 0 for completely aerobic systems and 1 for completely anaerobic systems. The default MCF values from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories were used for emission calculation (2006 IPCC, Volume 5: Waste, Chapter 6, pg. 6.13, Table 6.3).

For septic tanks, MCF value of 0.5 was used. Latrines are mostly used by only one or two elder people in a rural area and dry climate. MCF value of 0.1 was used for latrines. Centralized aerobic treatment plants are well managed, but some CH_4 can be emitted from settling basins and other pockets. The share of well managed aerobic treatment plants was estimated from information on the implementation of the Urban Waste Water Treatment Directive. In 2022 about 93 % of wastewater treated in centralized aerobic treatment plants is treated at aerobic treatment plants that are well managed, the remaining 7 % is treated at not well managed plants. The default MCF value of 0 for well managed and 0.3 for not well managed aerobic treatment plant were used for emission calculation.

Organic component removed as sludge (S)
For sludge removal from the wastewater default IPCC value of zero was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.9).

Methane recovery (R)
For the amount of methane recovered default IPCC value of zero was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, pg. 6.9).

N_2O EMISSIONS

Calculations of nitrous oxide emissions from wastewater treatment effluent that is discharged into aquatic environments were performed according to IPCC methodology.

As the first step, it is necessary to determine the total amount of nitrogen in the wastewater effluent ($N_{EFFLUENT}$). The equation for calculation of $N_{EFFLUENT}$ is:

$$N_{EFFLUENT} = (P * Protein * F_{NPR} * F_{NON\text{-}CON} * F_{IND\text{-}COM}) - N_{SLUDGE}$$

$N_{EFFLUENT}$	- total annual amount of nitrogen in the wastewater effluent (kg N/year)
P	- human population
Protein	- annual per capita protein consumption (kg/person/year)
F_{NPR}	- fraction of nitrogen in protein
$F_{NON-CON}$	- factor for non-consumed protein added to the wastewater
$F_{IND-COM}$	- factor for industrial and commercial co-discharged protein into the sewer system
N_{SLUDGE}	- nitrogen removed with sludge (kg N/year)

Finally, emissions of N_2O from wastewater effluent are calculated as follows:

$$N_2O \text{ emissions} = N_{EFFLUENT} * EF_{EFFLUENT} * 44 / 28$$

N_2O emissions	- N_2O emissions in inventory year (kg N_2O/year)
$N_{EFFLUENT}$	- nitrogen in the effluent discharged to aquatic environments (kg N/year)
$EF_{EFFLUENT}$	- emission factor for N_2O emissions from discharged to wastewater (kg N_2O-N/kg N)
44/28	- the conversion of kg N_2O-N into kg N_2O.

N_2O emissions from wastewater effluent for the period 1986 - 2022 are shown in Figure 7.5.3. Emissions have been relatively constant over two decades due to constant protein consumption. The drop of emissions in 1992 could be observed due to the poor economic situation and Slovenian war for independence. Due to the very high global warming potential of N_2O, relatively low amounts of N_2O formation can substantially contribute to GHGs emissions.

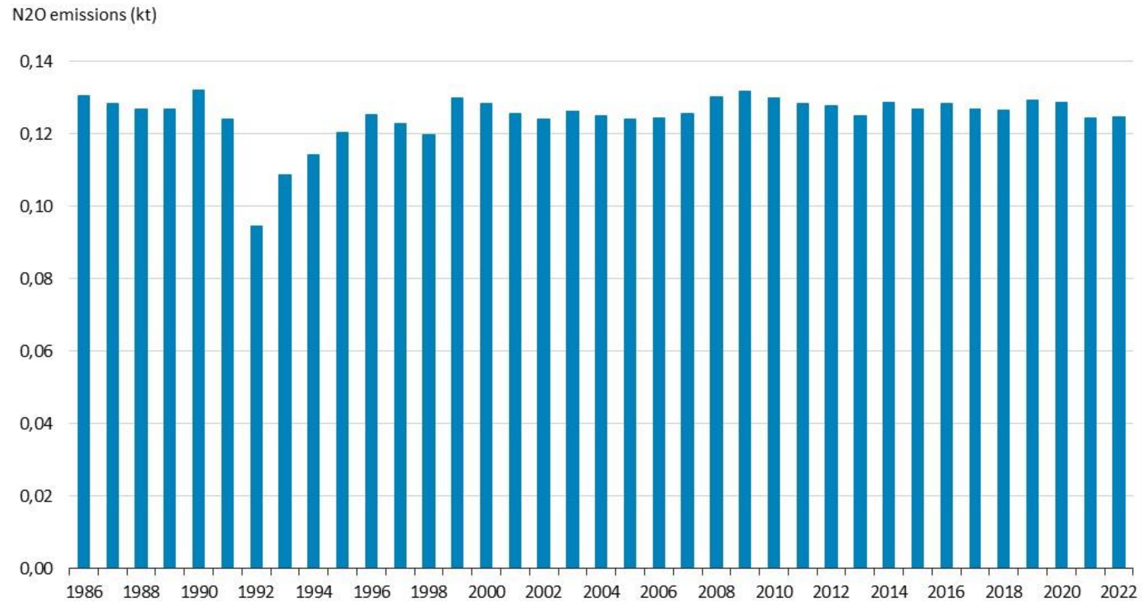

Figure 7.5.3: N_2O emissions from wastewater effluent.

Emission factor for N_2O emissions from discharged to wastewater ($EF_{EFFLUENT}$)

The IPCC default value of 0.005 kg N_2O-N/kg N was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, Table 6.11, pg. 6.27).

Human population (P)

The annual number of country population has been obtained from SORS.

Protein consumption (Protein)

The average consumption of protein per inhabitant in every individual year has been obtained from United Nations Food and Agriculture Organization (FAO). The publication of protein consumption data on the FAO's statistical database (FAOSTAT) has a time lag of four years. The last available consumption rate has been applied to the years with missing data as well. Since the consumption protein data has not been available for the years 2022 value for the year 2021 has been applied. We have also checked other potential sources of required data, but no other institution collects up-to-date data on protein consumption. Data on population and annual protein intake are presented in Table 7.5.4.

Fraction of nitrogen in protein (F_{NPR})

0.16 kg N/kg protein as an IPCC default fraction of nitrogen in protein was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.25).

Table 7.5.4: Population and protein consumption in the period 1986-2022.

Year	Population	Protein consumption (kg/person/year)	Year	Population	Protein consumption (kg/person/year)
1986	1985486	38.0	2005	2003358	35.8
1987	1994066	37.2	2006	2010377	35.8
1988	1996325	36.8	2007	2025866	35.9
1989	1996377	36.8	2008	2032362	37.1
1990	1999945	38.2	2009	2046976	37.2
1991	1998912	35.9	2010	2050189	36.7
1992	1994084	27.4	2011	2055496	36.1
1993	1989408	31.6	2012	2058821	35.9
1994	1989477	33.2	2013	2061085	35.1
1995	1990266	35.0	2014	2062874	36.1
1996	1986989	36.5	2015	2064188	35.5
1997	1984923	35.8	2016	2065895	36.0
1998	1978334	35.0	2017	2066880	35.6
1999	1987755	37.8	2018	2080908	35.2
2000	1990094	37.4	2019	2095861	35.7
2001	1994026	36.5	2020	2108977	35.3
2002	1995033	36.0	2021	2107180	34.2
2003	1996433	36.5	2022	2108739	34.2
2004	1997590	36.2			

Non-consumed protein added to the wastewater ($F_{NON-CON}$)
Additional 'non-consumed' protein discharged to wastewater pathways has to be taken into account for N_2O emission calculation. Food (waste) that is not consumed may be washed down the drain and also, bath and laundry water can be expected to contribute to nitrogen loadings. Since in Slovenia there is no garbage disposals the IPCC default factor of 1.1 was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, Table 6.11, pg. 6.27).

Industrial and commercial co-discharged protein into the sewer system ($F_{IND-COM}$)
Wastewater from industrial or commercial sources that is discharged into the sewer may contain protein. The IPCC default for this fraction is 1.25 and it was used for N_2O emission calculation (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.25).

Nitrogen removed with sludge (N_{SLUDGE})
For sludge removal default IPCC value of zero was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.25).

Industrial Wastewater

CH_4 EMISSIONS

IPCC methodology has been used in calculating the emissions of methane from industrial wastewater handling. This chapter includes CH_4 emissions from on-site industrial wastewater treatment. Assessment of CH_4 production potential from industrial wastewater streams is based on the concentration of degradable organic matter in the wastewater, the volume of wastewater, and the propensity of the industrial sector to treat their wastewater in anaerobic systems. Only industrial wastewater with significant carbon loading that is treated under intended or unintended anaerobic conditions will produce CH_4.

As the first step, it is necessary to determine the total amount of organically degradable material in the wastewater (TOW). It is expressed in terms of chemical oxygen demand (kg COD/year). The equation for calculation of TOW for particular industrial sectors is:

$$TOW_j = Q * COD_i$$

TOW - total organically degradable material in the wastewater for industry i (kg COD/year)
Q - quantity of wastewater
COD_i - degradable organics concentration in wastewater (kg COD/m^3)
i - industrial sector

Secondly, the emission factors for each industrial wastewater treatment and discharge pathways for each industrial sector have to be estimated.

$$EF_j = B0 * MCF_j$$

EF_j - emission factor (kg CH_4/kg COD)
j - each treatment and discharge pathway or system
B_0 - maximum CH_4 producing capacity (kg CH4/kg COD)
MCF_j - methane correction factor (fraction)

In the end, the total emission of methane from industrial wastewater is estimated. The equation for the calculation of annual CH_4 emissions is as follows:

$$CH_4\ emissions = \sum ((TOW_i - S_i) * EF_i) - R_i$$

CH_4 emissions	- CH_4 emissions (kg CH_4/year)
TOW	- total organically degradable material in the wastewater for industry i (kg COD/year)
S_i	- organic component removed as sludge for industry i (kg COD/year)
EF_i	- emission factor for industry i
R_i	- amount of CH_4 recovered (kg CH_4/year)
i	- industrial sector

CH_4 emissions from industrial wastewater treatment for the period 1986 - 2022 are shown in Figure 7.5.4. The drop in emissions in 1992 could be observed due to the poor economic situation and weaker industrial production as a consequence of the Slovenian war for independence. The decrease in emissions from 2005 onwards has been mainly due to the pre-treatment of wastewater in some large industrial facilities before releasing it into the centralized treatment plant to avoid high discharge fees and to meet regulatory standards. In that period a share of wastewater from the production of beverages and pulp and paper industry have been treated in industrial wastewater treatment plants.

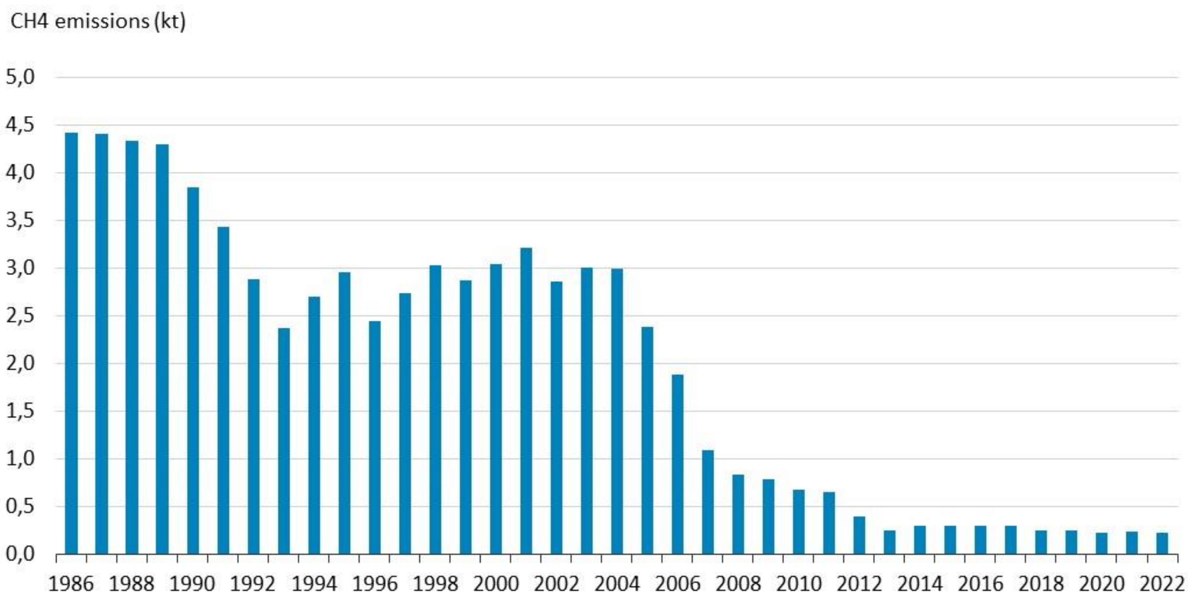

Figure 7.5.4: CH_4 emissions from industrial wastewater treatment.

Quantity of wastewater (Q)

According to the ERT recommendations, the description and the amount of industrial wastewater produced are included. Data on the amount of wastewater output for individual industries for the period 1986-2022 is presented in Table 7.5.5.

Table 7.5.5: Wastewater output with regard to various industries.

Year	Production of pulp and paper	Production of leather	Production of soft drinks and alcohol beverage	Production of food	Production of milk	Production of meat	Production of organic chemical industry	Production of pharmaceutical industry
	Wastewater output (m^3)							
1986	18612812	960966	1993330	513066	992776	854301	573968	850107
1987	18560824	948137	1993276	479440	1008278	908295	566773	860975
1988	18199349	935331	1993223	445821	1023777	962289	593392	925132
1989	17992579	922503	1993164	412196	1039279	1016283	655337	1049322
1990	17785835	909674	1993106	378570	1054778	1070278	471021	775146
1991	15813639	778661	1897174	369069	1034204	1059647	285682	483572
1992	13167759	736567	1773698	245566	921828	764296	431824	752443
1993	12056736	686178	1812219	272168	767155	650592	386055	693076
1994	13879156	678212	1906083	296905	835621	634050	483433	895019
1995	15431625	459865	1879191	304715	911369	574572	656937	1255475
1996	14369458	529332	1881993	300437	885387	662932	588977	1163117
1997	16266638	496348	1941510	282961	926754	663706	572488	1169539
1998	18163843	463364	2001042	265483	968119	664480	680999	1440901
1999	20061023	430379	2060559	248007	1009486	665255	714695	1568206
2000	21397736	397395	2120086	230529	1050850	666029	774051	1763770
2001	22734450	364411	2179603	213054	1092218	666803	641688	1520652
2002	24071163	331427	2239130	195578	1133582	667578	630656	1556779
2003	25407851	298442	2298652	178100	1174950	668352	683503	1760591
2004	27675000	274700	1970685	136140	1133980	662367	585981	1578000
2005	26950000	233185	1362038	178400	1230000	1420996	527540	1368600
2006	21120000	238400	2074000	164100	986700	1143262	553084	1545000
2007	12233000	281863	1771724	185000	985000	1393753	520545	1488000
2008	16500000	228651	1572889	191900	982000	1334951	540417	1523000
2009	15881919	11617	1533764	223853	901292	1162973	540513	1765726
2010	13596494	9224	1431036	167710	865144	1268351	557275	1633612
2011	12514742	22597	1507163	213732	871805	1161579	643003	1560375
2012	12773572	39893	1319973	297757	820968	1119638	653731	1465488
2013	10408933	44994	1238251	343151	835151	1074228	564340	1528190
2014	11206175	47428	1267076	320628	838646	1144594	605627	1578317
2015	11456759	40083	1166442	301864	750391	1307631	622207	1684019
2016	11491537	35961	1048714	232644	805551	1346137	526150	1747853
2017	11387032	45468	1031081	246433	854688	1457879	761554	1783843
2018	11464901	49773	1162256	235111	909694	1405198	662125	1793415
2019	11675106	46431	1352696	201818	1008039	1359105	664053	1752544
2020	10795758	40085	1146404	207140	1057467	1325690	644570	1580681
2021	9382489	56996	1315717	223076	1077120	1347185	510377	1616169
2022	10628879	59083	1354347	312730	1058711	1343597	577104	1592811

Emissions of methane from industrial wastewater are calculated for the chosen industrial sectors with a large output of wastewater and high content of degradable organic components. In Slovenia, these are:

- production of pulp and paper,

- production of soft drinks and alcohol beverage,
- production of leather,
- production of food,
- production of milk,
- production of meat,
- production of organic chemicals and
- production of the pharmaceutical industry.

The annual amount of wastewater output for an individual industry for the period 2004-2022 were obtained from a database of annual reports on operational monitoring of industrial effluents collected by the SEA. Since actual monitored volumes of wastewater are not available before the year 2004, estimation of volumes of wastewater for the years 1986-2003 was performed. We estimated volumes of wastewater for the period 1986-2003 in such a way that we multiplied the ratio between data of actual volumes and data of production units for the individual industries for the year 2004 with data on annual production of the individual industry for the period 1986-2003. We decided to choose ratios for the year 2004 since this year most closely represents a situation in previous years.

Industrial degradable organic component indicator (COD_i)

The principal factor in determining the CH_4 generation potential of wastewater is the amount of degradable organic material in the wastewater. A common parameter used to measure the organic component of industrial wastewater is Chemical Oxygen Demand (COD). Under the same conditions, wastewater with higher COD will generally yield more CH_4 than wastewater with lower COD concentrations. The COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable).

Data on COD of industrial water before treatment is not available. For this reason, the IPCC default values have been used. These values are available in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, in Table 6.9, pg.6.22 and presented in the NID, Table 7.5.6.

Table 7.5.6: Data on COD for the various type of industries.

Production of pulp and paper	Production of leather	Production of soft drinks and alcohol beverage	Production of food	Production of milk	Production of meat	Production of organic chemical	Production of pharmaceutical industry
COD (kg/m^3)							
9	3	5	5	2.7	4.1	3	3

The total organic product (TOW)

According to the ERT recommendations explanation in the decrease in the TOW values across the time series and on the assumptions of the reallocation of part of the TOW amount from centralized to industrial wastewater treatment plants is included. The total organically degradable material in industrial wastewater (total organic product - TOW) treated in the centralized wastewater treatment plants is presented in Table 7.5.7. Part of the amount of TOW (from 2004 onward) has been reallocated and considered under industrial wastewater treatment plants. Treatment of a share of industrial wastewater in the industrial wastewater treatment plants is the reason for the reduction in CH_4 emissions.

Table 7.5.7: Total organically degradable material (TOW) in industrial wastewater treated on the centralized wastewater treatment plant.

Year	Total organics in waste water (kt COD)	Year	Total organics in waste water (kt COD)	Year	Total organics in waste water (kt COD)	Year	Total organics in waste water (kt COD)
1986	191.3	1996	149.2	2006	192.8	2016	55.8
1987	190.9	1997	166.5	2007	111.7	2017	55.4
1988	187.8	1998	184.2	2008	107.3	2018	45.9
1989	186.2	1999	201.6	2009	102.1	2019	46.7
1990	183.7	2000	214.1	2010	86.7	2020	40.9
1991	164.2	2001	225.8	2011	83.9	2021	43.7
1992	138.1	2002	238.1	2012	72.6	2022	43.0
1993	127.2	2003	250.5	2013	46.5		
1994	144.7	2004	249.8	2014	56.3		
1995	158.6	2005	244.1	2015	55.3		

For the comparison Table 7.5.8. shows the entire amount of TOW considered to have been treated in centralized wastewater treatment plants.

Table 7.5.8: Entire total organically degradable material (TOW) in industrial wastewater treated on the centralized and industrial wastewater treatment plants.

Year	Total organics in waste water (kt COD)	Year	Total organics in waste water (kt COD)	Year	Total organics in waste water (kt COD)	Year	Total organics in waste water (kt COD)
1986	191.3	1996	149.2	2006	215.6	2016	124.5
1987	190.9	1997	166.5	2007	135.1	2017	124.9
1988	187.8	1998	184.2	2008	172.3	2018	125.9
1989	186.2	1999	201.6	2009	165.9	2019	128.5
1990	183.7	2000	214.1	2010	144.5	2020	119.0
1991	164.2	2001	225.8	2011	135.0	2021	107.1
1992	138.1	2002	238.1	2012	136.3	2022	119.0
1993	127.2	2003	250.5	2013	114.7		
1994	144.7	2004	272.7	2014	122.4		
1995	158.6	2005	265.8	2015	124.9		

Until 2003 all industrial wastewater was treated in the centralized wastewater treatment plants, therefore the TOW was the same as the total wastewater output. Since 2004 a share of wastewater from the production of beverages and paper industry have been treated in industrial wastewater treatment plants. Comparison of TOWs in Tables 7.5.7 and 7.5.8 shows a decrease in the TOW values. The TOW has been decreasing from 8% in 2004 to 64% in recent years. A share of industrial wastewater from the production of alcoholic beverage treated in industrial wastewater treatment plants was estimated to about 20% for the whole 2004-2022 period. A share of industrial wastewater from the production of pulp and paper treated in industrial wastewater treatment plant grown markedly, from 8% in 2004 to 78% in 2022.

Methane conversion factor (MCF):

Emissions of methane from industrial wastewater are calculated for the chosen industrial sectors with a large output of wastewater and high content of degradable organic components. In Slovenia, these are in particular production of alcohol beverage and pulp and paper industry. Industrial wastewater in these two productions is mainly treated in well managed aerobic industrial treatment plants with methane recovery. We have assumed that since 2004 around 20% of industrial wastewater from the production of soft drinks and alcohol beverages have been treated in the industrial wastewater treatment plant. In the pulp and paper industry, the first treatment plant with methane recovery started to work in 2004. In 2004 about 8% of industrial wastewater from this industry was treated in that industrial wastewater treatment plant. In 2022 the amount of such treated industrial wastewater increased to 79%. We have assumed, that all industrial wastewater from other productions has been treated in the centralized aerobic treatment plants together with the domestic wastewater for the whole period.

In 2022 75% of industrial wastewater from the production of soft drinks and alcohol beverages and 22% from the pulp and paper industry have been treated in centralized aerobic treatment plants together with the domestic wastewater. For all other industrial wastewater, we have assumed that 100% of industrial wastewater is treated in centralized aerobic treatment plants.

For all these facilities the MCF value of 0.022 was used for emission calculation in 2022. MCF was estimated in the same way as for domestic wastewater treatment plant. In 2022 about 93% of wastewater treated in centralized aerobic treatment plants is treated at aerobic treatment plants that are well managed, the remaining 7% is treated at not well managed plants. The share of well managed aerobic treatment plants was estimated from information on the implementation of the Urban Waste Water Treatment Directive. The default MCF value of 0 for well managed and 0.3 for not well managed aerobic treatment plant were used for emission calculation (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, pg. 6.13, Table 6.3).

MCF decreased from 0.048 in 1986 to 0.22 in 2012 and stay the same until present. A decrease is due to improvement in WW treatment.

Maximum methane producing capacity (B_0)

The default IPCC value of 0.25 kg CH_4/kg COD was used for all types of industries (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, pg. 6.12, Table 6.2).

Organic component removed as sludge (S)

For sludge removal from the wastewater default IPCC value of zero was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.9).

Methane recovery (R)

For the amount of methane recovered default IPCC value of zero was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.9).

7.5.3 Category-specific QA/QC and verification

According to the ERT recommendations transparent explanations of methodology, activity data and parameters for CH_4 and N_2O emission calculations from domestic and industrial wastewater treatment were provided. Changes in methodology and parameters used were performed according to 2006 IPCC Guidelines for National Greenhouse Gas Inventories and conclusions of the capacity building webinar of 2017 ESD Review. According to the ERT recommendations pharmaceutical industry has been introduced as an additional source of CH_4 emissions in industrial wastewater treatment.

According to the 2017 ESD Review modification of the application of equations, 6.1-6.3 in the 2006 IPCC guidelines (Volume 5, Chapter 6) was performed. The exact application of those equations seems to provide false results. Emissions of CH_4 from domestic wastewater were calculated per individual discharge pathway separately: first, multiply ((TOW-S) and EF) for each pathway. Sum up of all pathways results was performed subsequently.

Since the updated methodology has been applied all activity data and other parameters have been thoroughly checked as well. We have checked activity data used for CH_4 and N_2O emission calculation for domestic wastewater. SORS and FAOSTAT periodically report updated data. When updated data are published, we use them for emissions calculation. For data on protein consumption, we have compared data published by the Food and Agriculture Organization of the United Nations and World Health Organisation. We have also checked activity data used for CH_4 emission calculation for industrial wastewater. We have made a comparison of emissions derived from actual volumes of wastewater and emissions calculated from production units for individual industry. The peer review of wastewater was conducted in 2011 and no important errors have been found.

7.5.4 Uncertainty and time-series consistency

Uncertainty estimates from the 2006 IPCC GL for AD and other parameters have been used to determine the uncertainties of emissions from waste water treatment and discharge. In the following table 7.5.9 uncertainties which have been used in the calculations for domestic waste waters are presented.

A total uncertainty of AD is 30% for CH_4 emissions and 15,5% for N_2O emissions. Calculated uncertainty for CH_4 EF in 2022 is 70% and it is a coincidence that the same value is valid also for the 1986 base year. IPCC default emission factor for N_2O from effluent EF is 0.005 kg N_2O_N/kg N but the range of possible values is extremely wide. In the 2019 IPCCC refinement the same default value has a smaller ranges. For this reason we have estimate the uncertainty for this EF to be 500%

For industrial waste water amount of waste water since 2004 is measured with the accuracy ± 10 percent, while a COD value could be very uncertain. For this reason, following the information from the 2006 IPCC GL, AD uncertainty is 100%. Uncertainties of Bo and MCF are 30% each and combined uncertainty for CH_4 EF is 42%.

Table 7.5.4: Uncertainties used to determine AD and CH_4 EF uncertainties for domestic WW

Parameter	CH_4 emissions	Parameter	N_2O emissions
Urban population	5	Number of people in the country	10
BOD per person	30	Protein consumption per capita	10
Bo	50	Fraction of N in protein	6.25
MCF latrines and septic tanks	50	EF effluent (expert judgement)	500
MCF not well managed WWTP	30		
MCF well managed WWTP	10		
Correction factor I	20		

7.5.5 Source-specific recalculations

5.D.1 Domestic Wastewater, CH_4, N_2O

Emissions of CH_4 have been recalculated for the 1987-2019 due to the improve data on number of inhabitant treated in WWTP.

Emissions of N_2O have been recalculated for the years 2019-2021 due to new value on protein consumption applied.

5.D.2 Industrial Wastewater

Emissions of CH_4 have been recalculated for the entire period due to the correction of TOW from production of organic chemicals.

7.5.6 Future improvements

No improvements are planned for this category.

8 OTHER

No emissions have been reported in this sector.

9 INDIRECT CO_2 AND N_2O EMISSIONS

No emissions have been reported in this chapter.

10 RECALCULATIONS AND IMPROVEMENTS

10.1 Explanations and justification for recalculations, and implication for emission level

In the present submission almost all recalculations are due to the recommendations from the UNFCCC review which was held in October 2022. The impact of the recalculations on the total GHG emissions is presented in the Table 10.1.1.

Table 10.1.1: The total changes in kt CO_2 eq. due to the recalculation with a respect to the previous submission.

	1986	1990	2000	2005	2010	2015	2020	2021
1. Energy	0.00	0.00	0.04	3.28	0.00	-0.35	0.81	0.46
2. IPPU	0.05	0,07	0.20	0.24	0.32	0.93	4.81	16.31
3. Agriculture	8.97	8.77	-21.00	-29.59	-31.85	-35.89	-39.69	-39.74
4. LULUCF	15.16	15.13	3.23	-5.68	-0.81	-245.02	2,745.81	2,784.85
6. Waste	-3.00	-4.09	-12.17	-21.39	-25.03	-10.76	-11.00	-9.93
Total w/o LULUCF	6.02	4.75	-32.94	-47.47	-56.55	-46.07	-45.02	-32.89
Total with LULUCF	21.18	19.89	-29.70	-53.15	-57.36	-291.11	2,700.79	2,751.96
Total in % w/o LULUCF	0.03	0.03	-0.18	-0.23	-0.29	-0.27	-0.28	-0.20
Total in % with LULUCF	0.13	0.14	-0.24	-0.40	-0.46	-1.67	17.39	17.47

10.1.1 Energy

The impact of the recalculations on emissions in Energy sector is presented in the Table 10.1.2.

Table 10.1..2: Changes due to the recalculation with a respect to the previous submission in Energy sector in kt CO_2 eq.

Energy	1986	1990	2000	2005	2010	2015	2020	2021
A. Fuel Combustion	0.0	0.0	0.04	3.28	0.00	-0.35	0.81	0.46
1. Energy Industries								
2. Manufacturing Ind.				3.03				
3. Transport	0.0	0.0	0.04	0.01	0.00	0.10	0.23	0.04
4. Other Sectors				0.24		-0.44	0.59	0.43
5. Other								
B. Fugitive Emissions								
1. Solid Fuels								
2. Oil and Natural Gas								
Total of Energy in kt CO_2eq	0.00	0.00	0.04	3.28	0.00	-0.35	0.81	0.46
Total of Energy in %	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00

1.A.2.b Non-ferrous Metals, Solid Fuels, CO_2, CH_4, N_2O
Emissions for the year 1993 have been slightly changed due to the error in NCV used for domestic brown coal. The calorific value is now in line with domestic brown coal used in the other industrial sectors.

1.A.2.c Chemicals, 1.A.2.d Pulp and Paper, Liquid Fuels, CO_2, CH_4, N_2O
Emissions for the years 2005 and 2007 have been slightly changed due to the error in NCV used for gas diesel oil and residual fuel oil in the previous submission. The calorific value is now in line with other industrial sectors.

1.A.3.b Road transportation, CO_2, CH_4, N_2O
Recalculation of CO_2, CH_4 and N_2O emissions for the whole period 1986-2021 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.7.2) was used for emissions calculation.

1.A.4.b Residential, Biomass, CO_2, CH_4, N_2O
GHG emissions from wood biomass combustion in residential sector for the period 2011-2021 were recalculated due to the improved data on wood (TJ) used in this sector obtained from SORS. The improvement of SORS data was taking into account estimates from the model for determining the heating demand.

10.1.2 Industrial processes and product use

The impact of recalculations on emissions in this sector is presented in the Table 10.1.3 below.

Table 10.1.3: Changes due to recalculation with respect to the previous submission in the Industrial processes and product use sector in kt CO_2 eq.

IPPU	1986	1990	2000	2005	2010	2015	2020	2021
A. Mineral Products								
B. Chemical Industry								
C. Metal Production								
D. Non-energy Prod.								
F. ODS Substitutes							3.63	15.89
G. Other Products	0.05	0,07	0.20	0.24	0.32	0.93	1.18	0.43
Total IPPU in kt CO_2 eq.	0.05	0,07	0.20	0.24	0.32	0.93	4.81	16.31
Total of IPPU in %	0.00	0.01	0.02	0.02	0.03	0.08	0.42	1.45

2.D.1 Lubricant Use, CO_2
Recalculation of CO_2 emissions for the whole period 1986-2021 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.7.2) was used for emissions calculation. An amount of lubricant used in two-stroke engines was obtained by a new COPERT 5 model. That amount was subtracted from the total consumption of lubricant. Changes in the total consumption of lubricant led to a recalculation of CO_2 emissions in 2.D.1 sector.

2.D.3 Other

Recalculation of CO_2 emissions for the period 2013-2021 was performed due to changes in CO_2 emissions from urea-based additives used in catalytic converters in road transport. Emissions from urea-based catalysts were calculated with a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.7.2) was used for emissions calculation. Application of a new version of COPERT 5 for emissions calculation in road transportation led to a recalculation of CO_2 emissions in 2.D.3 sector.

2.F.1 Refrigeration and AC, HFC

Emissions of HFC for the period 2019-2021 were recalculated due to the change of product lifetime for medium and large commercial refrigerators from 10 to 15 years.

2.G.2 SF_6 and PFC from Other Product Use, SF_6

Emissions of SF_6 were recalculated for the entire period 1986-2021 due to inclusion of emissions of SF_6 from other uses like particle accelerators used in medicine, research and industry and electron microscopes. This emissions were calculated and included in the inventory for the first time. Due to the problems with adding the relevant child node in CRT Reporter, these emissions are included in the CRT category 2.G.2 Soundproofed Windows. We will report these emissions in the separate category when ETF Reporting Tools will be operational.

10.1.3 Agriculture

The impact of recalculations on the emissions in this sector is presented in the Table 10.1.4.

Table 10.1.4: Changes due to the recalculation with a respect to the previous submission in the Agricultural sector in kt CO_2 eq.

3. Agriculture	1986	1990	2000	2005	2010	2015	2020	2021
A. Enteric Fermentation	17.17	16.44	-12.91	-20.61	-21.41	-23.23	-29.98	-29.71
B. Manure Management	-2.14	-2.00	-2.08	-2.38	-2.87	-3.30	-2.42	-2.38
D. Agricultural Soils	-6.06	-5.67	-6.01	-6.60	-7.57	-9.36	-7.23	-7.16
G. Liming								-0.48
H. Urea application								
I. Other C-containing fertilizers								
Total in Agriculture in kt CO_2 eq.	8.97	8.77	-21.00	-29.59	-31.85	-35.89	-39.69	-39.74
Total of Agriculture in %	0.44	0.45	-1.12	-1.67	-1.84	-2.04	-2.23	-2.24

3.A.1 Enteric fermentation, CH_4

The methane conversion factors (YM) for cattle have been updated. The values from the 2006 IPCC Guidelines have been replaced by values from the 2019 Refinement to the 2006 IPCC Guidelines. In the case of dairy cows, the YM values were linked to the intensity of milk production.

3.B.1 Manure management, N_2O

The equations for estimating nitrogen excretion in dairy cows, which take into account the intensity of milk production, have been replaced by equations that also contain information on the milk urea concentration. The recalculations concern both direct (3.B.1.) and indirect emissions (3.B.5.).

3.D. Agricultural soils, N_2O

The equations for estimating nitrogen excretion in dairy cows, which take into account the intensity of milk production, have been replaced by equations that also contain information on the milk urea concentration. The recalculations concern both the direct and indirect emissions of the category (3.D.a.2 and 3.D.b). The estimates for the proportion of fertilization with low-emission slurry spreading techniques were also corrected. The estimates in previous submissions referred to the total area of arable land and meadows, now they refer to the

10.1.4 LULUCF

The impact of recalculations on the emissions in the LULUCF sector is presented in the Table 10.1.5.

Table 10.1.5: Changes due to the recalculation with a respect to the previous submission in LULUCF sector in kt CO_2 eq.

5. LULUCF	1986	1990	2000	2005	2010	2015	2020	2021
A. Forest Land			0.58	0.55	0.01	-244.95	2,726.66	2,762.23
B. Cropland	-2.20	-2.23	-1.56	-1.26	-0.71	-0.50	-0.33	-0.41
C. Grassland	-18.79	-18.79	-16.93	-14.12	-10.50	-6.84	-4.18	-4.05
D. Wetlands	39.99	-39.99	31.46	23.45	20.41	14.10	21.27	23.56
E. Settlements	-4.12	-4.12	-10.31	-13.91	-9.60	-6.60	1.73	3.21
F. Other Land	-0.13	-0.13	-0.14	-0.37	-0.42	-0.24	-0.10	-0.07
G. HWP								
Total in LULUCF	15.16	15.13	3.23	-5.68	-0.81	-245.04	2,745.81	2,784.85
Total of LULUCF in %	-0.32	-0.35	-0.08	0.07	0.01	-43.49	-691.77	-867.80

4. A Forest land

Recalculations were conducted for the period 2018-2021 for the forest land remaining forest due to updated emission factors for living biomass and dead wood, derived from recent estimates from the NFI 2020-2023. Minor adjustment have been applied to other years as well owing to refinements in the method used for calculating the merchantable volume. Additionally, recalculations were made for land converted to forest land, incorporating updated emission factors specifically for dead wood.

4. B Cropland

Recalculations have been undertaken for the period 1986-2021 concerning land converted to cropland, incorporating updated emission factors for living biomass and dead organic matter (conversions from forest land to cropland) and updated emission factors for mineral soil (conversions from settlements to cropland).

4. C Grassland

Recalculations for the period 1986-2021 for land converted to grassland were made based on updated emission factors for living biomass and dead organic matter (conversions from forest land to grassland) and updated emission factors for mineral soil (conversions from settlements to grassland and from wetlands to grassland).

4. D Wetlands

Recalculations have been made for the period 1986-2021 concerning land converted to wetlands based on updated emission factors for living biomass and dead organic matter (conversions from forest land to wetlands) and updated emission factors for mineral soil (conversions from forest land to wetlands and from grassland to wetlands).

4. E Settlements

Recalculations have been made for the period 1986-2021 for land converted to settlements based on updated emission factors for living biomass, dead organic matter and mineral soil.

4. F Other land

Recalculations have been made for the period 1986-2021 for land converted to other land based on updated emission factors for living biomass and dead organic matter (conversions from forest land to other land) and updated emission factors for mineral soil (conversions from settlements to other land).

Direct N2O emissions from N mineralization/immobilization and indirect N_2O emissions from managed soils (nitrogen leaching and run-off

Recalculations were made on the basis of updated emission factors for all land use changes where the change in soil organic carbon stocks is negative.

10.1.1 Waste

The impact of the recalculations on emissions in the Waste sector is presented in the Table 10.1.6.

Table 10.1.6: Changes due to the recalculation with a respect to the previous submission in Waste sector in kt CO_2 eq.

6. Waste	1986	1990	2000	2005	2010	2015	2020	2021
A. Solid waste disposal							-11.85	-8.88
B. Biological treatment								
C. Incineration								-0.33
D. Waste water treatment	-3.00	-4.09	-12.17	-21.39	-25.03	-10.76	-0.85	-0.71
Total in Waste in kt CO_2eq	-3.00	-4.09	-12.17	-21.39	-25.03	-10.76	-11.00	-9.93
Total of Waste in %	-0.43	-0.53	-1.43	--2.58	-4.36	-2.02	-2.50	-2.37

5.D.1 Domestic Wastewater, CH_4, N_2O

Emissions of CH_4 have been recalculated for the 1987-2019 due to the improve data on number of inhabitant treated in WWTP.

Emissions of N_2O have been recalculated for the years 2019-2021 due to new value on protein consumption applied.

5.D.2 Industrial Wastewater

Emissions of CH_4 have been recalculated for the entire period due to the correction of TOW from production of organic chemicals.

10.2 Response to the Review Process

In 2022 Slovenian GHG inventory was included in the ESD review and UNFCCC centralised review. The details of Slovenian response to the recommendations UNFCCC review processes are in the excel file SVN_2023_Art10_AnnexVIII_Recommendations v2.

There were no recommendations from the ESD review. A majority recommendations from UNFCCC review were implemented in this submission. The number of paragraph from the implemented review recommendation is included in the description of recalculations, if relevant.

Table 10.2.1: A response to the recommendations from the UNFCCC review process.

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
ENERGY				
Fuel combustion - RA, CO_2	Indicate, for the reference approach, which data sources were used for the NCVs of individual fuel types, along with the respective carbon EFs.	E1	implemented	NID 2023, Ch. 3.2.1
1.A Fuel combustion - liquid fuels, CO_2	Develop country-specific CO_2 EFs for all fuels that have a significant share in the fuel mix for each category	E3	Not implemented	No data available
1A.2.d Pulp, paper and print - biomass, CO_2, CH_4, N_2O	Include in the NID for this category the NCVs and EFs applied for all biomass types (black liquor, wood, fibrous sludge and biogas) and a description of the data sources used for the AD, NCVs and EFs.	E8	Implemented	NID 2023, Ch. 3.2.5
1A.3.b Road transportation - liquid fuels, CO_2	Include in the NID the verification information provided during the review of the 2020 submission demonstrating the correlation between the CO_2 EFs used by the Party (sourced from the COPERT 5 default values) and the country-specific EFs of Italy and Austria.	E10	Implemented	NID 2023, Ch. 3.2.6
1. General (energy sector) – solid fuels – CO_2, CH_4 and N_2O	The ERT recommends that the Party correct the NCV used for other bituminous coal for all years of the time series in which the plant for which the incorrect NCV was reported was in operation. The ERT also recommends that the Party recalculate the emission estimates for subcategory 1.A.2.b under the sectoral approach and implement relevant changes to the information reported on other bituminous coal in CRT table 1.A(b) under the reference approach.	E16	Implemented	CRT table 1.A(b)

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
1. General (energy sector) – solid fuels – CO2, CH4 and N2O	The ERT recommends that the Party correct the double counting of fuel consumption and the emission estimates for the pharmaceutical industry and clearly explain in the NID where the AD and emissions for consumption of other fossil fuels are allocated. The ERT also recommends that the Party correct the identified error in the consumption data for other fossil fuels for 2019 under the reference approach.	E17	Implemented	NID 2023, Ch. 3.2.5 CRT Tables
1A.3.b Road transportation - liquid fuels, CO2	The ERT recommends that the Party review the information on NCVs for gasoline used in road transportation reported in the most recent annual submissions of Austria and Italy to determine whether NCVs that are appropriate for use by Slovenia can be derived on the basis of the shares of gasoline imported into Slovenia and recalculate the time series using the updated NCVs, if it is determined that they better reflect national circumstances.	E18	Implemented	NID 2023, Ch. 3.2.6.1.4 CRT Tables
1.A.3.b.iii Heavy-duty trucks and buses – liquid fuels – CO2	The ERT recommends that the Party report in CRT table 1.A(a)s3 the quantity of gasoline consumed and associated emissions for heavy-duty trucks and buses for 1986–1991 in its next annual submission.	E19	Implemented	CRT table 1.A(a)s3
1.A.3.b.iii Heavy-duty trucks and buses – liquid fuels – CO2	The ERT recommends that the Party review the AD, EFs and NCVs for gasoline use for subcategory 1.A.3.b.iii (heavy-duty trucks and buses) and confirm in the NID whether accurate and time-series consistent data for fossil gasoline are reported. The ERT also recommends that the	E20	Implemented	NID 2023, Ch. 3.2.6

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	Party explain in the NID any anomalous trends and variations in the CO2 IEF for gasoline use in heavy-duty trucks and buses, including any significant differences compared with the trend and values observed for the CO2 IEF for gasoline use for subcategories 1.A.3.b.i (cars) and 1.A.3.b.ii (light-duty trucks).			
1.A.3.d Domestic navigation – liquid fuels – N2O	The ERT recommends that the Party describe in its NID the national circumstances for domestic navigation relating to vehicle classes and the extent to which they operate along the national coastline, and provide justification for choosing the default N2O EF for gas/diesel oil in table 3.3.1 of the 2006 IPCC Guidelines (vol. 2, chap. 3) instead of the default EF in table 3.5.3.	E21	Implemented	NID 2023, Ch. 3.2.6.2.2
1.A.4.a Commercial/institutional – biomass – CO2, CH4 and N2O	The ERT recommends that the Party clearly document the allocation of the emissions from combustion of landfill gas in the chapter of the NID on the energy sector, including justification for the assumptions used for classifying SWDS as autoproducers and ensure that the allocation of emissions from CH4 recovery for energy use for the entire time series in line with the allocation of emissions in the 2006 IPCC Guidelines (vol. 2, Chap. 2, table 2.1, p.2.7).	E22	Implemented	NID 2023, Ch. 3.2.7.1.2
International bunkers and multilateral operations – liquid fuels – CO2, CH4 and N2O	The ERT recommends that the Party report the missing quantity of gas/diesel oil consumption in CRT table 1.D for international marine bunkers (corresponding to approximately 28 kt CO2 eq) in its next annual submission.	E23	Implemented	CRT Table 1.D

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
Fuel combustion – reference approach – solid fuels – CO2	The ERT recommends that the Party correct the NCV for coke oven/gas coke for 2020 in CRT table 1.A(b) using the revised data from SORS (29.906 TJ/kt).	E24	Implemented	CRT Table 1.A(b)
NDUSTRIAL PROCESSES AND PRODUCT USE				
2.A.4. Other processes use of carbonates, CO2	Estimate the emission levels for bricks and ceramics production for 1990–1994 using a robust extrapolation method relevant to the country's circumstances, taking into account factors such as the peaking of the country's construction industry in 2006 and the 2008 economic crisis	I1	Implemented	NID 2023, Ch. 4.2.4 CRT Tables
2.C.1. Iron and steel, CO2	Estimate CO2 emissions from pig iron production on the basis of a basic carbon balance method considering the inputs (e.g. iron ore, coke) and outputs (e.g. pig iron) in the process and update the methodological description in the NID.	I4	Implemented	NID 2023, Ch. 4.4.1 CRT Tables
2.F.1 Refrigeration and air conditioning – HFCs	Provide in the NID evidence that all transport equipment is exported before decommissioning.	I5	Implemented	NID 2023, Ch. 4.6.2
2.F.1 Refrigeration and air conditioning – HFCs	Investigate whether part of the transport refrigeration equipment is disposed of on the national market without recovery (e.g. broken equipment but with a working refrigeration system, equipment containing less than 50 per cent fill-in and not efficiently cooling, leakage during accidents)	I6	Implemented	NID 2023, Ch. 4.6.2
2.G.1 Electrical equipment – SF6	Reassess the value of the disposal loss factor applied to estimate SF6 emissions from the disposal of electrical equipment and, on the basis of that analysis, provide documentation and	I8	Implemented	NID 2023, Ch. 4.7.1

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	references that justify the value of 0.10 per cent, or revise it accordingly.			
2.A.1 – Cement production – CO_2	The ERT recommends that Slovenia improve the explanation in the NID of the methodological change in the estimation of emissions from CKD, including the changes in the cement production process since 2019.	I9	Implemented	NID 2023, Ch. 4.2.1
2.A.4 – Other processes uses of carbonates – CO_2	The ERT recommends that Slovenia include in the NID details regarding the timing and frequency of the surveys conducted to determine that all carbonate use in the country is accounted for under category 2.A.4 (other process uses of carbonates).	I10	Implemented	NID 2023, Ch. 4.2.4
2.F.1 Refrigeration and air conditioning – HFCs	The ERT recommends that the Party check the time-series consistency of the values used for the product life factors and include in the NID an explanation for the inter-annual fluctuations in the product life factors for F-gases (HFC-134a, HFC-125, HFC-143a and HFC-32) for subcategory 2.F.1.c (industrial refrigeration). The ERT encourages the Party to continue improving the accuracy of the product life factors to ensure that they reflect the actual situation in the country as further data become available.	I11	Implemented	NID 2023, Ch. 4.6.2 CRT Tables
2.F.1 Refrigeration and air conditioning –HFC-134a	The ERT recommends that the Party correct the amount of HFC-134a remaining in products at decommissioning for subcategory 2.F.1.e (mobile air-conditioning) for 2019 in CRT table 2(II).B-Hs2.	I12	Implemented	CRT tables

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
2.F.1 Refrigeration and air conditioning –HFC-134a	The ERT recommends that the Party include in the NID an explanation of the trend in the disposal factors for HFC-134a for subcategory 2.F.1.e (mobile air-conditioning). The ERT also recommends that the Party correct the estimates of disposal emissions for HFC-134a for 2009–2020 in order to take into account the proportion of airconditioning equipment in disposed vehicles when reporting emissions in CRT table 2(II).B-Hs2.	I13	Implemented	NID 2023, Ch. 4.6.2 CRT Tables
2.F.1 Refrigeration and air conditioning – HFC-32 and HFC-125	The ERT recommends that the Party correct the disposal loss factors for HFC-32 and HFC-125 reported in CRT table 2(II),B-Hs2 for 2016–2020 for subcategory 2.F.1.f (stationary air-conditioning) and improve the QA/QC checks to avoid similar errors.	I14	Implemented	CRT tables
2.F.3 Fire protection – HFC-227ea	The ERT recommends that the Party improve the information in the NID on the methodology applied for the category, including details of the sources of data used to calculate HFCs in fire extinguishers and the sources of data for the product manufacturing factor for HFC-227ea across the time series, together with justification for the reduction in the value of the EF for first filling across the time series. The ERT further recommends that the correct values of the percentage of the EF are entered in CRT 2(II).B-Hs2 (as a per cent and not as a fraction).	I15	Implemented	NID 2023, Ch. 4.6.2 CRT Tables
AGRICULTURE				

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
3.B - Manure management - N2O	Provide additional information on nitrogen excretion rate and demonstrate that those parameters are appropriate in the specific national circumstances and more accurate than the default data provided in the 2006 IPCC Guidelines.	A2	Implemented	NID 2023, Ch. 5.4.2
3.B Manure management – CH4	The ERT recommends that Slovenia reassess the MCF value applied (which is currently zero) for anaerobic digestion of cattle and swine manure to ensure that CH4 emissions are not underestimated for this MMS.	A4	Implemented	CRT tables
3.B Manure management, N2O	Specify the source for each parameter used in estimating N2O emissions from manure management of cattle (in NID table 5.4.4) and swine (in NID table 5.4.5)	A5	Implemented	NID 2023, Ch. 5.4.2
3. General (agriculture)	The ERT recommends that the Party follow the protocol for expert elicitation when conducting the uncertainty analysis for the agriculture sector, in line with the 2006 IPCC Guidelines (vol. 1, chap. 2, annex 2A.1) and include references to the key assumptions based on expert judgment in the next annual submission.	A7	Not implemented	In the improvement plan
3.B Manure management, N2O	The ERT recommends that the Party correct the EF for manure stores for rabbits in NID table 5.4.7 and provide sufficient justification for the selection of EF values where there is no IPCC default value for a specific animal type.	A9	Implemented	NID 2023, Ch. 5.4.2
LULUCF				

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
4. General (LULUCF) – CO2	Improve the transparency of the reporting on the LULUCF sector by completing the table provided during the review (which shows carbon stocks for each carbon pool by land use type, further separated by subcategory) with values for gains and losses for living biomass and including the table in the next NID.	L2	Partly implemented	Average carbon stocks for each carbon pool by land use type are presented in Tables 6.3.10, 6.3.11 and 6.3.12. Values for gains and losses are included in subcategories under subchapters
4.A.1 Forest land remaining forest land – CO2	Includes in its next NID the information provided during the review concerning prohibition of fertilization of forest land and also a documentation (if possible a reference to a legal document) on the non-occurrence of drainage and rewetting of forests in Slovenia to justify the assumptions made.	L5	Implemented	NID 2023, Ch. 6.4.4.2
4.B.1 Cropland remaining cropland – CO2 4.C.2 Grassland remaining grassland – CO2	Develop a higher-tier method for estimating emissions/removals from the SOC pool in mineral soils for the subcategories annual grassland remaining annual grassland and annual cropland remaining annual cropland, or include in the NID the reason that national circumstances do not allow a higher-tier method to be applied.	L8	Implemented	NID 2023, Ch. 6.5.4.1, 6.6.4.1
4.B.1 Cropland remaining cropland – CO2 4.C.2 Grassland remaining grassland – CO2	Improve the transparency in the NID by including clarification on (1) how carbon stock change for mineral soil is calculated between annual and perennial grassland; (2) the SOC values applied for annual grassland remaining annual grassland; (3) the rationale justifying why carbon stock change for perennial grassland remaining perennial grassland is considered in equilibrium; (4) how carbon stock change for mineral soil is calculated	L9	Implemented	NID 2023, Ch. 6.5.4.1, 6.6.4.1

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	between annual and perennial cropland (i.e. that there is no differentiation in the method for calculating carbon stock change in mineral soils between annual cropland remaining annual cropland and perennial cropland remaining perennial croplands).			
4.B.2 Land converted to cropland – CO2 4.C.2 Land converted to grassland –CO2	Include the justification provided during the review concerning using zero as the value of carbon stocks in living biomass after land conversion (“Cafter”).	L12	Implemented	NID 2023, Ch. 6.5.4.2, 6.6.4.2
4.B.2 Land converted to cropland – CO2 4.C.2 Land converted to grassland –CO2	Apply equations 2.15 and 2.16 from the 2006 IPCC Guidelines (vol. 4) correctly by taking into account losses in biomass carbon stocks to avoid any possible overestimation of removals or an underestimation of emissions from the land-use category land converted to cropland and land converted to grassland. In case it is not possible to estimate losses in living biomass, apply a simple stock change approach (equations 2.4 and 2.5 from the 2006 IPCC Guidelines), thereby taking into account the mean values of the land use types (and not the values immediately after the conversion).	L13	Implemented	NID 2023, Ch. 6.5.4.2, 6.6.4.2
4.C.1 Grassland remaining grassland – CO2	Include in the NID explanation concerning the reasons that caused the drop in the values of net carbon stock change in mineral soils between 2006 and 2007 and for the continuing decreasing after 2007.	L14	Implemented	NID 2023, Ch. 6.6.4.1
4.E Settlements – CO2	Provide information on methodology used in living biomass in settlements remaining settlements in the NID, take further consideration	L15	Implemented	NID 2023, Ch. 6.8.4.1

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	whether carbon stock in settlements area is increasing or expected to be maturing in the future and examine application of actual growing period (AGP) if considered necessary.			
4.E.2 Land converted to settlements – CO2	Include in the NID the information underpinning the assumption that the carbon stock of soils for settlements is half of the carbon stock value for annual grassland (e.g references to scientific literature and to the study on visual interpretation of digital orthophotos, as well as to the expert judgement as described above).	L16	Implemented	NID 2023, Ch. 6.8.4.2
Land representation – CO2	The ERT recommends that the Party correct the information reported in the CRT tables on the area of forest land for 2020 and the area of settlements for 2015 and related CO2 estimates	L20	Implemented	CRT 2022 and 2023
4.A Forest land – CO2	The ERT recommends that the Party include in its NID comprehensive information on the methodology for estimating the country-specific BEF, including the parameters used, the results by species and an evaluation of the consistency of the country-specific BEFs with the values in the 2006 IPCC Guidelines (vol. 4, chap. 4).	L21	Implemented	NID 2023, Ch. 6.4.4.1
4.A.1 Forest land remaining forest land – CO2	The ERT recommends that the Party update the information in the NID on the growing stock volume in line with Global Forest Resources Assessment 2020 for Slovenia (section 2a, p.22) to reflect the recalculated estimates of CSC in living biomass for 2019 and 2020 provided in the revised CRT tables 4.A.	L22	Implemented	CRT 2023, table 4.A, NID 2023, Ch. 6.4.7

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
4.B Cropland – CO2	The ERT recommends that the Party include additional information in the NID on the method applied for estimating the country-specific value for carbon stock changes for living biomass in annual cropland, including crop types, and the size and representativeness of the sample	L23	Not implemented	In the improvement plan
4.C.1 Grassland remaining grassland – CO2	The ERT recommends that the Party estimate and report the losses in living biomass for perennial grassland remaining perennial grassland or include better justification in the NID why such estimates are not included in the inventory	L24	Implemented	NID 2023, Ch. 6.6.4.1
WASTE				
5.A Solid waste disposal on land – CH4	The ERT recommends that Slovenia ensure that it follows good practice for the reporting of gas recovery (i.e. 2006 IPCC Guidelines, vol. 5, chap. 3, p.3.19) and report in the NID information of the annual reports prepared by installations operating under the EU directive on integrated pollution prevention and control on monitoring of gas recovery both for flaring and for energy.	W3	Implemented	NID 2023, Ch. 7.2.2
5.D Wastewater treatment and discharge – CH_4	Make every effort to obtain plant-level data (volumes and water characteristics such as BOD-COD) in order to be able to apply a higher-tier method for estimating CH4 emissions from wastewater treatment and discharge in accordance with the 2006 IPCC Guidelines, and report in the NID the methods and data used, as well as the recalculation performed, in accordance with paragraphs 43–45 of the UNFCCC Annex I inventory reporting guidelines.	W4	Not implemented	No data available

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
5. General (waste) – CO2, CH4 and N2O	The ERT recommends that the Party improve the transparency of the NID by including, in the section on the overview of the waste sector, information (e.g. a flow chart) on the waste flows used in the inventory estimates; the amounts of all types of waste produced in the country (MSW, industrial, hazardous, clinical, sludge), considering both imports and exports; and the treatment applied to the different types of waste in the country, including recycling	W9	Implemented	NID 2023, Ch. 7.1.
5.A.1 Managed waste disposal sites – CH4	The ERT recommends that the Party correctly report in the chapter on the waste sector of the NID the category in the energy sector in which energy use of landfill gas occurs and the associated emissions are reported.	W10	Implemented	NID 2023, Ch. 7.2.2
5.B.2 Anaerobic digestion at biogas facilities – CH4	The ERT recommends that the Party include in the NID a section on subcategory 5.B.2 (anaerobic digestion), explaining that the activity started in 2009, and provide a detailed explanation and justification for reporting CH4 recovery and emissions from anaerobic digestion as "NE", in line with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.	W11	Implemented	NID 2023, Ch. 7.3.2
5.C.1 Waste incineration – CO2	The ERT recommends that the Party update the CO2 EF for clinical waste using the correct value for dm content from the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.6, p.2.16) and recalculate CO2 emissions from clinical waste for the entire time series	W12	Implemented	NID 2023, Ch. 7.4.2 CRT Tables

CRT category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
5.D.2 Industrial wastewater – CH4	The ERT recommends that the Party include, in the section of the NID on the MCF, information on the changes in the value of the MCF throughout the time series to clarify the improvement in treatment conditions for industrial wastewater and corresponding decrease in emissions.	W13	Implemented	NID 2023, Ch. 7.5.2

ABBREVATIONS

4AR	IPCC - Forth Assessment Report
AD	Activity data
CH_4	Methane
CKD	Cement kiln dust
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CNG	Compressed natural gas
CO	Carbon monoxide
COP	Conference of the Parties (to the United Nations Framework Convention on Climate Change)
COPERT	model and methodology for determination of emissions from road transport
CORINAIR	CORe INventory AIR emissions
CO_2	Carbon dioxide
CO_2 eq.	CO2 equivalent
CRT	Common Reporting Format
EEA	European Environment Agency
EF	Emission factor
EMEP	European Monitoring and Evaluation Programme
ETC-ACC	European Topic Centre on Air and Climate Change
ETS	Emission Trading Scheme
EU	European Union
FAO	The Food and Agriculture Organization of the United Nations
F–Gases	Hydrofluorocarbons (HFC), Perfluorocarbons (PFC) and Sulphur hexafluoride (SF6)
FOD	First order decay method for calculating CH4 emissions from waste
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gases
GWP	Global warming potential
HFC	Hydrofluorocarbons
IEA	International Energy Agency
IJS	Institute “Josef Stefan”
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
ISEE	Slovenian Information System for GHG Emission Inventories
JQ	Joint Questionnaire
LPG	Liquid Petroleum gas
LULUCF	Land Use, Land Use Change and Forestry
MAC	Mobile Air Conditioning
MKGP	Ministry of Agriculture, Forestry and Food
MMR	Monitoring Mechanism Regulation (525/2013)
MOP	Ministry of the Environment and Spatial Planning
NCV	Net caloric value

NECD	Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants
NH3	Ammonium hydroxide
NID	National Inventory Document
NMVOC	Non Methane Volatile Organic Compounds
NO_x	Nitrogen oxides
N_2O	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
PFC	Perfluorocarbons
QA/QC	Quality assurance / Quality control
RA	Reference approach
RS	Republic of Slovenia
SAR	IPCC - Second Assessment Report
SEA	Slovenian Environment Agency
SF_6	Sulphur hexafluoride
SWDS	Solid waste disposal sites
LEG	Statistical Yearbook of Energy Economics
SO_2	Sulphur dioxide
SORS	Statistical Office of the Republic of Slovenia
TE–TOL	Ljubljana heat and power plant
TEŠ	Šoštanj thermo-power plant
TET	Trbovlje thermo-power plant
TEB	Brestanica thermo-power plant
UNFCCC	UN Framework Convention for Climate Change

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